112th Congress, 1st Session – – – – – – – – – – – – House Document 112–21

SURF CITY AND NORTH TOPSAIL BEACH INTEGRATED FEASIBILITY REPORT AND EIS COASTAL STORM DAMAGE REDUCTION

COMMUNICATION

FROM

THE ASSISTANT SECRETARY OF THE ARMY, CIVIL WORKS, THE DEPARTMENT OF DEFENSE

TRANSMITTING

THE CORPS INTEGRATED FEASIBILITY REPORT AND ENVIRONMENTAL IMPACT STATEMENT

PART 1 OF 2



MAY 6, 2011.—Referred to the Committee on Transportation and Infrastructure and ordered to be printed

---

U.S. GOVERNMENT PRINTING OFFICE

66–208 WASHINGTON : 2011

AUTHENTICATED
U.S. GOVERNMENT
INFORMATION
GPO

DEPARTMENT OF THE ARMY
OFFICE OF THE ASSISTANT SECRETARY
CIVIL WORKS
108 ARMY PENTAGON
WASHINGTON DC 20310-0108

APR 13 2011

Honorable John Boehner
Speaker of the House
of Representatives
U.S. Capitol Building, Room H-232
Washington, D.C. 20515-0001

Dear Mr. Speaker:

This report is in response to two resolutions by the Committee on Transportation and Infrastructure of the U.S. House of Representatives, adopted on February 16, 2000 and April 11, 2000. Coastal storm damage reduction for Surf City and North Topsail Beach were studied by the Corps of Engineers as part of the West Onslow Beach and New River Inlet general investigation study from 1992, and was found not to be economically feasible. However, following a series of hurricanes that damaged Topsail Island between 1996 and 1999, interest in a coastal storm damage reduction project was renewed. This feasibility study is in response to renewed interest by Congress by way of the aforementioned House resolutions. The resolutions requested a review of the report of the Chief of Engineers on West Onslow Beach and New River Inlet, North Carolina, and other pertinent reports, to determine whether any modifications are advisable at the present time in the interest of shore protection for Surf City and North Topsail Beach, North Carolina. The Secretary of the Army recommends authorization of a plan to reduce coastal storm damages by construction of a berm and dune along the Surf City and North Topsail Beach shorelines which is outlined in the current Report of the Chief of Engineers, dated December 30, 2010.

The recommended plan includes a 52,150-foot long dune and berm system to be constructed to an elevation of 15 feet National Geodetic Vertical Datum (NGVD) fronted by a seven-foot NGVD (50-foot wide) beach berm with a main fill length of 52,150 feet, extending from the boundary between Topsail Beach and Surf City to the southern edge of the Coastal Barrier Resources Act (CBRA) Zone in North Topsail Beach. The recommended plan also includes renourishment at six-year intervals. Other associated features of the project are dune vegetation and construction of 60 dune walkover structures. Material for the dune and berm construction and renourishment will be dredged from borrow sites identified between one to six miles off the coast of Topsail Island. The recommended plan also includes post-construction monitoring over the period of Federal participation to ensure project performance and adjust renourishment plans as needed.

At the October 2010 price level, the estimated first cost of initial construction is $123,135,000. There will be 7 renourishments scheduled over the project lifetime, with a total cost estimated at $205,539,000. The total project cost which includes initial construction, monitoring, and periodic nourishment is estimated to be

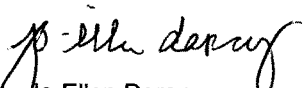
Printed on Recycled Paper

$353,924,000. Based on a 4.125 percent discount rate and a 50-year period of analysis, average annual costs are estimated at $10,702,000 while average annual storm damage reduction and recreation benefits are estimated at $40,129,000. Of the total annual benefits, $18,097,000 is attributed to coastal storm damage reduction (CSDR) and $22,032,000 is attributable to recreation. The benefit-to-cost ratio (BCR) based on total annual benefits, is approximately 3.7 and the BCR based solely on CSDR is 1.7. Total project net benefits are estimated at $29,427,000. The Recommended Plan is the National Economic Development (NED) Plan and is estimated to reduce average annual storm damages by 88%. The recommended plan is the environmentally preferred plan, however, ecosystem restoration benefits were not quantified or presented and no mitigation plan was required.

The towns of Surf City and North Topsail Beach are the non-Federal cost sharing sponsors. Cost sharing is applied in accordance with the provisions of Section 103 of the Water Resources Development Act (WRDA) of 1986, as amended by Section 215 of WRDA 1999. The Federal share of the total first cost of initial construction would be about $80,038,000 (65 percent) and the non-Federal share would be about $43,097,000 (35 percent). The cost of lands, easements, rights-of-way, relocations, and dredged or excavated material disposal sites (LERRD) is estimated at $4,814,000, all of which is eligible for LERRD credit. Based on WRDA 1996, as amended, subject to the availability of funds and conditions of public ownership and use of the shore, the Federal and non-Federal share of the renourishment costs is 50 percent, resulting in a total renourishment cost of about $102,769,500 each. The Town of Surf City and the Town of North Topsail Beach are legally capable of fulfilling the requirements for being the non-Federal sponsors.

The Office of Management and Budget (OMB) advises that there is no objection to the submission of the report to Congress and concludes that the report recommendation is consistent with the policy and programs of the President. A copy of its letter is enclosed. I am providing a copy of this transmittal and the OMB letter dated, March 25, 2011 to the House Committee on Appropriations Subcommittee on Energy and Water Development, and the House Committee on Transportation and Infrastructure Subcommittee on Water Resources and Environment.

Very truly yours,



Jo-Ellen Darcy
Assistant Secretary of the Army
(Civil Works)

Enclosures

11 Enclosures

1. Record of Decision, dated, April XX, 2011
2. OMB Clearance Letter, dated, March 25, 2011
3. Report of the Chief of Engineers, Dec 30, 2010
4. DOI letter to USACE, Nov 8, 2010
5. EPA letter to USACE, Nov 8, 2010
6. USDA letter to USACE, dated Nov 4, 2010
7. DOC letter, dated Nov 23, 2010
8. State of North Carolina integrated agency comments, dated Nov 5, 2010
9. Letter from North Topsail Beach, dated July 20, 2010
10. Letter from the Town of Surf City, dated July 19, 2010
11. Surf City and North Topsail Beach, North Carolina Coastal Storm Damage Reduction Report

RECORD OF DECISION

Surf City and North Topsail Beach, North Carolina
Coastal Storm Damage Reduction Project
Pender and Onslow Counties, North Carolina

The Final Integrated Feasibility Report and Environmental Impact Statement (FEIS), dated December 2010, addresses coastal storm damage reduction at Surf City and North Topsail Beach, North Carolina. Based on the report, the reviews of other Federal, State, and local agencies, input from the public, and the review by my staff, I find the plan recommended by the Chief of Engineers to be technically feasible, economically justified, in accordance with environmental statutes, and in the public interest. Thus, I approve the Surf City and North Topsail Beach project for construction.

The report documents the evaluation of various structural and non-structural alternatives to address the coastal storm damage reduction needs of Surf City and North Topsail Beach, North Carolina. The recommended plan is the National Economic Development plan and consists of a dune and berm system constructed of sand from offshore borrow sites. The selected plan consists of the following major features:

- A sand dune and beach berm system that extends along about 52,150 feet of Atlantic Ocean shorefront.
- Construction of the dune to an elevation of 15 feet above the National Geodetic Vertical Datum (NGVD). The dune will be vegetated and 60 walkover structures will be constructed.
- Construction of the 50-foot wide beach berm waterward of the dune to an elevation of 7 feet above NGVD.
- Renourishment of the system on approximately six-year intervals.
- Material for the initial construction and the renourishment cycles will be dredged from borrow sites located from one to six miles off shore.

In addition to a "no action" alternative, structural and non-structural measures for coastal storm damage reduction as well as borrow material sources were evaluated. The structural measures selected for detailed evaluation and consideration were various configurations of beachfill. Non-structural measures included retreat, relocation and demolition. These measures were considered independently and in combinations with each other to develop alternative plans.

The project is designed to reduce damage mainly from storm waves and storm-induced erosion, two major categories of storm damage. Compared to the future without-project condition, the recommended plan would reduce average annual storm damage by about 88 percent. Some wave and erosion damage would still occur over the 50-year project life. The project would not prevent damage from back bay flooding;

therefore, any ground-level floors of structures, ground-level floor contents, vehicles, landscaping, and property stored outdoors would remain subject to saltwater flooding from the back bay.

The Draft Feasibility Report and Draft Environmental Impact Statement were circulated for public review for 45 days in January 2010. All comments submitted were responded to in the FEIS. All practicable means to avoid or minimize adverse environmental effects have been incorporated into the recommended plan including future renourishment intervals. No compensatory mitigation is required. The recommended plan is the environmentally preferred alternative.

Technical, environmental, economic, and risk criteria used in the formulation of alternative plans were those specified in the Water Resource Council's Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies. All applicable laws, Executive Orders, regulations and local government plans were considered in the evaluation of alternatives. Based on review of these evaluations, I find that the public interest would be best served by implementing the recommended plan. This Record of Decision completes the National Environmental Policy Act process.

Date: APR 13 2011

Jo-Ellen Darcy
Assistant Secretary of the Army
(Civil Works)

03/28/2011 08:02 FAX 202 395 3049 E S D 002

EXECUTIVE OFFICE OF THE PRESIDENT
OFFICE OF MANAGEMENT AND BUDGET
WASHINGTON, D.C. 20503

March 25, 2011

The Honorable Jo-Ellen Darcy
Assistant Secretary of the Army (Civil Works)
108 Army Pentagon, Room 3E446
Washington, D.C. 20310-0108

Dear Ms. Darcy:

As required by Executive Order 12322, the Office of Management and Budget has completed its review of the Surf City and North Topsail Beach, North Carolina, coastal storm damage reduction project.

Our review found that the project is consistent with the policy and programs of the President. The Office of Management and Budget does not object to you submitting the report to Congress for authorization.

Sincerely,

Richard A. Mertens
Deputy Associate Director
Energy, Science, and Water

DEPARTMENT OF THE ARMY
OFFICE OF THE CHIEF OF ENGINEERS
WASHINGTON, D.C. 20314-1000

CECW-SAD (1105-2-10a)

DEC 30 2010

SUBJECT: Surf City and North Topsail Beach, North Carolina Coastal Storm Damage Reduction Report

THE SECRETARY OF THE ARMY

1. I submit for transmission my report on coastal storm damage reduction along the Atlantic Ocean shoreline of the towns of Surf City and North Topsail Beach, North Carolina. It is accompanied by the report of the district and division engineers. These reports are in response to two resolutions by the Committee on Transportation and Infrastructure of the House of Representatives, adopted on February 16, 2000 and April 11, 2000. The resolutions requested a review of the report of the Chief of Engineers on West Onslow Beach and New River Inlet, North Carolina, and other pertinent reports, to determine whether any modifications of the recommendations contained therein are advisable at the present time in the interest of shore protection and related purposes for Surf City and North Topsail Beach, North Carolina. Preconstruction engineering and design activities for this project will be continued under the authority provided by the resolutions cited above.

2. The reporting officers recommend authorization for a plan to reduce coastal storm damages by construction of a berm and dune along the Surf City and North Topsail Beach shorelines. The recommended plan includes a 52,150-foot long dune and berm system to be constructed to an elevation of 15 feet National Geodetic Vertical Datum (NGVD) fronted by a seven-foot NGVD (50-foot wide) beach berm with a main fill length of 52,150 feet, extending from the boundary between Topsail Beach and Surf City to the southern edge of the Coastal Barrier Resources Act (CBRA) Zone in North Topsail Beach. The recommended plan also includes renourishment at six-year intervals. Other associated features of the project are dune vegetation and construction of 60 dune walkover structures. Material for the dune and berm construction and renourishment will be dredged from borrow sites identified between one to six miles off the coast of Topsail Island. The recommended plan also includes post-construction monitoring over the period of Federal participation to ensure project performance and adjust renourishment plans as needed. Since the recommended plan would not have any significant adverse effects, no mitigation measures (beyond management practices and avoidance) or compensation measures would be required. The recommended plan is the National Economic Development (NED) Plan for coastal storm damage reduction.

3. The Towns of Surf City and North Topsail Beach are the non-Federal cost-sharing sponsors for all features. Based on October 2010 price levels the estimated total first cost of the plan is

$123,135,000. Renourishment is planned at six-year intervals. There will be seven renourishments with a total cost estimated at October 2010 price levels to be $205,539,000. The ultimate project cost, which includes initial construction, monitoring, and periodic renourishment is estimated to be $353,924,000. Cost sharing is applied in accordance with the provisions of Section 103 of the Water Resources Development Act (WRDA) of 1986, as amended by Section 215 of WRDA 1999. Additional access points and nearby public parking will be necessary to meet the requirements for federal cost sharing; the sponsors anticipate no obstacles to develop such additional access and parking. The Federal and non-Federal shares shown below reflect anticipated development and satisfaction of access and parking requirements, but the final cost-share amounts will be based upon the conditions of public access, parking, development and use of the shore at the time when the Project Partnership Agreement (PPA) is signed.

a. The Federal share of the total first cost would be about $80,038,000 (65 percent) and the non-Federal share would be about $43,097,000 (35 percent).

b. The cost of lands, easements, rights-of-way, relocations, and dredged or excavated material disposal areas (LERRD) is estimated at $4,814,000, all of which is eligible for LERRD credit.

c. The Federal share of the total renourishment cost would be about $102,769,500 (50 percent) and the non-Federal share would be about $102,769,500 (50 percent).

4. Based on a 4.125 percent discount rate and a 50-year period of analysis, the total equivalent average annual costs of the project are estimated to be $10,702,000, including monitoring and OMRR&R. All project costs are allocated to the authorized purpose of coastal storm damage reduction. The equivalent average annual benefits, which include recreation benefits, are estimated to be $40,129,000 with net average annual benefits of $29,427,000. The benefit cost ratio is approximately 3.7 to 1.

5. The goals and objectives included in the Campaign Plan of the U.S. Army Corps of Engineers have been fully integrated into the Surf City and North Topsail Beach study process. The project contains adaptive management measures through an annual project monitoring program in order to be able to reevaluate and adjust the periodic renourishment actions. The study was conducted using a systems perspective that considered the effects of other Federal (West Onslow and New River Inlet [Topsail Beach] Coastal Storm Damage Reduction study, New River and New Topsail Inlet Navigation features) and non-Federal projects in the area, particularly as related to borrow volume availability. A statistical, risk based model was used to formulate and evaluate the project. The study report fully describes risks associated with residual coastal storm damages and risks that will not be reduced, such as sound side flooding and wind damages. The project is intended to address erosion and prevent damages to structures and contents; it is not intended to

nor will it reduce the risk to loss of life during major storm events. Loss of life can only be prevented by the existing procedure of evacuating the barrier island completely well before expected hurricane landfall, thus removing people from harm's way. This study recommends continuation of the evacuation policy both with and without the project. Additional institutional nonstructural measures to be implemented by the local governments are contained in the study report recommendation. The selected plan would reduce average annual coastal storm damages by about 88 percent and would leave average annual damages estimated at $2,241,000. These residual risks have been communicated to both the Towns of Surf City and North Topsail Beach.

6. In accordance with the Corps Engineering Circular EC 1165-2-211 on sea level change, the study performed a sensitivity analysis to look at the economic effects that different rates of accelerated sea level rise could have on the recommended plan. The plan was formulated using a historical or low rate of sea level rise, and the sensitivity analysis used additional accelerated rates, which includes what the EC defines as medium and high rates. The sensitivity analysis indicates that at higher rates of sea level rise, the project costs increase; the project benefits however, increase even more.

7. In accordance with the Corps Engineering Circular EC 1165-2-209 on review of decision documents, all technical, engineering and scientific work underwent an open, dynamic and vigorous review process to ensure technical quality. This included an independent Agency Technical Review (ATR) and an Independent External Peer Review (IEPR). The IEPR was managed by an outside eligible organization (Battelle) that assembled a panel of five experts with combined expertise in the fields of geotechnical and coastal engineering, plan formulation, environment/biology, economics, and recreation analysis. Ultimately, the panel identified and documented sixteen comments. Eight of the panel comments were classified as having high significance. These comments raised questions regarding various aspects of the coastal and non-structural analysis in the report, the availability of sufficient borrow material for the life of the project, and the methods used to determine property values in the economic analysis. Based on these comments, the report's coastal appendix was greatly expanded. To address the concern regarding borrow volume availability, additional analysis was conducted and the discussion in the report regarding risks and uncertainty in borrow availability was expanded. Also information regarding the economic feasibility of obtaining additional borrow material if the currently identified borrow sites were to be depleted in the latter years of the project was added. The panel did not concur with this last response and maintained that the plan formulation should still have been constrained by borrow availability due to uncertainty. I have considered the borrow availability issue and concluded it has been appropriately addressed in the project's risk management plan through the identification of additional sites with similar borrow cost and volume to mitigate the uncertainty. Even though uncertainty remains regarding utilization of specific borrow sites, the recommendation is viable and economically justifiable. Overall the reviews have resulted in the improvement of the technical quality of the report including the enhanced communication of risk and uncertainty.

8. The United States Army Corps of Engineers Headquarters review indicates that the project recommended by the reporting officers is technically sound, environmentally and socially acceptable, and economically justified. The goal to reduce loss of life is incorporated into this project but it is a shared responsibility that can never be completely mitigated by structural solutions. Discussion in the report emphasizes that residual risk will remain after this project is executed; it also, emphasizes the roles of all partners in addressing and communicating residual risk to the public, including the need for a well coordinated hurricane storm warning and evacuation plan. The plan complies with all essential elements of the U.S. Water Resources Council's Economic and Environmental Principles and Guidelines for Water and Land Related Resources implementation studies and complies with other administrative and legislative policies and guidelines.

9. I concur in the findings, conclusions, and recommendations of the reporting officers. Accordingly, I recommend that the plan to reduce coastal storm damages for Surf City and North Topsail Beach, North Carolina be authorized in accordance with the reporting officers recommended plan at an October 2010 estimated initial cost of $123,135,000 with such modifications as in the discretion of the Chief of Engineers may be advisable. My recommendation is subject to cost sharing, financing, and other applicable requirements of Federal and State laws and policies, including Section 103 of the Water Resources Development Act (WRDA) of 1986, as amended by Section 215 of WRDA 1999. The non-Federal sponsors would provide the non-Federal cost share and all LERRD. Further, the non-Federal sponsors would be responsible for all Operation and Maintenance, Repair, Replacement and Rehabilitation (OMRR&R). This recommendation is subject to the non-Federal sponsors agreeing to comply with all applicable Federal laws and policies and in accordance with the required items of cooperation, and agreeing prior to project implementation, to perform as follows:

a. Provide 35 percent of initial project costs assigned to coastal storm damage reduction, plus 50 percent of initial project costs assigned to reducing damages to undeveloped public lands, plus 50 percent of initial project costs assigned to recreation, plus 100 percent of initial project costs assigned to reducing damages to undeveloped private lands and other private shores that do not provide public benefits; and 50 percent of periodic nourishment costs assigned to hurricane and storm damage reduction, plus 100 percent of periodic nourishment costs assigned to reducing damages to undeveloped private lands and other private shores that do not provide public benefits and as further specified below:

(1) Provide 25 percent of design costs in accordance with the terms of a design agreement entered into prior to commencement of design work for the project.

(2) Provide, during the first year of construction, any additional funds needed to cover the non-Federal share of design costs.

(3) Provide all lands, easements, and rights-of-way, and perform or ensure the performance of all relocations determined by the Federal Government to be necessary for the initial construction, periodic nourishment, operation, and maintenance of the project.

(4) Provide, during construction, any additional amounts as are necessary to make it total contribution equal to 35 percent of initial project costs assigned to coastal storm damage reduction, plus 50 percent of initial project costs assigned to reducing damages to undeveloped public lands, plus 50 percent of initial project costs assigned to recreation, plus 100 percent of initial project costs assigned to reducing damages to undeveloped private lands and other private shores that do not provide public benefits; and 50 percent of periodic nourishment costs assigned to hurricane and storm damage reduction, plus 100 percent of periodic nourishment costs assigned to reducing damages to undeveloped private lands and other private shores that do not provide public benefits.

b. Operate, maintain, repair, rehabilitate and replace the completed project, or functional portion of the project, at no cost to the Federal Government, in a manner compatible with the project's authorized purposes and in accordance with applicable Federal and State laws and regulations and any specific directions prescribed by the Federal Government.

c. Give the Federal Government a right to enter, at reasonable times and in a reasonable manner, on property that the non-Federal sponsors, now or hereafter, owns or controls for access to the project for the purpose of inspecting, operating, maintaining, repairing, replacing, rehabilitating, or completing the project. OMRR&R by the Federal Government will not relieve the non-Federal sponsors of responsibility to meet the non-Federal sponsors' obligations, or to preclude the Federal Government from pursuing any other remedy at law or equity to ensure faithful performance.

d. Hold and save the United States free from all damages arising from the initial construction, periodic nourishment, OMRR&R of the project and any project related betterments, except for damages due to the fault or negligence of the United States or its contractors.

e. Keep and maintain books, records, documents, and other evidence pertaining to costs and expenses incurred pursuant to the project, for a minimum of three years after completion of the accounting for which such books, records, documents, and other evidence is required, to the extent and in such detail as will properly reflect total costs of construction of the project, and in accordance with the standards for financial management systems set forth in the Uniform Administrative Requirements for Grants and Cooperative Agreements to State and Local Governments at 32 CFR 33.20.

f. Perform, or cause to be performed, any investigations for hazardous substances that are determined necessary to identify the existence and extent of any hazardous substances regulated under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), P.L. 96-510, as amended, 42 U.S.C. 9601–9675, that may exist in, on, or under lands, easements, or rights-of-way that the Federal Government determines to be required for the initial construction, periodic nourishment, operation, and maintenance of the project. However, for lands that the Federal Government determines to be subject to the navigation servitude, only the Federal Government will perform such investigations unless the Federal Government provides the non-Federal sponsors with prior specific written direction, in which case, the non-Federal sponsors will perform such investigations in accordance with such written direction.

g. Assume, as between the Federal Government and the non-Federal sponsors, complete financial responsibility for all necessary cleanup and response costs of any CERCLA-regulated materials in, on, or under lands, easements, or rights-of-way that the Federal Government determines to be necessary for the initial construction, periodic nourishment, operation, or maintenance of the project.

h. Agree that, as between the Federal Government and the non-Federal sponsors, the non-Federal sponsor will be considered the operators of the project for the purpose of CERCLA liability, and to the maximum extent practicable, operate, maintain, and repair the project in a manner that will not cause liability to arise under CERCLA.

i. Comply with the applicable provisions of the Uniform Relocation Assistance and Real Property Acquisition Policies Act of 1970, P.L. 91-646, as amended by (42 U.S.C. 4601–4655), and the Uniform Regulations contained in 49 CFR Part 24, in acquiring lands, easements, and rights-of-way required for the initial construction, periodic nourishment, operation, and maintenance of the project, including those necessary for relocations, borrow materials, and dredged or excavated material disposal, and inform all affected persons of applicable benefits, policies, and procedures in connection with that Act.

j. Comply with all applicable Federal and State laws and regulations, including section 601 of the Civil Rights Act of 1964, P.L. 88-352 (42 U.S.C. 2000d), Department of Defense Directive 5500.11 issued pursuant thereto, as well as Army Regulation 600-7, titled *Nondiscrimination on the Basis of Handicap in Programs and Activities Assisted or Conducted by the Department of the Army*, and all applicable Federal labor standards and requirements, including, 40 U.S.C. 3141–3148 and 40 U.S.C. 3701–3708 (revising, codifying, and enacting without substantial change the provisions of the Davis-Bacon Act (formerly 40 U.S.C. 276a *et seq.*), the Contract Work Hours and Safety Standards Act (formerly 40 U.S.C. 327 *et seq.*) and the Copeland Anti-Kickback Act (formerly 40 U.S.C. 276c *et seq.*).

k. Comply with section 402 of the WRDA of 1986, as amended (33 U.S.C. 701b-12), which requires the non-Federal interest to participate in and comply with applicable Federal floodplain management and flood insurance programs, prepare a floodplain management plan within one year after the date of signing a PPA, and implement the plan no later than one year after project construction is complete.

l. Provide the non-Federal share of that portion of the costs of data recovery activities associated with historic preservation, that are in excess of 1 percent of the total amount authorized to be appropriated for the project, in accordance with the cost-sharing provisions of the agreement.

m. Participate in and comply with applicable Federal floodplain management and flood insurance programs.

n. Do not use Federal funds to meet the non-Federal sponsors' share of total project costs unless the Federal granting agency verifies in writing that the expenditure of such funds is authorized.

o. Prevent obstructions of or encroachment on the project (including prescribing and enforcing regulations to prevent such obstructions or encroachments), which might reduce the level of damage reduction it affords, hinder operation and maintenance or future periodic nourishment, or interfere with its proper function, such as any new developments on project lands or the addition of facilities that would degrade the benefits of the project.

p. Not less than once each year, inform affected interests of the extent of damage reduction afforded by the project.

q. Publicize floodplain information in the area concerned and provide such information to zoning and other regulatory agencies for their use in preventing unwise future development in the floodplain and in adopting such regulations as might be necessary to prevent unwise future development and to ensure compatibility with damage reduction levels provided by the project.

r. For so long as the project remains authorized, the non-Federal sponsors must ensure continued conditions of public ownership, access, and use of the shore on which the amount of Federal participation is based.

s. Provide and maintain necessary access roads, parking areas, and other public use facilities, open and available to all on equal terms.

CECW-SAD (1105-2-10a)
SUBJECT: Surf City and North Topsail Beach, North Carolina Coastal Storm Damage Reduction Report

t. At least twice annually and after storm events, perform surveillance of the beach to determine losses of nourishment material from the project design section and provide the results of such surveillance to the Federal Government.

u. Comply with section 221 of P.L. 91-611, Flood Control Act of 1970, as amended (42 U.S.C. 1962d-5b), and section 103(j) of the WRDA of 1986, P.L. 99-662, as amended (33 U.S.C. 2213(j)), which provides that the Secretary of the Army must not commence the construction of any water resources project or separable element thereof, until the non-Federal interests have entered into a written agreement to furnish its required cooperation for the project or separable element.

10. The recommendation contained herein reflects the information available at this time and current departmental policies governing formulation of individual projects. It does not reflect program and budgeting priorities inherent in the formulation of a national civil works construction program or the perspective of higher review levels within the executive branch. Consequently, the recommendation may be modified before it is transmitted to the Congress as a proposal for authorization and implementation funding. However, prior to transmittal to Congress, the sponsors, the State, interested Federal agencies, and other parties will be advised of any significant modifications and will be afforded an opportunity to comment further.

R. L. VAN ANTWERP
Lieutenant General, US Army
Chief of Engineers

United States Department of the Interior

OFFICE OF THE SECRETARY
Washington, D.C. 20240

9043.1
PEP/NRM

NOV 8 2010

ER 10/849

Mr. Theodore A. Brown, P.E.
Chief, Planning and Policy Division
Directorate of Civil Works
Headquarters
U.S. Army Corps of Engineers
CECW-P (SA)
7701 Telegraph Road
Alexandria, VA 22315-3860

RE: Thirty--Day Review of Chief of Engineers Proposed Report, on Surf City and North Topsail Beach, NC

Dear Mr. Brown:

The U. S. Department of the Interior (Department) has reviewed the U. S. Army Corps of Engineers (USACE), Chief of Engineers Proposed Report on Surf City and North Topsail Beach, North Carolina.

The Department has no comments and no objections to the proposed project. We appreciate the opportunity to review the Chief of Engineers Proposed Report and supporting documents.

Sincerely,

Willie R. Taylor
Director, Office of Environmental Policy
and Compliance

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION 4
SAM NUNN
ATLANTA FEDERAL CENTER
61 FORSYTH STREET
ATLANTA GEORGIA 30303-8960

November 8, 2010

Scott Nicholson
Office of Water Project Review
Planning and Policy Division
U.S. Army Corps of Engineers
Washington, DC 20002

Subject: **Comments on the Final Integrated Feasibility Report and the Final Environmental Impact Statement (FEIS) for the Surf City and North Topsail Beach Project To Evaluate Coastal Storm Damage Reduction, Topsail Island, Pender and Onslow Counties, North Carolina FEIS Filed Date: 09/30/2010; CEQ Federal Register Date: 10/08/2010 CEQ Number: 20100391; ERP Number: COE-E39079-NC**

Dear Mr. Nicholson:

Pursuant to Section 309 of the Clean Air Act (CAA) and Section 102(2)(C) of the National Environmental Policy Act (NEPA), the U.S. Environmental Protection Agency (EPA) Region 4 has reviewed the combined Final Integrated Feasibility Report and Final Environmental Impact Statement (FEIS) for the proposed Coastal Storm Damage Reduction Project for Surf City and North Topsail Beach, North Carolina, which we received on 10/4/2010. The combined report was issued by the Wilmington District of the U.S. Army Corps of Engineers (Corps), and was intended to comply with the National Environmental Policy Act (NEPA), and therefore a separate EIS was not provided. The final document that we were provided has been termed "a fully-integrated report" that is intended to comply with all NEPA requirements, as well as the requirements of the Corps (and Federal) water resources planning process. EPA previously provided a comment letter on 2/24/2010 to the Wilmington District Project Manager (Mr. Glenn McIntosh) regarding the Draft version of the Integrated Feasibility Report and the Draft EIS (DEIS: CEQ Number: 20100010, ERP Number COE-E39079-NC).

EPA understands that the Wilmington District conducted a Civil Works Review Board (CWRB) with Corps Headquarters on 8/27/2010. The main purpose of the CWRB was to gain approval from HQ for release of the Final Integrated Feasibility Report and FEIS for Agency and Public review. We further understand that the purpose of the

combined Final Integrated Feasibility Report and FEIS is to evaluate coastal storm damage reduction for the Towns of Surf City and North Topsail Beach, NC, and then "develop the most suitable plan of damage reduction for the present and future conditions" for the selected 50-year period of analysis. Topsail Island is on the southeastern North Carolina coast, and (from south to north) the three towns on the island are Topsail Beach, Surf City and North Topsail Beach. The primary study area for the report we reviewed includes the towns of Surf City and North Topsail Beach and the associated nearby borrow sites. We understand that this report was authorized by two U.S. House Committee on Transportation and Infrastructure resolutions dated February 16, 2000 and April 11, 2000, and that a General Reevaluation Report has recently been completed for the Town of Topsail Beach under a separate authority.

The Wilmington District study team appropriately included representatives of Federal, State, and local governments, in an effort "to identify cost-effective and environmentally- and technically-sound alternatives to reduce damages within the two towns, and to the adjacent shoreline." The process integrated the Corps' "Campaign Plan" in all aspects of the study process, and "in particular, the study meets Goal 2 of the Campaign Plan, which is to deliver enduring and essential water resource solutions through collaboration with partners and stakeholders." The study effort ultimately identified a National Economic Development (NED) plan, which the Corps hopes will maximize net benefits through reduction of future storm damages. EPA understands that the Corps' recommended plan of action is construction of the NED Plan. The study we reviewed discloses what the Corps believes to be the most practicable plan of damage reduction for the primary study area: a berm and dune project along approximately 10 miles of the oceanfront. The southern limit of the project is the boundary between Topsail Beach and Surf City, and the northern limit is within North Topsail Beach at the southern edge of the Coastal Barrier Resources System (Topsail Unit, L06).

The final report appropriately included a stated "purpose and need" for the project, to include the "reduction of damages associated with coastal storm events and beach erosion," as well as "enhancing the beach strand available for recreation use and providing needed habitat for a variety of plants and animals." The final report also appropriately included an analysis of various measures and plans, and then recommended selection of the plan with the highest net benefits while determining that the improvement is justified under current planning criteria and policies. The selected NED Plan consists of a sand dune system constructed to an elevation of 15 feet above the National Geodetic Vertical Datum (NGVD), fronted by a 50-foot wide beach berm constructed to an elevation of 7 feet above NGVD, with the berm and dune extending along a reach of 52,150 feet in length (about 10 miles). This plan is identified among the other alternatives as "Plan 1550."

EPA understands that the report followed detailed guidance provided in the U.S. Army Corps of Engineers Planning Guidance Notebook (Engineer Regulation 1105-2-100) for studies of water and related land resources. This guidance is "based upon the Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies that were developed pursuant to Section 103 of the

Water Resources Planning Act.(P.L. 89-80) and Executive Order 11747, which were approved by the U.S. Water Resources Council in 1982 and by the President in 1983." EPA notes that the final report also references a number of prior studies conducted in the Topsail Island area, including engineering, planning, and environmental reports. These studies have addressed coastal storm damage reduction as well as navigational needs.

An economic analysis was appropriately conducted as part of the study, and a Benefit/Cost Ratio has been calculated (BCR = 3.5 to 1) for the recommended plan (based upon October 2010 price levels). First costs of the project are currently estimated at $127,973,000, and renourishment costs at 6-year intervals are estimated at $30,612,000. Expected annual costs are estimated at $11,585,000, with expected annual benefits estimated at $40,779,000 of which $17,275,000 are coastal storm damage reduction benefits, $20,505,000 are recreation benefits, and $2,999,000 are benefits during construction. The baseline cost estimate for construction in fiscal year (FY) 2015 is $133,255,000, and details on first costs, annual costs, annual and net benefits, and benefit cost ratios made at October 2010 price levels are shown in the final report.

The following are EPA's draft version comments and follow-up FEIS comments to updated information found in the Final Integrated Feasibility Report/Final EIS:

➢ EPA noted in our 2/24/2010 DEIS comment letter that we were at that time reviewing the Final Environmental Impact Statement (FEIS) for the proposed project adjacent to this one, known officially as the "Relocation of New River Inlet Ebb Tide Channel Between North Topsail Beach and Onslow Beach, and the Placement of the Dredged Material Along the Ocean Shoreline of North Topsail Beach in Onslow County, NC." The Corps has responded in this FEIS that our review has been acknowledged and that no change is required. EPA has since completed our review of the FEIS for the adjacent project and we sent our comments to Wilmington District Project Manager Mickey Sugg on 3/5/2010. A copy of those comments is included with this transmittal for your reference.

➢ EPA noted in our 2/24/2010 DEIS comment letter that the Sponsors have reportedly agreed to provide public access and parking in accordance with Corps guidelines as public funds are being expended. We understand that public access and parking will be installed at "intervals of no more than a half mile, throughout Surf City and the reach of North Topsail Beach benefitted by the cost-shared project." EPA recommended that the FEIS include an excerpt(s) from the Corps guidelines about public access and parking to ensure that the project interval "of no more than a half mile" meets these guidelines. The Corps reported in the FEIS that the Guidance simply states that parking should be available within a "reasonable walking distance of the beach" and should be sufficient to "accommodate the lesser of the peak hour demand or the beach capacity". We understand that the "half mile" guidelines were established by Wilmington District in coordination with the South Atlantic Division (SAD). EPA recommends that the Record of Decision (ROD) include information on whether the "no more than a half mile" standard for spacing is the same for all coastal Corps districts in SAD.

➢ EPA noted in our 2/24/2010 DEIS comment letter that the Council on Environmental Quality (CEQ) regulations (40 CFR 1502.15) require an EIS to describe the environment of the areas to be affected (or created) by the alternatives under consideration. The data and analysis in the DEIS were generally found to be commensurate with the importance of the impacts, although EPA still had some general concerns about the potential impacts from use of a hopper dredge on marine threatened and endangered resources (e.g., such as the potential for entrainment of sea turtles associated with hopper dredges). EPA had specific concerns about the project's impacts to the green sea turtle, loggerhead sea turtle, Kemp's ridley sea turtle, and the leatherback sea turtle, which are all known to nest in the project vicinity. These species could be affected by initial project construction and periodic renourishment, and the sea turtles that occur in offshore waters may be affected by hopper dredges. EPA strongly recommended initial construction and periodic renourishment activities not be conducted during the sea turtle nesting season. Further, EPA recommended that hopper dredging not be conducted during months when water temperatures are warm and the various turtle species may be present. The FEIS acknowledges our DEIS comments related to the project's impacts on turtles, and included information in Section 3.02.4 of Appendix I (Biological Assessment) that discusses in detail the potential impacts of the proposed action on nesting and in-water sea turtles, proposed commitments to reduce impacts, and subsequent effect determination. EPA notes that Section 4.00 of the FEIS ("Commitments To Reduce Impacts To Listed Species") includes specific commitments to avoid the sea turtle nesting season. EPA appreciates the inclusion of these detailed sections in the FEIS. Our only comment on the FEIS related to this topic is that we recommend that the USFWS compaction measurement guidelines be carefully followed, in particular those related to the compaction measurement of 500 PSI establishing the maximum level of beach hardness and determining when post-nourishment beach tilling should be done to reduce the shear resistance.

➢ EPA noted in our 2/24/2010 DEIS comment letter that we continue to have concerns about the project's impacts to the piping plover, which has been documented to feed along the 10-mile project reach. During the winter months the piping plover has been documented to be found in the surf zone. EPA strongly recommended the development and implementation of stringent construction criteria to ensure that the project does not affect the piping plover's foraging activities on the beach. EPA noted that we are particularly concerned that the piping plover's beach food resources may be affected by beachfill operations. The FEIS acknowledges our DEIS comments and includes in the FEIS the Section 3.02.8 of Appendix I (Biological Assessment), which provides a detailed discussion of the potential impacts of the proposed action on piping plovers and their foraging activities and subsequent effect determination. EPA concurs that beach placement of sand for this project during initial construction (and each periodic nourishment interval) should be scheduled to avoid the breeding and nesting season as well as peak recruitment periods for benthic invertebrate forage base. EPA concurs that the long-term effects of the project may restore lost roosting and nesting habitat through the addition of beach fill, and we recommend that the Corps seek to minimize the short-term impacts to foraging, sheltering, roosting habitat that occur during project construction.

➢ EPA recommended in our 2/24/2010 DEIS comment letter that the U.S. Fish and Wildlife Service and the National Marine Fisheries Service review and provide recent concurrence letters (to be included in the FEIS) regarding the adequacy of the Biological Assessment (BA) developed for this project pursuant to Section 7 (of the Endangered Species Act of 1973) and presented with the draft report. The FEIS notes that Corps concurs with our recommendation, and we understand that USFWS and NMFS have reviewed the draft report and have provided their concurrence letters regarding the adequacy of the BA pursuant to Section 7 of the ESA. Specifically, the USFWS has indicated that "overall, based on the information provided in the DEIS and BA, the USFWS believes that the proposed action is not likely to adversely affect federally listed species or their critical habitat as defined by the ESA of 1973, as amended. Therefore, the requirements of Section 7 (a)(2) of the ESA have been satisfied." The NMFS also reportedly agrees with the Corps' determination that the proposed beach renourishment action, consisting (in part) of utilizing hopper dredges to mine offshore sand sources for deposition of sand onto North Carolina beaches (a 17-mile section extending from Topsail Beach/Surf City town limits to the northern end of Topsail Island) falls under the authority of the current NMFS South Atlantic Regional Biological Opinion (SARBO) on hopper dredging of navigation channels and borrow areas in the southeastern United States, dated 9/25/1997. EPA understands that the SARBO is in the process of being revised and will eventually supersede the current opinion. EPA recommends that the Corps abide by the revised SARBO when it is ultimately issued, and we understand that sea turtle or shortnose sturgeon takes resulting from the proposed dredging action are authorized if conducted under the SARBO, and will be counted against the take limit as set forth in the SARBO.

➢ EPA noted in our 2/24/2010 DEIS comment letter that we were reviewing the FEIS for the adjacent project known as the "Relocation of New River Inlet Ebb Tide Channel Between North Topsail Beach and Onslow Beach, and the Placement of the Dredged Material Along the Ocean Shoreline of North Topsail Beach in Onslow County, NC." That FEIS describes a plan by the Town of North Topsail Beach to develop a non-Federal coastal storm damage reduction project for the parts of the town that lie within the Coastal Barrier Resources System (Topsail Unit, L06). EPA recommended careful coordination between the two projects to ensure that there are no conflicts between the Federal and non-Federal projects, either on the shoreline or in the borrow areas. EPA noted that the Corps has committed that, in the event that the non-Federal project is not in place when the Federal project begins, then the northern 2,000 ft of the dune and berm system would be replaced with a transition section. We asked that the FEIS include specific engineering details about what this 2,000 ft transition section would look like and how it would affect the overall NED Plan. The FEIS notes the Corps concurs with our recommendation for coordination between the two projects "to ensure that there are no conflicts between the Federal and non-Federal projects, either on the shoreline or in the borrow areas." EPA notes that the Corps did not provide specific engineering and design details about the transition section in the FEIS, as these are reportedly not to be completed "until the PED (Pre-Construction Engineering and Design) phase of the

study." EPA requests that a copy of these transition section details be provided to us when they are complete.

➢ EPA noted in our 2/24/2010 DEIS comment letter that an Agency Technical Review (ATR) was to be conducted in accordance with the Corps' "Peer Review of Decision Documents" process, meaning the proposed project would be reviewed by Corps staff outside the originating office, conducted by a "regional and national team of experts in the field, and coordinated by the National Planning Center of Expertise in Coastal Storm Damage Reduction, North Atlantic Division, U.S. Army Corps of Engineers." EPA recommended that the FEIS include all comments and responses developed as part of the ATR process. The Corps has apparently decided to withhold the ATR comments from inclusion in the FEIS, as "the Corps does not believe it will add to the report to include these comments with the report." EPA disagrees with this decision to withhold these comments, particularly since these comments were made by a regional and national team of federal experts in the field of storm damage reduction. We believe publishing these would have added significant value to the FEIS. Both EPA and the Public have significant interest in the ATR's expert comments on this federally funded project, and in the spirit of complete disclosure required by NEPA, both these comments and the Corps' responses should have been included as an appendix to the FEIS.

➢ EPA noted in our 2/24/2010 DEIS comment letter that an "Independent External Peer Review" (IEPR) was to be conducted (following the ATR) by a "non-USACE national team of experts in the field, and coordinated by the National Planning Center of Expertise in Coastal Storm Damage Reduction, North Atlantic Division, U.S. Army Corps of Engineers." EPA recommended that the FEIS include all comments and responses developed as part of the IEPR process. The FEIS states that the "IEPR comments and USACE responses are made public separately from the publication of the FEIS." As these are part of the NEPA process, EPA recommends that both the IEPR and the ATR comments and Corps responses be included as appendices to the ROD.

➢ EPA noted in our 2/24/2010 DEIS comment letter that CEQ regulations (40 CFR 1502.14(a)) require that an EIS "rigorously explore and objectively evaluate all reasonable alternatives" for a proposed action. The regulations (40 CFR 1502.14(b)) further require that substantial treatment be made of each alternative considered in detail, including the proposed action. The draft report appropriately notes that study team considered both structural and non-structural measures. EPA recommended that the FEIS include complete details on the nonstructural measures that were considered, such as removal and relocation, as well as final summaries of the economic analyses (using recent economic data) that found these nonstructural measures to have greater costs than benefits. The Corps concurred with our recommendation, and we noted that details on the non-structural analysis were provided in Appendix P of the FEIS.

➢ EPA noted in our 2/24/2010 DEIS comment letter that the DEIS appropriately assessed project risk, uncertainty, and consequences, and generally described these with sufficient detail so that that "decisions can be made with knowledge of the degree of reliability of the estimated benefits and costs and of the effectiveness of alternative

plans." EPA concurs that all recommendations made in the FEIS should be capable of being implemented through adaptive management should future conditions warrant such. EPA concurs that "renourishment may be needed more often or less often, depending on the occurrence of large storms and accompanying erosion."

➢ EPA noted in our 2/24/2010 DEIS comment letter that to avoid conflicts, the project should be coordinated with monitoring efforts led by the North Carolina Recreational Water Quality Program (NCRWQ), which regularly tests these coastal waters in order to protect public health by monitoring and notifying the public when bacteriological standards for safe bodily contact are exceeded. EPA also recommended that the project should be coordinated with the North Carolina Department of Environmental and Natural Resources, Division of Environmental Health, Shellfish Sanitation Section, which is also continually monitoring and classifying these coastal waters as to their suitability for shellfish harvesting for human consumption. The FEIS concurs and states that prior to commencement of construction activities, the Corps will coordinate with the NCWRQ as well as the NCDENR, shellfish sanitation section, and that "appropriate requirements will be incorporated into the project plans and specifications."

➢ EPA noted in our 2/24/2010 DEIS comment letter that the main channel of the Atlantic Intracoastal Waterway (AIWW) in North Carolina has been maintained by dredging for over 70 years to remove shoals that periodically develop. Some of the dredged material removed during maintenance activities is reported to be high quality beach sand. This material has been placed directly on nearby ocean beaches, or stockpiled in confined disposal areas near the shoreline of the AIWW. Other area sand sources are from dredging activities in the New Topsail Inlet and Connecting Channels, as well as the New River Inlet. EPA recommended that these sand sources be considered for renourishment activities for the 10-mile long project reach. The FEIS responded that "material available from the AIWW would be a very small amount compared to the size of the project, and would not be cost-effective for placement on Surf City/North Topsail Beach." EPA notes that information about this has been added to section 5.06.3 of the FEIS ("Borrow Site Comparisons").

➢ EPA recommended in our 2/24/2010 DEIS comment letter that the FEIS should include complete supporting geotechnical information, especially representative boring logs and/or grain size analysis plots from soil borings conducted in the finalized borrow areas. EPA notes that details on geotechnical information were included in Appendix C of the FEIS.

➢ EPA recommends in our 2/24/2010 DEIS comment letter that that areas with extensive hard bottom area and/or relatively low volumes of beach compatible material be ruled out as potential sources of borrow material for this project, and that final selection of borrow areas should be based upon high volumes of accessible, beach quality sands. We recommended rigorous delineation of all hard bottom resources within each prospective borrow area before commencement of work in order to avoid potential impacts to hard bottom resources (particularly from hopper dredging activities). The

State of North Carolina's hard bottom buffer rule language requires that dredging should not be conducted "on or within 500 meters of significant biological communities, such as high relief hard bottom areas." EPA supports the Corps' efforts to use divers to conduct ground truth confirmation in the potential borrow areas, as well as collecting sediment samples, conducting video documentation, and employing sidescan technology, all for the purpose of assisting with hardbottom avoidance. EPA concurs with the inclusion in the FEIS the statement that "during the planning process borrow areas with extensive hard bottom and/or relatively low volumes of beach compatible material were ruled out as potential sources of borrow material for this project. Specifically, borrow areas I, K, M, and R were excluded as noted in Figure A-1 of the report. Additional borrow area refinement will occur during the PED stage of the study." EPA notes that specific discussion of hard bottom within the proposed borrow areas as well as potential impacts and associated buffers and avoidance measures are discussed in Sections 2.01.10 and 8.01.8.2 of the report. EPA notes that Section 2.01.10 of the FEIS includes information on the geophysical investigation that was conducted to identify hard bottom presence and delineate hard bottom that was identified in and near several borrow areas. Hard-bottom buffers of 500 meters (1,640 ft.) were established for high- and moderate-relief hard bottom and 122 meters (400 ft.) were established for low relief hard bottom.

➢ EPA recommends in our 2/24/2010 DEIS comment letter that we support the on-going characterization of potential borrow areas during all 4 seasons in order to determine if there are significant differences in species composition and diversity for each sampling period. The FEIS does not include any information on whether this recommendation will be implemented.

➢ EPA recommends in our 2/24/2010 DEIS comment letter that the FEIS should cite North Carolina Division of Marine Fisheries (NCDMF) commercial finfish and shellfish updated data. EPA notes that Section 2.04.3 of the FEIS has been updated to include the North Carolina Division of Marine Fisheries (NCDMF) commercial finfish and shellfish updated data from 2009.

➢ EPA recommends in our 2/24/2010 DEIS comment letter the FEIS should discuss efforts to protect the 937-foot long Surf City Ocean Pier during construction, as it is apparently located within the proposed beach fill area. The FEIS notes that during Planning Engineering and Design (PED) and prior to construction, the Corps "will evaluate potential construction related concerns associated with placement of beach fill within the vicinity of the Surf City Ocean Pier."

➢ EPA notes in our 2/24/2010 DEIS comment letter that the DEIS has a section reporting on the Administration's position on funding of coastal storm damage reduction projects. As this report was under development in 2008, we requested this be clarified (e.g., the current Administration?). We understand that the Office of Management and Budget (OMB) advises that "while the Water Resources Development Act of 1999 (WRDA 99) changed the cost-sharing formula for the long-term sand renourishment component of certain future shore protection projects," these changes did not go far enough considering the long-term cost of most of these projects. Further, because

WRDA 99 delayed the effect of the change in cost sharing for up to a decade or more, it reportedly "did not address current constraints on Federal spending," and therefore the Administration intends to work with Congress to address these problems. However, EPA understands that until these issues are satisfactorily resolved, there will be no authorization of new shore protection projects "that involve significant long-term Federal investments beyond the initial construction of these projects, and will give new shore protection projects that are already authorized low priority for funding." EPA notes that language regarding the "Administration's position" has been removed from the FEIS. EPA also notes the FEIS shows that Project Authorization under WRDA is projected for December 2010. Please keep us informed when this occurs.

➢ EPA recommends in our 2/24/2010 DEIS comment letter that finalized mitigation measures should be presented in the FEIS, to include specific measures recommended by U.S. Fish and Wildlife Service (USFWS) and National Marine Fisheries Service (NMFS) for protection of all threatened and endangered species. EPA recommended that the finalized mitigation plan should include specific finalized protocols to be employed should any sea turtles be encountered during the dredging activity. EPA notes that the FEIS concurs with our recommendation, and that FEIS Appendix T states that "all planning considerations and final mitigation measures recommended by the Corps and other state and federal resource agencies, including measures recommended by the USFWS and NMFS for protection of threatened and endangered species, have been included in Table 7.1 and Section 10.06.1 of the main report as well as Section 4.00 of Appendix I." EPA notes that this should read Table 7.2 ("Project Commitments"), not Table 7.1 ("Summary of total costs and net benefits used for the selection of the project renourishment interval"). Finally, EPA recommends that the development of specific monitoring plans (i.e. hard bottom sedimentation monitoring and benthic invertebrate monitoring), as identified in the list of commitments to reduce environmental impacts, be coordinated with our agency, as well as other state and federal resource agencies prior to implementation.

Thank you for the opportunity to provide comments on this final report. We appreciate the responses in the FEIS to our concerns about the project's impacts on marine and threatened and endangered resources, and we recommend that any remaining issues should be addressed in the ROD. If you wish to discuss these comments or have any other questions, please contact me at (404) 562-9611 (mueller.heinz@epa.gov) or Paul Gagliano, P.E., of my staff at (404) 562-9373 (gagliano.paul@.epa.gov).

Sincerely,



Heinz J. Mueller, Chief
NEPA Program Office
Office of Policy and Management

Attachment:

EPA Comments (3/5/2010) on the Final Environmental Impact Statement (FEIS) for the Relocation of New River Inlet Ebb Tide Channel Between North Topsail Beach and Onslow Beach, and the Placement of the Dredged Material Along the Ocean Shoreline of North Topsail Beach in Onslow County, NC; CEQ Number: 20100025; ERP Number: COE-E30043-NC

cc Doug Piatkowski
U.S. Army Corps of Engineers
69 Darlington Avenue
Wilmington NC 28403

Patricia (Trish) Bee
Program Analyst
HQ - U.S. Army Corps of Engineers
Office of Water Project Review

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION 4
ATLANTA FEDERAL CENTER
61 FORSYTH STREET
ATLANTA, GEORGIA 30303-8960

March 5, 2010

Mr. Mickey Sugg
Project Manager
Wilmington Regulatory Field Office
U.S. Army COE of Engineers
Post Office Box 1890
Wilmington, North Carolina 28402-1890

Subject: **Comments on the Final Environmental Impact Statement (FEIS) for the Relocation of New River Inlet Ebb Tide Channel Between North Topsail Beach and Onslow Beach, and the Placement of the Dredged Material Along the Ocean Shoreline of North Topsail Beach in Onslow County, NC; CEQ Number: 20100025; ERP Number: COE-E30043-NC**

Dear Mr. Sugg:

Pursuant to Section 309 of the Clean Air Act (CAA) and Section 102(2)(C) of the National Environmental Policy Act (NEPA), the U.S. Environmental Protection Agency (EPA) Region 4 has reviewed the "Final Environmental Impact Statement (FEIS) for the Relocation of New River Inlet Ebb Tide Channel Between North Topsail Beach and Onslow Beach, and the Placement of the Dredged Material Along the Ocean Shoreline of North Topsail Beach in Onslow County, NC," which EPA received on February 11, 2010. The FEIS report was issued by the Wilmington District of the United States Army Corps of Engineers (COE), and was intended to comply with the National Environmental Policy Act (NEPA). EPA previously commented by letter dated February 11, 2008 to Colonel Pulliam, Commander of the Wilmington District, on the Draft Environmental Impact Statement (DEIS) for this project. The public commenting period on the FEIS will reportedly end on March 1, 2010.

EPA understands that this FEIS was developed in conjunction with the Town of North Topsail Beach's request for Department of the Army authorization, pursuant to Section 404 of the Clean Water Act and Section 10 of the Rivers and Harbor Act, to "protect residential homes and town infrastructures by nourishing approximately 11.1 miles of beachfront via repositioning the New River Inlet channel, implementing an inlet management plan to control the positioning of the new inlet channel, and utilizing an offshore borrow area." The new channel will be centrally located and the proposal will be to maintain that position, which "essentially will be located perpendicular to the adjacent shorelines of North Topsail Beach and Onslow Beach." The proposed sources of the material for the beach nourishment will come from the repositioning of the inlet and an identified offshore borrow area. The projected amount of material needed to initially nourish the oceanfront shoreline is approximately 3.11 million cubic yards. The placement of beach fill along the Town's shoreline would result in the initial widening of

the beach by 50 to 100 feet. The widened beach is to be maintained through a program of periodic beach nourishment events with the material extracted from the maintenance of the newly relocated channel. All work will reportedly be accomplished using a hydraulic cutterhead dredge. The proposed project construction will be conducted "in a five phase approach to correspond with the Town's anticipated annual generation of funds."

The ocean shoreline of the Town of North Topsail Beach measures approximately 11.1 miles along the northern end of Topsail Island, with approximately 7.25 miles of the shoreline contained within the project area except for two small areas located within the Coastal Barrier Resource System (CBRS). Those areas within the CBRS are banned by law from receiving federal funds for use on projects that would encourage development. The channel through New River Inlet has been maintained by the COE for commercial and recreational boating interest for over 55 years, and the COE is authorized by law to maintain the navigation channel in the inlet "to a depth of 6 feet mean low water (mlw) over a width of 90 feet, following the channel thalweg."

The Town of North Topsail Beach has proposed to fund the nourishment of the oceanfront shoreline and reposition New River Inlet channel as a means "to address a severe erosion problem in order to preserve the Town's tax base, protect its infrastructure, and maintain its tourist oriented economy." EPA notes that the entire stretch of the Town's shoreline has experienced a considerable amount of erosion over the last 20 years due primarily to the impact of numerous tropical storms and hurricanes during the mid to late 1990's and due to impacts of the shifting of the main ebb channel in New River Inlet. The Town believes that the shoreline erosion and residual effects of the storms have left North Topsail Beach in "an extremely vulnerable position with regard to its ocean front development and infrastructure," and the community has estimated that "over $250 million in property tax value as well as roads, water and sewer lines, and other utilities are at risk."

EPA notes that the FEIS' stated purpose and need for this project includes eight (8) elements:

(1) Long-term stabilization of the oceanfront shoreline located immediately south of New River Inlet;
(2) Providing short-term protection to 31 imminently threatened residential structures over the next five years;
(3) Providing long-term protection to the Town's infrastructure and approximately 1,200 homes;
(4) Reducing or mitigating for property damage associated with shoreline erosion along 11.1 miles of oceanfront shoreline of North Topsail Beach;
(5) Improving recreational opportunities along the Town's oceanfront shoreline;
(6) Ensuring all material utilized for shore protection is beach compatible;
(7) Maintaining the Town's tax base by protecting existing development and infrastructure on the oceanfront shoreline of North Topsail Beach;
(8) Balancing the needs of the human environment by minimizing and avoiding adverse effects to natural resources.

In "Appendix A, Subpart 4: Response to Comments" of the FEIS, the COE responds to the 31 comments on the DEIS that our agency provided by letter on February 22, 2008. The following are our comments and the remaining issues that EPA has identified as continuing concerns:

- The FEIS states that impacts of historic rates of rise in sea level "are implicitly included in the historic shoreline change data used to formulate the shoreline and inlet management plan for North Topsail Beach. The historic rate of rise in sea level applicable to the project area is 1.25 feet per century." The reference for the COE's projected 1.25 feet per century rise in sea level should be provided with this comment.
- Council on Environmental Quality (CEQ) regulations (40 CFR 1502.14(a)) require that an EIS is to "rigorously explore and objectively evaluate all reasonable alternatives" for a proposed action. The regulations (40 CFR 1502.14(b)) further require that substantial treatment be made of each alternative considered in detail, including the proposed action. EPA previously commented on the seven (7) alternatives presented in the DEIS including the No Action alternative. Because of the lengthy duration of the activities, it was unclear to our agency whether the COE has latitude in its authorizations or permitting of the project. EPA was concerned that this would become "an all or nothing approval of the project rather than a provision for interim mid-course review at an appropriate juncture." The FEIS states that it is anticipated that the record of decision (ROD) as determined by the COE "will include result in an appropriate permit including relevant permit conditions." Please provide a clarification on what the ROD will include.
- EPA previously commented on the Alternative 7 presented in the DEIS, which involves the construction of a terminal groin on the north end of North Topsail. This alternative was apparently eliminated because it is inconsistent with the State's coastal policies. Our agency commented that the COE should have considered other more innovative structural options that might be found suitable, including temporary subaqueous structures or wave baffles to modify the hydrodynamics and sand movement, or methods to lessen the wave energy at the eroded beach areas. The FEIS states that "hardened structures, including terminal groins, are currently illegal within the State of North Carolina." The COE should include the relevant citation from the state code.
- EPA previously suggested an investigation of whether remedial action on Onslow Beach would offer a long-term benefit to North Topsail Beach, as Onslow appears to provide better habitat quality than does North Topsail. The data presented in the DEIS indicated substantially greater erosion along Onslow Beach, with a trend towards an increasing rate of beach loss. The FEIS states that the U.S. Marine Corps (USMC), which controls Onslow Beach, "was a participant in the Project Delivery Team process and is fully aware of the potential impacts of the project on Onslow Beach." During the initial stages of the plan formulation process the plan reportedly included the placement of mitigation beach fill on the southern end of Onslow Beach to counter the predicted impacts, but the USMC "was not in favor of nourishing Onslow Beach as that activity was deemed to potentially have

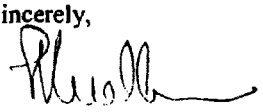
a negative impact on piping plover habitat, namely, an overwash area located on the south end of the island." Please provide a reference (and include) any communications from the USMC to the COE on this issue.

- The FEIS reports that the identified borrow source lies outside areas preliminary identified by the COE for the federal storm damage reduction project being evaluated for the southern end of North Topsail Beach and the town of Surf City which lies south of North Topsail Beach. Please provide a reference and include all copies of the most recent communication(s) with state and federal resource agencies regarding the selected offshore borrow area, which will reportedly eliminate adverse impacts on the offshore hardbottom resources.
- As mentioned previously, EPA is also currently reviewing the EIS developed for the adjacent project known as the "Draft Integrated Feasibility Report and Environmental Impact Statement for Coastal Storm Damage Reduction for Surf City and North Topsail Beach, North Carolina." This EIS evaluates coastal storm damage reductions for the Towns of Surf City and North Topsail Beach, NC, and then develops "the most suitable plan of damage reduction for the present and future conditions" for the selected 50-year period of analysis. The primary study area includes the towns of Surf City and North Topsail Beach and the associated nearby borrow sites. It describes a tentatively selected NED Plan that consists of a sand dune system constructed to an elevation of 15 feet above NGVD, fronted by a 50-foot wide beach berm constructed to an elevation of 7 feet above NGVD, with the berm and dune extending along a reach of 52,150 feet in length (about 10 miles). EPA recommends careful coordination to ensure that there are no conflicts between the federal and non-federal projects, either on the shoreline or in the borrow areas. The Draft Integrated Feasibility Report and Environmental Impact Statement states that in the event that the non-federal project is not in place when the federal project begins, then the northern 2,000 feet of the dune and berm system will be replaced with a transition section.
- The FEIS states that "in the absence of maintenance dredging, controlling depths over the outer edge of the ebb tide delta of New River Inlet would likely vary between 2 and 4 feet below MLW depending on antecedent tide and wave conditions." Please provide a citation or reference with this statement.
- To avoid conflicts, the project should be coordinated with monitoring efforts led by the North Carolina Recreational Water Quality Program (NCRWQ), which regularly tests these coastal waters in order to protect public health by monitoring and notifying the public when bacteriological standards for safe bodily contact are exceeded. Also, the project should be coordinated with the North Carolina Department of Environmental and Natural Resources, Division of Environmental Health, Shellfish Sanitation Section, which is also continually monitoring and classifying these coastal waters as to their suitability for shellfish harvesting for human consumption.
- Finally, CEQ regulations (40 CFR 1502.15) require an EIS to describe the environment of the areas to be affected (or created) by the alternatives under consideration. The data and analysis in the FEIS were found to be commensurate with the significance of the impacts, although EPA still has some general concerns about the potential impacts from dredging on marine threatened and

endangered resources, particularly if plans change and hopper dredges are eventually used. At present all work is tentatively planned to be accomplished using a hydraulic cutterhead dredge.

Thank you for the opportunity to provide comments on this FEIS. EPA rates this FEIS as EC-2, we have some environmental concerns and have requested additional information. If you wish to discuss these comments or have any other questions, please contact me at (404) 562-9611 (mueller.heinz@epa.gov) or Paul Gagliano, P.E., of my staff at (404) 562-9373 (gagliano.paul@epa.gov).

Sincerely,



Heinz J. Mueller, Chief
NEPA Program Office
Office of Policy and Management

Water Resources Planning Act (P.L. 89-80) and Executive Order 11747, which were approved by the U.S. Water Resources Council in 1982 and by the President in 1983." EPA notes that the final report also references a number of prior studies conducted in the Topsail Island area, including engineering, planning, and environmental reports. These studies have addressed coastal storm damage reduction as well as navigational needs.

An economic analysis was appropriately conducted as part of the study, and a Benefit/Cost Ratio has been calculated (BCR = 3.5 to 1) for the recommended plan (based upon October 2010 price levels). First costs of the project are currently estimated at $127,973,000, and renourishment costs at 6-year intervals are estimated at $30,612,000. Expected annual costs are estimated at $11,585,000, with expected annual benefits estimated at $40,779,000 of which $17,275,000 are coastal storm damage reduction benefits, $20,505,000 are recreation benefits, and $2,999,000 are benefits during construction. The baseline cost estimate for construction in fiscal year (FY) 2015 is $133,255,000, and details on first costs, annual costs, annual and net benefits, and benefit cost ratios made at October 2010 price levels are shown in the final report.

The following are EPA's draft version comments and follow-up FEIS comments to updated information found in the Final Integrated Feasibility Report/Final EIS:

1. ➢ EPA noted in our 2/24/2010 DEIS comment letter that we were at that time reviewing the Final Environmental Impact Statement (FEIS) for the proposed project adjacent to this one, known officially as the "Relocation of New River Inlet Ebb Tide Channel Between North Topsail Beach and Onslow Beach, and the Placement of the Dredged Material Along the Ocean Shoreline of North Topsail Beach in Onslow County, NC." The Corps has responded in this FEIS that our review has been acknowledged and that no change is required. EPA has since completed our review of the FEIS for the adjacent project and we sent our comments to Wilmington District Project Manager Mickey Sugg on 3/5/2010. A copy of those comments is included with this transmittal for your reference.

2. ➢ EPA noted in our 2/24/2010 DEIS comment letter that the Sponsors have reportedly agreed to provide public access and parking in accordance with Corps guidelines as public funds are being expended. We understand that public access and parking will be installed at "intervals of no more than a half mile, throughout Surf City and the reach of North Topsail Beach benefitted by the cost-shared project." EPA recommended that the FEIS include an excerpt(s) from the Corps guidelines about public access and parking to ensure that the project interval "of no more than a half mile" meets these guidelines. The Corps reported in the FEIS that the Guidance simply states that parking should be available within a "reasonable walking distance of the beach" and should be sufficient to "accommodate the lesser of the peak hour demand or the beach capacity". We understand that the "half mile" guidelines were established by Wilmington District in coordination with the South Atlantic Division (SAD). EPA recommends that the Record of Decision (ROD) include information on whether the "no more than a half mile" standard for spacing is the same for all coastal Corps districts in SAD.

3. ➢ EPA noted in our 2/24/2010 DEIS comment letter that the Council on Environmental Quality (CEQ) regulations (40 CFR 1502.15) require an EIS to describe the environment of the areas to be affected (or created) by the alternatives under consideration. The data and analysis in the DEIS were generally found to be commensurate with the importance of the impacts, although EPA still had some general concerns about the potential impacts from use of a hopper dredge on marine threatened and endangered resources (e.g., such as the potential for entrainment of sea turtles associated with hopper dredges). EPA had specific concerns about the project's impacts to the green sea turtle, loggerhead sea turtle, Kemp's ridley sea turtle, and the leatherback sea turtle, which are all known to nest in the project vicinity. These species could be affected by initial project construction and periodic renourishment, and the sea turtles that occur in offshore waters may be affected by hopper dredges. EPA strongly recommended initial construction and periodic renourishment activities not be conducted during the sea turtle nesting season. Further, EPA recommended that hopper dredging not be conducted during months when water temperatures are warm and the various turtle species may be present. The FEIS acknowledges our DEIS comments related to the project's impacts on turtles, and included information in Section 3.02.4 of Appendix I (Biological Assessment) that discusses in detail the potential impacts of the proposed action on nesting and in-water sea turtles, proposed commitments to reduce impacts, and subsequent effect determination. EPA notes that Section 4.00 of the FEIS ("Commitments To Reduce Impacts To Listed Species") includes specific commitments to avoid the sea turtle nesting season. EPA appreciates the inclusion of these detailed sections in the FEIS. Our only comment on the FEIS related to this topic is that we recommend that the USFWS compaction measurement guidelines be carefully followed, in particular those related to the compaction measurement of 500 PSI establishing the maximum level of beach hardness and determining when post-nourishment beach tilling should be done to reduce the shear resistance.

4. ➢ EPA noted in our 2/24/2010 DEIS comment letter that we continue to have concerns about the project's impacts to the piping plover, which has been documented to feed along the 10-mile project reach. During the winter months the piping plover has been documented to be found in the surf zone. EPA strongly recommended the development and implementation of stringent construction criteria to ensure that the project does not affect the piping plover's foraging activities on the beach. EPA noted that we are particularly concerned that the piping plover's beach food resources may be affected by beachfill operations. The FEIS acknowledges our DEIS comments and includes in the FEIS the Section 3.02.8 of Appendix I (Biological Assessment), which provides a detailed discussion of the potential impacts of the proposed action on piping plovers and their foraging activities and subsequent effect determination. EPA concurs that beach placement of sand for this project during initial construction (and each periodic nourishment interval) should be scheduled to avoid the breeding and nesting season as well as peak recruitment periods for benthic invertebrate forage base. EPA concurs that the long-term effects of the project may restore lost roosting and nesting habitat through the addition of beach fill, and we recommend that the Corps seek to minimize the short-term impacts to foraging, sheltering, roosting habitat that occur during project construction.

5. ➢ EPA recommended in our 2/24/2010 DEIS comment letter that the U.S. Fish and Wildlife Service and the National Marine Fisheries Service review and provide recent concurrence letters (to be included in the FEIS) regarding the adequacy of the Biological Assessment (BA) developed for this project pursuant to Section 7 (of the Endangered Species Act of 1973) and presented with the draft report. The FEIS notes that Corps concurs with our recommendation, and we understand that USFWS and NMFS have reviewed the draft report and have provided their concurrence letters regarding the adequacy of the BA pursuant to Section 7 of the ESA. Specifically, the USFWS has indicated that "overall, based on the information provided in the DEIS and BA, the USFWS believes that the proposed action is not likely to adversely affect federally listed species or their critical habitat as defined by the ESA of 1973, as amended. Therefore, the requirements of Section 7 (a)(2) of the ESA have been satisfied." The NMFS also reportedly agrees with the Corps' determination that the proposed beach renourishment action, consisting (in part) of utilizing hopper dredges to mine offshore sand sources for deposition of sand onto North Carolina beaches (a 17-mile section extending from Topsail Beach/Surf City town limits to the northern end of Topsail Island) falls under the authority of the current NMFS South Atlantic Regional Biological Opinion (SARBO) on hopper dredging of navigation channels and borrow areas in the southeastern United States, dated 9/25/1997. EPA understands that the SARBO is in the process of being revised and will eventually supersede the current opinion. EPA recommends that the Corps abide by the revised SARBO when it is ultimately issued, and we understand that sea turtle or shortnose sturgeon takes resulting from the proposed dredging action are authorized if conducted under the SARBO, and will be counted against the take limit as set forth in the SARBO.

6. ➢ EPA noted in our 2/24/2010 DEIS comment letter that we were reviewing the FEIS for the adjacent project known as the "Relocation of New River Inlet Ebb Tide Channel Between North Topsail Beach and Onslow Beach, and the Placement of the Dredged Material Along the Ocean Shoreline of North Topsail Beach in Onslow County, NC." That FEIS describes a plan by the Town of North Topsail Beach to develop a non-Federal coastal storm damage reduction project for the parts of the town that lie within the Coastal Barrier Resources System (Topsail Unit, L06). EPA recommended careful coordination between the two projects to ensure that there are no conflicts between the Federal and non-Federal projects, either on the shoreline or in the borrow areas. EPA noted that the Corps has committed that, in the event that the non-Federal project is not in place when the Federal project begins, then the northern 2,000 ft of the dune and berm system would be replaced with a transition section. We asked that the FEIS include specific engineering details about what this 2,000 ft transition section would look like and how it would affect the overall NED Plan. The FEIS notes the Corps concurs with our recommendation for coordination between the two projects "to ensure that there are no conflicts between the Federal and non-Federal projects, either on the shoreline or in the borrow areas." EPA notes that the Corps did not provide specific engineering and design details about the transition section in the FEIS, as these are reportedly not to be completed "until the PED (Pre-Construction Engineering and Design) phase of the

study." EPA requests that a copy of these transition section details be provided to us when they are complete.

7. ➢ EPA noted in our 2/24/2010 DEIS comment letter that an Agency Technical Review (ATR) was to be conducted in accordance with the Corps' "Peer Review of Decision Documents" process, meaning the proposed project would be reviewed by Corps staff outside the originating office, conducted by a "regional and national team of experts in the field, and coordinated by the National Planning Center of Expertise in Coastal Storm Damage Reduction, North Atlantic Division, U.S. Army Corps of Engineers." EPA recommended that the FEIS include all comments and responses developed as part of the ATR process. The Corps has apparently decided to withhold the ATR comments from inclusion in the FEIS, as "the Corps does not believe it will add to the report to include these comments with the report." EPA disagrees with this decision to withhold these comments, particularly since these comments were made by a regional and national team of federal experts in the field of storm damage reduction. We believe publishing these would have added significant value to the FEIS. Both EPA and the Public have significant interest in the ATR's expert comments on this federally funded project, and in the spirit of complete disclosure required by NEPA, both these comments and the Corps' responses should have been included as an appendix to the FEIS.

8. ➢ EPA noted in our 2/24/2010 DEIS comment letter that an "Independent External Peer Review" (IEPR) was to be conducted (following the ATR) by a "non-USACE national team of experts in the field, and coordinated by the National Planning Center of Expertise in Coastal Storm Damage Reduction, North Atlantic Division, U.S. Army Corps of Engineers." EPA recommended that the FEIS include all comments and responses developed as part of the IEPR process. The FEIS states that the "IEPR comments and USACE responses are made public separately from the publication of the FEIS." As these are part of the NEPA process, EPA recommends that both the IEPR and the ATR comments and Corps responses be included as appendices to the ROD.

9. ➢ EPA noted in our 2/24/2010 DEIS comment letter that CEQ regulations (40 CFR 1502.14(a)) require that an EIS "rigorously explore and objectively evaluate all reasonable alternatives" for a proposed action. The regulations (40 CFR 1502.14(b)) further require that substantial treatment be made of each alternative considered in detail, including the proposed action. The draft report appropriately notes that study team considered both structural and non-structural measures. EPA recommended that the FEIS include complete details on the nonstructural measures that were considered, such as removal and relocation, as well as final summaries of the economic analyses (using recent economic data) that found these nonstructural measures to have greater costs than benefits. The Corps concurred with our recommendation, and we noted that details on the non-structural analysis were provided in Appendix P of the FEIS.

10. ➢ EPA noted in our 2/24/2010 DEIS comment letter that the DEIS appropriately assessed project risk, uncertainty, and consequences, and generally described these with sufficient detail so that that "decisions can be made with knowledge of the degree of reliability of the estimated benefits and costs and of the effectiveness of alternative

plans." EPA concurs that all recommendations made in the FEIS should be capable of being implemented through adaptive management should future conditions warrant such. EPA concurs that "renourishment may be needed more often or less often, depending on the occurrence of large storms and accompanying erosion."

11. ➢ EPA noted in our 2/24/2010 DEIS comment letter that to avoid conflicts, the project should be coordinated with monitoring efforts led by the North Carolina Recreational Water Quality Program (NCRWQ), which regularly tests these coastal waters in order to protect public health by monitoring and notifying the public when bacteriological standards for safe bodily contact are exceeded. EPA also recommended that the project should be coordinated with the North Carolina Department of Environmental and Natural Resources, Division of Environmental Health, Shellfish Sanitation Section, which is also continually monitoring and classifying these coastal waters as to their suitability for shellfish harvesting for human consumption. The FEIS concurs and states that prior to commencement of construction activities, the Corps will coordinate with the NCWRQ as well as the NCDENR, shellfish sanitation section, and that "appropriate requirements will be incorporated into the project plans and specifications."

12. ➢ EPA noted in our 2/24/2010 DEIS comment letter that the main channel of the Atlantic Intracoastal Waterway (AIWW) in North Carolina has been maintained by dredging for over 70 years to remove shoals that periodically develop. Some of the dredged material removed during maintenance activities is reported to be high quality beach sand. This material has been placed directly on nearby ocean beaches, or stockpiled in confined disposal areas near the shoreline of the AIWW. Other area sand sources are from dredging activities in the New Topsail Inlet and Connecting Channels, as well as the New River Inlet. EPA recommended that these sand sources be considered for renourishment activities for the 10-mile long project reach. The FEIS responded that "material available from the AIWW would be a very small amount compared to the size of the project, and would not be cost-effective for placement on Surf City/North Topsail Beach." EPA notes that information about this has been added to section 5.06.3 of the FEIS ("Borrow Site Comparisons").

13. ➢ EPA recommended in our 2/24/2010 DEIS comment letter that the FEIS should include complete supporting geotechnical information, especially representative boring logs and/or grain size analysis plots from soil borings conducted in the finalized borrow areas. EPA notes that details on geotechnical information were included in Appendix C of the FEIS.

14 ➢ EPA recommends in our 2/24/2010 DEIS comment letter that that areas with extensive hard bottom area and/or relatively low volumes of beach compatible material be ruled out as potential sources of borrow material for this project, and that final selection of borrow areas should be based upon high volumes of accessible, beach quality sands. We recommended rigorous delineation of all hard bottom resources within each prospective borrow area before commencement of work in order to avoid potential impacts to hard bottom resources (particularly from hopper dredging activities). The

State of North Carolina's hard bottom buffer rule language requires that dredging should not be conducted "on or within 500 meters of significant biological communities, such as high relief hard bottom areas." EPA supports the Corps' efforts to use divers to conduct ground truth confirmation in the potential borrow areas, as well as collecting sediment samples, conducting video documentation, and employing sidescan technology, all for the purpose of assisting with hardbottom avoidance. EPA concurs with the inclusion in the FEIS the statement that "during the planning process borrow areas with extensive hard bottom and/or relatively low volumes of beach compatible material were ruled out as potential sources of borrow material for this project. Specifically, borrow areas I, K, M, and R were excluded as noted in Figure A-1 of the report. Additional borrow area refinement will occur during the PED stage of the study." EPA notes that specific discussion of hard bottom within the proposed borrow areas as well as potential impacts and associated buffers and avoidance measures are discussed in Sections 2.01.10 and 8.01.8.2 of the report. EPA notes that Section 2.01.10 of the FEIS includes information on the geophysical investigation that was conducted to identify hard bottom presence and delineate hard bottom that was identified in and near several borrow areas. Hard-bottom buffers of 500 meters (1,640 ft.) were established for high- and moderate-relief hard bottom and 122 meters (400 ft.) were established for low relief hard bottom.

15. ➢ EPA recommends in our 2/24/2010 DEIS comment letter that we support the on-going characterization of potential borrow areas during all 4 seasons in order to determine if there are significant differences in species composition and diversity for each sampling period. The FEIS does not include any information on whether this recommendation will be implemented.

16. ➢ EPA recommends in our 2/24/2010 DEIS comment letter that the FEIS should cite North Carolina Division of Marine Fisheries (NCDMF) commercial finfish and shellfish updated data. EPA notes that Section 2.04.3 of the FEIS has been updated to include the North Carolina Division of Marine Fisheries (NCDMF) commercial finfish and shellfish updated data from 2009.

17. ➢ EPA recommends in our 2/24/2010 DEIS comment letter the FEIS should discuss efforts to protect the 937-foot long Surf City Ocean Pier during construction, as it is apparently located within the proposed beach fill area. The FEIS notes that during Planning Engineering and Design (PED) and prior to construction, the Corps "will evaluate potential construction related concerns associated with placement of beach fill within the vicinity of the Surf City Ocean Pier."

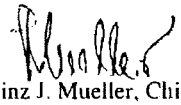
18. ➢ EPA notes in our 2/24/2010 DEIS comment letter that the DEIS has a section reporting on the Administration's position on funding of coastal storm damage reduction projects. As this report was under development in 2008, we requested this be clarified (e.g., the current Administration?). We understand that the Office of Management and Budget (OMB) advises that "while the Water Resources Development Act of 1999 (WRDA 99) changed the cost-sharing formula for the long-term sand renourishment component of certain future shore protection projects," these changes did not go far enough considering the long-term cost of most of these projects. Further, because

WRDA 99 delayed the effect of the change in cost sharing for up to a decade or more, it reportedly "did not address current constraints on Federal spending," and therefore the Administration intends to work with Congress to address these problems. However, EPA understands that until these issues are satisfactorily resolved, there will be no authorization of new shore protection projects "that involve significant long-term Federal investments beyond the initial construction of these projects, and will give new shore protection projects that are already authorized low priority for funding." EPA notes that language regarding the "Administration's position" has been removed from the FEIS. EPA also notes the FEIS shows that Project Authorization under WRDA is projected for December 2010. Please keep us informed when this occurs.

19. ➢ EPA recommends in our 2/24/2010 DEIS comment letter that finalized mitigation measures should be presented in the FEIS, to include specific measures recommended by U.S. Fish and Wildlife Service (USFWS) and National Marine Fisheries Service (NMFS) for protection of all threatened and endangered species. EPA recommended that the finalized mitigation plan should include specific finalized protocols to be employed should any sea turtles be encountered during the dredging activity. EPA notes that the FEIS concurs with our recommendation, and that FEIS Appendix T states that "all planning considerations and final mitigation measures recommended by the Corps and other state and federal resource agencies, including measures recommended by the USFWS and NMFS for protection of threatened and endangered species, have been included in Table 7.1 and Section 10.06.1 of the main report as well as Section 4.00 of Appendix I." EPA notes that this should read Table 7.2 ("Project Commitments"), not Table 7.1 ("Summary of total costs and net benefits used for the selection of the project renourishment interval"). Finally, EPA recommends that the development of specific monitoring plans (i.e. hard bottom sedimentation monitoring and benthic invertebrate monitoring), as identified in the list of commitments to reduce environmental impacts, be coordinated with our agency, as well as other state and federal resource agencies prior to implementation.

Thank you for the opportunity to provide comments on this final report. We appreciate the responses in the FEIS to our concerns about the project's impacts on marine and threatened and endangered resources, and we recommend that any remaining issues should be addressed in the ROD. If you wish to discuss these comments or have any other questions, please contact me at (404) 562-9611 (mueller.heinz@epa.gov) or Paul Gagliano, P.E., of my staff at (404) 562-9373 (gagliano.paul@.epa.gov).

Sincerely,



Heinz J. Mueller, Chief
NEPA Program Office
Office of Policy and Management

United States Department of Agriculture

NRCS

Natural Resources Conservation Service
4407 Bland Road, Suite 117
Raleigh, North Carolina 27609

Michael J. Hinton, ASTC-Easements & WR
Fax: (919) 873-2103
Fax: (919) 873-2156
Email: mike.hinton@nc.usda.gov

November 4, 2010

Headquarters
U. S. Army Corps of Engineers
CECW-P (SA)
7701 Telegraph Road
Alexandria, VA 22315-3860

ATTN: Theodore A. Brown, P. E.
Chief, Planning and Policy Division

Dear Mr. Brown:

Thank you for the opportunity to provide comments on the proposed reports and the Final Environmental Impact Statement for the Surf City and North Topsail Beach, North Carolina Coastal Storm Damage Reduction project.

The Natural Resources Conservation Service does not have any comments at this time.

If you need additional information, please feel free to contact me at (919) 873-2103.

Sincerely,

Michael J. Hinton
Assistant State Conservationist for Easements & Water Resources

Helping People Help the Land

An Equal Opportunity Provider and Employer

UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL MARINE FISHERIES SERVICE

Southeast Regional Office
263 13th Avenue South
St. Petersburg, Florida 33701-5505
(727) 824-5317; FAX (727) 824-5300
http://sero.nmfs.noaa.gov/

November 23, 2010 F/SER4:RS/pw

(Sent via electronic mail)

Colonel Jefferson Ryscavage, Commander
Wilmington District U.S. Army Corps of Engineers
P.O. Box 1890
Wilmington, North Carolina 28402-1890

Attention: Jan.P.Brodmerkel@usace.army.mil

Dear Colonel Ryscavage:

NOAA's National Marine Fisheries Service (NMFS) reviewed "Integrated Final Report and Final Environment Impact Statement (EIS) for Coastal Damage Reduction, Surf City and North Topsail Beach," dated August 2010, prepared by the Wilmington District, US Army Corps of Engineers. The Final EIS evaluates options for reducing erosion along the shoreline of the Town of Surf City and the Town of North Topsail Beach on Topsail Island, Pender and Onslow Counties. The FEIS includes a preferred plan and a determination that the proposed action would not have a significant adverse impact on essential fish habitat (EFH) and associated species. As the nation's federal trustee for the conservation and management of marine, estuarine, and anadromous fishery resources, the following comments and recommendations are provided pursuant to authorities of the Fish and Wildlife Coordination Act and the Magnuson-Stevens Fishery Conservation and Management Act (Magnuson-Stevens Act).

Response to EFH Conservation Recommendations
On March 8, 2010, NMFS provided the District with comments on the Draft EIS. Those comments included our evaluation of the District's EFH Assessment, comments on the Draft EIS, and three EFH conservation recommendations:

1. Before construction begins, the District shall provide NMFS with a map and description of the pipeline corridors relative to live/hardbottom habitats. The description shall include measures the District would take to ensure minimal impacts would occur to NOAA trust resources.
2. The District shall coordinate with NMFS on the final design of the sampling programs for examining impacts to benthic invertebrate communities and sedimentation on live/hardbottom areas; this coordination shall occur well in advance of baseline sampling.
3. The District shall reinitiate EFH consultation with the NMFS Habitat Conservation

Division should any in-water work be proposed outside the period of November 15 to March 31.

As described below, the District has addressed all three EFH conservation recommendations satisfactorily.

Regarding the first EFH conservation recommendation, environmental commitments 22 through 25 (Table 7.2, page 125) of the Final EIS indicate the District recognizes that live/hardbottom areas may only be exposed intermittently. All areas associated with potential pumpout and pipeline corridors will be surveyed before construction, and all information from the surveys will be coordinated with resource agencies before construction so that corridors with the least impact to live/hardbottom habitat can be chosen. On a related matter, NMFS is particularly interested in the outcome of monitoring of nearshore live/hardbottom habit associated with the private North Topsail Beach Nourishment Project, which involves the northernmost section of Topsail Island. If studies associated with this private project document impacts to nearshore live/hardbottom from beach nourishment, a more detail monitoring plan may be necessary for the federal project.

Regarding the second EFH conservation recommendation, environmental commitments 19 through 21 (Table 7.2, page 124) indicate the District will develop a monitoring plan in coordination with the resource agencies to assess project impacts on fisheries and their prey and environmental commitments 22 through 25 (Table 7.2, page 125) indicate the District will similarly develop a monitoring plan for live/hardbottom habitat. We also note that environmental commitments 1 through 3 (Table 7.2, page 120) address the quality of the sand that will be placed on the beach and provide a foundation for minimizing impacts to infaunal and live/hardbottom communities.

Regarding the third EFH conservation recommendation, the recommended plan includes a December 1 to March 31 environmental dredging window to minimize adverse impacts to fishery resources and a commitment to reinitiate consultation should dredging or sand placement occur outside this window.

Other Comments

For future projects, it would be preferable if the table that summarizes environmental commitments (e.g., Table 7.2 in this case) had a row for EFH and federally managed fisheries. This row would include a commitment that if further project planning or monitoring show EFH is at risk, appropriate measures would be incorporated into the project operations to avoid, minimize, and mitigate those losses.

In our comments on the Draft EIS, NMFS questioned whether the rate of sea level rise used in this EIS, 1mm/year, was consistent with "Engineer Circular 1165-2-211, Water Resource Policies and Authorities Incorporating Sea-Level Change Considerations in Civil Works Programs" because the North Carolina Division of Coastal Management accepted the recommendations of the state's Science Advisory Panel and is planning for a 1 meter (3.3 feet) increase in sea level by 2100. The section "Risk and Uncertainty in the Sea Level Rise Assumptions" in the Final EIS concludes "there is no expectation that accelerated sea level rise would result in the selection of other major categories of alternative plans such as the

nonstructural or hard structure plans." While we continue to question whether these assumptions are correct, we will defer to the District on this issue for this project.

Closing

Thank you for the opportunity to provide these comments. Related questions or comments should be directed to the attention of Mr. Ronald Sechler at our Beaufort Field Office, 101 Pivers Island Road, Beaufort, North Carolina 28516-9722, or at (252) 728-5090.

Sincerely,

/ for

Miles M. Croom
Assistant Regional Administrator
Habitat Conservation Division

cc:

COE, Jan.P.Brodmerkel@usace.army.mil
COE, Douglas.Piatkowski@usace.army.mil
USFWS, Howard Hall@fws.gov
SAFMC, Roger.Pugiliese@samfc.net
NCDCM, Doug.Huggett@ncmail.net
EPA, Fox.Rebecca@epa.gov
NOAA PPI, PPI.Nepa@noaa.gov
F, nmfs.hq.nepa@noaa.gov
F/SER, nmfs.ser.eis@noaa.gov
F/SER47, Ron.Sechler@noaa.gov

North Carolina
Department of Administration

Beverly Eaves Perdue, Governor

Moses Carey, Jr., Secretary

November 5, 2010

Mr. Doug Piatkowski
Department of the Army
Wilmington District
Corps of Engineers
69 Darlington Avenue
Wilmington, NC 28403-1343

Dear Mr. Piatkowski:

Re: SCH File # 11-E-0000-0098; FEIS; Develop Coastal Storm Damage Reduction plan for Surf City and North Topsail Beach

The above referenced environmental impact information has been submitted to the State Clearinghouse under the provisions of the National Environmental Policy Act. According to G.S. 113A-10, when a state agency is required to prepare an environmental document under the provisions of federal law, the environmental document meets the provisions of the State Environmental Policy Act. Attached to this letter for your consideration are the comments made by agencies in the course of this review.

If any further environmental review documents are prepared for this project, they should be forwarded to this office for intergovernmental review.

Should you have any questions, please do not hesitate to call.

Sincerely,

Sheila Green
State Environmental Review Clearinghouse

Attachments

cc: Region O
Region P

Mailing Address:
1301 Mail Service Center
Raleigh, NC 27699-1301

Telephone: (919)807-2425
Fax (919)733-9571
State Courier #51-01-00
e-mail state.clearinghouse@doa.nc.gov

Location Address:
116 West Jones Street
Raleigh, North Carolina

An Equal Opportunity/Affirmative Action Employer

North Carolina Department of Environment and Natural Resources

Beverly Eaves Perdue
Governor

Dee Freeman
Secretary



MEMORANDUM

TO: Sheila Green
State Clearinghouse

FROM: Melba McGee
Environmental Review Coordinator

RE: 11-0098 Surf City and North Topsail Beach's FEIS, Pender and Onslow Counties

DATE: November 4, 2010

The Department of Environment and Natural Resources has reviewed the proposed information. The attached comments are for the applicant's information.

Thank you for the opportunity to review.

Attachments

1601 Mail Service Center, Raleigh, North Carolina 27699-1601
Phone: 919-733-4984 \ FAX: 919-715-3060 Internet: www.enr.state.nc.us
An Equal Opportunity \ Affirmative Action Employer – 50% Recycled \ 10% Post Consumer Paper

One North Carolina Naturally



North Carolina Wildlife Resources Commission

Gordon Myers, Executive Director

MEMORANDUM



TO: Melba McGee
Office of Legislative & Intergovernmental Affairs

FROM: Molly Ellwood
Southeastern Permit Coordinator
Habitat Conservation Program

DATE: October 28, 2010

SUBJECT: Comments for Surf City and North Topsail Beach's Final Environmental Impact Statement, Pender and Onslow County; OLIA Project No. 11-0098

Biologists from the N. C. Wildlife Resources Commission (NCWRC) have reviewed the proposed project description. Our comments are provided in accordance with certain provisions of the North Carolina Environmental Policy Act (G.S. 113A-1 through 113A-10; 1 NCAC 25) and the Fish and Wildlife Coordination Act (48 Stat. 401, as amended; 16 U.S.C. 661et seq.).

The United States Army Corps of Engineers is assessing the feasibility of Federal coastal storm damage risk reduction for the Towns of Surf City and North Topsail Beach, which are located on Topsail Island in Pender and Onslow Counties. The preferred alternative as described in the Environmental Impact Statement (EIS) will be to dispose 11.5 mcy of beach compatible material from acceptable offshore sand sources to nourish approximately 52,150 lf in length of ocean front beach with a long dune a berm design constructed to a height of 15 ft NGVD fronted by a 7 ft NGVD (50 ft wide) beach berm. As proposed, the renourishment cycle would be every 6 years after the initial construction phases for a 50 year project.

The NCWRC have the following concerns and recommendations:

- The NCWRC recommends that all work to be conducted outside of the established moratoriums for nesting shorebirds (01 April-31 Aug) and nesting sea turtles (01 May – 15 Nov or until the lat known nest hatches). Any encroachment in these time frames will increase the chances for significant, adverse impacts to important wildlife species and would require further consultation with NCWRC biologists before the project can proceed.

- The NCWRC is continually concerned with the impacts of beach nourishment on benthic invertebrates. Benthic invertebrates are important food sources for foraging shorebirds and continued, frequent nourishment events can potentially have significant adverse impacts on these populations if they are not provided enough time to recover their populations to sustainable numbers.

Mailing Address: Division of Inland Fisheries • 1721 Mail Service Center • Raleigh, NC 27699-1721
Telephone: (919) 707-0220 • **Fax:** (919) 707-0028

The DEIS discusses the proposed 6 year renourishment cycle that would start 1 year after the initial nourishment event. To reduce impacts to benthic invertebrates, the NCWRC supports staggering the renourishment areas so that the first renourishment event would start at the section of the project area where initial construction began; avoiding the most recent beach disposal area Staggering these areas will allow a greater time for benthic invertebrates to adequately recover to sustainable levels.

Thank you for the opportunity to review and comment on this project. The NCWRC requests that our recommendations be considered throughout the 50 years of this project and that any modifications to this plan be reviewed by NCWRC staff. Moratorium windows are important for the protection of our state and federally listed wildlife species and we recommend that the project avoid any encroachment into these time frames. Please feel free to contact me at (910) 796-7240 if you have any additional questions or concerns pertaining to this project.

Cc: Matthew Godfrey, NCWRC
Sara Schweitzer, NCWRC
David Allen, NCWRC
Joanne Steenhuis, NCDWQ
Jessi O'Neal, NCDMF
Dave Timpy, USACE

North Carolina Department of Environment and Natural Resources
Office of Conservation, Planning, & Community Affairs
Beverly Eaves Perdue, Governor **Linda Pearsall, Director** Dee Freeman, Secretary

October 27, 2010



MEMORANDUM

TO: Melba McGee, DENR Environmental Coordinator

FROM: Harry LeGrand, Natural Heritage Program

SUBJECT: FEIS – Coastal Storm Damage Reduction Plan for Surf City and North Topsail Beach; Onslow County

REFERENCE: Project No. 11-0098

The Natural Heritage Program has a number of records of rare species within this large project area. These include the Federally listed seabeach amaranth (*Amaranthus pumilus*), loggerhead seaturtle (*Caretta caretta*), and other seaturtles. However, as the dredging window for the project is December 1 through March 31, to comply with regulations to avoid seaturtle nestings, our Program does not believe that these species will be impacted by the project, and we concur with the statements on pages 196-197 of the main report regarding these species.

In addition, the material for the beach renourishment is proposed to be taken from offshore zones, rather than from channels, existing islands, or the mainland. Thus, there will be no impact to any significant natural heritage areas from this project.

Please do not hesitate to contact me at 919-715-8697 if you have questions or need further information.

1601 Mail Service Center, Raleigh, North Carolina 27699-1601
Phone: 919-715-4195 \ FAX: 919-715-3060 Internet: www.oneNCNaturally.org

An Equal Opportunity \ Affirmative Action Employer – 50% Recycled \ 10% Post Consumer Paper

One NorthCarolina Naturally
Natural Resources Planning and Conservation

NORTH CAROLINA STATE CLEARINGHOUSE
DEPARTMENT OF ADMINISTRATION
INTERGOVERNMENTAL REVIEW

COUNTY: PENDER
ONSLOW

HOS: IRRIGATION/DRAINAGE/FLOOD CONTROL

STATE NUMBER: 11-E-0000-0098
DATE RECEIVED: 10/01/2010
AGENCY RESPONSE: 10/27/2010
REVIEW CLOSED: 11/01/2010

CLEARINGHOUSE COORDINATOR
CC&PS - DIV OF EMERGENCY MANAGEMENT
FLOODPLAIN MANAGEMENT PROGRAM
MSC # 4719
RALEIGH NC

REVIEW DISTRIBUTION

CAPE FEAR COG
CC&PS - DIV OF EMERGENCY MANAGEMENT
DENR - COASTAL MGT
DENR LEGISLATIVE AFFAIRS
DEPT OF AGRICULTURE
DEPT OF CULTURAL RESOURCES
DEPT OF TRANSPORTATION
EASTERN CAROLINA COUNCIL





PROJECT INFORMATION

APPLICANT: Department of the Army
TYPE: National Environmental Policy Act
Final Environmental Impact Statement

DESC: Develop Coastal Storm Damage Reduction plan for Surf City and North Topsail Beach

CROSS-REFERENCE NUMBER: 10-E-0000-0249

The attached project has been submitted to the N. C. State Clearinghouse for intergovernmental review. Please review and submit your response by the above indicated date to 1301 Mail Service Center, Raleigh NC 27699-1301.

If additional review time is needed, please contact this office at (919)807-2425.

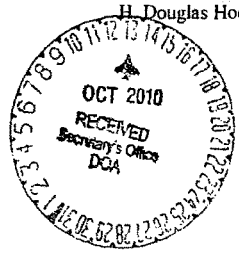
AS A RESULT OF THIS REVIEW THE FOLLOWING IS SUBMITTED: ☐ NO COMMENT ☒ COMMENTS ATTACHED

SIGNED BY: _____ DATE: 10/12/2010

North Carolina Department of Crime Control and Public Safety
Division of Emergency Management
Office of Geospatial and Technology Management

Beverly Eaves Perdue, Governor
Reuben F. Young, Secretary

H. Douglas Hoell, Jr., Director



October 12, 2010

Ms. Sheila Green
State Clearinghouse
N.C. Department of Administration
1301 Mail Service Center
Raleigh, North Carolina 27699-1301

Subject: Intergovernmental Review State Number: 11–E-0000-0098
Develop Coastal Storm Damage Reduction Plan for Surf City and North Topsail Beach

Dear Ms. Green:

As requested by the North Carolina State Clearinghouse, the North Carolina Department of Crime Control and Public Safety Division of Emergency Management Office of Geospatial and Technology Management (GTM) reviewed the proposed project listed above and offer the following comments:

1) Federal Executive Order 11988 requires all federal agencies to comply with the National Flood Insurance Program requirements. 44 CFR 65.3 states "*A community's base flood elevations may increase or decrease resulting from physical changes affecting flooding conditions. As soon as practicable, but not later than six months after the date such information becomes available, a community shall notify the Administrator of the changes by submitting technical or scientific data in accordance with this part. Such a submission is necessary so that upon confirmation of those physical changes affecting flooding conditions, risk premium rates and flood plain management requirements will be based upon current data.*" The documents provided as support for 11-E-000-0098 do not include documentation of expected impacts to the effective Flood Insurance Rate Maps or a reference to plans to update the effective FEMA Flood Insurance Rate Maps for the project area.

2) The NCFMP provided comments on NC State Clearinghouse 09-E-0000-0040 including a formal request for the USACE Wilmington District to coordinate information and data for the 09-E-0000-0040 project with the on-going NCFMP coastal surge study, as well as a formal request for the USACE Wilmington District to assist with outreach regarding the 09-E-0000-0040 project during the NCFMP's outreach of the new coastal surge study. The NCFMP

requests the USACE Wilmington District also coordinate these activities for this project as well.

3) Appendix D Coastal Engineering section 6. Storm Damage Analysis d. EST Analysis 2) Modifications to EST Frequency Curves states "*Water level frequency curves generated by EST for low frequency events (50-, 100-, and 500-year events) were unreasonable and exceed FEMA surge level estimates for Topsail Beach by 10 to 20 percent. Adjustments were made to these response curves so that they better reflected the FEMA surge elevations. Also, the EST erosion distance frequency curves were "smoothed" in some cases to result in more uniform and expected erosion responses. An additional analysis using Automated Coastal Engineering System (ACES) software module Extremal Significant Wave Height Analysis corroborated the FEMA extrapolated values.*" The effective FEMA surge was published circa 1980 and exclude post-1980 storm events including the hindcast storms listed in Appendix D (Bertha, Fran, Dennis, Floyd, Bonnie and Irene). The coastal storm surge study is currently being updated by the NC Floodplain Mapping Program in partnership with FEMA, the Renaissance Computing Institute, USACE Duck Field Research Facility and the UNC Chapel Hill Institute of Marine Sciences and will supersede the effective flood study. The NCFMP is concerned that adjusting the response curves to "better reflect the FEMA surge elevations" is inappropriate and ignores any changes in expected surge levels resulting from inclusion post-1980 to present coastal storm events. The NCFMP requests copies of the EST analysis and ADCIRC results for review and potential inclusion in the NCFMP coastal surge restudy.

Thank you for your cooperation and consideration. If you have any questions concerning the above comments, please contact John Gerber, P.E., CFM, the NC NFIP State Coordinator at (919) 715-5711, by email at jgerber@ncem.org or at the address shown on the footer of this documents.

Sincerely,

Kenneth W. Ashe, P.E., CFM
Assistant Director

c: John Gerber, NFIP State Coordinator

State Clearinghouse Comment Responses

NCDENR

NCWRC – Comments acknowledged, no responses needed
NC Natural Heritage Program - Comments acknowledged, no responses needed

NC Department of Crime Control and Public Safety (Emergency Management)

Comment 1: The project will not affect Flood Insurance Rate Maps, therefore no documentation regarding changes the FIRMS was included.

Comment 2: Comment acknowledged. USACE will coordinate the activities for this project as requested. USACE regularly communicates with the local sponsors of both this and the other referenced project (West Onslow GRR). Residual project risks have been communicated to the sponsors, and are also discussed in the feasibility report.

Comment 3: The agency's concern is noted. The study used the data available at the time the analysis was conducted. The purpose of the study is to determine the economic feasibility of the proposed project and any increase in the likelihood of larger storms would only strengthen the economic benefits. Copies of the EST analysis and ADCIRC inputs will be provided to the agency as requested.

From: Lin, Jeffrey P SAW
To: Lin, Jeffrey P SAW
Subject: FW: DEIS/FEIS for Surf City and North Topsail Beach, NC (UNCLASSIFIED)
Date: Monday, November 22, 2010 3:42:46 PM

Classification: UNCLASSIFIED
Caveats: FOUO

-----Original Message-----
From: Sutton, Loretta B [mailto:Loretta_Sutton@ios.doi.gov]
Sent: Wednesday, October 27, 2010 12:19 PM
To: Brodmerkel, Jan P SAW
Cc: Piatkowski, Douglas SAW; Reddick, Virginia
Subject: DEIS/FEIS for Surf City and North Topsail Beach, NC

Ms. Brodmerkel,

The attached document retransmits the Department of the Interior's (DOI) comments on the subject DEIS. The final document appears to address the comments of our Fish and Wildlife Service and our Bureau of Ocean Energy Management, however the FEIS does not appear to contain or address DOI's comments of March 9, 2010.

A copy was previously resubmitted to Mr. Piatkowski on October 25, 2010.

We ask that you review and consider these comments during the development of your record of decision.

Thank you,

Loretta B. Sutton
Program Analyst
U.S. Department of the Interior (MS-2462); Room: 2444 Office of Environmental Policy and Compliance (PEP)
Voice: 202-208-7565; Fax: 202-208-6970
Loretta_Sutton@ios.doi.gov

Classification: UNCLASSIFIED
Caveats: FOUO

Town of North Topsail Beach

Daniel Tuman, Mayor
Michael Yawn, Mayor Pro Tem
Aldermen:
Richard Farley
Deborah Lanci
Richard Macartney
Robert Swantek



Steven H. Foster
Town Manager

Carin Z. Faulkner, MPA
Town Clerk

July 20, 2010

Colonel Jefferson M. Ryscavage, District Commander
Department of the Army
Wilmington District, Corps of Engineers
69 Darlington Ave.
Wilmington, NC 28403-1343

Regarding: Surf City and North Topsail Beach Coastal Storm Damage Reduction Project Letter of Support

Dear Colonel Ryscavage,

The purpose of this correspondence is to express and confirm our continued support of the proposed Surf City and North Topsail Beach Coastal Storm Damage Reduction Project. The feasibility study was authorized by two Transportation and Infrastructure Committee resolutions dated February 16, 2000 and April 11, 2000.

We support the selected National Economic Development Plan (NED) consisting of a sand dune constructed to an elevation of 15 feet above the National Geodetic Vertical Datum (NGVD), fronted by a 50-foot wide beach berm constructed to an elevation of 7 feet above NGVD with a six-year re-nourishment cycle. The berm and dune project extends along a reach of 52,150 feet.

Further, we have been advised that the Initial Construction cost is $127,973,000, and the total cost for the 7 planned renourishments is $215,525,000. The estimated costs are based on October 2010 price levels and an interest rate of 4.375 percent. The estimated operating and maintenance cost is approximately at $52,000 per year.

We understand the obligation of the local sponsors to cost share the initial construction at a rate of 65% Federal and 35% non-Federal and the obligation to cost share in the post construction re-nourishment costs at a rate of 50% Federal and 50% non-Federal. We have been informed by the U.S. Army Corps of Engineers that the sponsors will be required to provide public beach access at a minimum of one access point and associated parking every half mile of the proposed project or the Federal cost sharing percentages will be reduced.

Sincerely,

Dan Tuman
Mayor

2008 LOGGERHEAD COURT NORTH TOPSAIL BEACH, NC 28460 PHONE (910) 328-1349 FAX (910) 328-4508
www.north-topsail-beach.org

Town of North Topsail Beach

Daniel Tuman, Mayor
Michael Yawn, Mayor Pro Tem
Aldermen:
Richard Farley
Deborah Lanci
Richard Macartney
Robert Swantek

Steven H. Foster
Town Manager

Carin Z. Faulkner, MPA
Town Clerk

June 11, 2010

Colonel Jefferson M. Ryscavage
Department of the Army
Wilmington District, Corps of Engineers
69 Darlington Ave.
Wilmington, NC 28403

Regarding: Surf City and North Topsail Beach Coastal Reduction Project- North Topsail Beach Board of Aldermen Assurance of Compliance to the Required Public Access and Parking Requirement

Dear Colonel Ryscavage,

The purpose of this letter is to state that the Board of Aldermen recognizes the parking and public access requirement that is required under Sections 3.04 and 9.02 from the revised Feasibility Report and Environmental Impact Statement. Further this is to verify the Board is committed to provide the required parking and access as outlined in those sections. The Board further assures that the Town will acquire the property that will provide an additional 20 parking spaces, and an additional access way. (Please find attached a map that will indicate those areas)

The Town understands that the Federal cost share of the project would be decreased if the Town does not comply with the parking and access requirements. That share would decrease from 65% to 51.3% for initial construction and from 50% to 39% for subsequent maintenance renourishment.

Thank you for all of the assistance that you and your staff have provided in this project, and should you have any additional request, please advise.

Sincerely,

Mayor Dan Tuman

Enclosure

TOWN OF SURF CITY

P. O. BOX 2475 214 N. NEW RIVER DRIVE SURF CITY, NC 28445
Telephone: (910) 328-4131 Fax: (910) 328-4132
www.townofsurfcity.com

A. D. (Zander) Guy, Jr., Mayor
Douglas C. Medlin, Mayor Pro-tem
Nelva R. Albury, Council Member

Michael H. Curley, Council Member
Donald R. Helms, Council Member
William J. (Buddy) Fowler, Council Member

July 19, 2010

Colonel Jefferson M. Ryscavage, District Commander
Department of the Army
Wilmington District, Corps of Engineers
69 Darlington Avenue
Wilmington, NC 28403-1343

Dear Colonel Ryscavage:

On behalf of Surf City I would like to express and confirm our continued support of the proposed Surf City and North Topsail Beach Coastal Storm Damage Reduction Project. The feasibility study was authorized by two Transportation and Infrastructure Committee resolutions dated February 16, 2000 and April 11, 2000.

We support the selected National Economic Development Plan (NED) consisting of a sand dune constructed to an elevation of 15 feet above the National Geodetic Vertical Datum (NGVD), fronted by a 50-foot wide beach berm constructed to an elevation of 7 feet above NGVD with a six-year re-nourishment cycle. The berm and dune project extends along a reach of 52,150 feet.

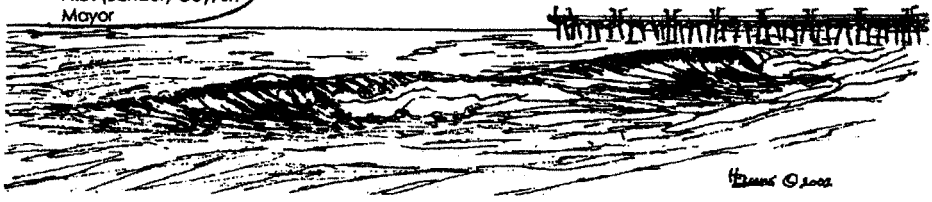
Further, we have been advised that the initial Construction cost is $127,973,000, and the total cost for the 7 planned re-nourishments is $215,525,000. The estimated costs are based on October 2010 price levels and an interest rate of 4.375 percent. The estimated operating and maintenance cost is approximately at $52,000 per year.

We understand the obligation of the local sponsors to cost share the initial construction at a rate of 65% Federal and 35% non-Federal and the obligation to cost share in the post construction re-nourishment costs at a rate of 50% Federal and 50% non-Federal. We have been informed by the U.S. Army Corps of Engineers that the sponsors will be required to provide public beach access at a minimum of one access point and associated parking every half mile of the proposed project or the Federal cost sharing percentages will be reduced.

With Warm Personal Regards I am,

Sincerely yours,

A.D. (Zander) Guy, Jr.
Mayor



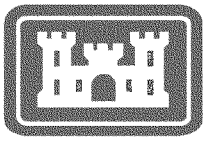
INTEGRATED
FEASIBILITY REPORT
AND
ENVIRONMENTAL IMPACT STATEMENT

COASTAL STORM DAMAGE REDUCTION

SURF CITY AND NORTH TOPSAIL BEACH

NORTH CAROLINA

DECEMBER 2010



US Army Corps of Engineers

Wilmington District

INTEGRATED

FEASIBILITY REPORT
AND
ENVIRONMENTAL IMPACT STATEMENT

COASTAL STORM DAMAGE REDUCTION

SURF CITY AND NORTH TOPSAIL BEACH
NORTH CAROLINA

EXECUTIVE SUMMARY, JUNE 2010

The purpose of this study is to evaluate coastal storm damage reduction for the towns of Surf City and North Topsail Beach, North Carolina, and develop the most suitable plan of damage reduction for the present and future conditions for a 50-year period of analysis. Topsail Island is on the southeastern North Carolina coast. From south to north, the three towns on the island are Topsail Beach, Surf City, and North Topsail Beach. The primary study area for this report includes the towns of Surf City and North Topsail Beach and associated nearby borrow sites. Two Transportation and Infrastructure Committee resolutions dated February 16, 2000, and April 11, 2000, authorized this report. A *General Reevaluation Report* has been completed for the town of Topsail Beach under a separate authority.

The study team integrated representatives of federal, state, and local governments, in the effort to identify cost-effective and environmentally and technically sound alternatives to reduce damages within the two towns and to the adjacent shoreline. The process integrated the U.S. Army Corps of Engineers' (Corps') Campaign Plan in all aspects of the study process. In particular, the study meets Goal 2 of the Campaign Plan, which is to deliver enduring and essential water resource solutions through collaboration with partners and stakeholders. The study effort identified a *National Economic Development* (NED) plan, which would maximize net benefits to the nation through reduction of future storm damages. The recommended plan of action is construction of the NED Plan.

This study discloses that the most practicable plan of damage reduction for the primary study area is a berm and dune project along approximately 10 miles of the oceanfront. The southern limit of the project is the boundary between Topsail Beach and Surf City. The northern limit is within North Topsail Beach at the southern edge of the Coastal Barrier Resources System (Topsail Unit, L06).

The principal project purpose is coastal storm damage reduction. The primary damages reduced are those resulting from beach erosion. In addition, if implemented the project would enhance the beach strand available for recreation use and provide habitat for a variety of plants and animals.

The selected NED Plan consists of a sand dune constructed to an elevation of 15 feet (ft.) above the National Geodetic Vertical Datum (NGVD), fronted by a 50-foot-wide beach berm constructed to an elevation of 7 ft. above NGVD. The berm and dune project extends along a reach of 52,150 ft. That plan is identified among the other alternatives as *Plan 1550*. No Locally Preferred Plan was suggested. The NED Plan is the recommended plan of improvement. The project plan is shown schematically in Figure i. Details of geographic scope, project features, and source borrow area are summarized in Table i. At the project ends, the cross sections would begin transitions to terminate gradually according to conditions existing at construction.

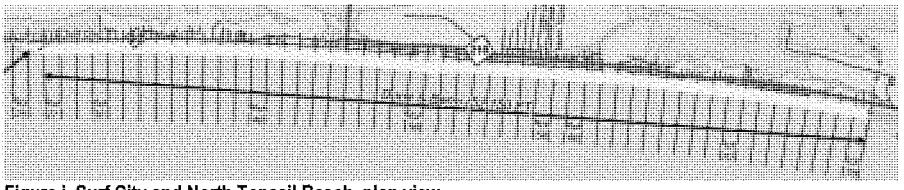


Figure i. Surf City and North Topsail Beach, plan view.

Table i. Plan quantities

Dune, topwidth	25 feet
Dune, elevation, NGVD	15 feet
Dune, landward slope	5H:1V
Dune, seaward slope	10H:1V
Berm, width	50 feet
Berm, elevation, NGVD	7 feet
Berm, seaward slope	15H:1V
Dune and berm fill, length	52,150 feet
North transition section, length (if required)	Variable
South transition section, length (if required)	Variable
Total Length	52,150 feet
Volume, initial, borrow, cubic yards	11,855,000
Volume, renourishment, average, borrow, cubic yards	2,642,000
Renourishment interval	6 years
Borrow source	Offshore

The recommended plan was evaluated using a discount rate of 4.125 percent at October 2010 price levels. First costs of the project are estimated at $123,135,000. Renourishment costs at 6-year intervals are estimated at $27,724,000. Expected annual costs are estimated at $10,702,000, with expected annual benefits estimated at $40,129,000 of which $16,820,000 are coastal storm damage reduction benefits, $20,505,000 are recreation benefits, and $2,804,000 are benefits during construction. The project benefit-cost ratio is 3.7 to 1. The baseline cost estimate for construction in fiscal year (FY) 2015 is $132,648,000. Details of first costs, annual costs, annual and net benefits, and benefit-cost ratios made at October 2010 price levels are shown in Table ii.

Table ii. Economic analysis, October 2010 price levels, 4.125% interest rate

Item	Amount
Total First Cost	$123,135,000
Interest During Construction	$9,513,000
Total Investment Cost	$132,648,000
Renourishments, every 6 years (total cost)	$205,539,000
Present Value, TIC & Renourishments.	$213,344,000
Annual Costs	
Interest and Amortization	$10,145,000
Monitoring	$505,000
OMRR&R	$52,000
Total	$10,702,000
Average Annual Benefits	
CSDR Benefits (incl. $1,277,000 BDC)	$18,097,000
Net Benefits (CSDR only)	$7,395,000
BCR (CSDR only)	1.7 to 1
Recreation Benefits (incl. $1,527,000 BDC)	$22,032,000
Total Benefits (all)	$40,129,000
Net Benefits (all)	$29,427,000
BCR (all)	3.7 to 1

On the basis of the recommendation using public funds for the reduction of damages along this shoreline, the Sponsors (towns of Surf City and North Topsail Beach) would provide public access and parking in accordance with Corps guidelines, at intervals of no more than one-half mile, throughout Surf City and the reach of North Topsail Beach benefitted by the cost-shared project.

The NED Plan of improvement is considered to be environmentally acceptable. However, piping plover were documented to feed along the primary study area. That species is most common as a winter resident of the state and frequently uses the surf zone. The project may affect piping plover foraging distribution on the beach because beach food resources may be affected by beachfill operations. The green sea turtle, loggerhead sea turtle, Kemp's ridley sea turtle, and leatherback sea turtle are known to nest in North Carolina and could nest in the project area. For that reason, they could be affected by initial project construction and periodic nourishment. The sea turtles occur in offshore waters and may also be affected by hopper dredges. Initial construction and periodic nourishment activities would be timed, to the extent practicable, to avoid the sea turtle nesting season and avoid hopper dredging during months when water temperatures are warm and turtles may be present. The project combined Feasibility Report and Environmental Impact Statement includes a biological assessment of project impacts as Appendix I. The U.S. Fish and Wildlife Service (USFWS) and the National Marine Fisheries Service (NMFS)

have reviewed this biological assessment pursuant to section 7 of the Endangered Species Act of 1973 and have concurred with the Corps findings. The USFWS concurrence is for initial construction only and re-consultation will be initiated prior to the first renourishment. The requirements of section 404(r) of P.L. (P.L.) 92-500, as amended, have been met. The town of North Topsail Beach is developing a nonfederal coastal storm damage reduction project for the parts of town that lie within the Coastal Barrier Resources System (Topsail Unit, L06). There is no conflict between the federal and nonfederal project, either on the shoreline or in the borrow areas. If the nonfederal project is not in place when the federal project begins, the northern 2,000 ft. of the dune and berm would be replaced with a transition section.

Agency Technical Review (ATR) on both the draft and final versions of this report was conducted in accordance with the Corps' *Peer Review of Decision Documents* process. The report has been reviewed by Corps staff outside the originating office, with the review being conducted by a regional and national team of experts in the field, and coordinated by the National Planning Center of Expertise in Coastal Storm Damage Reduction, North Atlantic Division, and the Corps comments and responses will accompany the report to the Assistant Secretary of the Army for Civil Works (ASA(CW)) and the Office of Management and Budget (OMB). Documentation of ATR certification will accompany the final report.

An Independent External Peer Review (IEPR) was conducted following the ATR of the draft report. The IEPR was conducted by a non-Corps national team of experts in the field and coordinated by the National Planning Center of Expertise in Coastal Storm Damage Reduction, North Atlantic Division, and the Corps comments and responses from the IEPR will accompany the report to the ASA(CW) and the OMB. Documentation of IEPR certification will accompany the final report.

In analyzing potential measures, the study team considered, in all cases where technically sound and environmentally feasible, both structural and nonstructural measures. Nonstructural measures, such as removal and relocation, were found to have greater cost than benefits, and therefore, were not recommended for the purposes of storm damage reduction. However, the recommendations of the study team that accompany all structural recommendations for dune and berm construction is that of continued and vigilant attention to the need for proactive hurricane and coastal storm threat education, coastal storm and hurricane warning and evacuation planning procedures, floodplain management, and other nonstructural activities directed at both damage reduction and preservation of life and safety. Those activities are provided as recommended actions, although many do not fall within current Corps implementation authorities.

The analyses and design of the recommendations contained in this report comply with the National Environmental Policy Act (NEPA). A separate Environmental Impact Statement (EIS) will not be provided because the final document is a fully integrated report that complies with both NEPA requirements and the Corps (and federal) water resources planning process and its requirements. The report complies with all applicable environmental statutes.

The final report fully discusses areas of risk, uncertainty, and consequences, where that information is appropriate, and describes them with sufficient detail that decisions can be made with knowledge of the degree of reliability of the estimated benefits and costs and of the effectiveness of alternative plans. All recommendations made in the report are capable of being adaptively managed, if such capability is needed. For instance, renourishment may be needed more often or less often, depending on the occurrence of large storms and accompanying erosion.

Substantial, long-term federal investments would be required to implement the current project proposal. The total first cost of the project, at Oct 2010 price levels, is $123,135,000. The federal share of the total first project cost is estimated at $80,038,000 (65 percent). The nonfederal share of the total first project cost is estimated at $43,097,000 (35 percent). The total cost of all renourishments is $205,539,000. The Federal share of the total renourishment cost would be about $102,769,500 (50 percent) and the non-Federal share would be about $102,769,500 (50 percent). As previously indicated, the total project benefit-cost ratio is 3.7 to 1, which means that for every dollar spent for the project, 3 dollars and 70 cents are realized in NED benefits from the project.

Recommendations

Hurricane Risk Education

Numerous people die each year as a result of hurricanes, primarily because of the failure to evacuate to an area of safety. Any loss of life is tragic, and any number of those deaths may have been prevented. Even one death prevented is sufficient reason to improve our methods of educating the public on hurricane and storm threats and to ensure that all is done to warn all those residents or visitors to the coastline of North Carolina as to the dual hazards of wind and surge/waves. It is particularly vital to inform the public as to the potential for hurricane occurrence, particularly within the dangerous hurricane season, so that they pay continued attention to media reports on weather. Education needs to include articulation of effects related to the potential magnitude of the threat, the urgency to heed potential calls to evacuate, and providing the means by which to make wise choices on evacuation methods and route (see recommendations given below under Hurricane Evacuation Planning). The following are suggested guidelines for implementation by state and local government, in the interests of good education on hurricane storm threats:

- Provide good science and information to the residents and visitors to coastal North Carolina, so they can understand the nature of the threat and its possibility of happening at any time within the hurricane season. That information should be provided in both written form and as an initial *page* on televisions provided in visitor's housing, and in a variety of venues, including the following:
    - Posted and televised education in supermarkets, libraries, and public buildings
    - Teacher-provided, posted, and televised education in schools and at public meetings and gatherings, at intervals not to exceed 1 year
    - Publicly posted and visitor-housing-posted information on evacuation routes, and procedures, on publicly accessible Web sites, updated regularly (minimum once a year)

There is nothing humanly possible to maintain the lives and safety of coastal North Carolina residents and visitors during hurricanes if they do not have sufficient warning, and if they then do not use that knowledge to evacuate in a timely manner.

Education of hurricane risks is an ongoing effort of multiple agencies and educational institutions and not a funded program under existing Corps authorities. Updating Web sites containing evacuation routes and procedures should be done under existing programs implemented by the state and local governments.

Hurricane and Storm Warning

Residents and visitors to the coast of North Carolina need to recognize that they live in, or visit, a high-hazard area. Although certain times of the year pose less risk than others, each year's hurricane season provides a strong possibility of hurricane impact somewhere along the coast of North Carolina. All residents and visitors need to be made aware of the

current hurricane threat; but first, meteorological conditions must be evaluated, and any threat must be assessed and characterized by experts with the National Oceanic and Atmospheric Administration's (NOAA's) National Weather Service, and that interpretation must be passed to national and local media for dissemination. Continued support of NOAA's program, and the following supportive activities is critical to an adequate warning process:

- Ongoing efforts to upgrade the existing system of NOAA buoys, transmission capabilities, and advanced warning measures that provide data on the location and nature of weather conditions.
- Efforts directed at the interpretation of that data and its dissemination to the media and public, through the National Weather Service.
- Public appreciation for the need to be aware at all times of, and the need to listen to weather reports and advice given on various media. Television weather reports, radio, and the Internet all provide excellent, up-to-date information on weather conditions and the development of threatening situations. Simply living in or visiting the barrier islands of North Carolina should be sufficient to create a consistent and ongoing process of being exceptionally aware of the weather and its potential consequences.
- The vital importance of heeding the advice of experts. One should know what needs to be done if a storm is approaching. Family members should conduct evacuation drills, keep needed phone numbers and travel supplies on hand, and be prepared to leave on short notice. One should be aware of evacuation routes, keeping a full tank of gas during the hurricane season, and having a plan for where one should go, how to maintain contact with other family members, and where one will relocate temporarily, particularly if the event is longer than expected.

Hurricane Evacuation Planning Upgrading

The critical need for adequate evacuation planning was borne out by hurricanes Bertha, Fran, and Floyd, of the late 1990s and brought even more to the forefront by the monumental impacts of Hurricane Katrina in 2005. An evacuation plan is an essential component of a comprehensive plan for ensuring the safety of residents of and visitors to the coast of North Carolina. The preservation of life is the single most important goal and objective of the recommendations. Joint Federal Emergency Management Agency (FEMA)/NOAA/Corps/North Carolina studies of evacuation routes and populations along the coastline have provided a tremendous amount of value to-date in aiding local government and individual and family readiness in the face of approaching events. Support for this program is a critical element of the recommendations for the towns of Surf City and North Topsail Beach, in support of its residents and visitors. The towns of Surf City and North Topsail Beach both have evacuation and emergency response plans already in place. Important facets of these plans include:

- Annual review of hurricane evacuation plans
- State evacuation route signage
- Reverse 911 phone systems
- Low frequency AM Station

- NIMMS (emergency response command and control) training for all emergency personnel
- WEBEOC.org – a website for coordinating communication during emergencies
- Mutual aid agreements with inland emergency agencies
- Coordination of evacuation and emergency shelters with Onslow/Pender County Emergency Management
- Active re-entry pass system, for safe re-entry after an event

The following are important additional recommendations in support of efforts to support Hurricane Evacuation Planning:

- There is still much that can be done to update this ongoing effort, and to provide new, and more widely disseminated data and tools for evacuation planning by the state and the towns of Surf City and North Topsail Beach, and also for use by individuals and families in their preparation for an impending event.
- Evacuation route signage is an important part of a successful evacuation campaign. Maintenance of hurricane evacuation route signage is viewed as a vital link in ensuring the safety of residents and visitors alike.
- The provision of additional signage illustrating surge height achieved during past events would be an added and continual link to ongoing education efforts. That could take the form of signs placed in locations in which there is significant traffic, such as major thoroughfares, where pedestrians walk, and particularly in those highest hazard zones according to elevation/depth data.

Evacuation Planning is an ongoing effort of multiple agencies, including the Corps, but its implementation is not a funded program under existing Corps authorities. Periodic updating of Web sites containing evacuation routes and procedures should be conducted under existing programs implemented by North Carolina.

Floodplain Management

Management of the floodplain is a nonfederal responsibility, yet it is considered a key component of all plans for coastal storm damage reduction. The towns of Surf City and North Topsail Beach participate in the National Flood Insurance Program, which requires the towns to engage in active and responsible floodplain management. Within Surf City, property owners have 2,148 flood insurance policies composed of nearly $480 million insurance in force. North Topsail Beach property owners possess 1,384 flood insurance policies providing approximately $240 million insurance in force. Because so much of the towns of Surf City and North Topsail Beach are within a recognized floodplain, the towns continue to engage in activities that reduce threats to existing and potential future development, including structure setbacks, building code and construction monitoring, and flood zone management. The towns are encouraged to continue to update building codes, and encourage strong pursuit of activities such as first-floor elevation and building code upgrading, in the effort to reduce the potential for future structural and content damage.

Building Codes

Surf City and North Topsail Beach have adopted the International Building Code (IBC) to guide the design and construction of residential and commercial structures in the study area. To ensure that the latest design and construction techniques are being used that apply to hurricane-resistant construction, all future construction should to follow the latest version of the IBC (2007) and enforcement of the codes should occur through diligent building permit processing and on-site inspections of construction. Annual training classes on the use and enforcement of the new IBC should be conducted. In addition, Surf City and North Topsail Beach should consider adopting the document *FEMA 550 Recommended Residential Construction for Coastal Areas* (FEMA 2009) as a part of their updated building codes for construction, because of the possibility of surge inundation associated with hurricane events.

Long-term Critical Infrastructure and Services Upgrading

Upgrading critical infrastructure and services, such as Fire and Police services, is considered a vital recommendation in the reduction of threats to lives and property. The need to bring the services up to immediate restoration in the wake of a hurricane is of vital importance to the community. The methodical upgrading of the towns' Fire and Police services facilities as part of their Capital Improvement Programs would provide long-term savings in capital outlay, and potentially save lives and residential and commercial property damage. As funds become available, such a program may be instituted under a modified Capital Improvement Program, where structures reaching the end of their economic life are successively replaced by upgraded structures, locating vital communications and power supplies above the elevation of a Maximum Probable Surge event, and capable of surviving the ravages of wind and/or surge.

Upgrading or replacing services is primarily a local charge, implemented through capital improvement plans, with funding from a variety of federal, state, and local resources, and would take many years to accomplish, because of the varying age and condition of each facility.

Item Page

CONTENTS

1. STUDY OVERVIEW 1
- 1.01 Report Organization 3
- 1.02 Study Authority 3
- 1.03 Study Area 5
- 1.04 Purpose and Need for Action 6
- 1.05 Scope of Study 6
- 1.06 Study Process 7
- 1.07 National Objective 7
- 1.08 Prior Studies and Reports 7
- 1.09 Existing Federal and Nonfederal Projects 9

2. AFFECTED ENVIRONMENT 11
- 2.01 Marine Environment 11
  - 2.01.1 Wetlands and Flood Plains 12
  - 2.01.2 Inlet, Flats, and Sounds 13
  - 2.01.3 Nearshore Ocean 14
  - 2.01.4 Surf Zone Fishes 14
  - 2.01.5 Larval Fishes 15
  - 2.01.6 Anadromous Fishes 16
  - 2.01.7 Nekton 16
  - 2.01.8 Benthic Resources—Beach and Surf Zone 19
  - 2.01.9 Benthic Resources—Nearshore Ocean 20
  - 2.01.10 Hard Bottoms 22
  - 2.01.11 Essential Fish Habitat 36
  - 2.01.12 Shellfish 47
- 2.02 Terrestrial Environment 50
  - 2.02.1 Maritime Shrub Thickets 50
  - 2.02.2 Beach and Dune 51
  - 2.02.3 Birds 51
  - 2.02.4 Endangered and Threatened Species 59
- 2.03 Physical Resources 63
  - 2.03.1 Wave Conditions 63
  - 2.03.2 Shoreline and Sand Transport 63
  - 2.03.3 Geology and Sediments 64
  - 2.03.4 Climate 64
  - 2.03.5 Physical Oceanography 65
- 2.04 Socioeconomic Resources 65
  - 2.04.1 Demographics 65
  - 2.04.2 Aesthetic and Recreational Resources 67
  - 2.04.3 Commercial and Recreational Fishing 67
- 2.05 Cultural Resources 68
- 2.06 Water Resources 73
  - 2.06.1 Hydrology 73
  - 2.06.2 Water Quality Classification 73
  - 2.06.3 Groundwater 74

CONTENTS (continued)

Item Page

2.07 Other Significant Resources (P.L. 91-611, Section 122) 74
2.07.1 Air, Noise, and Water Pollution 74
2.07.2 Man-made and Natural Resources, Aesthetic Values, Community Cohesion, and the Availability of Public Facilities and Services 76
2.07.3 Hazardous, Toxic and Radioactive Wastes (HTRW) 76

3. PROBLEMS, NEEDS, AND OPPORTUNITIES 79
3.01 Hurricane and Storm Damage 79
3.02 Beach Erosion 79
3.03 Beach Recreation 80
3.04 Public Access 81
3.05 Loss of Sea Turtle Nesting Habitat 85
3.06 Existing Shore Condition 85
3.07 Without-Project Hydraulic Analysis 89
3.08 Without-Project Economic Analysis 89
3.09 Without-Project Environmental Analysis 93

4. PLANNING OBJECTIVES 95
4.01 Goals and Objectives 95
4.02 Constraints 95

5. PLAN FORMULATION AND EVALUATION OF ALTERNATIVES 96
5.01 Formulation and Evaluation Criteria 96
5.02 Identification, Examination, and Screening of Measures 97
5.03 Identification of Initial Alternative Plans 98
5.04 Screening of Alternative Plans 99
5.05 Evaluation of Alternative Plans 99
5.05.1 Nonstructural Evaluation 99
5.05.2 Beachfill Evaluations 101
5.06 Optimization and Comparison of Beachfill Alternative Plans 102
5.06.1 Cross Sections 102
5.06.2 Economic Comparisons 103
5.06.3 Borrow Site Comparisons 104
5.06.4 Environmental Comparisons of Plans 106

6. PLAN SELECTION 112
6.01 National Economic Development Plan 112
6.02 Locally Preferred Plan (LPP) 112
6.03 Other Plans 112
6.04 Selected Plan 112

7. THE SELECTED PLAN 113
7.01 Plan Description and Components 113
7.01.1 Main fill 113
7.01.2 Transition Sections 114
7.02 Rationale for Support of the Locally Preferred Plan 116
7.03 Design and Construction Considerations 116

CONTENTS (continued)

Item Page

7.03.1 Initial Construction and Renourishment ... 116
7.03.2 Dune Vegetation ... 117
7.03.3 Construction Access and Public Access ... 117
7.03.4 Renourishment Interval ... 117
7.03.5 Beachfill Monitoring ... 118
7.03.6 Environmental Monitoring and Other Commitments ... 119
7.04 Borrow Areas ... 129
7.04.1 Borrow Area Material Compatibility ... 130
7.04.2 Regional Sand Requirements ... 133
7.04.3 Borrow Area Use Plan ... 134
7.04.4 Borrow Area Contingency Plan ... 134
7.05 Dredging and Material Shaping ... 135
7.05.1 Dredging Production ... 135
7.05.2 Dredging Window ... 135
7.05.3 Recommended Construction Plan ... 136
7.06 Real Estate Considerations ... 136
7.06.1 Borrow Areas ... 136
7.06.2 Pipeline ... 136
7.06.3 Construction Area ... 137
7.06.4 Real Estate Costs ... 137
7.07 Operation and Maintenance Considerations ... 137
7.08 Plan Accomplishments ... 138
7.09 Economics of the Selected Plan ... 139
7.09.1 Selected Plan—Benefits ... 139
7.09.2 Selected Plan—Costs ... 139
7.09.3 Benefit to Cost Ratio ... 143
7.09.4 Incremental Analysis ... 143
7.10 Evaluation of Risk and Uncertainty ... 146
7.10.1 Residual Risks ... 146
7.10.2 Risk and Uncertainty in Economics ... 147
7.10.3 Risk and Uncertainty in Borrow Availability ... 147
7.10.4 Risk and Uncertainty in Sea Level Rise Assumptions ... 149
7.11 System of Accounts Evaluation ... 151

8. ENVIRONMENTAL EFFECTS ... 160
8.01 Marine Environment ... 160
8.01.1 Wetlands and Floodplains ... 160
8.01.2 Inlet, Flats, and Sounds ... 160
8.01.3 Surf Zone Fishes ... 161
8.01.4 Larval Entrainment ... 162
8.01.5 Nekton ... 163
8.01.6 Benthic Resources—Beach and Surf Zone ... 164
8.01.7 Benthic Resources—Nearshore Ocean ... 166
8.01.8 Essential Fish Habitat ... 170
8.02 Terrestrial Environment ... 191
8.02.1 Maritime Shrub Thicket ... 191
8.02.2 Beach and Dune ... 192

CONTENTS (continued)

Item Page

8.02.3 Birds ... 193
8.02.4 Endangered and Threatened Species ... 195
8.03 Physical Resources ... 199
8.03.1 Wave Conditions ... 199
8.03.2 Shoreline and Sand Transport ... 199
8.03.3 Geology and Sediments ... 200
8.04 Socioeconomic Resources ... 202
8.04.1 Commercial and Recreational Fisheries ... 202
8.05 Recreation and Aesthetic Resources ... 202
8.06 Cultural Resources ... 203
8.07 Water Resources ... 206
8.07.1 Hydrology ... 206
8.07.2 Water Quality ... 206
8.07.3 Groundwater ... 207
8.08 Other Significant Resources (P.L. 91-611, Section 122) ... 207
8.08.1 Air, Noise, and Water Pollution ... 207
8.08.2 Man-made and Natural Resources, Aesthetic Values, Community Cohesion, and the Availability of Public Facilities and Services ... 212
8.08.3 Hazardous, Toxic and Radioactive Wastes (HTRW) ... 213
8.09 Summary of Cumulative Effects ... 214

9. PLAN IMPLEMENTATION ... 216
9.01 Project Schedule ... 216
9.02 Division of Plan Responsibilities ... 217
9.02.1 General ... 217
9.02.2 Cost Sharing ... 217
9.02.3 Financial Analysis ... 219
9.02.4 Project Partnership Agreement ... 219
9.03 Views of the Nonfederal Sponsor ... 220
9.04 Views of North Carolina ... 220
9.05 Views of the U.S. Fish & Wildlife Service ... 220

10. COMPLIANCE WITH ENVIRONMENTAL REQUIREMENTS ... 221
10.01 General ... 221
10.02 Water Quality ... 221
10.02.1 Section 401 of Clean Water Act of 1977 ... 221
10.02.2 Section 404 of Clean Water Act of 1977 ... 221
10.03 Marine, Protection, Research, and Sanctuaries Act ... 221
10.04 Essential Fish Habitat ... 221
10.05 Fish and Wildlife Resources ... 222
10.06 Endangered and Threatened Species ... 222
10.06.1 Commitments to Reduce Impacts to Listed Species ... 222
10.07 Cultural Resources ... 224
10.08 Executive Order 11988 (Flood Plain Management) ... 224
10.09 Executive Order 11990 (Protection of Wetlands) ... 227
10.10 Executive Order 13186 (Responsibilities of Federal Agencies to Protect Migratory Birds) ... 228

CONTENTS (continued)

Item Page

10.11 Outer Continental Shelf Lands Act 228
10.12 North Carolina Coastal Management Program 229
10.12.1 Areas of Environmental Concern (15A NCAC 07H .0204) 229
10.12.2 Use Standards (15A NCAC 07H .0208) 232
10.12.3 Shoreline Erosion Policies (15A NCAC 07M .0202) 233
10.12.4 Shorefront Access Policies (15A NCAC 07M .0300) 234
10.12.5 Mitigation Policy (15A NCAC 07M .0701) 234
10.12.6 Coastal Water Quality Policies (15A NCAC 07M .0800) 235
10.12.7 Policies on Beneficial Use and Availability of Materials Resulting From the Excavation or Maintenance of Navigational Channels (15A NCAC 07M .1100) 235
10.12.8 Policies on Ocean Mining (15A NCAC 07M .1200) and 15A NCAC 07H. 0208(b)(12) Submerged Lands Mining 236
10.12.9 Other State Policies 236
10.12.10 Local Land Use Plans 237
10.13 Coastal Barrier Resources Act 238
10.14 Estuary Protection Act 238
10.15 Sedimentation and Erosion Control 239
10.16 Prime and Unique Agriculture Land 239

11. SUMMARY OF AGENCY AND PUBLIC INVOLVEMENT 243
11.01 Scoping 243
11.02 Cooperating Agencies 243
11.03 Fish and Wildlife Coordination 243
11.04 Coordination of this Document 254
11.05 Recipients of this Document 255

12. CONCLUSIONS 258

13. RECOMMENDATIONS 259

14. POINT OF CONTACT 268

15. REFERENCES 268

16. LISTS OF PREPARERS 285
16.01 Preparers 285
16.02 Reviewers 285

CONTENTS (continued)

Item Page

TABLES

Table 2.1 Marine mammal species found in the project area..... 18
Table 2.2. Most abundant benthic species within the Topsail Island offshore borrow sites 22
Table 2.3. Hard-bottom locations within waters off Surf City, North Topsail Beach, and Onslow Beach, North Carolina, according to Moser and Taylor (1995) 24
Table 2.4. Consolidated species list for all 12 transects investigated throughout borrow areas T, O, L, J, and G in March 2008..... 35
Table 2.5. Artificial reefs 36
Table 2.6. EFH species for coastal North Carolina[a] 38
Table 2.7. Categories of EFH and HAPC identified in FMP Amendments affecting the South Atlantic Area.[a, b] 47
Table 2.8. List of waterbirds that occur in the Surf City and North Topsail Beach project area and their status 53
Table 2.9. Summary of annual shorebird surveys..... 55
Table 2.10. Summary of colonial nesting waterbird data (1972–2007) conducted by NCWRC in the SCNTB vicinity 56
Table 2.11. Summary of key waterbird species identified along the inlet and ocean facing shorelines of North Topsail Beach based on ongoing pre-construction monitoring performed by CPE as a component of the bird monitoring plan for the Nonfederal North Topsail Beach Shoreline Protection Project (USACE, 2007b) 58
Table 2.12. Federally listed T&E species for the project area (Pender and Onslow counties, North Carolina) 61
Table 2.13. Summary of state-listed species for Pender and Onslow counties, North Carolina, that are not already federally listed as defined in Table 2.12 62
Table 2.14. Socioeconomic conditions of Pender and Onslow counties, North Carolina 66
Table 2.15. North Carolina Division of Archives and History, Underwater Archaeology Section shipwreck files..... 72
Table 3.1. Direct landfalling hurricanes and tropical storms in southeastern North Carolina since 1800..... 80
Table 3.2. Public access and parking, Surf City, July 2008 82
Table 3.3. Public access and parking, North Topsail Beach, July 2008..... 82
Table 3.4. Estimated value of damages, without-project conditions, October 2010 price levels, 4.125% interest rate..... 91
Table 5.1. Nonstructural plan economics, present worth, October 2004 levels, 5.375% interest rate 100
Table 5.2 Beachfill plan names..... 102
Table 5.3 Dune and berm plans, alternative screening, reaches 27 to 28..... 104
Table 5.4. Comparative impacts of the proposed plan to the Nonstructural and No Action alternatives, (part 1 of 5) 107
Table 7.1. Summary of total costs and net benefits used for the selection of the project renourishment interval. 118
Table 7.2. Project commitments 120
Table 7.3. Topsail Island borrow area characteristics..... 129
Table 7.4. Surf City/North Topsail Beach compatibility table 132
Table 7.5. Lifetime borrow requirements, Topsail Island 134
Table 7.6. Real estate estimate (2010 price level), beachfill plan 137

CONTENTS (continued)

Item Page

Table 7.7. Peak visitation and parking required and available at the SCNTB project area 139
Table 7.8. Expected annual benefits, October 2010 levels, 4.125% interest rate 139
Table 7.9. Project first costs, Plan 1550 NED (October 2010 price levels) 140
Table 7.10. Total investment cost, Plan 1550 NED (October 2010 price levels) 140
Table 7.11. Project renourishment costs, Plan 1550 NED (October 2010 price levels): First event 141
Table 7.12. Project renourishment costs, Plan 1550 NED (October 2010 price levels): Second through sixth events 141
Table 7.13. Project renourishment costs, Plan 1550 NED (October 2010 price levels): Final (seventh) event. 142
Table 7.14. Project annual costs, Plan 1550 NED (October 2010 price levels) 143
Table 7.15. Incremental analysis 144
Table 7.16. Residual risks, average annual values, 50-year duration, 4.125% interest rate, October 2010 levels 146
Table 7.17. (1 of 7). System of Accounts, NED 152
Table 7.17. (*continued*) 2 of 7. System of Accounts, Regional Economic Development 153
Table 7.17. (*continued*) 3 of 7. System of Accounts, Other Social Effects, Part 1 154
Table 7.17. (*continued*) 4 of 7. System of Accounts, Other Social Effects, Part 2 155
Table 7.17. (*continued*) 5 of 7. System of Accounts, Risk Evaluation 156
Table 7.17. (*continued*) 6 of 7. System of Accounts, Environmental Quality, Part 1 157
Table 7.17. (*continued*) 7 of 7. System of Accounts, Environmental Quality, Part 2 158
Table 8.1. Anticipated dredge cut depths and subsequent post-dredge surface elevations for borrow areas located offshore of Topsail Island based on vibracore data 167
Table 8.2. Categories of EFH and HAPC and potential impacts 171
Table 8.3. Physical characteristics of hard bottom at each transect 178
Table 8.4. T&E species effects determination for beach placement and dredging activities associated with the proposed project area 195
Table 8.5. Project emissions analysis 210
Table 9.1. Project schedule 216
Table 9.2. Cost allocation and apportionment, October 2010 price levels 218
Table 9.3. Cost sharing based on shoreline category 219
Table 10.1. The relationship of the proposed action to federal laws and policies 240

CONTENTS (continued)

Item Page

FIGURES

Figure 1.1. Location and vicinity map. 2
Figure 1.2, Datum relationships 11
Figure 2.1, Population history and projections. 67
Figure 3.1. Public access and parking, Surf City. 83
Figure 3.2. Public access and parking, North Topsail Beach. 84
Figure 3.3. Surf City, typical profiles. 87
Figure 3.4. North Topsail Beach, typical profiles. 88
Figure 3.5 Estimated damages by reach, present value. 92
Figure 7.1. Plan 1550, NED Plan, cross section. 114
Figure 7.2. Plan 1550, NED Plan, plan view. 115
Figure 7.3. Example of escarped dune and eroded berm. 118
Figure 7.4 Topsail Island proposed federal and nonfederal coastal storm damage reduction projects. 133
Figure 7.5. Net benefits by project reach. 145
Figure 7.6. SLR projections 150
Figure 7.7. SLR effects on project economics. 151
Figure 7.8. Example of differences in damages sustained in an area with and without a storm damage reduction project in place. (From USACE 2000). 159
Figure 8.1. Hopper dredge sedimentation processes.. 180
Figure 8.2. Sediment trap permanently installed at each end of a monitoring transect. 187

CONTENTS (continued)

Item Page

APPENDICES

Appendix A Project Maps
Appendix B Economic Analyses
Appendix C Geotechnical Analyses
Appendix D Coastal Engineering
Appendix E Sand Compatibility Analysis
Appendix F - unassigned -
Appendix G Section 404(b)(1) Guidelines Analysis
Appendix H Correspondence
Appendix I Biological Assessment - Endangered Species
Appendix J Cumulative Effects
Appendix K Scoping Letters & List of Respondents
Appendix L Fish & Wildlife Coordination Act Report
Appendix M Real Estate Plan
Appendix N Project Costs
Appendix O Recreation Analyses
Appendix P Nonstructural Alternatives
Appendix Q Larval Entrainment
Appendix R Nearshore and Offshore Hard Bottom Survey Reports
Appendix S Benthic Community Characterization Survey
Appendix T Comments and Responses
Appendix U Archaeological Report

FEASIBILITY REPORT
AND ENVIRONMENTAL IMPACT STATEMENT

COASTAL STORM DAMAGE REDUCTION

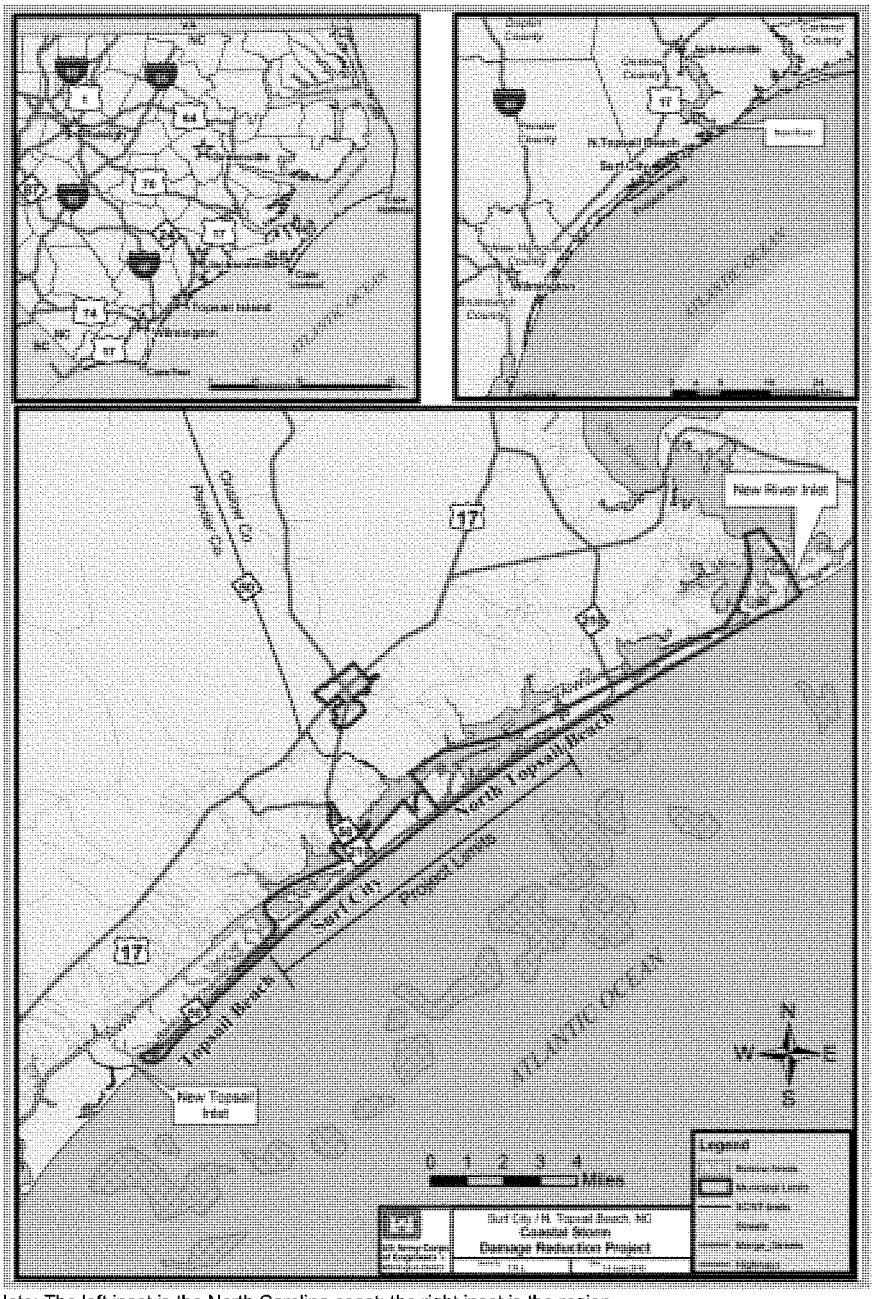
SURF CITY AND NORTH TOPSAIL BEACH

NORTH CAROLINA

---

1. STUDY OVERVIEW

This Feasibility Report and Environmental Impact Statement (FEIS) presents the results of studies to reexamine the feasibility of federal coastal storm damage risk reduction for the towns of Surf City and North Topsail Beach, which are on Topsail Island. The third of three towns on the island, Topsail Beach, comprises the southern 5 miles of the island. Topsail Island lies in Pender and Onslow counties, North Carolina, as indicated in Figure 1.1, Location and Vicinity Map. Surf City and North Topsail Beach are the project sponsors. The study evaluated alternative plans for reducing damages to the commercial and residential structures and infrastructure of Surf City and North Topsail Beach. The study has resulted in a recommendation to construct a berm and dune project with continuing renourishment. The scale and costs of the project have been optimized to produce the maximum net economic benefits, or National Economic Development (NED) Plan, as directed by federal planning guidelines.



Note: The left inset is the North Carolina coast; the right inset is the region.

Figure 1.1. Location and vicinity map.

1.01 Report Organization

This report is a combined Feasibility Study and Environmental Impact Statement (FEIS), meaning it contains elements that are required for both a U.S. Army Corps of Engineers (Corps) planning feasibility report as well as an EIS per the National Environmental Policy Act (NEPA). Chapter 1 of the report is an overview of the feasibility study. Chapter 2 contains background information on the environment that could be affected by a Corps project resulting from the study. Chapters 3 to 6 discuss the plan formulation process that led to the selection of the final plan recommended in this report. Chapter 7 is a detailed description of the selected plan. Chapter 8 contains more expansive discussions on the resources that are discussed in Chapter 2 and describes in detail the environmental effects the selected plan would have on those resources. The chapter also contains briefer descriptions of the environmental effects of other major categories of alternatives (No Action and Nonstructural) that were considered during the formulation process. Chapter 9 contains information on plan implementation such as schedule and cost-sharing. Chapter 10 lists the study's compliance with all applicable environmental laws and Executive Orders. Chapter 11 is a summary of agency and public involvement that has been undertaken throughout the course of the study. Chapters 12 to 16 contain, respectively, the report's conclusions, recommendations, main point of contact, literature references, and a list of report preparers.

1.02 Study Authority

Four congressional resolutions lead up to the initiation of this project. The most applicable text is underlined.

- Resolution adopted June 24, 1970 by the United States Senate

  > Resolved by the Committee on Public Works of the United States Senate, that the Board of Engineers for Rivers and Harbors, created under Section 3 of the River and Harbor Act, approved June 13, 1902, be, and is hereby, requested to review the reports of the Chief of Engineers on the Inland Waterway from Beaufort to Jacksonville, N.C., and New River to Jacksonville, published as House Document Numbered 421, Eightieth Congress, on Bogue Inlet to Moore Inlet, North Carolina, published as House Document Numbered 480, Eighty-ninth Congress, and other pertinent reports with a view to determining whether any modification of the existing project is advisable at the present time, particularly for the stabilization and deepening of New River Inlet.

- Resolution adopted 2 December 1970 by the United States House of Representatives

  > Resolved by the Committee on Public Works of the House of Representatives, United States, that the Board of Engineers for Rivers and Harbors is hereby requested to review the reports of the Chief of Engineers on the Intracoastal waterway from Beaufort, North Carolina, to

the Cape Fear River, published as House Document Numbered 450, 69th Congress, on the Inland Waterway from Beaufort to Jacksonville, North Carolina, and New River to Jacksonville, published as House Document Numbered 421, 80th Congress, on Bogue Inlet to Moore Inlet, North Carolina, published as House Document 480, 89th Congress, and other pertinent reports with a view to determining whether any modification of the existing project is advisable at the present time, particularly for the stabilization and deepening of New River Inlet and Bogue Inlet.

- Resolution adopted 23 June 1971 by the United States House of Representatives

  Resolved by the Committee on Public Works of the House of Representatives, United States, that, in accordance with Section 110 of the River and Harbor Act of 1962, the Secretary of the Army is hereby requested to direct the Chief of Engineers to make a survey of the shores of West Onslow Beach, Onslow County, North Carolina, and such adjacent shores as may be necessary in the interest of beach erosion control, hurricane protection, and related purposes.

- Resolution adopted 14 November 1979 by the United States House of Representatives

  Resolved by the Committee on Public Works and Transportation of the House of Representatives, United States, that, in accordance with Section 110 of the River and Harbor Act of 1962, the Secretary of the Army is hereby requested to direct the Chief of Engineers to make a survey of Topsail Beach and Surf City, North Carolina, and adjacent beaches and inlets, in the interest of beach erosion control, hurricane protection, and related purposes.

The four study resolutions between 1970 and 1979 were combined and used to initiate studies separated by function and location. Studies for navigation improvement at Bogue Inlet were combined with other congressional authorities related to Bogue Banks. Navigation needs at New River Inlet were later investigated under the Chief of Engineers Section 107 Continuing Authority program. The remaining study resolutions, pertaining to West Onslow Beach (North Topsail Beach), New River Inlet, Topsail Beach, and Surf City, were combined in 1980 at the direction of the Chief of Engineers, and designated the *West Onslow Beach and New River Inlet, North Carolina* general investigation study. That study was therefore a coastal storm damage reduction study and did not include navigation.

The study area originally included all Topsail Island, including the towns of Topsail Beach and Surf City, the community of West Onslow Beach, the community of New Topsail Shores, and New River Inlet. In 1990 West Onslow Beach and New Topsail Shores were incorporated as the town of North Topsail Beach. The recommended plan, authorized in 1992, consisted of a beachfill for the southern portion of Topsail Beach.

Storm damage reduction was not found economically feasible for the rest of the island at that time.

Following a series of hurricanes that damaged Topsail Island between 1996 and 1999, interest in a coastal storm damage reduction project was renewed. This feasibility study is in response to the two following resolutions adopted February 16, 2000, and April 11, 2000, respectively:

- Resolved by the Committee on Transportation and Infrastructure of the United States House of Representatives, That the Secretary of the Army is requested to review the report of the Chief of Engineers on West Onslow Beach and New River Inlet, North Carolina, published as House Document 393, 102nd Congress, 2nd Session, dated September 23, 1992, and other pertinent reports, to determine whether any modifications of the recommendations contained therein are advisable at the present time in the interest of shore protection and related purposes for Surf City, North Carolina.

- Resolved by the Committee on Transportation and Infrastructure of the United States House of Representatives, That the Secretary of the Army is requested to review the report of the Chief of Engineers on West Onslow Beach and New River Inlet, North Carolina, published as House Document 393, 102nd Congress, 2nd Session, dated September 23, 1992, and other pertinent reports, to determine whether any modifications of the recommendations contained therein are advisable at the present time in the interest of shore protection and related purposes for North Topsail Beach, North Carolina.

1.03 Study Area

Topsail Island is a 22-mile-long and 0.5-mile-wide barrier island approximately 40 miles northeast of Wilmington, North Carolina. Because of the northeast-southwest orientation of the coastline, the island faces the Atlantic Ocean on the southeast. Other waterbodies in the vicinity consist of the New River Inlet immediately to the northeast, Banks Channel and the Atlantic Intracoastal Waterway (AIWW) to the northwest, and New Topsail Inlet at the far southwestern end of the island.

The study area is uniformly developed with few undeveloped lots and a wide range of structures consisting mostly of single-family dwellings, some multi-unit apartment and condominium buildings, about 30 various commercial buildings, and a few hotels. Most of the developable land in the study area is already occupied with structures. Roadway access to the mainland is provided via North Carolina (N.C.) Highway 50 to Surf City and then by bridges on N.C. Highway 50/210 at Surf City and N.C. Highway 210 at North Topsail Beach. Public access to the beach is provided by numerous parking areas and dune walkovers.

Over the past 35 years, the study area has developed rapidly as a family ocean resort community for outdoor recreation. On summer weekends the population can be in the

tens of thousands. In the off-season, the population drops to about 2,200 residents. During the summer months, a large portion of the homes within the study area are available as summer rentals to vacationers primarily from inland North Carolina and other locations around the Eastern United States. Two fishing piers are in the study area.

The sponsors' interest is in developing a plan of storm damage reduction for 17 miles of shoreline extending from the Topsail Beach/Surf City town limits to the northern end of Topsail Island. From the shoreline, the study area extends landward approximately 500 feet (ft.). Seaward, the study area extends from the shoreline approximately 1 mile. The study area also includes offshore borrow areas lying 1 to 6 miles from the shoreline and borrow areas in New River Inlet. For purpose of incremental analysis, the shoreline has been divided into study reaches approximately 1,000 ft. in length. The study area, consisting of town limits, bodies of water, Coastal Barriers Resources Act (CBRA) zone, and reaches, is shown in Figure 1.1.

1.04 Purpose and Need for Action

The purpose and need for coastal storm damage reduction is to reduce damages resulting from beach erosion and waves along the ocean shoreline of the study area. A wide variety of possible measures would reduce the impacts of erosion, flooding and waves on commercial and residential structures and infrastructure of the island. Some of the measures would provide incidental environmental and recreational benefits. The purpose of this action is to authorize the use of OCS sand (or other sediment) resources in beach nourishment and coastal restoration projects undertaken by federal, state or local government agencies, and/or in other federally authorized construction projects. Beach nourishment measures, which include dredging of sediment from offshore borrow areas on the Outer Continental Shelf (OCS) may require authorization by the Minerals Management Service (MMS) for use during initial or maintenance construction or both (see Section 10.11). The MMS Leasing Division is charged with environmentally responsible management of federal OCS sand and gravel resources. P.L. 102-426 [43 United States Code (U.S.C.) 1337(k)(2)], enacted October 31, 1994, gave MMS the authority to negotiate, on a noncompetitive basis, the rights to OCS sand, gravel, and shell resources for coastal storm damage reduction projects; beach or wetlands restoration projects; or for use in construction projects funded in whole or part by or authorized by the federal government. The MMS, as a cooperating federal agency, may undertake a connected action (i.e., authorize use of the OCS borrow area) that is related to, but unique from the Corps' proposed action. The MMS's proposed action is to issue a negotiated agreement pursuant to its authority under the Outer Continental Shelf Lands Act.

1.05 Scope of Study

This study consists of the analysis of measures and plans to select the plan with the highest net benefits, or determine that no plan of improvement is justified under current planning criteria and policies.

1.06 Study Process

The Corps studies for water and related land resources follow detailed guidance provided in the *Planning Guidance Notebook* (Engineer Regulation 1105-2-100). This guidance is based on the *Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies* that were developed pursuant to section 103 of the Water Resources Planning Act (P.L. 89-80) and Executive Order 11747, which were approved by the U.S. Water Resources Council in 1982 and by the President in 1983. A defined six-step process is used to identify and respond to problems and opportunities associated with the federal objective and specific state and local concerns. The process involves an orderly and systematic approach to making evaluations and decisions at each step so that the public and the decision makers can be informed of basic assumptions made, the data and information analyzed, risk and uncertainty, the reasons and rationales used, and the significant implications of each alternative plan. The process concludes with the selection of a recommended plan. Specific aspects of the process are described in more detail in other sections of this document.

1.07 National Objective

The federal objective of water and related land resources project planning is to contribute to national economic development in a manner consistent with protecting the nation's environment, pursuant to national environmental statutes, applicable executive orders, and other federal planning requirements. If the projected benefits of coastal storm damage reduction measures exceed their estimated costs and are judged environmentally acceptable, their construction as a federal project would contribute to this objective and be in the federal interest.

1.08 Prior Studies and Reports

The USACE has conducted a number of prior studies regarding the Topsail Island area and has prepared a number of related engineering, planning, and environmental reports. These studies have addressed coastal storm damage reduction as well as navigation needs. Reports particularly pertinent to the present study are briefly described below. Other reports related to the study area are cited in the Section 15, References.

Coastal Storm Damage Reduction

- House Document No. 480, 89th Congress, *Topsail Beach and Surf City, North Carolina*. This report, approved by Congress in 1966, presents the results of an investigation of Topsail Island conducted during the period 1963 – 1965 as part of a comprehensive study of coastal storm damage reduction needs for the segment of the North Carolina coast extending between Bogue and Moore Inlets. With approval of this report, Congress authorized coastal storm damage reduction projects for the towns of Topsail Beach and Surf City. Improvements along the northernmost 11.7 miles of Topsail Island, referred to as West Onslow Beach, were determined to be economically infeasible. The improvements authorized by

this report were not constructed, and the project was deauthorized August 5, 1977. The reason for this deauthorization was that there was no apparent nonfederal interest in the project following authorization.

- House Document No. 393, 102nd Congress, 2nd Session, *West Onslow Beach and New River Inlet, North Carolina*. This report (HD 393/102/2) was conducted pursuant to four congressional resolutions adopted between 1970 and 1979. The resolutions addressed beaches, channels and inlets in the greater vicinity of Topsail Island. Studies for navigation purpose were conducted separately. The recommendation of the Final Feasibility Report and Environmental Impact Statement on Hurricane Protection and Beach Erosion Control was a dune and berm system at Topsail Beach as described below in Section 1.09, Authorized Project.

Navigation

- House Document No. 450, 69th Congress, *Inland Waterway, Beaufort – Cape Fear River*. This house document, approved by Congress in 1927, authorized construction of the AIWW from Beaufort to the Cape Fear River, with dimensions of 12 ft. deep by 90 ft. wide.

- House Document No. 421, 80th Congress, *Inland Waterway from Beaufort to Jacksonville, NC and New River to Jacksonville*. The natural river channel is considered adequate for existing river traffic and no improvements are being considered.

- House Document No. 691, 75th Congress, *Channel to New River Inlet*. This house document, approved by Congress June 20, 1938, authorized construction of a 6-foot deep by 90-foot wide channel from the AIWW through New River Inlet to the Atlantic Ocean.

- *Detailed Project Report on Improvement of Navigation, New Topsail Inlet and Connecting Channels*. This July 1965 report, approved by the Chief of Engineers April 7, 1966, authorized construction of a channel 8 ft. deep by 150 ft. wide through New Topsail Inlet. A connecting channel through Banks Channel to the AIWW was also authorized under Continuing Authorities Program, Section 107 of the River and Harbor Act of July 14, 1960.

- *Detailed Project Report on Improvement of Navigation, New River Inlet, December 1987*. This report by the Wilmington District addresses that portion of the study authority concerning navigation at New River Inlet. The report recommends deepening of the authorized navigation channel from 6 to 8 ft. and widening from 90 to 150 ft.

1.09 Existing Federal and Nonfederal Projects

The nearest existing federal coastal storm damage reduction project is at Wrightsville Beach, which is 16 miles to the southwest and beyond this study area. There is authorization for a federal coastal storm damage reduction project at the southern half of the Town of Topsail Beach. The sponsor did not execute the Project Partnership Agreement (PPA), and no project was built. A General Reevaluation Report (GRR) for Topsail Beach (formally known as the West Onslow and New River Inlet GRR) was completed in 2008, and a record of decision (ROD) was issued in April 2010. The report proposes a berm and dune plan along approximately 5 miles of shoreline in the town of Topsail Beach Appendix D (Coastal Engineering) contains additional information on the size of these and other federal coastal storm damage reduction projects in the state of NC.

Construction of both the Topsail Beach and Surf City/North Topsail Beach projects would potentially have cumulative environmental effects in the study area. Potential cumulative effects include effects on benthic organisms in borrow areas (both projects would use some of the same borrow areas) and beach impacts resulting from beach maintenance activities. Of specific concern are macroinvertebrate, fisheries, shorebird, and sea turtle species that use or occur on or adjacent to ocean beaches. A detailed discussion of the cumulative effects of the projects (and other federal and nonfederal projects in the area and in the state) is in Appendix J. Although the potential for cumulative effects does exist, the federal projects include environmental and monitoring commitments (described in sections 7.03.6 and 10.06.1 of this report) that would either minimize or avoid such effects.

A number of federal navigation projects are in this study area. They are listed and briefly described below.

- **Atlantic Intracoastal Waterway (AIWW)**—The AIWW provides an important inland navigation route from Norfolk, Virginia, to the St. Johns River, Florida. The 308-mile-long North Carolina portion is the state's only north-south commercial navigation thoroughfare. The authorized project includes a navigation channel with a depth of 12 ft. and widths varying from 90 ft. in land cuts to 300 ft. in open waters; side channels and basins at a number of locations; and five highway bridges. The Beaufort to Cape Fear River section was authorized by House Document No. 450, 69th Congress, *Inland Waterway, Beaufort – Cape Fear River*. The main channel of the AIWW in North Carolina was completed in 1940, and it has since been maintained by dredging to remove shoals that develop periodically. Some of the dredged material removed during maintenance activities is beach-quality sand. That material is placed directly on nearby ocean beaches, when practicable; otherwise, it is stockpiled in confined disposal areas near the shoreline of the AIWW. The sand can serve as a viable source of beachfill where it exists in sufficiently large volumes and in proximity to beaches.

- **New Topsail Inlet and Connecting Channels**—These consist of a channel 8 ft. deep and 150 ft. wide through New Topsail Inlet, with connecting channels 7 ft.

deep and 80 ft. wide to the AIWW. The connecting channels are through Old Topsail Creek (1.42 miles) and Banks Channel (6.27 miles), both between the AIWW and New Topsail Inlet.

- **New River Inlet**—This consists of a channel 6 ft. deep and 90 ft. wide through New River Inlet to the AIWW, a length of 2.3 miles. The channel continues another 18.8 miles from the AIWW to U.S. highway 17 at Jacksonville, North Carolina, but has not been maintained.

Additionally, over the past 25 to 30 years, material resulting from maintenance dredging of New River, the AIWW, and connecting channels has been placed on the northernmost mile of the study area in the vicinity of New River Inlet. Records from FY 1998 through FY 2007 show that this total placement of 680,000 cubic yards has occurred on an irregular basis, generally every 1 to 3 years, with dredging quantities varying from 70,000 to 170,000 cubic yards and averaging about 110,000 cubic yards per event.

The towns of North Topsail Beach and Topsail Beach are also proposing nonfederally funded beach renourishment actions. North Topsail Beach has proposed putting 4 million cubic yards of material in the CBRA zone, which is outside the federal project study area. Topsail Beach has proposed putting about 1.3 million cubic yards of material as an interim renourishment plan that would occur before construction of a federal plan.

Also of note, North Carolina has begun creating a Beach and Inlet Management Plan (BIMP). The long-term goal of that plan is implementing a consensus-based regional strategy for the state, federal, and local governments to manage beach and inlet projects across the entire state.

2. AFFECTED ENVIRONMENT

The project is in Pender and Onslow counties in the towns of Surf City and North Topsail Beach, North Carolina. Topsail Island is a 22-mile-long barrier island on North Carolina's south-central coast consisting of three communities, from south to north—Topsail Beach, Surf City, and North Topsail Beach. The footprint of the proposed action includes the sub-aerial beaches of Surf City and North Topsail Beach as well as the marine environment offshore of the barrier island. Significant resources found within the vicinity of the project area, in both the marine and terrestrial environment, are described below. Physical resources, socioeconomic resources, recreation and aesthetic resources, cultural resources, Section 122, P.L. 91-611 Resources, and water quality conditions are also discussed in this section. Vertical datum for this report is NGVD29.

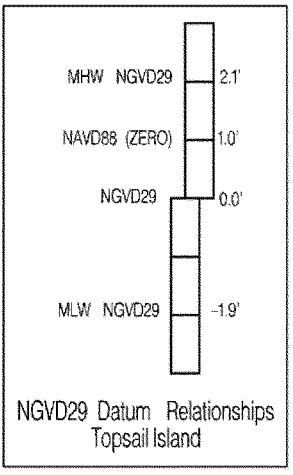


Figure 1.2, Datum relationships

2.01 Marine Environment

Marine waters in the vicinity of the beach nourishment area and offshore borrow sites provide habitat for a variety of ocean fish and are important commercial and recreational fishing grounds (Appendix A, Figure A-1). Kingfish, spot, bluefish, weakfish, spotted sea trout, flounder, red drum, king mackerel, and Spanish mackerel are actively fished from boats, the beach, and local piers. According to the North Carolina Division of Marine Fisheries (NCDMF) commercial and recreational harvest statistics, those species compose approximately 18 and 37 percent, respectively, of the total pounds of fish landed in North Carolina in 2007 (http://www.ncfisheries.net/statistics/index.html). The surf zone typically exhibits a high diversity of fish fauna. According to data collected from surf zone seine sampling along the South Atlantic Bight, 130 species of fishes are known from the surf zone between North Carolina and southern Georgia of which 47 species have been recorded from North Carolina beaches. The major recruitment period for juvenile fishes to surf zone nurseries is late spring through early summer. The waters also accumulate juvenile, ocean spawning, and estuarine-dependent fish and invertebrates in the late winter and early spring before their transport through New Topsail and New River Inlets (Hackney et al., 1996).

The intertidal zone in the proposed beach nourishment area serves as habitat for invertebrates including mole crabs, coquina clams, amphipods, isopods, and polychaetes, which are adapted to the high-energy, sandy-beach environment. The species are not commercially important; however, they provide an important food source for surf-feeding fish and shore birds. Offshore bottoms also provide habitat for benthic-oriented organisms. Special concerns are hard-bottom areas, which generally support a diversity of soft corals, anemones and sponges and provide habitat for reef fish such as black sea bass, red porgy, and groupers. Hard bottoms are also attractive to pelagic species such as king mackerel, amberjack, and cobia.

Sargassum is an abundant seaweed that occurs near the surface in warm waters of the western North Atlantic. With an exceptionally fast growth rate, floating rafts of Sargassum represent a highly renewable natural resource that can be harvested for various uses. Sargassum supports a wide range of marine organisms that include micro- and macro-epiphytes, fungi, more than 100 species of invertebrates, more than 100 species of fishes, and four species of sea turtles. The South Atlantic Fishery Management Council (SAFMC) previously designated Sargassum as essential fish habitat (EFH) for snappers, groupers, and coastal migratory pelagic fishes of the South Atlantic region (Coston-Clements et al., 1991)

2.01.1 Wetlands and Flood Plains

Coastal wetlands of the project vicinity include tidal salt marshes, which occur along the shorelines and island fringes along the backside of Topsail Island (Appendix A, Figure A-2). Intertidal wetlands of the area are very important ecologically because of their high primary productivity, their role as nursery areas for larvae and juveniles of many marine species, and their refuge/forage value to wildlife. In addition, they provide aesthetically valuable natural areas. Many types of wetland communities are present in the project area including smooth cordgrass marsh, needlerush marsh, saltmeadows, and high marsh. All are important primary producers of organic matter and, therefore, serve as part of the base of the aquatic food chain. Smooth cordgrass (*Spartina alterniflora*) marshes occur within the intertidal zone along the sounds and tidal creeks and provide valuable nursery habitat for many commercially valuable species of marine and estuarine organisms. The frequent removal of organic material and the daily tidal sedimentation processes make salt marsh communities very productive (Schafale and Weakley 1990). Needlerush marsh is dominated by black needlerush (*Juncus romerianus*) and occurs in areas that are irregularly flooded. Saltmeadows are essentially pure stands of salt meadow cordgrass (*Spartina patens*), which can occur between 3.5–5.0 ft. above mean sea level. Salt grass (*Distichlis spicata*), sea lavender (*Limonium carolinianum*), glasswort (*Salicornia* spp.), and sea ox-eye (*Borrichia frutescens*) are also prominent plants in this community. High marsh is a transitional community between high ground areas and wetlands and, depending on location and frequency of flooding, may have characteristics of either. It is important in stabilizing the shifting sands of the barrier island. Given time and protection, it will eventually become vegetated with dominant shrub species such as marsh elder (*Iva frutescens*), wax myrtle (*Myrica cerifera*), and yaupon (*Ilex vomitoria*) (Wilson 1981).

North Carolina defines Primary Nursery Areas (PNAs) as tidal saltwaters, which provide essential habitat for the early development of commercially important fish and shellfish (Appendix A, Figure A-3). It is in such estuarine areas that many fish species undergo initial post-larval development. PNAs are designated by the North Carolina Marine Fisheries Commission and total 80,144 acres statewide. With the exception of navigation channels, they include most estuarine waters of the project vicinity, including those bounded by New River (north), New Topsail Inlet (south), AIWW (west), and the landward side of Topsail Island. Protection of juvenile fish is provided in those areas through prohibition of many commercial fishing activities, including the use of trawls,

seines, dredges, or any mechanical methods of harvesting clams or oysters (http://www.ncfisheries.net/rules.htm; 15 NC Administrative Code 3B .1405).

2.01.2 Inlet, Flats, and Sounds

New Topsail Inlet separates Topsail Beach to the northeast from Lea Island to the southwest and serves as the major ocean outlet for the waters of the AIWW through Howard's Creek, Topsail Creek, and Banks Channel (see Figure 1.1). The mean minimum inlet width for the past 60 years has been 480 meters (1,575 ft.) and over the past decade, the average rate of migration has been southwest 30 meters (98 ft.) per year. New River Inlet separates North Topsail Beach to the southwest from military-controlled Onslow Beach to the northeast and serves as an ocean outlet for New River (see Figure 1.1). In recent history, the width of New River inlet has varied considerably and has been influenced by dredging activities. Since the initiation of maintenance dredging activities in 1963, inlet migration rates have altered and the average inlet width has been 225 meters. North Topsail Beach is experiencing oceanfront erosion trends related the changing shape of the ebb-tidal delta, which in turn is primarily governed by the ebb-channel orientation (Cleary and Marden, 1999). Ebb channel orientation and subsequent inlet migration response at New Topsail inlet and New River inlets has a dramatic effect on the accretion and erosion patterns experienced at Topsail Beach and North Topsail Beach, respectively. As New Topsail inlet migrates southwest toward Lea Island, the southern spit of Topsail Beach continues to accrete; whereas, North Topsail Beach continues to erode under the current ebb-channel alignment of New River inlet. Portions of the sound around New Topsail Inlet and the mouth of New River inlet may contain large intertidal shoals and mud flats, which are very important to migrating and wintering waterbirds, including the Piping Plover; however, the quantity and quality of that habitat is dependent on the inlet dynamics and subsequent shape of the ebb tidal delta and ebb-channel orientation at any time. Both inlets are a critical migratory pathway for many organisms entering and exiting the sounds and river, including larval fishes and crustaceans (Section 2.01.5), and anadromous and catadromous fishes.

An estuary is a partly enclosed body of water where freshwater from rivers mixes with saltwater from the sea. North Carolina has the largest estuarine system of any state on the Atlantic Coast with estuarine-dependent species composing 90 percent of commercial landings and 60 percent of recreational landings (by weight) (Street et al. 2004). The large estuarine system within the vicinity of Surf City and North Topsail Beach, including the sounds (i.e., Topsail and Stump sounds) and bays (i.e., Chadwick and Alligator bays), are separated from the ocean by Topsail Island. Many variables influence the character of the estuary including wind direction and force, inlet flows, river discharge, and such. Salinity near New Topsail and New River inlets varies depending on tides and freshwater discharge and could range between 10 and 32 parts per thousand (ppt) (Hettler and Barker 1993). Tides near those inlets normally follow those of the sea; however, at times, the combined forces of freshwater discharge and wind overwhelm incoming tides and force water out of the inlet throughout the tidal cycle. Below the surface of the estuarine environment around the inlets is a mosaic of shifting sand habitats. Small areas of submerged aquatic vegetation (SAV) habitat have been observed in the past few years by biologists from NCDMF Topsail Sound (NCDENR 2005). The

Carolina diamondback terrapin is a state-listed species of concern for Pender County, North Carolina, and may be found on the sound side of Topsail Island in brackish water areas and feeds mostly feed on clams, shrimp, crabs, snails, and small fish. They have been known to eat some vegetation, but they are primarily carnivores (http://www.chelonia.org/).

2.01.3 Nearshore Ocean

Sand excavation and material disposal for beach and berm construction would occur in the nearshore ocean in an area described by Day et al. (1971) as the *turbulent zone*. The turbulent zone includes ocean waters from below low tide to a depth of about 60 ft. NGVD (National Geodetic Vertical Datum). Identified sediment borrow areas proposed for project construction and periodic nourishment are approximately 1 to 6 miles offshore between –35 foot to –50 foot Mean Lower Low Water (MLLW) (Appendix A, Figure A-6). Those borrow sites beyond 3 nautical miles offshore are subject to federal mining requirements imposed by the MMS. Beach nourishment would introduce fill into nearshore waters with a depth of closure of –23 ft. NGVD. Benthic organisms, phytoplankton, and seaweeds are the major primary producers in this community with species of *Ulva* (sea lettuce), *Fucus*, and *Cladocera* (water fleas) being fairly common where suitable habitat occurs. Many species of fish-eating birds are typically found in that area including gulls, terns, cormorants, loons, and grebes (Section 2.02.3). Marine mammals and sea turtles also are frequently seen in the area (See Appendix I). Fishes and benthic resources of the area are discussed in Sections 2.01.7 and 2.01.9, respectively.

2.01.4 Surf Zone Fishes

The surf zone along the area beaches provides important fishery habitat on which some species are dependent. Surf zone fisheries are typically diverse, and 47 species have been identified from North Carolina; however, the actual species richness of fishes using the North Carolina surf area for at least part of their life history is much higher (Ross, 1996; Ross and Lancaster, 1996). According to Ross (1996), the most common species in the South Atlantic Bight surf zone are Atlantic menhaden (*Brevoortia tyrannus*), striped anchovy (*Anchoa hepsetus*), bay anchovy (*A. mitchilli*), rough silverside (*Membras martinica*), Atlantic silverside (*Menidia menidia*), Florida pompano (*Trachinotus carolinus*), spot (*Leiostomus xanthurus*), Gulf kingfish (*Menticirrhus littoralis*), and striped mullet (*Mugil cephalus*). Two species in particular, the Florida pompano and gulf kingfish (*M. littoralis*) seem to use the surf zone exclusively as a juvenile nursery area and are rarely found elsewhere. The major recruitment time for juvenile fishes to surf zone nurseries is late spring through early summer (Hackney et al., 1996). Recent studies by Ross and Lancaster (1996) indicate that the Florida pompano and gulf kingfish may have high site fidelity to small areas of the beach and extended residence time in the surf zone, suggesting its function as a nursery area. Major surf zone species consume a variety of benthic and planktonic invertebrates, with most of the prey coming from the water column. The dominant benthic prey are coquina clams; however, that is not the dominant food item throughout the South Atlantic Bight. Furthermore, many surf zone fishes exhibit prey switching in relation to prey availability, which could mitigate effects of beach nourishment (Ross, 1996).

2.01.5 Larval Fishes

New Topsail and New River Inlets are important passageways for the larvae of many species of commercially or ecologically important fish. Spawning grounds for many marine fishes are believed to occur on the continental shelf with immigration to estuaries during the juvenile stage. The shelter provided by the marsh and creek systems in the sound serves as nursery habitat where young fish undergo rapid growth before returning to the offshore environment.

Transport from offshore shelves to estuarine nursery habitats occurs in three stages: offshore spawning grounds to nearshore, nearshore to the locality of an inlet or estuary mouth, and from the mouth into the estuary (Boehlert and Mundy, 1988). Hettler et al. (1997) documented, through analysis of larvae otoliths, that a large number of young Atlantic menhaden (*B. tyrannus*) larvae averaging 55 days post hatch arrived in mid-March on the date of maximum observed daily concentration (160 larvae per 100 cubic meters (m^3)(3,531 cubic feet [ft^3]). For all species recorded in this study, abundance varied as much as an order of magnitude from night to night. The methods the larvae use to traverse large distances over the open ocean and find inlets are uncertain. Various studies have hypothesized such mechanisms as passive wind and depth-varying current dispersal and active horizontal swimming transport. However, little is known regarding larval distribution in the nearshore area.

Little research has been conducted within the New Topsail and New River Inlet systems regarding larval species composition and abundance. However, the Beaufort Inlet system about 40 miles north/northeast of New River Inlet has been extensively studied, and significant amounts of data have been collected regarding larval transport of commercially and ecologically important fish. Considering the close proximity of the inlet systems, it can be expected that species composition would be similar (Larry Settle, personal communication, June 27, 2002; Thomas Lankford, personal communication, August 12, 2004). During the winters of 1992–1993 and 1993–1994, Hettler and Hare (1998) conducted an experiment at Beaufort Inlet, North Carolina, to further understand the estuarine ingress of offshore spawning species. A complex lateral structure in estuarine circulation, independent of the inlet opening size, was found in regards to larval concentration with significant interactions among inlet side, distance offshore, and date of ichthyoplankton tows. Length of species caught varied by cruise, inlet side, and distance offshore. The differences in larval concentration offshore and inshore and the species differences in length suggest species-specific rates controlling the net number of larvae entering the nearshore from offshore, the net number of larvae entering the inlet mouth from nearshore, and the larval mortality in the nearshore zone. Results from the study suggest two bottlenecks for offshore-spawning fishes with estuarine juveniles: the transport of larvae into the nearshore zone and the transport of larvae into the estuary from the nearshore zone (Hettler and Hare, 1998).

Egg and larval transport from offshore spawning grounds to the inshore environment of Beaufort Inlet was studied by Hettler and Hare (1998) in seven estuarine-dependent species, including Atlantic menhaden (*B. tyrannus*), spot (*L. xanthurus*), Atlantic croaker

(*Micropogonias undulatus*), pinfish (*Lagodon rhomboides*), summer flounder (*Paralichthys dentatus*), southern flounder (*P. lethostigma*) and Gulf flounder (*P. albigutta*). Research conducted by the NMFS Beaufort Laboratory through June 2002 collected a total of 120 species of larval fish fauna off the Beaufort Inlet and adjacent waters. According to Hettler and Hare (1998), average weekly concentration (number per 100 m^3 (3,531 ft^3)) for all of the above estuarine dependent species, with the exception of Gulf flounder, was calculated during the October 1994 to April 1995 immigration season. Concentrations were 22.9, 4.8, 25.7, 12.4, 0.3, and 0.8 larvae/100m^3 (3,531 ft^3) respectively (Hettler, 1998). According to the spring tide flow calculated by Jarret (1976) and the calculated daily larval concentration within the water column, approximately 32.5, 6.8, 36.5, 17.6, 0.43, and 1.1 million larvae pass through the inlet during a single spring tide for each respective species. Concentrations for all species combined (Appendix Q) entering the inlet during a single tidal prism range from 0.5 to 5 larvae/m^3. Therefore, daily calculated larval concentration at Beaufort Inlet for all species within the tidal prism ranges between 66 to 710 million (Larry Settle, personal communication, June 27, 2002).

2.01.6 Anadromous Fishes

A number of anadromous fish species occur in ocean waters along the North Carolina coast (within ~3 miles) and migrate into rivers and their tributaries to spawn in freshwater. These include the striped bass (*Morone saxatilis*), Atlantic sturgeon (*Acipenser oxyrhynchus*) and shortnosed sturgeon (*Acipenser brevirostrum*), and several members of the herring family (Clupeidae) such as the American shad (*Alosa sapidissima*), hickory shad (*Alosa mediocris*), alewife (*Alosa pseudoharengus*), and blueback herring (*Alosa aestivalis*). Historically, the species used most accessible coastal streams in North Carolina, and the highest use occurred from mid-winter to mid-spring during the spawning runs. Sampling in the New River in 1974 and 1975 by NCDMF identified the presence of blueback herring, alewife, American shad, and Atlantic sturgeon, although egg-netting results indicated very poor spawning success for all anadromous species. That 1975 study concluded that anadromous fish stocks in New River were very low and that, as a result, there was little or no use of the fishery (Sholar, 1975) and no recent anadromous fish studies have been completed in New River since then (Fritz Rhode, personal communication, August 9, 2008). Recent reports from the NCDMF indicate the presence of juvenile Atlantic sturgeon in the lower New River and inlet vicinity; however, no recent records exist of shortnose sturgeon in the project area (Fritz Rhode, personal communication, August 9, 2008) (see Appendix I, Biological Assessment). Because of the lack of suitable freshwater spawning areas in the project area and the requirement of low salinity waters by juveniles, any shortnose sturgeons present would most likely be non-spawning adults (NMFS, 1998).

2.01.7 Nekton

Nekton collectively refers to aquatic organisms capable of controlling their location through active movement rather than depending on water currents or gravity for passive movement. Nekton of the nearshore Atlantic Ocean along Topsail Island, North Carolina, can be grouped into three categories: estuarine dependent species, permanent resident species, and seasonal migrant species. The most abundant nekton of these waters are the estuarine-

dependent species, which inhabit the estuary as larvae and the ocean as juveniles or adults. That group includes species that spawn offshore, such as the Atlantic croaker (*Micropogon undulatus*), spot (*L. xanthurus*), Atlantic menhaden (*B. tyrannus*), star drum (*Stellifer lanceolatus*), southern kingfish (*Menticirrhus americanus*), flounders (*Paralichthys* spp.), mullets (*Mugil* spp.), anchovies (*Anchoa* spp.), blue crab (*Callinectes sapidus*), and penaeid shrimp (*Farfantepenaeus* spp. and *Lilopenaeus* sp.), as well as species that spawn in the estuary, such as red drum (*Sciaenops ocellatus*) and weakfish (*Cynoscion regalis*). Species that are permanent residents of the nearshore marine waters include the black sea bass (*Centropristis striata*), longspine porgy (*Stenotomus caprinus*), Atlantic bumper (*Chloroscombrus chrysurus*), inshore lizardfish (*Synodus foetens*), and searobins (*Prionotus* spp.). Common warm water migrant species include the bluefish (*Pomatomus saltatrix*), Spanish mackerel (*Scomberomorus maculatus*), king mackerel (*Scomberomorus cavalla*), cobia (*Rachycentron canadum*), Florida pompano (*T. carolinus*), and spiny dogfish (*Squalus acanthias*). Oceanic large nekton offshore of Topsail Island are composed of a wide variety of bony fishes, sharks, and rays, as well as fewer numbers of marine mammals and reptiles.

All marine mammals are protected by the Marine Mammal Protection Act (MMPA) of 1972, as amended, but the West Indian manatee and six large whales are also listed as endangered and, therefore, are afforded additional protection under the Endangered Species Act (ESA). The MMPA prohibits, with certain exceptions, the *take* of marine mammals in U.S. waters and by U.S. citizens on the high seas, and the importation of marine mammals and marine mammal products into the United States. All marine mammals and reptiles that may be present within the project area and are federally listed as threatened or endangered under the ESA are addressed in the biological assessment (see Appendix I).

Several marine mammal species occur in the project, which are not federally listed but are protected under the MMPA. The Navy uses the Marine Resource Assessment program to develop a comprehensive data and literature compilation of protected and managed marine resources within its various operating areas. The document is used for planning purposes and for various types of environmental documentation, such as biological and environmental assessments, that must be prepared in accordance with NEPA, MMPA, ESA, and Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA). Thirty-eight marine mammal species have been recorded in or adjacent to the Surf City and North Topsail Beach project area. Those species include 33 cetaceans (whales, dolphins, and porpoises), 4 pinnipeds (seals, sea lions, and fur seals), and 1 sirenian. Only 24 of those species are expected to regularly occur in the region (Table 2.1). Some cetacean species occur in the project area year-round (e.g., bottlenose dolphin, beaked whales), while others (e.g., right whale, humpback whale) occur seasonally as they migrate through the area. Only rare occurrences of the West Indian manatee are anticipated. Although bottlenose dolphins are common in the project area, the Corps has never documented a direct effect on bottlenose dolphins from dredging activities during its numerous dredging projects throughout the United States; therefore, an Incidental Harassment Authorization in accordance with the MMPA is not anticipated for this project. In the April 25, 2005, notice in the *Federal Register* for the issuance of

an Incidental Harassment Authorization for blasting at the Port of Miami, NMFS concluded, "According to the Corps, bottlenose dolphins and other marine mammals have not been documented as being directly affected by dredging activities and, therefore, the Corps does not anticipate any incidental harassment of bottlenose dolphins. NMFS concurs" (Geo-Marine, 2005). Therefore, no further coordination under the MMPA is anticipated for this project.

Table 2.1. Marine mammal species found in the project area.

Order Cetacea
Suborder Mysticeti (baleen whales)
Family Balaenidae
North Atlantic right whale *Eubalaena glacialis* ENDANGERED
Family Balaenopteridae (rorquals)
Humpback whale *Megaptera novaeangliae* ENDANGERED
Minke whale *Balaenoptera acutorostrata*
Bryde's whale *Balaenoptera edeni*
Sei whale *Balaenoptera borealis* ENDANGERED
Fin whale *Balaenoptera physalus* ENDANGERED
Blue whale *Balaenoptera musculus* ENDANGERED

Suborder Odontoceti (toothed whales)
Family Physeteridae
Sperm whale *Physeter macrocephalus* ENDANGERED
Family Kogiidae
Pygmy sperm whale *Kogia breviceps*
Dwarf sperm whale *Kogia sima*

Family Ziphiidae (beaked whales)
Cuvier's beaked whale *Ziphius cavirostris*
True's beaked whale *Mesoplodon mirus*
Gervais' beaked whale *Mesoplodon europaeus*
Blainville's beaked whale *Mesoplodon densirostris*
Sowerby's beaked whale *Mesoplodon bidens*
Northern bottlenose whale *Hyperoodon ampullatus*

Family Delphinidae (dolphins)
Rough-toothed dolphin *Steno bredanensis*
Bottlenose dolphin *Tursiops truncatus*
Pantropical spotted dolphin *Stenella attenuata*
Atlantic spotted dolphin *Stenella frontalis*
Spinner dolphin *Stenella longirostris*
Striped dolphin *Stenella coeruleoalba*
Clymene dolphin *Stenella clymene*
Short-beaked common dolphin *Delphinus delphis*
Fraser's dolphin *Lagenodelphis hosei*
Risso's dolphin *Grampus griseus*
Melon-headed whale *Peponocephala electra*
Pygmy killer whale *Feresa attenuate*
False killer whale *Pseudorca crassidens*
Killer whale *Orcinus orca*
Long-finned pilot whale *Globicephala melas*
Short-finned pilot whale *Globicephala macrorhynchus*
Family Phocoenidae
Harbor porpoise *Phocoena phocoena*

Order Carnivora
Suborder Pinnipedia (seals, sea lions, walruses)
Family Phocidae (true seals)
Harbor seal *Phoca vitulina*
Gray seal *Halichoerus grypus*
Harp seal *Pagophilus groenlandicus*
Hooded seal *Cystophora cristata*

Order Sirenia
Family Trichechidae
West Indian manatee *Trichechus manatus*

Source: Geo-Marine, 2008

Note: Those species identified as endangered under the ESA are addressed in the biological assessment (Appendix I).

2.01.8 Benthic Resources—Beach and Surf Zone

The intertidal zone of the beach shoreface is extremely dynamic and is characterized as the area from mean low tide landward to the high tide mark. The area serves as habitat for invertebrate communities adapted to the high-energy, sandy-beach environment. Important invertebrates of the surf zone and beach/dune community include the mole crab (*Emerita talpoida*), coquina clams (*Donax variabilis*), polychaete worms, amphipods, and ghost crabs (*Ocypode quadrata*). Mole crabs and coquinas represent the largest component of the total macrofaunal biomass of North Carolina intertidal beaches, and they are consumed in large numbers by important fish species such as flounders, pompanos, silversides, mullets, and kingfish (Reilly and Bellis, 1978; Leber, 1982; Johnson, 1994). Beach intertidal macrofauna are also a seasonally important food source for numerous shorebird species.

Through recent studies supported by the U.S. Fish and Wildlife Service (USFWS) and the Corps, the distributions and abundance of these animals on nearby beaches is fairly well documented. Extensive sampling of the intertidal and nearshore beach environment was performed and documented in the Corps New York District's biological monitoring report titled, *Final Report for The Army Corps of Engineers New York District's Biological Monitoring Program for the Atlantic Coast of New Jersey, Sea Bright to Manasquan Inlet, Beach Erosion Project* (2001). Results of that study indicate that the intertidal infaunal assemblage was dominated by rhynchocoels; the polychaetes *Scolelepis squamata*, *Protodriloides (LPIL)*, and *Microphthalmus* spp.; oligochaetes; the mole crab *E. talpoida*; and a number of haustoriid amphipods. The nearshore infaunal assemblage included many of the same taxa but was dominated by the wedge clam, *D. variabilis*, the polychaete *Magelona papillicornis*, the clams *Spisula solidissima* and *Tellina agilis,* and the amphipods *Acanthohaustorius millsi* and *Psammonyx nobilis*, and the polychaete *Asabellides oculata*. Those documented infaunal assemblages are consistent with other studies throughout the Atlantic Coast (USACE, 2001). In North Carolina, along Bogue Banks and Topsail Island, infaunal assemblages are dominated by *D. variabilis*, *D. parvula*, and *E. talpoida*, which function as an important first link in the flow of energy in the intertidal system (Leber, 1982; Reilly and Bellis, 1978). Other

organisms occurring less frequently are Amphipods (*Haustorius canadensis, Talorchestia megalopthalma*, and *Amphiporia virginiana*) and Polychaetes (*S. squamata* and *Nephtys picta*) (Lindquist and Manning, 2001; Nelson, 1989; Leber, 1982; Reilly and Bellis, 1978).

2.01.9 Benthic Resources—Nearshore Ocean

Aquatic organisms that live in close association with the bottom, or substrate, of a body of water, are collectively called the benthos. Benthos communities provide a link between planktonic and benthic production and commercially important fish species (Posey, 1991). Benthic communities of the project area exhibit a wide range of organism composition and density, and community structure may vary considerably depending on substrate type, salinity regime, proximity to structural habitat, and the like. Benthic substrate type and structural habitat within the project area range between fine- to coarse-grained sand; gravel and shell hash; and low-, moderate-, and high-relief hard bottom. Specifically, the nearshore *soft bottom* environment just offshore of the beach face consists of transitioning regions of coarse gravel and shell hash and sand. Those features, common to North Carolina, are defined in the literature as, rippled scour depressions (RSD), rippled channel depressions (RCD), or sorted bed forms. They are thought to be the result of a feedback mechanism whereby an existing deposit of coarse-shell hash and gravel material is built on and segregated from fine material due to wave motion interacting with the enhanced roughness of the seafloor bed around patches of coarse material (Cacchione et al., 1984; Thieler et al., 1999, 2001; Murray and Thieler, 2004) (see Section 8.01.8.2). The specific biological functions of those features have not been heavily studied; however, the benthic species composition, population, and community structure likely shift depending on the substrate type. Most nearshore benthic invertebrates in soft-bottom substrates tend to be r-strategists, which are characteristically small-bodied, short-lived, and have high fecundity, efficient dispersal mechanisms, and rapid growth rates. Thus, recolonization of a disturbed area is generally initiated by r-strategists (Bowen and Marsh, 1988).

As discussed in Section 2.01.10, *hard-bottom* communities are in the offshore environment of the project area and are found within the proposed borrow areas and consist of low-, moderate-, and high-relief features (Moser and Taylor, 1995; Moser et al., 1995). Benthic organisms and community structure associated with hard-bottom features are unique from other soft-bottom, benthic communities. Section 2.01.10 and Appendix R4 discuss the specific organisms identified within representative hard-bottom communities found in the study area. In summary, moderate- to high-relief, hard-bottom communities were more diverse and supported predominantly *Oculina* sp. colonies, tunicates, sponges, macro-algae (i.e., benthic sargassum), bryozoans, and hydrozoans; whereas, low-relief communities were characterized by lower stony coral cover and higher cover by fast-growing octocorals.

A myriad of benthic surveys of representative soft-bottom, nearshore ocean sites have been conducted throughout the Mid-Atlantic and South Atlantic regions, including within the vicinity of the proposed project area. Three nearshore ocean sites off Virginia Beach were conducted for the U.S. Department of Interior's MMS in 1996 and 1997 by Cutter

and Diaz (1998). They collected a total of 119 taxa from 13 Smith-Macintyre grabs collected in 1996. Half of the top 14 taxa (occurrence and abundance) were polychaetes. The remainder included representatives from the amphipods, decapods, bivalves, nemerteans, tanaids, echinoderms, and chordates. They found the overall community composition to be typical for sandy, shallow, continental shelf habitats and with similar species composition for similar depths and sediment types reported by Day et al. (1971) for North Carolina (Table 2.2). Day et al. (1971) define the nearshore ocean as the *turbulent zone*, which includes ocean waters from below low tide to a depth of about 60 ft. According to Day et al., polychaete species are highly represented in this zone with pelecypods, decapods, amphipods, echinoderms, and cephalochordates also present. Biological characterization results from field surveys performed by MMS of offshore shallow shelf habitats in the Outer Banks, North Carolina, identified members of the major invertebrate and vertebrate groups commonly found in the general area. Dominant infaunal groups consisted of crustaceans, echinoderms, mollusks, and polychaetes, while epifaunal taxa consisted primarily of decapods, sea stars, and squid. Dominant demersal fish species included clearnose skate (*Raja eglanteria*), flounder (*Paralichthys* sp.), scup (*Stenotomus chrysops*), and sea robin (*Prionotus scitulus*) (Byrnes et al., 2003). Posey and Alphin (2000), collected offshore benthic infaunal samples at depths of 30–40 ft. from pre-borrow sites of Kure Beach, North Carolina. Results indicate that the benthic community was very diverse, with more than 600 species, and largely dominated by polychaetes, with crustaceans and bivalves composing most of the remaining taxa.

Benthic infaunal samples were collected by Dial Cordy and Associates Inc. within six borrow sites offshore of Topsail Beach in 2007 (USACE, 2009, 2007a). Benthic invertebrate abundance, species composition, and biomass were calculated and qualitative comparisons of the data were made to the results of other pertinent benthic studies in the Mid- and South-Atlantic regions. Results indicate that the benthic resources in the sampled borrow areas off of Topsail Beach are similar in composition and taxa dominance to those described in other studies along the North Carolina and South Carolina coasts (Table 2.2) (Byrnes et al., 2003; Van Dolah et al., 1984; Versar, 2002 and 2006; and Posey and Alphin 2000 and 2002). However, the benthic community found offshore of Topsail Beach was less diverse and abundant than baseline sampling performed for the Kure Beach restoration project (Posey and Alphin, 2000 and 2002) and for the Dare County beach coastal storm damage reduction project (Versar, 2006). It is likely that the differences between the benthic community off Topsail Beach and the two referenced studies are due to the more extensive sampling effort associated with baseline monitoring programs as compared to a less intensive sampling regime for a general characterization study (i.e., 10 sampling stations per site off Dare County as compared to three to five stations per site for the Topsail Beach benthic characterization study). Of the 104 total taxa collected for the one-time sampling performed off Topsail Beach, polychaetes also dominated the community, composing over 30 percent of the relative abundance at four of the six borrow sites (USACE, 2009, 2007a).

Table 2.2. Most abundant benthic species within the Topsail Island offshore borrow sites

Group	Species
Polychaeta	*Mediomastus* sp.
	Onuphidae sp.
	Armandia maculate
	Bhawania heteroseta
	Glyceridae sp.
	Goniada littorea
	Goniadides carolinae
	Caulleriella sp. *J*
	Magelona papillicornis
	Spionidae sp.
Malacostraca	*Rhepoxynius hudsoni*
	Eudevenopus honduranus
Ostracoda	*Eusarsiella texana*
Leptocardia	*Branchiostoma* sp.
Ophiuroidea	*Ophiuroidea* sp.
Bivalvia	*Crassinella dupliniana*
	Crassinella lunulata
	Lucinidae sp.
	Tellina sp.
Gastropoda	*Acteocina canaliculata*
	Cylichna alba
	Caecum pulchellum
Turbellaria	*Turbellaria* sp.
Rhynchocoela	*Rhynchocoela* sp.

Source: USACE, 2007a

Though specific borrow areas identified for the Surf City and North Topsail Beach Coastal Storm Damage Reduction Project have not been sampled, considering (1) the similarities in species composition and taxa dominance throughout all previously conducted benthic studies offshore of Virginia, North Carolina, and South Carolina, (2) the nearness of the Topsail Island sampled borrow areas (USACE, 2009, 2007a) to the proposed Surf City North Topsail Beach (SCNTB) project borrow areas, and (3) the similarity in sediment characteristics among the previous studies, it is expected that the benthic infaunal communities within the borrow areas offshore of SCNTB would be similar to previous studies.

2.01.10 Hard Bottoms

Historical Database

Hard bottoms are defined as localized areas not covered by unconsolidated sediments, where the ocean floor consists of hard substrate. In the South Atlantic Bight, such hard bottoms vary in relief from high (higher than 2.0 m (6.6 ft) to low (lower than 0.5 m (1.6 ft) profile and range nearshore (within the states' 3-nautical-mile territorial sea limit) to beyond the continental shelf edge (more than 200 m [656 ft] [Moser et al. 1995]). Hard bottoms are also called *live bottoms* because they support a rich diversity of invertebrates such as corals, anemones, and sponges, which are refuges and food sources for fish and other marine life. They provide valuable habitat for reef fish such as black sea bass, red porgy, and groupers. Hard bottoms are also attractive to pelagic species such as king

mackerel, amberjack, and cobia. While hard bottoms are most abundant in southern portions of North Carolina, they are along the entire coast. Storms play a major role in distributing hard-bottom, benthic communities as they remove sediments accumulated from bioerosion and redistribute the ephemeral bottom sediments, exposing or burying hard-bottom surfaces (Riggs et al., 1998). The surficial sand sheet on the upper, flat, hard bottom is generally very thin, has an irregular distribution, and is highly mobile (Riggs et al., 1996). According to Cleary (2003), the environment offshore of the proposed Surf City and North Topsail Beach (SCNTB) project area is characterized by undulating, relatively flat, hard-bottom platform punctuated by scattered, low-relief, hard-bottom scarps (moldic limestone and siltstone) and sediment-filled depressions.

Existing databases of hard-bottom habitat throughout North Carolina, including offshore of Topsail Island, are fairly limited. In 1985 the Southeast Area Monitoring and Assessment Program (SEAMAP–South Atlantic) established a bottom-mapping workgroup to develop a regional database that describes the location and characteristics of bottom habitats throughout the South Atlantic Bight. The primary focus of the effort was to identify the location and quantify the extent of hard-bottom reef habitats for state and federal resource agencies to adequately assess reef-fish populations and the effects of changes in fishing pressure as well as to provide protection of the habitats from adverse effects related to various anthropogenic stresses. The three major objectives of SEAMAP were to (1) conduct an extensive search of existing databases to classify the presence of hard-bottom reef habitats, (2) use standardized protocols to analyze whether hard-bottom habitat is present, possibly present, or absent, and to identify the location of artificial reef habitats, and (3) summarize the data into easy-to-use databases for researchers and mangers.

As a component of the SEAMAP database, Moser et al. (1995) and Moser and Taylor (1995) provided a summary of the distribution and aerial extent of hard-bottom habitats on the continental shelf of North Carolina. Existing hard-bottom data (i.e., fisheries, in-situ observations, core data, artificial reef data, and geophysical data) were compiled and evaluated to map bottom types on the continental shelf. Bottom-type classifications for North Carolina were based primarily on geophysical and fish trawl surveys. A total of 11,890 observations were added to the SEAMAP hard-bottom database. The location of the hard-bottom communities offshore of Surf City, North Topsail Beach, and Onslow Beach, as identified in this study, are in Table 2.3 and shown in Figure A-1 in Appendix A.

Table 2.3. Hard-bottom locations within waters off Surf City, North Topsail Beach, and Onslow Beach, North Carolina, according to Moser and Taylor (1995)

Location # According to Moser and Taylor (1995)	Nearest Town	Nearest Inlet Access	Vertical Distances		Reef Site Location		
			Approximate Water Depth (Ft)	* Relief High (H), Medium (M), Low (L)	Latitude	Longitude	Type of Location
24	Surf City	New River	25-40	M	3422.59	7732.87	Point
25	Surf City	New River	25-40	M	3422.67	7732.83	Point
26	Surf City	New River	25-40	M	3422.98	7733.12	Point
27	Surf City	New River	25-40	M	3423.13	7733.21	Point
28	Surf City	New River	25-40	NA	3423.46	7732.64	Point
29	Surf City	New River	25-40	M	3422.69	7732.31	Point
30	Surf City	New River	25-40	NA	3422.97	7732.04	Point
31	Surf City	New River	25-40	NA	3423.25	7732.11	Point
32	Surf City	New River	25-40	NA	3423.6	7731.95	Point
33	Surf City	New River	25-40	M	3424.47	7731.26	Point
34	Surf City	New River	25-40	NA	3424.7	7731.26	Point
35	Surf City	New River	25-40	M	3424.66	7731.07	Point
36	Surf City	New River	25-40	H	3425.51	7729.71	Point
37	Surf City	New River	25-40	H	3423.63	7730.62	Point
38	Surf City	New River	25-40	H	3424.04	7730.53	Point
94	N. Topsail	New River	30	NA	3428.32	7722.25	Point
95	N. Topsail	New River	30	NA	3429.08	7721.02	Point
110	N. Topsail	New River	40	NA	3425.68	7724.17	Point
117	N. Topsail	New River	35-40	NA	3429.45	7721.1	Line
					3429.45	7722.2	Line
145	Surf City	New River	35-40	NA	3421.73	7730.71	Point
146	Surf City	New River	35-40	NA	3423.24	7729.56	Point
151	Surf City	New River	45	NA	3422	7736	Line
					3424	7734	Line
155	Surf City	New River	25	NA	3426.1	7727.8	Line
					3426.5	7728.2	Line
156	Onslow	New River	25	NA	3430.3	7717.9	Line
					3429.8	7718.5	Line

Table 2.3. (*continued*)

Location # According To Moser And Taylor (1995)	Nearest Town	Nearest Inlet Access	Vertical Distances Ft		Reef Site Location		
			Approximate Water Depth (Ft)	* Relief High (H), Medium (M), Low (L)	Latitude	Longitude	Type Of Location
171	N. Topsail	New River	35-40	H	3428.1	7723.1	Polygon
					3427.2	7722.3	Polygon
					3427	7722.5	Polygon
					3427.9	7723.4	Polygon
180	N. Topsail	New River	25-35	NA	3427.6	7722.7	Point
181	N. Topsail	New River	25-35	NA	3427.9	7723	Point
182	N. Topsail	New River	25-35	NA	3428.1	7723.1	Point
183	N. Topsail	New River	25-35	NA	3429.4	7723.9	Point
184	N. Topsail	New River	25-35	NA	3429.7	7723.2	Point
185	N. Topsail	New River	25-35	NA	3429.9	7722.6	Point
186	N. Topsail	New River	25-35	L	3430.2	7722.3	Line
					3430.5	7721.6	Line
187	N. Topsail	New River	25-35	L	3430.7	7721.3	Point
188	N. Topsail	New River	25-35	L	3430.7	7720.9	Point
189	N. Topsail	New River	25-35	H	3430	7721.3	Polygon
					3430.7	7722.2	Polygon
					3428.6	7723.8	Polygon
					3429.3	7724.2	Polygon
190	Onslow	New River	25-35	H	3431.2	7719.3	Polygon
					3432.4	7717.9	Polygon
					3431.5	7717.5	Polygon

* Low relief (L) was defined as < 0.5m (1.6 ft), Moderate relief (M) was defined as 0.5–2.0 m (1.6–6.6 ft), and High relief (H) was defined as profiles > 2 m (> 6.6 ft) (Moser and Taylor, 1995).

Summary of Corps Sand Resource and Hard-Bottom Investigations Contracts
To identify and delineate the most economical and environmentally acceptable borrow areas in the offshore environment (more than –7 m [–23 ft.]) NGVD) that could provide a sufficient volume of sediment for the SCNTB Coastal Storm Damage Reduction project, the Corps contracted with multiple engineering and environmental companies. The objectives of the contracts were to provide an assessment of the availability of beachfill-quality sand offshore and an assessment of underlying geology and exposed, offshore, hard-bottom features. Furthermore, to assess the potential effects of the proposed project on: (1) nearshore, hard-bottom habitat as a result of burial or sedimentation from the beachfill equilibration process and (2) offshore habitat from hopper-dredging activities, the Corps contracted side-scan sonar, multibeam, and diver ground truth data collection. The following paragraphs summarize, in chronological order, the hard-bottom data-collection components of both the offshore and nearshore survey contracts.

Offshore (more than –7 m (–23 ft.) MLLW)

(1) USACE. 2003. *An Assessment of the Availability of Beachfill Quality Sand Offshore North Topsail Beach and Surf City, North Carolina.* HDR Engineering Inc. of the Carolinas in association with William J. Cleary, PhD, PG (Appendix R; Attachment 1).

The goals of this study were to: (1) investigate the area offshore of North Topsail Beach and Surf City using published reports and available unpublished data, (2) summarize existing vibracore, fathometer, seismic, and side-scan sonar data, (3) ground truthing of side-scan sonar seafloor mosaic—SCUBA based diver mapping and seafloor sampling surveys, and (4) identify and delineate the most economical and environmentally acceptable borrows sites that could support the proposed projects on Topsail Island while avoiding environmentally sensitive hard bottoms.

Results of the report indicated an extremely complex exposure pattern of hard bottom throughout the study area, extending from the –9.1 m (–30 ft.) contour seaward to a distance of ~8 kilometers (km) (5.0 miles) offshore between Surf City through the southern end of Onslow Beach. Throughout the offshore environment, surface sediments are easily reworked during storms, exposing hard-bottom platforms and low-relief scarps in areas where the sediment cover is thin. As identified in the side-scan imagery, a patchy veneer of silty sand and gravel produces a *pock-marked* or *patchwork* appearance on the surface of the underlying flat hard-bottom areas. The southern portion of North Topsail Beach and Surf City was characterized by undulating, relatively flat hard-bottom platform punctuated by scattered low-relief hard-bottom scarps (moldic limestone and siltstone) and sediment filled depressions; whereas, high-relief hard-bottom locations dominate the North Topsail Beach vicinity (Alligator Bay to New River Inlet [Onslow Beach]). Two notable areas of high-relief hard-bottom were located (1) offshore of Mile Hammock Bay on the Onslow Beach portion of the shoreface and (2) between Alligator Bay and New River Inlet. Furthermore, several linear, shore-normal depressions that were interpreted to be channel remnants or RSD features were identified through the study area.

Using the information collected by HDR Engineering, Inc., the Corps was able to refine the locations of potential borrow site locations and implement a detailed vibracore plan to adequately assess the compatibility of sediments within the target borrow areas. Additional recommendations for future work in the proposed borrow areas included: (1) geophysical analysis to better interpolate potential sediment quantities relative to underlying geology, and (2) high-resolution side-scan sonargraph surveys of the borrow sites to assess the presence of exposed hard-bottom resources.

(2) USACE. 2004a. *Marine Geophysical Investigation for the Evaluation of Sand Resource Areas Offshore Topsail Island North Carolina.* Final Report. Contract DACW54-02-D-0006, Delivery Order 0002. Prepared by Greenhorne and O'Mara, Inc., with consultant Ocean Surveys, Inc., (OSI) (Appendix C; Attachment 1).

Using *Chirp* and *boomer* profiles, Corps Core Samples (412), hydrographic survey, and previous studies (HDR 2002 and 2003), OSI was able to further delineate limits of suitable borrow material for the proposed project. Specific goals of the study were to: (1) determine water depths and general morphology, (2) map aerial extent and thickness of available unconsolidated sediment, (3) delineate the extent of bedrock units on and below the seafloor, and (4) use data to evaluate proximity of sand borrow areas to hard-bottom outcrops.

The OSI investigation further confirmed that Onslow Bay is a sediment-starved system consisting mostly of a thin, patchy veneer (less than 0.9–1.8 m [3–6 ft.]) of modern sediments covering the low-relief Oligocene limestone and siltstone. Consistent with HDR, OSI also identified numerous quaternary channel fill sequences or RSD features. Wave and current action move the surface material periodically exposing the rock units just below the seafloor. The moldic sandy limestone protrudes above the seafloor as scarps exhibiting relief of 0.6–4.6 m (2–15 ft.) in some areas with areas of relatively flat low-lying hard-bottom in between; however, the siltstone unit rarely identified outcropping. The thicker sediment deposits (~3 m [10 ft.]) have filled in the broad depressions of the rock surface.

Though this study further refined the limits of the proposed offshore borrow areas, and the extent of the exposed offshore hard bottom, the spacing of the hydrographic survey data was still too wide; thus, small-scale features could not be identified. High-resolution side-scan sonar was necessary to identify and define hard bottom within the refined borrow areas.

(3) USACE. 2005. *An Archaeological Remote Sensing Survey of Surf City – North Topsail Beaches Offshore Borrow Areas.* Contract Number DACW 54-03-D-0002, Delivery Order 0005. Submitted by Mid-Atlantic Technology and Environmental Research (MATER), Principal Investigator Wes Hall (Appendix U).

Within the limits of the refined borrow areas identified by HDR, OSI, and the Corps, MATER implemented high-resolution side-scan sonar to identify and delineate hard bottom within the proposed borrow areas. Side scan sonar is a marine geophysical technique used

to map underwater topography and for identifying features on the surface of waterbody bottoms. Generally, hard materials provide high-amplitude echoes and soft, fine-grained materials provide weak signals. As a result, side-scan sonar provides a visual representation of the change in density of the surface material of a waterbody bottom. Data were collected along parallel lines spaced at 20-m (65-ft.) intervals using a Marine Sonic 600-kilohertz (kHz) side-scan sonar. Relief was classified in accordance with Moser and Taylor (1995) and Moser et al. (1995:): (1) **Low-relief**—the majority of the area less than 0.5 m (1.6 ft.) above the bottom, (2) **Moderate-relief**—the majority of the area between 0.5 m (1.6 ft.) and 2.0 m (6.6 ft.) above the bottom, and (3) **High-relief**—the majority of the area more than 2 m (6.6 ft.) above the bottom.

On the basis of the interpretation of the acoustic signatures from the side-scan sonar data, hard bottom was identified and delineated within all proposed borrow areas as follows:

Borrow Area G	2% hard bottom all low relief.
Borrow Area I	73% hard bottom with mix of low, moderate, and high relief.
Borrow Area H, J, L, N, O, P	13% hard bottom with mix of low, moderate, and high relief.
Borrow Area K, M	48% hard bottom with mix of low, moderate and high relief.
Borrow Area S	19% hard bottom all low relief.
Borrow Area Q, R	20% hard bottom with mix of low and moderate relief.
Borrow Area T	46% hard bottom with mix of low to moderate relief.

The extensive hard bottom plus the remaining low volume of beach compatible material identified in borrow areas I, K, and M, resulted in their removal from consideration for borrow material. Borrow area T has enough accessible, beach-compatible material for continued consideration. Delineation of hard-bottom resources within each borrow area allowed for further refining of the proposed borrow areas to avoid potential impacts to hard-bottom resources from hopper dredging activities.

Nearshore (less than –7 m (–23 ft.) NGVD)

(1) USACE. 2006. *High-Resolution Remote Sensing of Potential Hard Bottom Habitats: Topsail Island, NC.* July 2006 Contract DACW54-02-D-0006. Submitted by: : Greenhorne and O'Mara Consulting Engineers with sub-consultant Geodynamics (Appendix R; Attachment 2).

To assess potential project impacts to nearshore hard-bottom resources, as a result of the equilibration process associated with the constructed beach template, surveys for hard-bottom resources within the calculated depth of closure (i.e., –7 m [–23 ft.] NGVD) for this project were necessary. As a component of the Corps scope of work for identifying nearshore (less than 9.1 m [30 ft.]) hard-bottom resources off SCNTB, the Corps requested a two-phased effort to (1) locate and quantify *potential hard bottom* sites within the project impact area using side-scan sonar and, if targets were identified, (2) use multibeam survey techniques to assess the bathymetry (i.e., relief). The scope of work was coordinated with and received approvals from the environmental resource

agencies. Nearshore survey data outside the scope of the contract in North Topsail Beach were collected by Coastal Planning and Engineering, Inc., (CPE) as a component of the EIS for the local, nonfederal *North Topsail Beach Shoreline Protection Project.* CPE's procedural steps for identifying hard-bottom communities were consistent with the Corps' procedures and entailed: (1) side-scan sonar data collection and interpretation, (2) identifying and delineating potential hard-bottom features, and (3) diver ground truthing and biological characterization of representative sites. Details of the CPE investigation of the nearshore environment of North Topsail Beach are in the November 2007 Draft Environmental Impact Statement for the *North Topsail Beach Shoreline Protection Project* (USACE, 2007b).

The Corps nearshore side-scan sonar survey (phase 1) began in July 2006 and was composed of six planned survey lines spaced 100 m apart (320 ft.) in depths ranging from ~1.5 m (5 ft.) MLLW to ~9.1 m (30 ft.) MLLW. The distance between survey lines was calculated in separate zones of relatively equal depths using 42 times the water depth for multibeam and 120-m swaths (394 ft.) for side-scan as indicated on the NOAA digital nautical chart 11541_4.kap. Interpretation of the side-scan sonar data identified several areas in SCNTB that had higher density material than the adjacent area. Those high backscatter features were located cross-shore throughout the survey area. On the basis of those density differences, the areas of high backscatter were considered *potential hard bottom* anomalies and were delineated. Generally, the potential hard-bottom targets identified started approximately 244 m (800 ft) offshore (2004 wet/dry line) and extended to the end of the survey, approximately 545 m (1,800 ft.) offshore (2004 wet/dry line).

(2) USACE. 2007c. *High-Resolution 3D Bathymetric Assessment of Potential Hard Bottom Habitats: Topsail Island, Surf City and North Topsail Island, NC.* January / February 2007. Contract DACW54-02-D-0006. Submitted by: Greenhorne and O'Mara Consulting Engineers with sub-consultant Geodynamics (Appendix R; Attachment 3).

Using information gained from the Corps 2006 side-scan sonar survey, the Corps implemented a multibeam survey contract to further investigate the bathymetry of the target potential hard-bottom areas. The multibeam survey was composed of 18 planned survey lines (6 lines per survey area) spaced 21 m (70 ft.) to 27 m (90 ft.) apart to obtain 100 percent seafloor coverage. The total area of the survey encompassed 0.85 square mile with a total of 57 line miles and employed a Simrad EM3002 shallow-water multibeam sonar system to collect spatially dense bathymetric data for developing an accurate surface model. Data interpretation of seafloor bathymetry indicated that areas of high backscatter with cross-shore orientation identified in the phase one side-scan sonar survey were areas of gradual seafloor depressions with approximately 0.5-m (1.5-ft.) vertical relief per 101 m (330 ft.) horizontal distance. Additional ground-truth investigations of potential hard-bottom features were necessary to confirm the absence or presence of hard bottom to better interpolate the features from the acoustic signatures.

(3) USACE. 2008. *Surf City/North Topsail Beach, NC Shore Protection Project, Hard Bottom Resource Confirmation and Characterization Study.* Contract W912HN-08-C-

0009. Submitted by ANAMAR Environmental Consulting Inc. and Coastal Planning and Engineering, Inc. (Appendix R; Attachment 4).

During a Project Delivery Team (PDT) meeting with environmental resource agencies held on August 8, 2007, a summary of all nearshore and offshore hard-bottom data collection contracts conducted off of Topsail Island were presented to the resource agencies. Furthermore, details of the North Carolina hard-bottom buffer rule language (NCAC 07H. 0208(b) (12)(A)(iv)) were discussed. Specifically, the rule states that, "Mining activities shall not be conducted on or within 500 meters of significant biological communities, such as high relief hard bottom areas. High relief is defined for this standard as relief greater than or equal to one-half meter per five meters of horizontal distance." In accordance with the state's definition of *high relief* hard bottom, the Corps created a buffer around all identified high-relief, hard bottom delineated by MATER in 2005. However, the Corps questioned the interpretation of the 500-m (1,640-ft.) buffer rule with respect to hard-bottom relief that is less than the defined characteristics of high-relief hard-bottom identified in the state rule language. Adherence to a 500-m (1,640-ft.) buffer for all identified hard bottom (i.e., low, medium, and high relief) would result in a reduction of available sediment to a volume that is less than that required for the 50-year life of the project. To provide sufficient compatible sand resources for the 50-year project, the Corps proposed to implement a 122-m (400-ft.) dredging buffer around the low-relief hard bottom (less than 0.5 m [1.6 ft.]) identified by MATER in the offshore borrow sites while still adhering to the 500-m buffer for high-relief hard bottom as defined in the state rule language. Implementing a 122-m (400-ft.) buffer is consistent with the recommended buffer distances in Florida, which recommends a 122-m (400-ft.) dredging buffer around hard bottom communities, including coral reefs, in their state dredging permit conditions. Additionally, the NMFS recommends a 122-m (400-ft.) dredging buffer in its *Gulf Regional Biological Opinion* (GRBO) for dredging activities in the Gulf of Mexico to avoid impacts to hard-bottom foraging grounds for sea turtles. The buffer recommendation is based on lessons learned from a history of sedimentation and turbidity monitoring data collected in association with dredging projects in the vicinity of coral reefs throughout Florida. Though the Florida does include a 122-m (400-ft.) buffer in its state permit conditions, site-specific circumstances are considered for individual projects that may warrant a decrease or increase in the buffer guideline (for additional information pertaining to Florida monitoring reports, see Section 8.01.8.2).

Recognizing the room for interpretation of the North Carolina rule pertaining to *low-relief* hard bottom and the Corps' subsequent request to dredge closer to low-relief hard-bottom resources than outlined in the state rule language, on the basis of limited sediment availability, the PDT requested additional in-situ biological characterization of identified low-relief hard bottoms using divers. Furthermore, to assess potential beach nourishment effects as a result of beach profile equilibration process, the PDT requested in-situ diver ground truthing of the nearshore side-scan sonar survey data. The purpose of that investigation was to confirm the presence or absence of hard bottom in high-backscatter areas identified by Geodynamics as *potential hard bottom*. As identified in the contract scope of work, which was approved by the environmental resource agencies, the Corps required a phased approach in the nearshore environment to (1) confirm the presence or

absence of *potential* hard-bottom resources identified by Geodynamics and, if necessary, (2) biologically characterize the identified hard-bottom habitat including fish species observation and identification. The nearshore investigation sites are approximately 335 m (1,100 ft.) from the shore between the –5.5 m (–18 ft.) and the –9.1 m (–30 ft.) NGVD contours from the Surf City/Topsail Beach town border and extending through the southern end of North Topsail Beach and consisted of eight bounce dives. The ground-truth investigation of offshore sites identified by MATER consisted of biological characterization of the delineated hard-bottom community and observation and identification of fish species. Confirmation and characterization of hard bottom was conducted at five borrow sites for a total of 12 transects (G=2, J=2, L=2, O=3, and T=3). The borrow sites are approximately 1 to 6 miles from the coast in water depths of between –9.1 m (–30 ft.) to –14.3 m (–47 ft.) MLLW. All dives included in–water, digital video documentation of the site.

To refine sampling locations and maximize site diversity, previously collected remote sensing data conducted by Geodynamics and MATER were thoroughly evaluated before transect site selection. That analysis of the remote-sensing data helped determine if previously identified potential hard-bottom anomalies could be further classified as unconsolidated sediments, shell hash, or rubble before in-situ dive efforts. Furthermore, transect site locations, relative to distance offshore and cross-shore, were considered to optimize the data collection to ensure that the diversity of habitat type and area were captured. The following paragraphs summarize the data collected from the nearshore and offshore dives.

Nearshore

Diver ground truth confirmation of the eight selected areas previously identified as potential hard bottom, in conjunction with the side-scan interpretation, support the conclusion that no hard bottom was identified landward of the calculated –7 m (–23 ft.) depth of closure. Additional refined analyses of the remote sensing data coupled with the (1) diver ground truth transects, (2) collected sediment samples, and (3) digital video, identified the previously defined *high-backscatter anomalies* to be regions of coarse gravel and shell hash. Careful selection of dive sites enabled divers to traverse backscatter transitional areas identified in the remote-sensing data. Diver confirmation and corresponding sediment samples identified the transitional areas to be a sorting of sediment characteristics from fine-grained to course-grained sediments. Those features identified in the nearshore environment off Surf City and North Topsail Beach are consistent with previously identified RSD (Cacchione et al., 1984; Thieler et al., 1999, 2001), RCD (McQuarrie, 1998), or *sorted bedform* (Murray and Thieler, 2004) features identified throughout the coast of North Carolina (Wrightsville Beach, Figure Eight Island, Topsail Island, and such). The features are thought to be the result of a feedback mechanism whereby an existing deposit of coarse shell hash and gravel material is built on and segregated from fine material due to wave motion interacting with the enhanced roughness of the seafloor bed around the patches of coarse material (Murray and Thieler, 2004). The interaction between wave motion and seafloor roughness results in near-bed turbulence that is greatly enhanced relative to other areas of the seafloor. The increase in

near-bed turbulence enhances entrainment and inhibits settling of fine material, thereby further expanding and maintaining the coarse patches of material.

After the eight nearshore dives were completed and the confirmation was made that no hard-bottom resources are in the –7 m (–23 ft.) contour, the Corps requested the contractor ground truth two additional features located approximately 183 m (600 ft.) offshore of the –7 m (–23 ft.) contour. On the basis of preliminary side-scan data interpretation, ANAMAR documented that the sites closely resembled exposed rock outcrops. Using diver ground-truth data from the previous dives, a more refined analysis and interpolation of side-scan imagery for hard-bottom resources was possible. Diver confirmation of hard bottom in areas that, in the side-scan interpretation, appeared to more closely resemble exposed rock outcrops on the seafloor than any of the seafloor features landward of the depth of closure, added further confidence to the side-scan data interpretation for presence/absence of hard bottom. Divers verified the presence of low-relief ephemeral hard-bottom features at both sites with a maximum vertical relief of approximately 15 centimeters (cm).

Offshore

A total of 12 temporary transects were established among the five borrow areas (T=3, O=3, L=2, J=2, and G=2) identified for biological characterization of hard bottoms. Hard bottom of varying low (lower than 0.5 m [1.6 ft.]) to moderate (0.5 m [1.6 ft.] to 2.0 m [6.6 ft.]) relief (i.e., large, contiguous, hard bottom; patchy outcroppings; or distinct ledges) and total area were confirmed and characterized for all sites, with the exception of one transect in borrow area J (J1) in which no hard bottom was identified. Remote-sensing data was carefully analyzed before selecting transect locations to maximize diversity of habitat covered within a transect line by traversing areas of relief transition. Furthermore, transects were also distributed among borrow areas to capture the potential differences associated with the distance offshore and the location alongshore, as well as potential association with nearness to New River Inlet. According to the data collected, the hard–bottom, benthic community did not differ relative to nearness to New River inlet or distance offshore. The surveyed borrow areas contained intermittent areas of well-developed benthic cover and areas of frequent burial. Some of the sites contained small, hard-bottom patches interspersed with sand and had relatively undeveloped benthic communities; whereas other sites contained more extensive communities. Furthermore, there was evidence of periodic burial or sand scouring in areas with less rugosity and site relief was not correlated with diversity or amount of benthic growth. Vertical surfaces (i.e., outcroppings/ledges) had an increased diversity of organisms (i.e., bryozoans, tunicates, hydrozoans) as well as adult *Oculina* sp. colonies, thus, indicating a more stable environment along the vertical faces. The horizontal surfaces of the hard-bottom outcrops were predominantly covered with macro-algae. About 80 percent of the transects were low-relief hard bottom that contained little biotic diversity dominated by emergent octocorals and sponges. However, borrow area G represented a unique area of low-relief hard bottom that contained diverse and persistent benthic communities. The following contains brief summaries of the data for each borrow area investigated:

Borrow area G: : Sites investigated in borrow area G were indicative of a more persistent low-relief, hard-bottom community as evidenced by the mature colonies of *Oculina* sp. and highest percent stony coral cover and density (i.e., transect G1).

Borrow area J: : The sites contained the least amount of confirmed hard bottom of any of the investigated borrow areas. Specifically, no hard bottom was identified in transect J1, an area previously delineated as potential hard bottom on the basis of side-scan sonar interpretation provided by MATER. Furthermore, transect J2 was confirmed to be an extremely ephemeral system on the basis of the observation of *L. virgulata* colonies attached to buried hard bottom and protruding through a thin veneer of sand.

Borrow area L: Transects L1 and L2 were placed along previously identified transition areas of moderate- and high-relief hard bottom, on the basis of side-scan sonar data. As expected, those transects contained the highest maximum relief of all sites. The myriad relief patterns, crevices, ledges, and such, resulted in the highest diversity index identified for L1. However, although those transects had the highest maximum relief of .50 m (1.6 ft.) and .55 m (1.8 ft.), respectively, according to in-situ dive investigations, they were previously mapped as *moderate* and *high* relief on the basis of side-scan sonar interpretation. The confirmed in-situ maximum relief of the sites is on the low end of the moderate-relief classification as defined by Moser and Taylor (1995) and Moser et al. (1995). Furthermore, the average relief of the sites was 0.16 m (0.5 ft.) and 0.07 m (.23 ft.), respectively, indicating that the areas of moderate relief were isolated peaks rather than a continuous moderate relief shelf.

Borrow area O: Three transects were placed throughout borrow area O to capture previously determined areas of low, moderate, and high relief. Although two transects were placed along areas of moderate and high-relief transitions on the basis of side-scan sonar interpretation and mapping, the in-situ dive confirmation indicated only areas of intermittent, varying, low-relief hard bottom with interspersed patches of sand. Although the side-scan sonar interpretation and subsequent mapping indicated differing relief patterns between the three transects (i.e., O1, O2, and O3), the in-situ dive confirmation did not support the preliminary delineation of hard bottom.

Borrow area T: : Transect locations throughout borrow area T were specifically located to capture site diversity. Transect T1 was unique in that it traversed a distinct moderate relief ledge (i.e., maximum relief of 0.47 m [1.5 ft.]) and extended into a low relief ledge with an average relief of 0.05 m (0.16 ft.). Transects T3 and T4 were generally low relief (i.e., maximum relief of 0.14 m [0.5 ft.] and 0.22 m [0.7 ft.]), respectively) and ephemeral in nature as evidenced by sediment cover and less site diversity. However, *Oculina* sp. were identified in areas with higher relief.

Although the study was limited to the winter months during limited biological activity, similar work has been conducted by CPE in the project area vicinity in June, August, and October of 2005 (USACE, 2007). Field investigations with similar methodologies were performed to ground truth potential hard-bottom resources and characterize the benthic community of representative locations. Sessile benthos observed along the hard bottom

were dominated by macroalgae, octocorals, encrusting red algae, sessile worms, and stony corals and were consistent with those identified during the Corps March 2008 investigation (Table 2.4). Therefore, the offshore hard bottom habitats of borrow areas have been characterized during the spring, summer, fall, and winter and there does not appear to be significant differences in species composition and diversity for each sampling period. However, as expected, the finfish species observed during the warm water sampling periods were more diverse than the cold water sampling period.

Table 2.4. Consolidated species list for all 12 transects investigated throughout borrow areas T, O, L, J, and G in March 2008.

	Species	Common Name
INVERTEBRATES		
SPONGES	*Cliona celata**	Boring sponge
	Unidentified gray sponge (Possibly *Ircinia* sp.)*	
	Several unidentified species*	
HYDROIDS	Several unidentified species	
BRYOZOANS	*Bugula turrita**	Spiral-tufted bryozoan
	Hippopodina feegeensis	Pearly orange encrusting bryozoan
	Unidentified fan bryozoans*	
ANEMONES	Cerianthid anemone*	Tube-dwelling anemone
	Several unidentified species*	
SCLERACTINIAN CORAL	*Oculina sp.**	Ivory tree coral
OCTOCORAL	*Leptogorgia hebes**	Regal sea fan
	*Leptogorgia virgulata**	Colorful sea whip
	Telestaceans (*Carijoa riisei* and/or *Telesto sp.)**	Telestos
	*Titanideum frauenfeldii**	Brilliant sea fingers
MOLLUSCS	*Fasciolaria tulipa*	Tulip snail
	Simnia sp.*	Simnia
ECHINODERMS		
Urchins	*Arbacia punctulata**	Common Arbacia urchin
	*Lytechinus variegatus**	Variegated urchin
Sea Stars	*Astropecten articulatus**	Beaded sea star
	*Asterias forbesii**	Forbe's sea star
	*Echinaster sp.**	Orange-ridged sea star
	*Luidia alternata**	Banded sea star
Sea Cucumbers	Unidentified sea cucumber*	
ARTHROPODS	*Anoplodactylus lentus*	Lentel sea spider
	Various hermit crabs	
	Balanus sp.	Barnacles
TUNICATES	*Botryllus/Botrylloides* spp.*	Flat/row/geometric encrusting tunicates
	*Distaplia corolla**	Button tunicate
	Eudistoma spp.	Condominium tunicates
	Several unidentified species*	
VERTEBRATES		
FISH	*Archosargus probatocephalus**	Sheepshead
	*Centropristis striatus**	Black sea bass
	*Diplodon holbrookii**	Spottail pinfish
PLANTS		
MACROALGAE	*Caulerpa*	green alga
	*Codium**	Dead man's fingers
	Cryptonemia	red alga
	*Dasya**	red alga
	Gelidiella	red alga
	Gelidium	red alga
	*Halymenia**	red alga
	*Lobophora**	Encrusting fan-leaf alga
	*Sargassum**	Sargassum weed
	Wrangelia	red alga
	Encrusting Red Algae	

Source: USACE 2008b

Artificial Reef

North Carolina Department of Environment and Natural Resources, NCDMF Artificial Reef Program manages six reefs that are off Topsail Island. They are AR 355, AR 360, AR 362, AR 364, AR 366, and AR 368. Of those managed reefs, AR360 *Topsail Reef* is in close proximity of the proposed offshore borrow areas and is at 34° 20'59" N and

77° 36'11" W (Table 2.5). It was deployed in 1984 and modified in 1992 and consists of about 49,000 tires and 850 4'x8' pieces of concrete pipe. The reef no longer exists in its confined location but is broken up and spread out well beyond its original footprint and is exposed or buried at different locations. The location of the hard-bottom habitats and artificial reef sites, in relation to project features, is shown in Appendix A, Figure A-1.

Table 2.5. Artificial reefs

NC Reef Site No.	Nearest Inlet Access and Distance	Approx. Water Depth (ft.)	LORAN Position Coordinates	Latitude and Longitude	Comment
355	New River 9.7 miles	60	27210.0 39324.4	34°21'11" 77°20'00"	230' Bridge span
360	New Topsail 2.5 miles	44	27256.9 39252.5	34° 20'59" 77°36'11"	Concrete pieces
362	New Topsail 8.7 miles	54	27233.1 39244.5	34°15'43" 77°30'27"	Concrete pieces
364	New Topsail 6.0 miles	44	27267.4 39169.6	34°14'50" 77°42'50"	174' JELL II Boat mold
366	New Topsail 13.9 miles	66	27214.6 39255.0	34°12'57" 77°25'15"	Concrete pieces
368	New Topsail 15.5 miles	66	27211.7 39195.0	34°09'34" 77°25'50"	Small vessel

Source: NCDMF, http://www.ncfisheries.net/download/ReefGuide2005.pdf

Since the placement of tire-based artificial reefs throughout North Carolina, many tires have broken loose from their original footprint and wash up consistently throughout the North Carolina beaches. In 2001 (December–April), during Phase I of the Bogue Banks Beach Nourishment project in Bogue Banks, North Carolina, the dredging contractor encountered about 5,000 tires in the borrow sites that had broken free from an artificial reef site. On the basis of that history, the NCDMF has identified concerns that, although the historical placement of tire-based artificial reefs are outside the identified borrow sites, a potential exists for loose tires to be in the borrow sites. The NCDCM's Artificial Reef Program has a team to document and pick up tires that wash up on the local beaches (Appendix A, Figure A-1).

2.01.11 Essential Fish Habitat

The 1996 congressional amendments to the MSFCMA (P.L. 94-265) set forth new requirements for the NMFS, regional fishery management councils (FMC), and other federal agencies to identify and protect important marine and anadromous fish habitat. Those amendments established procedures for identifying EFH and a requirement for interagency coordination to further the conservation of federally managed fisheries. Table 2.6 lists the federally managed fish species of North Carolina for which Fishery

Management Plans (FMPs) have been developed by the SAFMC, Mid-Atlantic Fishery Management Council (MAFMC), and NMFS. In addition, the table shows EFH by fish life stage and ecosystem type for those species that have designated EFH. Table 2.7 shows the categories of EFH and Habitat Areas of Particular Concern (HAPC) for managed species that were identified in the FMP Amendments affecting the South Atlantic area. A description of specific HAPC resources (i.e., hard bottom, coral, artificial reef, and *sargassum*) in the project area is in Sections 2.01.9, 2.01.10, and Appendix R (Attachment 4). The fish species and habitats shown in those tables require special consideration to promote their viability and sustainability. The potential effects of the proposed action on those fish and habitats are discussed in Section 8.01.8 of this report.

Table 2.6. EFH species for coastal North Carolina[a]

Management Plan Agency[b]	Management Plan Species Group	Common Name of Species	Scientific Name of Species	EFH for Life Stages by Ecosystem[c]		Geographically Defined Habitat Areas of Particular Concern (HAPC) (North Carolina Locations Only)
				Marine	Estuarine	
SAFMC	Calico Scallop	Calico scallop	*Argopecten gibbus*	**A**		
SAFMC	Coastal Migratory Pelagics	Cobia	*Rachycentron canadum*	**E L P J A**	**L P J A**	Capes Fear, Lookout, & Hatteras sandy shoals; The Point; Ten Fathom Ledge; Big Rock; Bogue Sound; New River; hardbottom
SAFMC	Coastal Migratory Pelagics	Dolphin	*Coryphaena hippurus*	**L P J A**		Capes Fear, Lookout, & Hatteras sandy shoals; The Point; Ten Fathom Ledge; Big Rock; Bogue Sound; New River; hardbottom
SAFMC	Coastal Migratory Pelagics	King mackerel	*Scomberomorus cavalla*	**J A**		Capes Fear, Lookout, & Hatteras sandy shoals; The Point; Ten Fathom Ledge; Big Rock; Bogue Sound; New River; hardbottom
SAFMC	Coastal Migratory Pelagics	Spanish mackerel	*Scomberomorus maculatus*	**L J A**	**J**	Capes Fear, Lookout, & Hatteras sandy shoals; The Point; Ten Fathom Ledge; Big Rock; Bogue Sound; New River; hardbottom
SAFMC	Coral & Coral Reef	Corals	100s of species	Florida only		Big Rock; Ten Fathom Ledge; The Point
SAFMC	Golden Crab	Golden crab	*Chaceon fenneri*	**A**		
SAFMC	Red Drum	Red drum	*Sciaenops ocellatus*	**E L A**	**P J S A**	tidal inlets, state nursery, spawning sites, SAV
SAFMC	Shrimp	Brown shrimp	*Farfantepenaeus aztecus*	**E L A**	**P J S**	tidal inlets, state nursery, overwintering habitats

Table 2.6. (*continued*)

Management Plan Agency[b]	Management Plan Species Group	Common Name of Species	Scientific Name of Species	EFH for Life Stages by Ecosystem[c]		Geographically Defined Habitat Areas of Particular Concern (HAPC) (North Carolina Locations Only)
				Marine	Estuarine	
SAFMC	Shrimp	Pink shrimp	*Farfantepenaeus duorarum*	**E L A**	**P J S**	tidal inlets, state nursery, overwintering habitats
SAFMC	Shrimp	Rock shrimp	*Sicyonia brevirostris*	**A**		
SAFMC	Shrimp	Royal red shrimp	*Pleoticus robustus*	**A**		
SAFMC	Shrimp	White shrimp	*Litopenaeus setiferus*	**E L A**	**P J S**	tidal inlets, state nursery, overwintering habitats
SAFMC	Snapper Grouper	Blackfin snapper	*Lutjanus buccanella*	**J A**		hardbottom, SAV, oyster/shell, inlets, state nursery, The Point, Ten Fathom Ledge, Big Rock, Hoyt Hills
SAFMC	Snapper Grouper	Blueline tilefish	*Caulolatilus microps*	**E A**		hardbottom, SAV, oyster/shell, inlets, state nursery, The Point, Ten Fathom Ledge, Big Rock, Hoyt Hills
SAFMC	Snapper Grouper	Golden tilefish	*Lopholatilus chamaeleonticeps*	**A**		hardbottom, SAV, oyster/shell, inlets, state nursery, The Point, Ten Fathom Ledge, Big Rock, Hoyt Hills
SAFMC	Snapper Grouper	Gray snapper	*Lutjanus griseus*	**L A**	**P J A**	hardbottom, SAV, oyster/shell, inlets, state nursery, The Point, Ten Fathom Ledge, Big Rock, Hoyt Hills
SAFMC	Snapper Grouper	Greater amberjack	*Seriola dumerili*	**J A**		hardbottom, SAV, oyster/shell, inlets, state nursery, The Point, Ten Fathom Ledge, Big Rock, Hoyt Hills

Table 2.6. (*continued*)

Management Plan Agency[b]	Management Plan Species Group	Common Name of Species	Scientific Name of Species	EFH for Life Stages by Ecosystem[c]		Geographically Defined Habitat Areas of Particular Concern (HAPC) (North Carolina Locations Only)
				Marine	Estuarine	
SAFMC	Snapper Grouper	Goliath Grouper	*Epinephelus itajara*	Florida only	Florida only	hardbottom, SAV, oyster/shell, inlets, state nursery, The Point, Ten Fathom Ledge, Big Rock, Hoyt Hills
SAFMC	Snapper Grouper	Mutton snapper	*Lutjanus analis*	Florida only	Florida only	hardbottom, SAV, oyster/shell, inlets, state nursery, The Point, Ten Fathom Ledge, Big Rock, Hoyt Hills
SAFMC	Snapper Grouper	Red snapper	*Lutjanus campechanus*	**L P J A**		hardbottom, SAV, oyster/shell, inlets, state nursery, The Point, Ten Fathom Ledge, Big Rock, Hoyt Hills
SAFMC	Snapper Grouper	Scamp	*Mycteroperca phenax*	**A**		hardbottom, SAV, oyster/shell, inlets, state nursery, The Point, Ten Fathom Ledge, Big Rock, Hoyt Hills
SAFMC	Snapper Grouper	Silk snapper	*Lutjanus vivanus*	**J A**		hardbottom, SAV, oyster/shell, inlets, state nursery, The Point, Ten Fathom Ledge, Big Rock, Hoyt Hills
SAFMC	Snapper Grouper	Snowy grouper	*Epinephelus niveatus*	**E L A**		hardbottom, SAV, oyster/shell, inlets, state nursery, The Point, Ten Fathom Ledge, Big Rock, Hoyt Hills
SAFMC	Snapper Grouper	Speckled hind	*Epinephelus drummondhayi*	**A**		hardbottom, SAV, oyster/shell, inlets, state nursery, The Point, Ten Fathom Ledge, Big Rock, Hoyt Hills

Table 2.6. (*continued*)

Management Plan Agency[b]	Management Plan Species Group	Common Name of Species	Scientific Name of Species	EFH for Life Stages by Ecosystem[c]		Geographically Defined Habitat Areas of Particular Concern (HAPC) (North Carolina Locations Only)
				Marine	Estuarine	
SAFMC	Snapper Grouper	Red snapper	*Lutjanus campechanus*	**L P J A**		hardbottom, SAV, oyster/shell, inlets, state nursery, The Point, Ten Fathom Ledge, Big Rock, Hoyt Hills
SAFMC	Snapper Grouper	Scamp	*Mycteroperca phenax*	**A**		hardbottom, SAV, oyster/shell, inlets, state nursery, The Point, Ten Fathom Ledge, Big Rock, Hoyt Hills
SAFMC	Snapper Grouper	Silk snapper	*Lutjanus vivanus*	**J A**		hardbottom, SAV, oyster/shell, inlets, state nursery, The Point, Ten Fathom Ledge, Big Rock, Hoyt Hills
SAFMC	Snapper Grouper	Snowy grouper	*Epinephelus niveatus*	**E L A**		hardbottom, SAV, oyster/shell, inlets, state nursery, The Point, Ten Fathom Ledge, Big Rock, Hoyt Hills
SAFMC	Snapper Grouper	Speckled hind	*Epinephelus drummondhayi*	**A**		hardbottom, SAV, oyster/shell, inlets, state nursery, The Point, Ten Fathom Ledge, Big Rock, Hoyt Hills
SAFMC	Snapper Grouper	Vermillion snapper	*Rhomboplites aurorubens*	**J A**		hardbottom, SAV, oyster/shell, inlets, state nursery, The Point, Ten Fathom Ledge, Big Rock, Hoyt Hills
SAFMC	Snapper Grouper	Warsaw grouper	*Epinephelus nigritus*	**E A**		hardbottom, SAV, oyster/shell, inlets, state nursery, The Point, Ten Fathom Ledge, Big Rock, Hoyt Hills
SAFMC	Snapper Grouper	White grunt	*Haemulon plumieri*	**E L A**		hardbottom, SAV, oyster/shell, inlets, state nursery, The Point, Ten Fathom Ledge, Big Rock, Hoyt Hills

Table 2.6. (*continued*)

Management Plan Agency[b]	Management Plan Species Group	Common Name of Species	Scientific Name of Species	EFH for Life Stages by Ecosystem[c]		Geographically Defined Habitat Areas of Particular Concern (HAPC) (North Carolina Locations Only)
				Marine	Estuarine	
SAFMC	Snapper Grouper	Wreckfish	*Polyprion americanus*	**A**		hardbottom, SAV, oyster/shell, inlets, state nursery, The Point, Ten Fathom Ledge, Big Rock, Hoyt Hills
SAFMC	Spiny Lobster	Spiny Lobster	*Panulirus argus*	**L J A**	**L J A**	Spiny lobster EFH and HAPC located only in Florida
SAFMC	Dolphin-Wahoo	Common Dolphin	*Coryphaena hippurus*	**ELPJSA**		The Point, Ten Fathom Ledge, and Big Rock, Pelagic Sargassum
SAFMC	Dolphin-Wahoo	Pompano Dolphin	*C. equiselis*	**ELPJSA**		The Point, Ten Fathom Ledge, and Big Rock, Pelagic Sargassum
SAFMC	Dolphin-Wahoo	Wahoo	*Acanthocybium solanderi*	**ELPJSA**		The Point, Ten Fathom Ledge, and Big Rock, Pelagic Sargassum
SAFMC	Sargassum	Sargassum	*Sargassum* sp.			
MAFMC	Atlantic Mackerel, Squid, Butterfish	Atlantic butterfish	*Peprilus triacanthus*			
MAFMC	Atlantic Mackerel, Squid, Butterfish	Atlantic mackerel	*Scomber scombrus*			
MAFMC	Atlantic Mackerel, Squid, Butterfish	Long finned squid	*Loligo pealei*			
MAFMC	Atlantic Mackerel, Squid, Butterfish	Short finned squid	*Illex illecebrosus*			
MAFMC	Atlantic Surfclam & Ocean Quahog	Ocean quahog	*Artica islandica*			
MAFMC	Atlantic Surfclam & Ocean Quahog	Surfclam	*Spisula solidissima*			

Table 2.6. (*continued*)

Management Plan Agency[b]	Management Plan Species Group	Common Name of Species	Scientific Name of Species	EFH for Life Stages by Ecosystem[c]		Geographically Defined Habitat Areas of Particular Concern (HAPC) (North Carolina Locations Only)
				Marine	Estuarine	
MAFMC	Bluefish	Bluefish	*Pomatomus saltatrix*	**L J A**	**J A**	
MAFMC	Spiny Dogfish	Spiny dogfish	*Squalus acanthias*	**J A**		
MAFMC	Summer Flounder, Scup, Black Sea Bass	Scup	*Stenotomus chrysops*			
MAFMC	Summer Flounder, Scup, Black Sea Bass	Scup	*Stenotomus chrysops*			
MAFMC	Summer Flounder, Scup, Black Sea Bass	Summer flounder	*Paralichthys dentatus*	**L J A**	**L J A**	SAV for larvae and juveniles
MAFMC	Summer Flounder, Scup, Black Sea Bass	Black sea bass	*Centropristis striata*			
MAFMC	Atlantic Mackerel, Squid, Butterfish	Atlantic butterfish	*Peprilus triacanthus*			
MAFMC	Summer Flounder, Scup, Black Sea Bass	Scup	*Stenotomus chrysops*			
MAFMC	Summer Flounder, Scup, Black Sea Bass	Summer flounder	*Paralichthys dentatus*	**L J A**	**L J A**	SAV for larvae and juveniles

Table 2.6. (*continued*)

Management Plan Agency[b]	Management Plan Species Group	Common Name of Species	Scientific Name of Species	EFH for Life Stages by Ecosystem[c]		Geographically Defined Habitat Areas of Particular Concern (HAPC) (North Carolina Locations Only)
				Marine	Estuarine	
NMFS	Billfish	Blue marlin	*Makaira nigricans*	**E L J A**		
NMFS	Billfish	Longbill spearfish	*Tetrapturus pfluegeri*	**J A**		
NMFS	Billfish	Sailfish	*Istiophorus platypterus*	**E L J A**		
NMFS	Billfish	White marlin	*Tetrapturus albidus*	**J A**		
NMFS	Sharks	Atlantic angel shark	*Squatina dumerili*			
NMFS	Sharks	Atlantic sharpnose shark	*Rhizoprionodon terraenovae*	**J A**	**J**	
NMFS	Sharks	Basking shark	*Cetorhinos maximus*			
NMFS	Sharks	Big nose shark	*Carcharhinus altimus*	**J**		
NMFS	Sharks	Bigeye sand tiger shark	*Odontaspis noronhai*			
NMFS	Sharks	Bigeye sixgill shark	*Hexanchus vitulus*			
NMFS	Sharks	Bigeye thresher shark	*Alopias superciliosus*	**E L P J S A**		
NMFS	Sharks	Blacknose shark	*Carcharhinus acronotus*	**J A**		
NMFS	Sharks	Blacktip shark	*Carcharhinus limbatus*	**J A**		
NMFS	Sharks	Blue shark	*Prionace glauca*	**J S A**		
NMFS	Sharks	Bonnethead	*Sphyrna tiburo*	**J A**	**J A**	
NMFS	Sharks	Bull shark	*Carcharhinus leucas*	**J**	**J**	
NMFS	Sharks	Caribbean reef shark	*Carcharhinus perezi*	**Florida only**		
NMFS	Sharks	Carribean sharpnose shark	*Rhizoprionodon porosus*			
NMFS	Sharks	Dusky shark	*Carcharhinus obscurus*	**A**	**J A**	

Table 2.6. (*continued*)

Management Plan Agency[b]	Management Plan Species Group	Common Name of Species	Scientific Name of Species	EFH for Life Stages by Ecosystem[c]		Geographically Defined Habitat Areas of Particular Concern (HAPC) (North Carolina Locations Only)
				Marine	Estuarine	
NMFS	Sharks	Finetooth shark	*Carcharhinus isodon*	**E L P J S A**		
NMFS	Sharks	Longfin mako shark	*Isurus paucus*	**E L P J S A**		
NMFS	Sharks	Narrowtooth shark	*Carcharhinus brachyurus*			
NMFS	Sharks	Night shark	*Carcharhinus signatus*	**J A**		
NMFS	Sharks	Nurse shark	*Ginglymostoma cirratum*	**J A**		
NMFS	Sharks	Oceanic whitetip shark	*Carcharhinus longimanus*	**J S A**		
NMFS	Sharks	Porbeagle shark	*Lamna nasus*			
NMFS	Sharks	Sand tiger shark	*Odontaspis taurus*	**J A**		
NMFS	Sharks	Sandbar shark	*Carcharhinus plumbeus*	**J A**	**J A**	Pamlico Sound adjacent to Hatteras and Ocracoke Islands and offshore
NMFS	Sharks	Scalloped hammerhead	*Sphyrna lewini*	**J A**		
NMFS	Sharks	Sharpnose sevengill shark	*Heptranchias perlo*			
NMFS	Sharks	Shortfin mako shark	*Isurus oxyrinchus*	**E L P J S A**		
NMFS	Sharks	Silky shark	*Carcharhinus falciformis*	**J**		
NMFS	Sharks	Sixgill shark	*Hexanchus griseus*			
NMFS	Sharks	Smalltail shark	*Carcharhinus porosus*			
NMFS	Sharks	Smooth hamerhead	*Sphyrna zygaena*			
NMFS	Sharks	Spinner shark	*Carcharhinus brevipinna*	**J A**		
NMFS	Sharks	Thresher shark, common	*Alopias vulpinus*			
NMFS	Sharks	Tiger shark	*Galeocerdo cuvieri*	**J S A**		
NMFS	Sharks	White shark	*Carcharodon carcharias*	**J**		

Table 2.6. (*continued*)

Management Plan Agency[b]	Management Plan Species Group	Common Name of Species	Scientific Name of Species	EFH for Life Stages by Ecosystem[c]		Geographically Defined Habitat Areas of Particular Concern (HAPC) (North Carolina Locations Only)
				Marine	Estuarine	
NMFS	Swordfish	Swordfish	*Xiphias gladius*	**E L J S A**		
NMFS	Tuna	Albacore	*Thunnus alalunga*	**A**		
NMFS	Tuna	Atlantic bigeye tuna	*Thunnus obesus*	**J A**		
NMFS	Tuna	Atlantic Yellowfin tuna	*Thunnus albacares*	**E L J S A**		
NMFS	Tuna	Skipjack tuna	*Katsuwonus pelamis*	**E L J S A**		
NMFS	Tuna	Western Atlantic bluefin tuna	*Thunnus thynnus*	**E L J S A**		

Notes:

a. These EFH species were compiled from *Essential Fish Habitat: A Marine Fish Habitat Conservation Mandate for Federal Agencies*. February 1999 (Revised 08/2004) (Appendices 2, 3, 6, 7, and 8). Although 46 species are listed in Appendix 3 under NMFS management, only 35 of the species have EFH listed in Appendix 8.

b. Organizations responsible for FMPs consist of: SAFMC = South Atlantic Fishery Management Council; MAFMC = Mid-Atlantic Fishery Management Council; NMFS = National Marine Fisheries Service.

c. Life stages include E = Eggs, L = Larvae, P = PostLarvae, J = Juveniles, S = SubAdults, A = Adults

(End of Table 2.6)

Table 2.7. Categories of EFH and HAPC identified in FMP Amendments affecting the South Atlantic Area.[a, b]

EFH	GEOGRAPHICALLY DEFINED HAPC
Estuarine Areas	**Area-wide**
Estuarine Emergent Wetlands	Council-designated Artificial Reef Special Management Zones
Estuarine Scrub/Shrub Mangroves	Hermatypic (reef-forming) Coral Habitat & Reefs
Submerged Aquatic Vegetation (SAV)	Hard Bottoms
Oyster Reefs & Shell Banks	Hoyt Hills
Intertidal Flats	*Sargassum* Habitat
Palustrine Emergent & Forested Wetlands	State-designated Areas of Importance of Managed Species
Aquatic Beds	Submerged Aquatic Vegetation
Estuarine Water Column[2]	
Seagrass	
Creeks	
Mud Bottom	
Marine Areas	**North Carolina**
Live/Hard Bottoms	Big Rock
Coral and Coral Reefs	Bogue Sound
Artificial/Man-made Reefs	Pamlico Sound at Hatteras/Ocracoke Islands
Sargassum	Capes Fear, Lookout, & Hatteras (sandy shoals)
Water Column[2]	New River
	The Ten Fathom Ledge
	The Point

Notes:

a.EFH areas are identified in FMP Amendments for the South Atlantic and Mid-Atlantic Fishery Management Councils. Geographically Defined HAPC are identified in FMP Amendments affecting the South Atlantic Area. Information in this table was derived from *Essential Fish Habitat: A Marine Fish Habitat Conservation Mandate for Federal Agencies*. February 1999 (Revised 08/2004) (Appendices 4 and 5).

b. EFH for species managed under NMFS Billfish and Highly Migratory Species generally falls within the marine and estuarine water column habitats designated by the Fishery Management Councils.

2.01.12 Shellfish

The commercial fishing industry is a very important economic component to North Carolina. According to Burgess and Bianchi (2004), shellfish (i.e., bivalves, crustaceans, and other species that do not have fins) as a whole are more economically important than finfish in North Carolina. The commercial shell fishing industry in North Carolina consists of Eastern oysters, hard clams, bay scallops, blue crabs, and shrimp. Between 1972 and 2002, the total shellfish composition of North Carolina commercial landings has varied, total shellfish landings have exhibited an overall increase, and the value for shellfish landed exhibited an overall increase. From 1994 to 2002, the majority of shellfish landings and revenue was attributable to hard blue crabs and shrimp (Burgess

and Bianchi, 2004).

Eastern Oyster
Eastern oysters (*Crassostrea virginica*) are managed under the North Carolina Oyster FMP dated June 2008, as amended (NCDMF, 2008b). The Eastern oyster is designated by the NCDMF as a species of concern. It is a very successful estuarine bivalve and can tolerate a wide variety of salinities, temperatures, currents, and turbidities. The preferred habitat for Eastern oysters is from just below mean low water to one meter (3.28 ft.) above mean low water (Burrel, 1986). Vast intertidal reefs formed by oysters are significant biological and physical formations in the estuaries of North Carolina. Fish, crabs, and shrimp use oyster beds as refuge and as a source of food. The intertidal oyster beds also provide habitat for various infaunal and epifaunal species. Although traditionally harvested from Pamlico Sound in the northern part of the state, disease has caused the stock to decline in this area. Consequently, landing trends indicate that the Eastern oyster is primarily harvested from the southern part of the state including Topsail Sound, Lockwood Folly, Masonboro Sound, the New River, the Newport River, and the Shallotte River (Burgess and Bianchi, 2004).

Oysters are the primary component of shell bottom habitat and the North Carolina Marine Fisheries Commission, SAFMC, and Atlantic States Marine Fisheries Commission all recognize the importance of this habitat. The SAFMC defines this shell bottom habitat as, "the natural structures found between (intertidal) and beneath (subtidal) tide lines, that are composed of oyster shell, live oysters and other organisms that are discrete, contiguous and clearly distinguishable from scattered oysters in marshes and mudflats, and from wave-formed shell windrows" and has designated oyster reefs as EFH for red drum (SAFMC, 1998). Additionally, shell bottom is federally designated as an HAPC for estuarine–dependent, snapper-grouper species. Shell bottom provides critical fisheries habitat for oysters and for recreationally and commercially important finfish, other mollusks, and crustaceans. Several studies have found higher abundance and diversity of fish on shell bottom than adjacent soft bottom, particularly pinfish, blue crabs (*Callinectes sapidus*), and grass shrimp (Street et al., 2005).

The action area of the proposed project is within the marine environment and would not be expected to directly or indirectly affect Eastern oysters or shell bottom habitat or any associated EFH or HAPCs.

Hard Clams
Hard clams (*Mercenaria mercenaria*) are managed under the North Carolina hard clam FMP dated June 2008 (NCDMF, 2008a). Hard clams are an estuarine-dependent mollusk found primarily in sandy and vegetated bottoms. Juvenile and adult habitats for hard clams include intertidal sand flats, shell bottom, and SAV (Street et al., 2005). Increased fishing, poor water quality, and habitat loss have affected this fishery. The NCDMF shellfish habitat and abundance mapping program has documented the current distribution of clam habitat. Survey data through January 2007 (including Carolina Beach north to Core Sound, west to Clubfoot Creek on the lower Neuse River, and north to Pungo River) indicate that approximately 2 percent (6,736 acres) of the bottom was

classified as intertidal soft bottom, 75 percent (309,814 acres) was classified as subtidal soft bottom, and 4 percent (14,600 acres) was classified as shell bottom. The EFH for the hard clam, as designated by the SAFMC, is subtidal and intertidal flats, oyster reefs and shell banks, and SAV. In North Carolina, hard clams are commonly harvested from Core Sound, the New River, and the Newport River (Burgess and Bianchi, 2004).

The action area of the proposed project is within the marine environment and is not expected to directly or indirectly affect hard clams or any associated EFH or HAPs.

Bay Scallop

Bay scallops (*Argopecten irradians*) are managed under the North Carolina bay scallop FMP, which was adopted in November 2007 (NCDMF, 2007). The bay scallop is an estuarine dependent bivalve found in seagrass beds. They have a short life span, and their populations are mainly affected by environmental conditions such as temperature, salinity, habitat, and water quality (NCDMF, 2007). Bay scallops are rarely found attached, although they do have the ability to attach by byssal threads mainly as juveniles but as they mature, scallops sink to the bottom and continue to grow. Adult scallops prefer calm waters, secluded from high winds, storms, with tides and depths of 0.3 to 10 m (98 to 32.8 ft). In North Carolina, the majority of bay scallops are harvested from Core and Bogue sounds (Burgess and Bianchi, 2004).

The action area of the proposed project is within the marine environment and is not expected to directly or indirectly affect bay scallops or any associated EFH or HAPCs.

Blue Crabs

Blue crabs (*Callinectes sapidus*) are managed under the North Carolina blue crab FMP dated December 2004 (NCDMF, 2004). Increased concern for the health of the stock and fishery is due to reduced landings of hard blue crabs during 2000–2002 and 2004–2007, following record-high landings observed during 1996–1999. With increasing concerns over fluctuating blue crab landings and increasing fishing effort, numerous requests have been made to further protect the spawning stock of blue crabs in North Carolina. The blue crab life cycle consists of an offshore phase and an estuarine phase and uses a wide range of habitats depending on its life stage, sex, maturity, and associated salinity preferences (NCDMF, 2004). After mating, females migrate to high-salinity waters in lower estuaries, sounds, and nearshore spawning areas. They over-winter before spawning by burrowing in the mud. Most females spawn for the first time 2 to 9 months after mating, usually from May through August the following season. Juveniles (i.e., typically 2.5 millimeters [mm] wide) gradually migrate into shallower, less-saline waters in upper estuaries and rivers where they grow and mature. When air temperatures drop below 50 degrees Fahrenheit (°F) (10 °Celsius [C]), adult crabs leave shallow, inshore waters and seek deeper areas where they bury themselves and remain in a state of torpor throughout the winter (Zinski, 2006). Crab spawning sanctuaries are at Oregon Inlet, Hatteras Inlet, Ocracoke Inlet, Drum Inlet and Bardens Inlet; however, no spawning sanctuaries have been established south of Cape Lookout, North Carolina. The majority of blue crabs are harvested from the Albemarle-Pamlico estuarine system (Burgess and Bianchi, 2004).

The action area of the proposed project is within the marine environment and is not expected to directly or indirectly affect blue crabs and associated critical habitat, spawning sanctuaries, or designated EFH and HAPCs.

Shrimp

Shrimp are managed under the North Carolina shrimp FMP dated April 2006 (NCDMF, 2006). The most common commercially important species in North Carolina are the Penaeid shrimp (white shrimp (*Litopenaues setiferus*), pink shrimp (*Farfantepenaeus duorarum*), and brown shrimp (*F. aztecus*)). Penaeid shrimp are spawned in the ocean and carried by tides and wind driven currents into the estuaries. As the shrimp increase in size, they migrate from the upper reaches of small creeks to deeper, saltier rivers and sounds. By late summer and fall, they return to the ocean to spawn (NCDMF, 2009). The most significant threat to shrimp stocks is loss or degradation of habitat from pollution or physical alteration. Critical habitat types that support juvenile shrimp nursery areas include salt marsh and inshore seagrass habitat (NCDMF, 2006). In North Carolina, the majority of shrimp landings occur in Pamlico Sound, Core Sound, and the Atlantic Ocean fewer than 3 miles offshore (Burgess and Bianchi, 2004). Inshore waters account for 76 percent and ocean waters 24 percent of the total harvest. In the southern portion of the state, the fishery is characterized by a large number of small boats fishing internal waters (primarily the Intracoastal Waterway, New and Cape Fear rivers) and larger craft fishing the Atlantic Ocean primarily off New River, Carolina Beach, and Brunswick County (NCDMF, 2006).

The action area of the proposed project is within the marine environment and is not expected to directly or indirectly affect penaeid shrimp species or any associated EFH or HAPCs.

2.02 Terrestrial Environment

2.02.1 Maritime Shrub Thickets

The maritime shrub thicket community normally occurs landward of the dune where it is protected from salt spray and the full force of ocean winds. Maritime shrub thicket occurs sporadically throughout Surf City and North Topsail Beach—on the backside of the island, west of the highway, and interspersed with marsh areas that border the sound. Dominant shrubs and trees in the community are wax myrtle (*M. cerifera*), yaupon (*I. vomitoria*), red cedar (*Juniperus virginica*), live oak (*Quercus virginiana*), and loblolly pine (*Pinus taeda*). Vines are also common with greenbriar (*Smilax bonanox*), pepper-vine (*Ampelopsis arborea*) and grape (*Vitus rotundifolia*) being particularly abundant. The community type offers excellent cover for neotropical, migrating songbirds. Other important species that may be found in the maritime thicket include the seaside sparrow, painted bunting, saltmarsh sharp-tailed sparrow, Nelson's sharp-tailed sparrow, and marsh and sedge wrens. Raptors may also be common during migration (e.g., American kestrel, merlin, peregrine falcon, bald eagle, northern harrier) (Sue Cameron, personal communication, September 8, 2004).

2.02.2 Beach and Dune

Terrestrial areas that may be influenced by the proposed actions include a 9.9-mile area that includes all Surf City (reaches 27–58) and the southern 3.8 miles of North Topsail Beach (reaches 58–78). Terrestrial habitat types within the areas include sandy or sparsely vegetated beaches and vegetated dune communities. The first line of stable vegetation is outside or landward of the proposed project limits. Utility corridors may have herbaceous or shrub cover. Barren areas are also widespread because of the disturbed nature of the utility corridors. Mammals occurring in this environment are opossums, cottontails, red foxes, gray foxes, raccoons, feral house cats, shrews, moles, voles, and house mice.

Among North Carolina's upland habitats, the beach and dune community could be considered depauperate in both plants and animals. The beach environment is severe because of constant exposure to salt spray, shifting sands, wind, and sterile soils with low water retention capacity. Common vegetation of the upper beach includes beach spurge (*Euphorbia polygonifolia*), sea rocket (*Cakile edentula*) and pennywort (*Hydrocotyle bonariensis*). The dunes are more heavily vegetated, and common species are American beach grass (*Ammophila breviligulata*), panic grass (*Panicum amarum*), sea oats (*Uniola paniculata*), broom straw (*Andropogon virginicus*), seashore elder (*Iva imbricata*), and salt meadow hay (*Spartina patens*) (Nash and Rogers, 2003). Seabeach amaranth is present throughout Surf City and North Topsail Beach and is addressed in Appendix I. Important macroinvertebrates of the beach/dune community are the mole crab (*E. talpoida*), coquina clams (*D. variabilis*) (see Section 2.01.8), and ghost crabs (*O. quadrata*).

Ghost crabs occupy the upper zone of the beach environment and function as an important predator in the beach community. Up to 60 percent of their diet consists of mole crabs; up to 25 percent consists of coquina clams (Wolcott, 1978). During the sea turtle nesting season, ghost crabs are also known to prey on incubating sea turtle eggs and newly hatched sea turtle hatchlings. *O. quadrata* is the only ghost crab occurring in the southeastern United States and, though little is known regarding its life history aspects, their various reproductive and larval components most likely reflect that of other decapods. Although timing of recruitment is poorly understood, it most likely occurs between late spring and early fall (Hackney et al., 1996).

2.02.3 Birds

Birds common to the nearshore ocean in the project area are loons, grebes, gannets, cormorants, scoters, red-breasted mergansers, gulls, and terns (LeGrand, 1983; USACE 2007b; Sauer et al., 2008). The habitat and food source of such seabirds is the marine environment, whether coastal, offshore or pelagic. They can be divided into four groups by their feeding strategies, which are reflected in their anatomy, physiology, and habitat niche: surface feeders, surface swimmers/pursuit divers, plunge-divers, and scavengers and pirates (i.e., steal from other birds). The waters off of Topsail Island are very important to migrating and wintering northern gannets, loons, and grebes because of the abundant hard-bottom habitat offshore of Surf City and North Topsail Beach (see Section

2.01.10) (Sue Cameron, personal communication, September 8, 2004). Those hard-bottom communities support a rich diversity of invertebrates, which are refuges and food sources for fish and other marine life. The diverse communities support a variety of reef and pelagic fish species that, in-turn, provide a forage base for migrating and wintering sea birds. The USFWS indicates that sea ducks raft in large numbers in the nearshore ocean waters of the project area during spring and fall migrations. Ducks, geese, and many kinds of shorebirds may also be found here during the spring and fall (Sauer et al., 2008).

The beaches and inlets of the project vicinity are heavily used by migrating shorebirds. However, dense development and high public use of project area ocean front beaches may reduce their value to shorebirds. Along the ocean beach, black-bellied plovers, ruddy turnstones, whimbrels, willets, red knots, semi-palmated sandpipers, and sanderlings may be found (LeGrand, 1983; USACE 2007b; Sauer et al., 2008). Table 2.8 provides a more complete list of waterbirds found in the project area. The dunes of the project area support fewer numbers of birds but can be very important habitats for resident species and for other species of songbirds during periods of migration. The maritime forest along Topsail Island is important for painted buntings and in the herbaceous dune areas, the American kestrel, merlin, bald eagle, peregrine falcon, northern harrier, and other raptors may be found during migration. Other birds occurring in the area are mourning doves, swallows, fish crows, starlings, meadowlarks, redwinged blackbirds, boat tailed grackles, and savannah sparrows (Douglas and Dechant-Shaffer, 2002; Sauer et al., 2008).

The black skimmer, least tern, and common tern are state-listed species of concern for Pender and Onslow counties, North Carolina, and are found on Topsail Island year round during both the breeding season and during migration, with peak abundance occurring in the summer months. Terns feed by diving from the air on insects and small fish, and the black skimmer feeds on shrimp or small fish by flying just above the water with the tip of the long lower mandible shearing the surface. All these bird species may use Topsail Island for roosting, foraging, breeding, and nesting (Potter et al., 1980).

Table 2.8. List of waterbirds that occur in the Surf City and North Topsail Beach project area and their status

Common name	Scientific name	Season[a]	NC status[b]
Red-throated loon	*Gavia stellata*	M, W	
Common loon	*Gavia immer*	M, W	
Horned Grebe	*Podiceps auritus*	M, W	
Brown pelican	*Pelecanus occidentalis*	B, M, W	SR
Double-crested cormorant	*Phalacrocorax auritus*	B, M, W	SR
Northern Gannet	*Morus bassanus*	M, W	
Great blue heron	*Ardea herodias*	B, M, W	
Great egret	*Ardea albus*	B, M, W	
Snowy egret	*Egretta thula*	B, M	SC
Reddish egret	*Egretta rufescens*	M	
Tricolored heron	*Egretta tricolor*	B, M	SC
Little blue heron	*Egretta caerulea*	B. M. W	SC
Black-crowned night heron	*Nycticorax nycticorax*	B, M, W	
White ibis	*Eudocimus albus*	B, M, W	
Glossy ibis	*Plegadis falcinellus*	B, M	SC
Osprey	*Pandion haliaetus*	B, M	
Clapper rail	*Rallus longirostris*	B, M, W	
Black-bellied plover	*Pluvialis squatarola*	M, W	
Wilsons plover	*Charadrius wilsonia*	B, M	SC
Semipalmated plover	*Charadrius semipalmatus*	M	
Piping plover	*Charadrius melodus*	B, M, W	T (T)
Killdeer	*Charadrius vociferus*	B, M, W	
American oystercatcher	*Haematopus palliatus*	B, M, W	SC
American avocet	*Recurvirostra americana*	M	
Black-necked stilt	*Himantopus mexicanus*	B, M	SR
Greater yellowlegs	*Tringa melanoleuca*	M, W	
Lesser yellowlegs	*Tringa flavipes*	M, W	
Willet	*Catoptrophorus semipalmatus*	B, M, W	
Spotted sandpiper	*Actitis macularia*	M	
Whimbrel	*Numenius phaeopus*	M	
Marbled godwit	*Limosa fedoa*	M, W	
Ruddy turnstone	*Arenaria interpres*	M, W	
Sanderling	*Calidris alba*	M, W	
Semipalmated sandpiper	*Calidris pusilla*	M	
Western sandpiper	*Calidris mauri*	M, W	
Least sandpiper	*Calidris minutilla*	M, W	
Red Knot	*Calidris canutus*	M, W	
Dunlin	*Calidris alpina*	M, W	

Table 2.8. (*continued*)

Common name	Scientific name	Season[a]	NC status[b]
Short-billed dowitcher	*Limnodromus griseus*	M, W	
Bonaparte's gull	*Larus philadelphia*	M, W	
Laughing gull	*Larus atricilla*	B, M	
Ring-billed gull	*Larus delawarensis*	M, W	
Herring gull	*Larus argentatus*	B, M, W	
Great black-backed gull	*Larus marinus*	B, M, W	
Gull-billed tern	*Sterna nilotica*	B, M	T
Caspian tern	*Sterna caspia*	B, M, W	SR
Royal tern	*Sterna maxima*	B, M, W	
Sandwich tern	*Sterna sandvicensis*	B, M	
Common tern	*Sterna hirundo*	B, M	SC
Forster's tern	*Sterna forsteri*	B, M, W	
Least tern	*Sterna antillarum*	B, M	SC
Black tern	*Chlidonias nigra*	M	
Black skimmer	*Rynchops niger*	B, M	SC

Source: LeGrand, 1983

a. Season: B = Breeding; M = Migrating; W = Wintering

b. North Carolina Status: Endangered (E); Threatened (T); Special Concern (SC); Significantly Rare (SR). E, T, and SC status species are given legal protection status by the North Carolina Wildlife Resources Commission. SR status is defined as any species which has not been listed by the North Carolina Wildlife Resources Commission as E, T, or SC species, but which exists in the state in small numbers and has been determined by the North Carolina Natural Heritage Program to need monitoring. federal status is indicated in parentheses.

Annual shorebird surveys conducted by the North Carolina Wildlife Resources Commission (NCWRC) in the project vicinity are limited, and complete surveys for American oystercatchers and Wilson's plovers have been conducted only in 2004 and 2007. However, annual surveys for nesting piping plovers in appropriate habitat have been conducted since 1989, and complete coast-wide wintering surveys were conducted most recently in 1996, 2001, and 2006. Table 2.9 summarizes the Topsail Island vicinity annual shorebird surveys and database provided by NCWRC. Surveys encompassed the wintering, breeding, and spring and fall migration periods.

Table 2.9. Summary of annual shorebird surveys

Species	Site	Birds	Breeding pairs
American Oystercatcher	AIWW Bogue Inlet south to North Topsail	14	6
	AIWW North Topsail south to S. Figure Eight	32	14
	AIWW South Topsail	21	10
	New River Inlet	23	10
	Topsail Beach North	2	1
	UNI, New River Channel 1	2	1
	UNI, New River Channel 2	4	2
	UNI, New River Channel 3	10	5
	UNI, New River Channel 4	2	1
	TOTAL	**110**	**50**
Black-necked Stilt	Surf City, AIWW 1	1	
	TOTAL	**1**	**0**
Killdeer	AIWW Bogue Inlet south to North Topsail	4	2
	AIWW North Topsail south to S. Figure Eight	4	2
	AIWW South Topsail	2	1
	North Topsail Overwash	2	1
	Topsail Beach North	4	2
	UNI, New River Channel 2	4	2
	UNI, New River Channel 3	4	2
	TOTAL	**24**	**12**
Piping Plover*	North Topsail Overwash	0	0
	Topsail Beach North	10	2
	TOTAL	**10**	**2**
Willet	AIWW Bogue Inlet south to North Topsail	20	10
	AIWW North Topsail south to S. Figure Eight	22	11
	AIWW South Topsail	1	1
	New River Inlet	24	12
	North Topsail Overwash	2	1
	Topsail Beach North	20	10
	UNI, New River Channel 2	4	2
	UNI, New River Channel 3	20	10
	UNI, New River Channel 4	6	3
	TOTAL	**119**	**60**
Wilsons Plover	AIWW Bogue Inlet south to North Topsail	22	11
	North Topsail Overwash	40	19
	Topsail Beach North	41	18
	UNI, New River Channel 1	4	2
	UNI, New River Channel 2	14	7
	UNI, New River Channel 3	4	2
	TOTAL	**125**	**59**

Note: *Piping plover surveys conducted during the winter did not identify any birds. (AIWW – Atlantic Intracoastal Waterway; UNI – Un-named Island). Source: NCWRC 2009.

Colonially nesting waterbirds are an important part of the project area ecosystem. The species formerly nested primarily on the barrier islands of the region, but development or recreational activities have usurped the nesting sites. With the loss of their traditional nesting areas, the species have retreated to the relatively undisturbed dredged material disposal islands that border the navigation channels throughout the state. Those islands often offer ideal nesting areas because they are close to food sources, well removed from human activities, and are isolated from mammalian egg and nesting predators. Other species also use the islands for loafing or roosting during migratory periods or the winter months including painted buntings. Surveys conducted by the NCWRC for American oystercatchers and Wilson's plovers indicate that the dredge islands, natural islands, and shell rakes behind Topsail Island are very important nesting areas for the species. However, dredged material islands in the immediate vicinity of the project area that are diked are used by only a small number of nesting waterbirds. Since 1972, coast-wide breeding colonial waterbird surveys have been conducted every 2–3 years with the most recent completed survey conducted in 2007. Seven of the survey sites are in the project vicinity and, between 1972 and 2007, have supported a total of 978 nests from 9 different species of colonial nesting waterbirds (Table 2.10).

Table 2.10. Summary of colonial nesting waterbird data (1972–2007) conducted by NCWRC in the SCNTB vicinity

Site	Colonial nesting waterbirds (# of nests from 1972 through 2007)								
	Green heron	Least tern	Black skimmer	Common tern	Gull billed tern	Cattle egret	Little blue heron	Snowy egret	Tri-colored heron
UNI, New River Channel 1	2	66							
UNI, New River Channel 2	65	297	25	6					
UNI, New River Channel 3	64	18	5	14	4				
UNI, New River Channel 4	13								
UNI, Alligator Bay 1	33					75	49	10	11
ICW, Dredge Island South of Surf City		29							
New Chadwick Bay Inlet		192							
TOTAL	177	602	30	20	4	75	49	10	11

Note: AIWW = Atlantic Intracoastal Waterway; UNI = Unnamed Island; shaded areas represent 0 documented nesting records.

Though most of the project area is heavily developed, the southern end of Topsail island the north end of North Topsail Beach, and nearby Lea and Hutaff islands and Onslow beaches provide important and unique, undeveloped habitat for breeding birds including terns, skimmers, piping plovers, Wilson's plovers, and American oystercatchers. The

undeveloped barrier island areas are rare in the project vicinity and are very important breeding habitats for those species. The north end of North Topsail Beach is important for many shorebird and water bird species and secretive marsh birds such as sharp-tailed sparrows. Though historically the north end of North Topsail Island had not been roped off for nesting shorebirds, in 2008 NCWRC was permitted to post a section of the north end for nesting birds, and a colony of least terns (~40 pairs) attempted to nest. Furthermore, a single migrant piping plover was identified using an area on the north end. Information on birds using the north end of North Topsail Beach and the ocean-facing beaches of the project area during the nonbreeding season are limited. However, as a component of the ongoing shorebird monitoring plan for the nonfederal North Topsail Beach coastal storm damage reduction project, CPE has been conducting regular surveys of the North Topsail Beach and New River Inlet vicinity. Specifically, CPE has surveyed seven bird-monitoring transect areas in the New River Inlet complex since November 19, 2007. As identified in the preconstruction bird-monitoring plan of the November 2007 *Draft Environmental Impact Statement* (USACE, 2007b), the transect sites include: transect No. 1 - Riverside of North Topsail Beach inlet shoreline beginning at River Road; transect No. 2 - Oceanside of North Topsail Beach inlet shoreline beginning at the southeastern end of Topsail Reefs Condominiums and ending at River Road; transect No. 3 - Onslow Beach inlet shoreline extending approximately 1,060 m (3,500 ft.) to the northeast; transect No. 4 - shoal formations approximately 609 m (2,000 ft.) north of inlet mouth; and transect No. 5 - subtidal habitat of New River Inlet and oceanfront surf zones of transects 2 and 3. CPE has not yet completed the pre-project data collection component of the monitoring plan and a detailed analysis and summary of the data. However, to provide a preliminary assessment of key species in the proposed federal project vicinity that use habitat on the north end of North Topsail Beach, a summary of the current data within transects 1 and 2 (on the north end of North Topsail Beach) is provided in Table 2.11. Of particular importance are the state-listed species: the black skimmer (*Rynchops niger*) (n=2) (species of concern), least tern (*Sterna antillarum*) (n=197) (species of concern), and common tern (*Sterna hirundo*) (n=57) (species of concern), Wilsons plover (*Charadrius wilsonia*) (n=38) (species of concern), American oystercatcher (*Haematopus palliates*) (n=61) (species of concern), and the federally listed Piping plover (threatened) (n=1).

Table 2.11. Summary of key waterbird species identified along the inlet and ocean facing shorelines of North Topsail Beach based on ongoing pre-construction monitoring performed by CPE as a component of the bird monitoring plan for the Nonfederal North Topsail Beach Shoreline Protection Project (USACE, 2007b)

Species	Survey period				Total
	Winter (Nov–Feb)	Spring (Mar–Jun)	Summer (Jul–Aug)	Fall (Sept–Oct)	
Common loon	7	1	0	0	**8**
Brown pelican	84	73	22	42	**221**
Double-crested cormorant	112	22	3	1	**138**
Great Blue heron	1	0	5	4	**10**
Great egret	0	0	77	46	**123**
Snowy egret	0	0	17	19	**36**
Little Blue heron	0	0	11	5	**16**
Tricolored heron	0	0	1	1	**2**
White ibis	13	0	12	35	**60**
Glossy ibis	0	0	0	0	**0**
Black-bellied plover	22	16	17	38	**93**
Wilson's plover	0	3	30	5	**38**
Semipalmated plover	0	0	61	66	**127**
Piping plover	0	0	1	0	**1**
Killdeer	0	2	3	0	**5**
American oystercatcher	0	2	28	31	**61**
Greater yellowlegs	9	3	6	10	**28**
Solitary sandpiper	0	0	0	0	**0**
Willet	6	11	31	15	**63**
Spotted sandpiper	0	0	2	1	**3**
Whimbrel	0	0	0	0	**0**
Marbled godwit	0	0	1	0	**1**

Table 2.11. (*continued*)

Species	Survey period				Total
	Winter (Nov–Feb)	Spring (Mar–Jun)	Summer (Jul–Aug)	Fall (Sept–Oct)	
Ruddy turnstone	15	3	9	24	**51**
Red knot	59	0	4	0	**63**
Sanderling	22	7	101	114	**244**
Semipalmated sandpiper	0	0	29	29	**58**
Western sandpiper	17	22	4	28	**71**
Least sandpiper	0	0	31	44	**75**
Pectoral sandpiper	0	0	0	0	**0**
Dunlin	309	87	0	12	**408**
Short-billed dowitcher	39	0	104	95	**238**
Long-billed dowitcher	0	0	0	1	**1**
Laughing gull	432	30	479	1174	**2115**
Bonaparte's gull	167	104	0	0	**271**
Ring-billed gull	658	147	88	138	**1031**
Herring gull	256	12	68	184	**520**
Lesser black-backed gull	0	0	0	2	**2**
Great black-backed gull	129	2	18	51	**200**
Gull-billed tern	0	0	0	0	**0**
Caspian tern	0	0	16	186	**202**
Royal tern	0	2	147	232	**381**
Sandwich tern	1	1	96	148	**246**
Common tern	0	0	7	50	**57**
Forster's tern	14	5	0	147	**166**
Least tern	0	76	121	0	**197**
Black tern	0	0	1	0	**1**
Black skimmer	0	0	2	93	**95**
TOTAL	**2,372**	**631**	**1,653**	**3,071**	**7,727**

2.02.4 Endangered and Threatened Species

The ESA of 1973, as amended (16 U.S.C. 1531–1543), provides a program for the conservation of threatened and endangered (T&E) plants and animals and the habitats in which they are found. The lead federal agencies for implementing the ESA are the USFWS (http://www.fws.gov/) and the NOAA Fisheries Service (http://www.nmfs.noaa.gov/). The USFWS has primary responsibility for terrestrial and freshwater organisms, while the responsibilities of NMFS are mainly marine wildlife such as whales and anadromous fish such as salmon. Section 7 of the ESA requires federal agencies to use their legal authorities to promote the conservation purposes of the ESA and to consult with the USFWS and NMFS, as appropriate, to ensure that effects of actions they authorize, fund, or carry out will not jeopardize the continued existence of listed species or result in the destruction or adverse modification of designated critical habitat of such species. The law also prohibits any action that causes a *taking* of any listed species of endangered fish or wildlife without a permit. Take is defined as, "to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect or attempt to engage in any such conduct." Through regulations, the term *harm* is defined as, "an act

[that] actually kills or injures wildlife. Such an act may include significant habitat modification or degradation where it actually kills or injures wildlife by significantly impairing essential behavioral patterns, including breeding, feeding, or sheltering." Likewise, import, export, interstate, and foreign commerce of listed species are all generally prohibited. In accordance with section 7 (a)(2) of the ESA, the Corps has been in consultation with the USFWS and NMFS since beginning this study to ensure that effects of the proposed project would not jeopardize the continued existence of listed species or result in the destruction or adverse modification of designated critical habitat of such species.

Updated lists of federally listed T&E species for the project area (Pender and Onslow counties, North Carolina) were obtained from the NMFS (Southeast Regional Office, St. Petersburg, Florida) (http://sero.nmfs.noaa.gov/pr/pdf/North%20Carolina.pdf) and the USFWS (Field Office, Raleigh, North Carolina) (http://www.fws.gov/raleigh/es_tes.html) Web sites. Those were combined to develop a composite list of T&E species that could be present in the area according to their historical occurrence or potential geographic range (Table 2.12). However, the actual occurrence of a species in the area depends on the availability of suitable habitat, the season of the year relative to a species' temperature tolerance, migratory habits, and other factors. The likelihood of occurrence and potential project effects regarding T&E species are provided in the Biological Assessment (Appendix I.)

Chapter 113 (Conservation and Development), Subchapter IV (Conservation of Marine and Estuarine and Wildlife Resources), and Article 25 (Endangered and Threatened Wildlife and Wildlife Species of Special Concern) of the North Carolina General Statute comprises the state's endangered species provisions. Under that North Carolina statutory section, endangered species is defined as any native or once-native species of wild animal whose continued existence as a viable component of the state's fauna is determined by the Wildlife Resources Commission to be in jeopardy or any species of wild animal determined to be an *endangered species* pursuant to the ESA. Species are listed by the North Carolina Wildlife Resources Commission under specific criteria as defined by the statute. Under the act, it is unlawful to take, possess, transport, sell, barter, trade, exchange, export, or offer for sale, barter, trade, exchange or export, or give away for any purpose including advertising or other promotional purpose any animal on a protected wild animal list.

Table 2.12. Federally listed T&E species for the project area (Pender and Onslow counties, North Carolina)

Species common names	Scientific name	Federal status
Mammals		
West Indian Manatee	*Trichechus manatus*	Endangered
North Atlantic Right whale	*Eubaleana glacialis*	Endangered
Sei whale	*Balaenoptera borealis*	Endangered
Sperm whale	*Physeter macrocephalus*	Endangered
Finback whale	*Balaenoptera physalus*	Endangered
Humpback whale	*Megaptera novaeangliae*	Endangered
Blue Whale	*Balaenoptera musculus*	Endangered
Birds		
Piping Plover	*Charadrius melodus*	Threatened
Red-cockaded woodpecker	*Picoides borealis*	Endangered
Reptiles		
American alligator	*Alligator mississippiensis*	T(S/A)
Green sea turtle	*Chelonia mydas*	Threatened[1]
Hawksbill turtle	*Eretmochelys imbricata*	Endangered
Kemp's ridley sea turtle	*Lepidochelys kempii*	Endangered
Leatherback sea turtle	*Dermochelys coriacea*	Endangered
Loggerhead sea turtle	*Caretta caretta*	Threatened
Fish		
Shortnose sturgeon	*Acipenser brevirostrum*	Endangered
Smalltooth sawfish	*Pristis pectinata*	Endangered
Vascular Plants		
Golden sedge	*Carex lutea*	Endangered
Chaffseed	*Schwalbea Americana*	Endangered
Cooley's meadowrue	*Thalictrum cooleyi*	Endangered
Rough-leaved loosestrife	*Lysimachia asperulaefolia*	Endangered
Seabeach amaranth	*Amaranthus pumilus*	Threatened

Status	Definition
Endangered	A taxon "in danger of extinction throughout all or a significant portion of its range."
Threatened	A taxon "likely to become endangered within the foreseeable future throughout all or a significant portion of its range."
T(S/A)	Threatened due to similarity of appearance (e.g., American alligator)--a species that is threatened due to similarity of appearance with other rare species and is listed for its protection. These species are not biologically endangered or threatened and are not subject to Section 7 consultation.

An updated list of state-listed species for Pender and Onslow counties, North Carolina, was obtained from the North Carolina Natural Heritage Program Web site, http://www.ncnhp.org. (Table 2.13). Bird species are addressed in Sections 2.02.3 and 8.02.3, and the Carolina diamondback terrapin is addressed in Sections 2.01.2 and 8.01.2 of this FEIS.

Table 2.13. Summary of state-listed species for Pender and Onslow counties, North Carolina, that are not already federally listed as defined in Table 2.12

Species common name	Scientific name	State status
Birds		
Wilsons plover	*Charadrius wilsonia*	SC
American oystercatcher	*Haematopus palliatus*	SC
Bald Eagle	*Haliaeetus leucocephalus*	T
Least bittern	*Ixobrychus exilis*	SC
Eastern painted bunting	*Passerina ciris ciris*	SC
Black skimmer	*Rynchops niger*	SC
Common tern	*Sterna hirundo*	SC
Least tern	*Sternula antillarum*	SC
Gull-billed tern	*Gelochelidon nilotica*	T
Black necked stilt	*Himantopus mexicanus*	SR
Black rail	*Laterallus jamaicensis*	SC
Brown pelican	*Pelecanus occidentalis*	SR
Double-crested cormorant	*Phalacrocorax auritus*	SR
Snowy egret	*Egretta thula*	SC
Tricolored heron	*Egretta tricolor*	SC
Little blue heron	*Egretta caerulea*	SC
Glossy ibis	*Plegadis falcinellus*	SC
Caspian tern	*Sterna caspia*	SR
Reptiles		
Carolina diamondback terrapin	*Malaclemys terrapin centrata*	SC

Endangered (E); Threatened (T); Special Concern (SC); Significantly Rare (SR). E, T, and SC status species are given legal protection status by the NC Wildlife Resources Commission. SR status is defined as any species which has not been listed by the NC Wildlife Resources Commission as E, T, or SC species, but which exists in the state in small numbers and has been determined by the NC Natural Heritage Program to need monitoring.

Bald eagles were removed from the federal endangered species list in June 2007 because their populations recovered sufficiently, although they are still listed in North Carolina as threatened (Table 2.13) and their protection under the Bald and Golden Eagle Protection Act continue to apply. When the bald eagle was delisted, the USFWS proposed regulations to create a permit program to authorize limited take of bald eagles and golden eagles where take is associated with otherwise lawful activities. The Bald and Golden Eagle Protection Act (16 U.S.C. 668–668c), enacted in 1940, and amended several times since, prohibits anyone, without a permit issued by the Secretary of the Interior, from *taking* bald eagles, including their parts, nests, or eggs. The act provides criminal penalties for persons who, "take, possess, sell, purchase, barter, offer to sell, purchase or barter, transport, export or import, at any time or any manner, any bald eagle...[or any golden eagle], alive or dead, or any part, nest, or egg thereof." The act defines take as, "pursue, shoot, shoot at, poison, wound, kill, capture, trap, collect, molest or disturb." The bald eagle is found throughout North America including Pender and Onslow counties; however, the proposed action is not expected to affect specific habitat requirements of the bald eagle.

2.03 Physical Resources

2.03.1 Wave Conditions

Waves selected as input for the study were taken from the Corps' Coastal and Hydraulics Laboratory Wave Information Study. Updated wave hindcast data for station 292, about 10 miles offshore of Topsail Island for 1990 to 1999 were used. On the basis of the data, waves commonly approach the southeast-facing study area from east through south directions (nearly two-thirds of the time), with east-southeast and southeast approaching waves occurring most frequently (nearly one-third of the time). Annually, the most frequently occurring wave heights range from 1.6 to 3.2 ft., with a mean wave height of about 3.3 ft. In winter, the most frequently occurring wave heights range from 1.6 up to 4.9 ft. because of storms, with easterly to northeasterly approaching waves increasing in frequency. Summer wave conditions have more of a southeasterly component and are commonly in the 1- to 3-foot range, except for tropical systems that can generate the infrequent, but extreme waves of 15 ft. or more.

2.03.2 Shoreline and Sand Transport

The contiguous 9.9 miles of the study area consisting of Surf City and the southern portion of North Topsail Beach were divided into 52 reaches (27–78), each of which is about 1,000 ft. wide, except for the southernmost reach (27), which is 1,300 ft. wide. The two separate, smaller non-CBRA sections were each divided into 2 smaller reaches of varying lengths (reaches 107–108 and 114–115). The 1,000-foot-long study reaches are visible in Section 7, Figure 7.2 and in Appendix A, Figures A-7 and A-8.

Aside from the two small non-CBRA sections, the study area is more than 7 miles south of New River Inlet and more than 5 miles north of New Topsail Inlet—well out of the direct influence of the inlet complex. The authorized depth of those channels is relatively shallow (8 ft for New River and 7 ft for New Topsail). Both navigation channels are laid out to follow naturally deep water, and any maintenance dredging of these channels occurs along the unfixed channels. Dredging of those ocean bar channels has historically occurred predominately using sidecast dredging vessels, and the sediment remains in the inlet complex. External to this feasibility report effort, additional steps related to sediment allocation are being taken. The Corps' Regional Sediment Management program is analyzing the North Carolina coast and will include development of a sediment budget for the Topsail Island area. Some preliminary results are briefly presented in Appendix D. A grosser scale sediment budget for the island has been calculated for a previous report and showed a gross sediment rate of about 1,289,000 cubic yards per year and a net sediment transport rate of about 200,000 cubic yards per year to the north. For additional details, see Appendix D.

Long-term shoreline changes were determined by comparing Mean High Water (MHW) shoreline positions for each reach. Between 1963 and 2002, erosion rates were relatively low (less than one foot per year) in the southern half of the main study area (reaches 27–43); however, erosion rates in the northern half of the main study area (reaches 44–78) averaged nearly 2 ft. per year. This change in erosion rates may indicate the presence of a sediment transport reversal in this area. Appendix D discusses ongoing regional sediment

management studies which, when completed, will help clarify the sediment transport processes and the presence of transport reversals. Erosion rates increased significantly to more than 5 ft. per year in portions of the non-study CBRA area (reaches 79-106), but they decreased to 2 to 3 ft. per year in reaches 107–108 study segment. Shoreline changes in reaches 114–115 study segment begin to be significantly influenced by inlet processes as erosion precipitously changed to minor accretion and then back to significant erosion in a span of only a few reaches approaching New River Inlet.

2.03.3 Geology and Sediments

The study area is in the Atlantic Coastal Plain Physiographic Province bordering Onslow Bay. The geomorphology of the area is characterized by beaches, dunes, and marshes typical of a barrier island complex. The Atlantic Coastal Plain and Onslow Bay are both underlain by relatively flat-lying sedimentary units that gently dip and thicken to the southeast. That large sedimentary wedge includes both sediments that have not been indurated or cemented and rock units. The sedimentary units range in age from Cretaceous to Quaternary and overlie crystalline basement rock. A patchy veneer of Holocene sands and gravels overlies the Quaternary strata. The sand soils found on the Topsail Island beaches are classified as fine- to medium-grained, poorly graded sands (SP) according to the Unified Soils Classification System.

The small rivers and streams entering Onslow Bay contribute small sediment loads as a significant fraction is deposited in the estuaries. That, in turn, contributes to the sand-starved nature of the coast in the area.

2.03.4 Climate

The climate of Surf City and North Topsail beaches is typically seasonal and generally mild. Temperatures are moderated by the ocean temperature, which ranges between 65 °F to 80 °F in the spring and summer and 50 °F to 65 °F in the fall and winter. The summers are warm and humid with highs averaging between 80 °F to 90 °F and winters are short and mild averaging around 55 °F. Predominant winds in the winter are from the north and northeast, whereas in the summer the winds are predominantly out of the south to southeast. Average monthly precipitation ranges from 3 to 8 inches throughout the year. October through December are the driest months, averaging 2–3 inches of precipitation, and July through September are the wettest months, averaging between 6–7 inches of precipitation.

Surf City and North Topsail Beach are low elevation and narrow barrier islands, and the orientation of the coastal communities on the Atlantic coastline lend them particularly vulnerable to tropical systems, including a long history of hurricanes. Though a significant number of historic hurricanes have approached the vicinity of Topsail Island, Hurricane Bertha, in 1996, was the first direct hit on it since Hurricane Donna in 1960. In the same year Hurricane Fran, a category 3 hurricane, struck the same area hit by Bertha with sustained winds of about 115 miles per hour and gusts to at least 125 miles per hour with significant coastal property loss extending from Cape Fear northward to Topsail Island.

Northeasters occur far more frequently than hurricanes and are much larger and longer lasting. The North Carolina coastline is vulnerable to large, persistent northeasters because of its orientation to the winter track of the polar jet stream. Significant coastal storm damage can result from these storm events. The most memorable coastal northeasters of the 20th century include the 1962 Ash Wednesday Storm and the 1993 Storm of the Century which caused extensive damage on Topsail Island and the rest of coastal North Carolina.

2.03.5 Physical Oceanography

The coastline of Surf City and North Topsail Beach is controlled by tidal and wind driven currents and experiences semi-diurnal tides with an average tidal range of about 3 ft. The longshore current is predominantly toward the northeast in the summer and toward the southwest in the winter. The predominant wave direction is from the south to southeast in the spring and summer and from the north to northeast in the fall and winter (see Section 2.03.1).

2.04 Socioeconomic Resources

The local economic impact area includes all Topsail Island and the nearby areas of both Pender and Onslow Counties, North Carolina. Topsail Island includes Surf City and North Topsail Beach on the north end of the island and Topsail Beach on the south end of Topsail Island. Highways 50 and 210 connect the island to the mainland portion of the two counties.

2.04.1 Demographics

Demographics for the existing economic conditions for the two-county study area, which includes census data for population, housing, and personal income are shown in Table 2.14. The total population of the two-county area was more than 190,000 in 2000. The study area had 2,236 permanent residents in 2000. According to the towns of Surf City and North Topsail Beach officials, the estimated peak summer time population of the two towns is greater than 30,000.

Table 2.14. Socioeconomic conditions of Pender and Onslow counties, North Carolina

Category	Pender County	Onslow County	Surf City	North Topsail Beach
Population year-round (2007 estimate)	50,430	169,302	1,766	898
Population year-round (2000 census)	41,082	150,355	1,393	843
Population peak season (Estimated)			15,438	15,000–20,000
Households				
Ave. household size	2.49	2.72	2.02	1.87
Housing units	20,798	55,726	2,578	2,085
Occupied year-round	16,054	48,122	689	451
Seasonal or vacant	4,744	7,604	1,889	1,634
Employment				
In labor force	19,087	85,054	754	545
Civilian	18,972	52,670		
Unemployed	1,076	3,650		
Armed Forces	115	32,384		
Employment by leading industry				
Construction	2,468	5,022		
Manufacturing	2,632	2,682		
Retail trade	2,367	7,496		
Education, health & social services	2,704	10,865		
Per capita and household income				
Per capita money income	$17,882	$14,853	$25,242	$33,972
Median household income 1999	$35,902	$33,756	$40,521	$45,982

Source: U.S. Census Bureau (http://factfinder.census.gov) and U.S. Department of Commerce, Bureau of Economic Analysis (http://bea.doc.gov/bea)

Office of State Budget and Management (2007 population estimates)

The population of Pender County grew from 28,855 in 1990 to 41,082 in 2000, an increase of 42 percent. Onslow County population was virtually unchanged during the same period. North Carolina grew by 21 percent during that same period. Figure 2.1 shows both historical population from 1920 to 2000 and population projections by the North Carolina State Demographer for Pender and Onslow counties through 2029. Personal per capita income for Pender and Onslow counties was reported to be $27,720 and $25,317, respectively. Personal per capita income for North Carolina was $20,307.

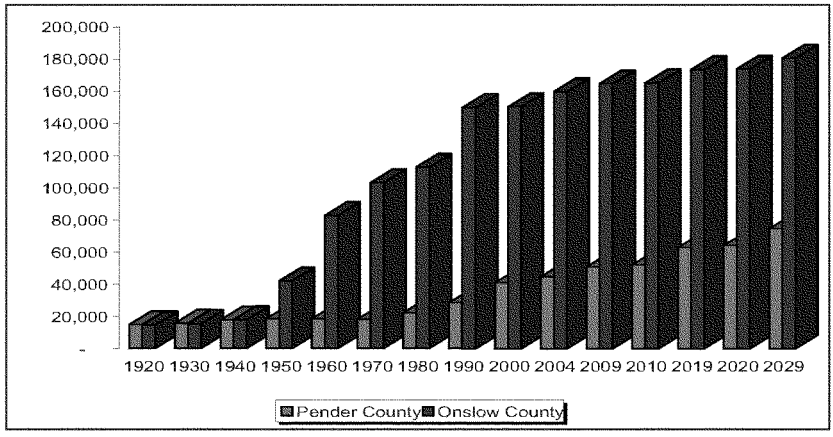


Figure 2.1, Population history and projections.

2.04.2 Aesthetic and Recreational Resources

The towns of Surf City and North Topsail Beach are urbanized beach communities characterized by paved streets, bridges, parking lots, hotels, single-family dwellings, hotels, and low-rise condominiums. Land use is primarily recreational and residential with few commercial properties. A scenic setting is provided by waters of the Atlantic Ocean, New River Inlet, the AIWW and Stump Sound, and the numerous vessels common to those waters. The marine environment provides opportunities for boating and fishing, as well as an escape from the faster pace of land-based activities. Beaches generally offer extensive recreational opportunities for activities such as swimming, sunbathing, walking, surfing, bird watching, and fishing. In addition, two ocean fishing piers are in the study area (one in the project area) and are considered important recreational facilities at Topsail Island. Although Surf City and North Topsail Beach have lost some of their visual appeal because of severe erosion caused by the hurricanes of 1996–1999 and 2003, the enduring aesthetic value of the beach community is evidenced by the popularity of the area for family oriented use and tourism. During the summer months, many of the homes in the study area are available as summer rentals to vacationers primarily from inland North Carolina and other locations around the eastern United States. Table B-2 (Appendix B), shows that the number of housing units at Surf City and North Topsail Beach is 2,578 and 2,085, respectively. Of those units, 689 at Surf City and 451 at North Topsail Beach are occupied year-round. The remaining units are designated as seasonal or vacant. The estimated peak seasonal populations for Surf City and North Topsail Beach are 15,438 and 15,000–20,000, respectively. In the off-season, the populations drop to about 1,400 residents at Surf City and 840 residents at North Topsail Beach.

2.04.3 Commercial and Recreational Fishing

According to the North Carolina commercial fish landings report produced annually by the NCDMF, the commercial finfish harvest was up 17 percent from 2008 to 2009.

However, the commercial shellfish harvest was down 7.3 million pounds in 2009 mostly because of a 43 percent decrease in shrimp harvest from 2009. Total commercial landings in 2009 were 68.6 million pounds, which is about 2.5 million pounds lower than in 2008 (NCDMF, 2009). NCDMF reported approximately 136,000 pounds of commercial reported approximately 136,000 pounds of commercial finfish and shellfish landings in the vicinity of Stump Sound in 2006 and nearly 162,000 pounds in 2007 (NCDMF, 2008a,b). The top five species included blue crabs (hard), oysters, white shrimp, southern flounder and clams (hard). Total commercial seafood landings by county for 2006 and 2007 were as follows: —Pender: 635,549 pounds in 2006, valued at $754,742 and 695,051 pounds in 2007, valued at $1,083,330; Onslow: 2,549,223 pounds in 2006 valued at $5,060,902 and 2,550,206 pounds in 2007, valued at $5,542,501 (NCDMF, 2008a,b). Areas in the vicinity of the study area that are closed to shellfishing are shown in Appendix A, Figure A-4.

Recreational fishing includes fishing from head boats, charter boats, private boats, piers, and the surf. Fishing from head boats is best in the winter months for snapper and grouper. Fishing from charter boats is excellent for king mackerel and bottomfish during the winter. Offshore, gulfstream species, like yellowfin tuna and wahoo are available. Inside fishing has been successful for inshore species such as red drum, speckled trout, and flounder.

Private boat anglers can find bluefin tuna in the nearshore area, king mackerel, and other bottomfish species in the offshore, and other species such as speckled trout, red drum, and flounder can be found in the inside areas of the creeks and AIWW.

2.05 Cultural Resources

Recent archaeological findings in the mid-Atlantic and southeastern regions demonstrate that coastal areas were being exploited soon after human occupations began in North America. The most complete regional evidence of these early Americans comes from the Cactus Hill site, on the coastal plain of the Nottaway River in Sussex County, Virginia. The site has abundant evidence of a Clovis occupation, which is so named after the distinctive fluted Clovis projectile point. This point is a marker for this nationally widespread horizon. The Clovis occupation at Cactus Hill is firmly dated and supports other dates from throughout North America, which place Clovis occupations around 13,000 B.P. (McAvoy 1997). Research at this and other sites throughout the mid-Atlantic and southeastern coasts of Virginia and North and South Carolina demonstrate that Paleoindian occupation of the coastal plain was widespread during those times of much lower sea level and cooler climate.

Glaciation during the late Pleistocene (circa 18,000 to 14,000 B.P.) may have lowered sea level south of Cape Hatteras, North Carolina, 60 or more meters below present level, exposing the entire continental shelf for settlement and exploitation (Boss and Hoffman 2001; Science Applications, Inc. 1981). Some exposed areas, however, lacked stabled land surfaces and mature estuaries because of downcutting and other fluvial dynamics associated with lower stream base level (Sassaman 1996). Some research, particularly at

Cactus Hill, suggests a pre-Clovis occupation going back to 18,000 B.P. Both archaeological and geological research suggest that the Paleoindians and the megafauna they hunted disappeared or became very scant in the archaeological record around 12,900 B.P., presumably as a result of a catastrophic event (Goodyear 2006).

Warming trends produced a major rise in sea level from water released from melting glaciers after 14,000 B.P. (Faught 2004). The rise in sea level was interrupted during the Younger Dryas (circa 11.000 to 10,000 B.P.) as the climate returned to near glacial conditions. Sea levels were within a few meters of present levels by 9,000 B.P. and reached present sea level circa 2,000 to 5,000 B.P. (Anderson et al. 1996; Haynes 2002; Lewis 2000).

After the demise of post-Pleistocene mega-fauna, Native Americans adapted with a new lifestyle and associated tool kit. Those people, referred to by archaeologists as Archaic, focused on plant gathering and the hunting of modern game animals. Their tool kit remained limited but elegant, including a variety of projectile points, ground stone tools, and basketry. Archaic populations appear in the archaeological record around 10,000 years ago and persist until the advent of agriculture around 3,000 years ago. Social organization probably still centered on extended families and bands, with possible larger seasonal gatherings; however, Russo (1996) proposes, on the basis of analyses at a number of mid-Holocene coastal deposits, estuarine environments at that time were capable of supporting year-round occupation. The Archaic period was an extremely important foundation on which later, more complex societies would grow. The early Woodland period, in particular, probably inhabited the same riverside locations and followed much the same lifestyle as their Archaic predecessors. However, regional subsistence specialization and incipient agriculture allowed for the development of a more settled lifestyle, support of larger permanent populations, and the establishment of defended territories.

While many scattered coastal Archaic and Early Woodland period sites and artifact finds exist, the most significant occupations tend to occur during Middle- and Late-Woodland periods (Ward and Davis 1999). Those are times of increasing reliance of agriculture, more settled village life, the development of pottery, and especially sophisticated political organization. Through time, many regional cultures appear along the coast with several cultural and language affiliations with groups to the north, west, and south (Phelps 1983; Ward and Davis 1999). Seasonal exploitation of sound-side resources is now full blown, and some villages persisted long enough to establish large settlement, complete with ossuary pits (mass burials). The Colington phase of the Woodland Period is equated with the Carolina Algonkian culture, who greeted the first English explorers (Phelps 1983).

To date, few indications exist that Native American populations made significant use of oceanside resources. Littoral zones, especially intertidal areas, appear to have been more important extractive locales than ocean-facing beaches (Phelps 1981; Science Applications, Inc. 1981). Inner and outer coast populations of North Carolina during the Middle Woodland period shared similar settlement and foraging strategies, with fish,

shellfish, deer, rabbit, and raccoon being important food resources (Hargrove 1983; Hutchinson 2002). Indeed, the intensive use of the sounds may indicate that resources there were so plentiful that an interest in exploiting the open-ocean never developed.

The proposed borrow areas are 1 to 5.5 miles offshore of the towns of Topsail Beach, Surf City and North Topsail Beach and stretch from the New Topsail Inlet to the New River Inlet. The area has seen significant maritime activity since at least the early eighteenth century when permanent settlement began. One of the earliest land grants included the inlet and area surrounding the sound, and by 1755 New Topsail Sound was designated as an official inspection point for export commodities in New Hanover County, along with counties Brunswick, Wilmington, and New Exeter (Angley 1984). Inspections were conducted for export commodities of fish, flour, butter, flax seed, beef, pork, rice, tar, pitch and turpentine, staves and headings, sawed lumber and shingles.

Throughout the Colonial Period, the inlet was relatively stable and was suitable for passage by schooners and small sloops. During the latter part of the eighteenth century and throughout most of the nineteenth century, New Topsail Inlet migrated significantly to the north. According to Wilson Anglely's (1984) analysis, the Mouzon Map of 1775 and the Price-Strother Map of 1808, the inlet migrated northward some 2 miles. While the Mac Rae-Brazier Map of 1833 indicates no significant change, the U.S. Coast Survey Map of 1865 shows that an additional migration of 2 miles occurred during that period. The migration appears to have abated during the end of that century, as is suggested by review of the Kerr-Cain Map of 1882 and the Post Route Map of 1896. A detailed U.S. Coast Survey Map of 1885 indicates that the New Topsail Inlet was approximately 3,000 ft. wide at that time.

Five miles northeast of North Topsail Beach lies New River, another important waterway in coastal North Carolina history. In 1705 three Englishmen established a settlement at Town Point, the first in Onslow County. Within 20 years, the population had grown to approximately 35 families with English, German, and French Huguenot ancestry. The Moseley map of 1733 indicates that settlement spread along the coast and up the rivers and streams, a pattern typical of the southern colonies. A county seat was platted at Mittam's Point on New River in 1742. The town, called Johnston, was struck by a hurricane in 1752 that devastated much of the coastal southeast. In response to the destruction of the storm, the county seat was moved inland. Land was acquired from James Wantland, who operated a ferry and tavern at the site where the Boston–Charleston Post Road crossed the New River. That road was the precursor to U.S. Highway 17, following nearly the same route as the present-day road. In 1775 a bill officially established a town at the ferry to be known as Onslow Courthouse, but in 1842 the name of the town was changed to Jacksonville in honor of Andrew Jackson.

Production of turpentine and naval stores (tar and pitch) represented the primary occupation of small and large landholders in Onslow County. Substantial acres were planted in corn, with smaller investments in wheat, flax, and rice. In 1860 several military companies were formed. Hostilities were concentrated along the lower New River and Bear Inlet. Union raids, intended to quash blockade running and to demolish

the coastal saltworks, occurred from 1862 to 1864. As was the case elsewhere in the South, the Civil War resulted in poverty, economic stagnation, and strained relations in Onslow County. Share-cropping and tenancy replaced plantation agriculture. In response to the gradual decline of the naval stores industry in southeastern North Carolina, local people turned to crop and livestock farming, mostly on relatively small-scale farms. Cotton began to emerge as a prominent market crop in the first postbellum decade, followed by tobacco in the 1890s, though neither became a dominant factor in the county's economy.

Eleven vessels are reported or believed to have been lost in the area of Topsail Inlet (Table 2.15) and an additional 19 recorded in the vicinity of New River Inlet. That number includes one of four vessels lost in 1750 as part of the Spanish Plate Fleet. That ship, the packet boat, *El Salvador*, was lost in the vicinity of Topsail Inlet on August 18, 1750. Because of the shifting sands, the surviving remains were buried in a matter of days, making salvaging operations difficult.

Table 2.15. North Carolina Division of Archives and History, Underwater Archaeology Section shipwreck files

1737	UNK, wrecked at mouth of New River with 10 lives lost
1750	EL SALVADOR, wrecked at Topsail Inlet
1765	UNK, sloop lost in vicinity of New River
1769	UNK, brigantine lost below Topsail Inlet
1771	BETSY, merchant ship lost at Old Topsail Inlet
1799	SALLY, schooner lost east of New River Inlet bar channel
1815	UNK, vessel and cargo and crew (?) lost at mouth of New River
1837	SEAMAN, lost in or near New River Inlet
1838	PULASKI, wrecked off-shore of New River with 141 lives lost
1841	SUPERIOR, schooner driven ashore near Topsail Inlet
1858	ALBION, lost inside New River Inlet bar
1862	ADELAIDE, schooner wreck at mouth of New Topsail Inlet
1863	ALEXANDER COOPER, schooner wrecked at New Topsail
1863	INDUSTRY, schooner lost 5 miles north of Topsail Inlet
1863	PHANTOM, steamer sunk 200 yards off Topsail Inlet in 30 ft. of water
1863	UNK, schooner lost west of Stump Inlet
1864	NUTFIELD, blockade runner, run ashore at New River Inlet
1867	ELLIS, federal gun boat lost 5 miles above New River Inlet, possibly salvaged
1871	HERTFORD, steamer aground inside New River Inlet bar, may have gotten off
1879	MARION GAGE, schooner lost in New River, total loss
1880	UNK, lost at mouth of New River
1881	N.W. DREW, schooner disabled and ashore 3 miles south of New River Inlet
1881	UNK, shipwreck at mouth of New River
1881	MARY BEAR, schooner wrecked 4 miles south of New River Inlet
1884	UNK, shipwreck at mouth of New River
1890	CHARLES, schooner aground on New River inlet bar, total loss
1892	LORENZO, schooner wrecked in New River Inlet, total loss
1894	UNK, lost in New River Inlet
1895	UNK, sharpie sunk at its mooring near Jacksonville
1919	WILLIAM H. SUMNER

Before the Civil War, the following vessels were lost in the vicinity: schooner *Superior*, driven ashore November 24, 1841; an unknown brig in September 1769, run ashore below Topsail Inlet; and English merchantman *Betsy* in 1771 at Old Topsail Inlet. The Civil War also resulted in a number of wrecks, including the schooner *Adelaide* of Halifax, an unidentified schooner west of Stump Inlet, the iron-hulled steamer *Phantom*, and the schooner *Industry*. During the late-nineteenth and early-twentieth centuries the following losses are recorded: the schooner *Mary Bear* on September 9, 1881, at New Topsail Inlet; and schooner *William H. Sumner* on September 7, 1919, grounded at Topsail Inlet.

As indicated by the vessels seized, the inlet was active in salt production. An 1864 military map shows at least two Confederate salt works on either side of Holmes Landing. The presence of the salt works is further substantiated in a letter from

November 1, 1862, written by USS Lieutenant William Cushing to his superior (Angley 1984).

In 1932 a 12-ft.-deep and 90-ft.-wide segment of the AIWW between Beaufort and the Cape Fear south of Wilmington was completed (USACE 1961). The channel allowed for an increase in vessel traffic from 33,710 tons in 1932 to 243,000 tons in 1939. As reported the previous year, the character of the vessel traffic—of around 9,000 vessel trips—consisted of approximately 8,500 motor vessels, 300 tugs, 200 barges, and a smattering of pleasure craft. Cargo vessels transported agricultural commodities, lumber, petroleum products, seafood, fertilizer, and general merchandise.

2.06 Water Resources

This section describes water resources, including the availability and quality of both freshwater and saltwater.

2.06.1 Hydrology

Tides in the area are semidiurnal, and the mean tidal range is about 3.0 ft. at New River Inlet and at New Topsail Inlet. Regular reversals of flow occur with each tidal cycle except during periods of high freshwater flow. The salinity of the area varies because of many factors including freshwater inflow, tidal action, and wind. From 2002 to 2004, average salinities in the Topsail Island vicinity range from an average of 14.2 ppt near New River Inlet, to 23.9 ppt in the AIWW behind Topsail Island, to 35.9 ppt in the nearshore ocean at the Surf City Pier (Stan Sherman, personal communication).

2.06.2 Water Quality Classification

All surface waters in North Carolina are assigned a primary classification by the North Carolina Division of Water Quality (NCDWQ) (15A NC Administrative Code 02B .0301 to .0317). Waters in the vicinity of Topsail Island fall into three classifications. Waters of the Atlantic Ocean between Drum Inlet and Baldhead Island are classified as *SB* and are suitable for primary recreation, including frequent or organized swimming and all *SC* uses (secondary recreation such as fishing, boating, and other activities involving minimal skin contact; aquatic life propagation and survival; and wildlife). Stormwater controls are required under the Coastal Area Management Act (CAMA), and there are no categorical restrictions on discharges.

All other surface waters of the vicinity, including the New River, AIWW, Topsail Sound, and Banks Channel, meet the *SA HQW* classification and are suitable for shellfishing for marketing purposes as well as all *SB* and *SC* uses (see Appendix A, Figure A-5). All *SA* waters are *HQW* (High Quality Waters) by definition, and stormwater controls are required, and domestic discharges are prohibited. Waters of the AIWW from Daybeacon # 17 (between Chadwick Bay and Alligator Bay) to Morris Landing (south of Spicer Bay) and waters of Topsail Sound southward from approximately New Topsail Inlet to Middle Sound are classified as *SA ORW*. The ORW (Outstanding Resource Waters) designation is a supplemental classification intended to protect unique and special waters having excellent water quality and an exceptional state or national ecological or recreational significance. Waters of that classification must have one of the following outstanding resource values:

- Outstanding fish habitat or fisheries
- Unusually high level of water-based recreation
- Some special designation such as North Carolina or National Wild/Scenic/Natural/Recreational River, National Wildlife Refuge
- Important component of state or national park or forest
- Special ecological or scientific significance (rare or endangered species habitat, research, or educational areas)

No new or expanded wastewater discharges are allowed in these waters. ORW are HQW by definition.

2.06.3 Groundwater

The sole source of water supply for both public and private systems in Pender and Onslow counties is groundwater. A vast aquifer system from which potable water can be drawn lies below the counties. The cretaceous aquifer is used as the water source for the various communities on Topsail Island. Pender County does not have a countywide water system, and the system is concentrated in the southern part of the county in the Rocky Point area (Pender County, 2006). In Surf City, water is supplied through two wells on the mainland. A third well has been constructed but is not fully operational yet (Town of Surf City, 2005). Water is supplied to North Topsail Beach by the Onslow County water system and is initiated at the Sneads Ferry elevated storage tank near the intersection of Highway 210 and Highway 172. A 12-inch water main carries the water from the tank to the intersection of Highway 210 and SR 1568 where it intercepts a water main that extends into the Town of North Topsail Beach where it is further distributed (Holland Consulting Planners, Inc, 1996).

Regionally, the horizontal groundwater movement is eastward with some southeast movement. The resultant groundwater movement is toward the coast.

2.07 Other Significant Resources (P.L. 91-611, Section 122)

Section 122 of P.L. 91-611 identifies other significant resources that must be considered during project development. Such resources and their occurrence in the study area are described in the following subsections.

2.07.1 Air, Noise, and Water Pollution

Areas of the country where air pollution levels persistently exceed the national ambient air quality standards may be designated *nonattainment*. All Topsail Island is in an attainment area. No known air quality problems are in the study area.

Noise is a prominent feature in the study area because of the sound of the breakers and at times, tourists and traffic on the beach. The sounds of breakers are tranquil and add to the pleasure experienced by visitors. Complaints of municipal residents concerning noise in the downtown area of Surf City are normal. However, the town does not experience a problem to the extent that maximum densities for residential dwellings have been established nor have noise level reduction standards (outdoor to indoor or indoor to

outdoor) been established. No large manufacturing, industrial, or mining-type operations are in town. No airports or other area establishments or entities are affecting unbearable noise levels on the community (Town of Surf City, 2005). North Topsail Beach has a Noise Ordinance Code (Article VII) that is enforced 24 hours a day (Town of North Topsail Beach, 1998).

Any harbor or open-water coastal environment has a number of underwater ambient noise sources such as commercial and recreational vessel traffic, dredges, wharf/dock construction (e.g., pile driving), natural sounds (e.g., storms, biological), and so on. To better assess potential species effects (i.e., disturbance of communication among marine mammals) associated with dredge specific noise from navigation maintenance, deepening, or borrow area dredging operations, Clarke et al. (2002) performed underwater field investigations to characterize sounds emitted by bucket, hydraulic cutterhead, and hopper dredge operations. A summary of results from the study are presented below and are a first step toward developing a dredge sounds database that will encompass a range of dredge plant sizes and operational features:

Cutterhead Suction Dredge

Noise generated by a cutterhead suction dredge is continuous and muted and results from the cutterhead rotating within the bottom sediment and from the pumps used to transport the effluent to the placement area. The majority of the sound generated was from 70 to 1,000 hertz (Hz) and peaked at 100 to 110 decibel (dB) range. Although attenuation calculations were not completed, reported field observations indicate that the cutterhead suction dredge became almost inaudible at about 500 meters (Clarke et al., 2002).

Hopper Dredge

The noise generated from a hopper dredge is similar to a cutterhead suction dredge except there is no rotating cutterhead. The majority of the noise is generated from the dragarm sliding along the bottom, the pumps filling the hopper, and operation of the ship engine/propeller. Similar to the cutterhead suction dredge, most of the produced sound energy fell within the 70- to 1,000-Hz range; however peak pressure levels were at 120 to 140 dB (Clarke et al., 2002).

Bucket Dredge

Bucket dredges are relatively stationary and produce a repetitive sequence of sounds generated by winches, bucket impact with the substrate, bucket closing, and bucket emptying. The noise generated from a mechanical dredge entails lowering the open bucket through the water column, closing the bucket after impact on the bottom, lifting the closed bucket up through the water column, and emptying the bucket into an adjacent barge. On the basis of the data collected for this study, which included dredging of coarse sands and gravel, the maximum noise spike occurs when the bucket hits the bottom (120 dB peak amplitude). A reduction of 30 dB re 1 μPa/m occurred between the 150 m and 5,000 m listening stations with faintly audible sounds at 7 km. All other noises from the operation (i.e., winch motor, spuds) were relatively insignificant (Clarke et al., 2002).

Water quality is discussed in Section 2.06.2 and in the section 404(b)(1) (P.L. 95-217) evaluation that is included as Appendix G of this document.

2.07.2 Man-made and Natural Resources, Aesthetic Values, Community Cohesion, and the Availability of Public Facilities and Services

Only one pier, the Surf City Ocean Pier, is within the proposed beachfill area. The pier complex includes a bait and tackle shop, restaurant facilities with a screened dining area and a game room. The 937-ft.-long ocean pier is open from March through November. Aesthetic values are discussed in Section 2.04.2.

In regard to wastewater disposal, nearly all of Surf City's residential and commercial structures are connected to the town's wastewater collection and treatment system. The wastewater collection and treatment system discharge is pumped to a land-application treatment facility off of North Carolina Highway 50 between Surf City and Holly Ridge. The system includes 30 pump stations. No private wastewater systems are operating in Surf City (Town of Surf City, 2005). North Topsail Beach sewer services are provided by a private utility under state regulatory authority.

Water supply is discussed in Section 2.06.3, Groundwater. No private water supply systems are operating in the planning jurisdiction of Surf City or North Topsail Beach.

Topsail Island—including Topsail Beach, Surf City, and North Topsail Beach—is served by two bridges. Surf City has a system of well-maintained roads, and accident rates in Surf City's jurisdiction are low because of a well-designed traffic system (Town of Surf City, 2005). In the southern end of Surf City, Highway 50 is very vulnerable to ocean erosion and required repair after Hurricane Fran in 1996. That section of road is the only access by land to the entire town of Topsail Beach to the south. Highway 210 from the high-rise bridge south to the Pender County line is the only primary roadway in North Topsail Beach. The most serious transportation issue at North Topsail Beach continues to be the overwash of the road (SR 1568) at Galleon Bay (Holland Consulting Planners, Inc, 1996).

The Surf City Volunteer Emergency Medical Services and Pender Emergency Medical Services provide emergency services to Surf City. Other emergency services at Surf City are provided by the town's Fire and Police departments. Emergency services at North Topsail Beach are provided by the North Topsail Beach Police Department, Fire Department, and Rescue and Emergency Medical Services. Electricity is provided by Jones-Onslow Electric Membership Corporation. Sprint provides telecommunications service in the town limits, and the cable television franchise is operated by Charter Communications.

Details regarding beach access and parking are in Section 3.04 and in Appendix O.

2.07.3 Hazardous, Toxic and Radioactive Wastes (HTRW)

Because of past military activities in the project area, the presence of Hazardous, Toxic and Radiological Wastes (HTRW) warrants discussion. The potential for encountering HTRW in the project area is discussed below as documented in the *Defense*

Environmental Restoration Program For Formerly Used Defense Sites (DERP-FUDS), Ordnance And Explosive Waste, Archives Search Report, Findings For The Former Camp Davis, Holly Ridge, North Carolina, Project Number 104nc001702, May 1994.

In 1941 Camp Davis was established as an Anti-Aircraft Training Center at Holly Ridge, North Carolina. Acquisition of land for Camp Davis took place from 1941 to 1943. Approximately 46,682 acres were acquired by lease from numerous individuals, corporations, and governmental agencies by the War Department for a World War II Army Air Corps training facility. The Training Center was later used as a convalescent hospital and rehabilitation center and became home to various military units. Coast Artillery Anti-Aircraft Regiments were the dominant groups, moving thousands of recruits through basic training and anti-aircraft weaponry. Although the main part of Camp Davis was on the mainland, northwest of Topsail Island, the Coastal Gunnery Range Emplacement Area was on Topsail Island near the Surf City bridge and the Coastal Gunnery Potential Range Impact Area was offshore of Topsail Island (Appendix A, Figure A-1).

The Gunnery Emplacement area was 4.5 miles southeast of the main portion of the former Camp Davis. The site was known as the Sears Landing and occupied a narrow strip of land between the inland waterway and the ocean. As a gun emplacement, the ordnance used on-site would have been fired or returned to the point of issue; therefore, the possibility of ordnance residue is extremely remote. The inspection team did not observe any Ordnance or Explosive Wastes (OEW) in the area, and there are no reports of OEW within the gun emplacement area.

The Coastal Gunnery Range Impact Area, which was offshore of Topsail Island, was viewed by inspectors from the beach (no offshore survey was conducted). The AA coastal gunnery range impact area has potential ordnance contamination because of its use when it was active; however, no evidence of residual OEW contamination has been found or documented since the anti-aircraft gunnery range was closed. No records or documentation were located as to the exact types of ordnance used, although it is presumed that mostly practice rounds were used because gunners fired at a target that was pulled/towed behind an aircraft. Practice round sizes would have varied but are presumed to consist of : 37 mm (1.46 inches), 40 mm (1.57 inches), 3-inch, 90 mm (3.54 inches), 105 mm (4.13 inches), and 155 mm (6.10 inches).

After World War II, Camp Davis was assumed by the Navy for its secret guided missile testing program, code named Operation Bumblebee. Topsail Island was the third of three widespread test sites established along the Atlantic seaboard in the closing years of World War II and the first permanent ground for missile testing. The Topsail Island site, placed in operation in March 1947, incorporated rigid structures that were designed and built for specific uses related to the assembly, firing, monitoring and perfecting of experimental ramjet missiles. The Navy used only a small portion of Camp Davis for testing rocket motor propulsion systems. An arsenal center for assembling and storing rockets was built on the sound-side of the island, and launching pads were constructed on the oceanfront. Concrete observation towers were built throughout the island to monitor

the experimental launchings, and many of the military structures remain today. During the 18 months that Operation Bumblebee was active at Topsail Island, an estimated 200 experimental rockets, each measuring 6 inches in diameter and between 3 and 13 ft. in length, were fabricated at the Assembly Building, dispatched to the launch site, and fired along a northeasterly angular deflection of 15 degrees to the shoreline for a maximum clear distance of 40 miles. Despite the initial success of the U.S. Naval Ordnance Testing facility at Topsail Island, its location did not fulfill completely the needs of a permanent base because weather conditions and increased sea traffic interfered with testing, and Navy abandoned the facility and moved its equipment to other sites (http://www.cr.nps.gov/nr/travel/aviation/usn.htm).

Although, more than 200 rocket launchings took place on the island between 1946 and 1948, no OEW was associated with the testing procedures, and all leased land was returned to the original landowners. Most of the former Camp Davis lands are being used for state wildlife game lands (Holly Shelter) and for producing forestry products.

Several databases were reviewed to obtain information pertaining to releases, treatment, storage, and disposal of hazardous substances in the project area. On the basis of that review and the review of the Camp Davis Archives Search Report, referenced above, no documented active or inactive hazardous waste sites are on Topsail Island.

3. PROBLEMS, NEEDS, AND OPPORTUNITIES

The main public concerns identified in the study area are economic losses resulting from (1) damages to structures and their contents due to hurricane and storm activity, and (2) the loss of beachfront land due to progressive shoreline erosion. In addition, periods of severe shoreline recession have adversely affected nesting habitat for endangered and threatened sea turtles. The economic losses and environmental concerns are discussed below.

3.01 Hurricane and Storm Damage

Being between Cape Lookout and Cape Fear, Topsail Island is a frequent target for hurricanes and tropical storms tracking along the mid-Atlantic coast. Table 3.1 is excerpted from hurricane history information on the State Climate Office of North Carolina Web site and shows the frequency and severity of hurricanes and tropical storms directly affecting southeastern North Carolina since 1800. In addition to the direct landfalling storms, many storms that have passed offshore without making landfall have also affected the study area. Local effects on the study area varied depending on the landfall location and strength of the storm. However, hurricanes Bertha and Fran in 1996 and Floyd in 1999 were among the most damaging and costly storms ever to hit North Carolina.

3.02 Beach Erosion

Between 1963 and 2002, erosion rates were relatively low (less than one foot per year) in the southern half of the main study area (reaches 27–43); however, erosion rates in the northern half of the main study area (reaches 44–78) averaged nearly 2 ft. per year. Erosion rates increased significantly to more than 5 ft. per year in portions of the non-study CBRA area (reaches 79–106) but decreased to 2 to 3 ft. per year in reaches 107–108 study segment. Shoreline changes in reaches 114–115 study segment begin to be significantly influenced by inlet processes as erosion precipitously changed to minor accretion and then back to significant erosion within a span of only a few reaches approaching New River Inlet. Major storms in the late 1990s caused significant erosion and decimated the island's natural dunes, resulting in major property damage.

Table 3.1. Direct landfalling hurricanes and tropical storms in southeastern North Carolina since 1800

Approximate date of landfall	Storm name	Saffir-Simpson intensity at landfall	Approximate location of landfall	Estimated wind speed (knots)	Storm surge (ft.)
9/16/1999	Floyd	2	Topsail Island	95	9–10
8/26/1998	Bonnie	3	Cape Fear	100	6–8
9/6/1996	Fran	3	Cape Fear	100	8–12
7/13/1996	Bertha	2	Topsail Beach	90	5
9/9/1984	Diana	1	Long Beach	80	5–6
9/11/1960	Donna	2	East of Wilmington	95	6–8
8/17/1955	Diane	1	Carolina Beach	75	5–9
10/15/1954	Hazel	4	NC/SC border	125	10–20
7/6/1946		Tropical Storm	Wilmington	60	
8/1/1944		1	Southport	80	
12/2/1925		1	Wilmington/Hatteras	65	
9/22/1920		1	Topsail Beach	65	
9/6/1916		Tropical Storm	Southport	35	
10/31/1899		1	Wrightsville Beach	80	8
9/11/1883		1	Southport	85	
9/9/1881		NA	Wilmington/Wrightsville		
08/18/1879		4	Wilmington/Cape Lookout	120	
9/17/1876		Tropical Storm	NC/SC border	60	
11/10/1875		NA	Long Beach		
9/28/1874		NA	Southport	60	
8/19/1871		NA	Southport		
9/4/1856		NA	Wrightsville Beach		
8/18/1837		NA	Cape Fear		
9/4/1834		NA	NC/SC border		
9/3/1815		NA	Wilmington/New Bern		10

3.03 Beach Recreation

All reaches in the study area are available for typical beach recreation activities—swimming, surfing, wading, walking, sightseeing, picnicking, sunbathing, surf fishing, jogging, and so on. As the state population increases, the number of visitors to North Topsail Beach and Surf City is expected to increase as well. The concern regarding beach recreation is that shore erosion will continue, resulting in a narrowing of the width between the surf, especially at high tide, and the landward limits of recreational use. Such landward limits are the toe of the dune, streets, or existing structures. As the available width decreases, some of those activities are hindered and eventually prevented. For

example, the recreation benefits analysis conducted (Appendix O) indicates that a 50-ft. decrease in berm width would decrease average annual recreation value at the two beaches by almost $8 million.

3.04 Public Access

Many public beach access points and parking areas are in the limits of the study area. Surf City has 33 public beach access points in the allowable project limits, and North Topsail has 22. The access sites are shown in Figures 3.1 and 3.2. The access points generally consist of small parking areas and wooden walkways to the beach. Only three areas of the study area do not have access points within one-quarter mile. Those areas are indicated in red on the access site figures. One such area in Surf City near Elizabeth Street in reaches 34 and 35 is 900 ft. long. Two sites are in North Topsail Beach. One site between Sloan and Lincoln streets in reaches 62 and 63 is 900 ft. long. Another site north of 2nd Street in reaches 76 and 77 is 1,000 ft. long. The total length without adequate public access is 2,800 ft. Additional access points would be necessary to meet the requirements for federal cost sharing.

In addition to direct access pathways to the beach, nearby public parking would be necessary to provide public access to the shoreline. A wide variety of public parking spaces are throughout Surf City and North Topsail Beach. They are at the access sites, on nearby street right-of-ways, and at four large parking lots. In 2003 and in 2008 parking space counts were conducted on site visits by the Wilmington District and town officials. All right-of-way areas were considered eligible for parking with the exception of areas that met designated restrictions (e.g., driveways, fire hydrants, intersection, physical barriers). For North Topsail Beach, only the reaches south of the CBRA zone were included in the count. The combined total from the 2008 count was 1,992 spaces, with 785 at Surf City and 1,207 at North Topsail. Those numbers are included in Tables 3.2 and 3.3. The distribution of parking spaces is uneven, with some areas not meeting a minimum of 10 publicly available parking spaces within one-quarter mile. Areas having access, but needing parking, are indicated in yellow in the access site figures. One area in the southern part of Surf City is 7,600 ft. long. Another area in North Topsail Beach is 600 ft. long. The total length of study area with access but without minimum parking requirements is 8,200 ft. A total of 37 additional parking spaces would needed in the southern portion of the project limits in Surf City and a minimum of 20 in North Topsail Beach would be needed to satisfy the 10-space minimum requirements.

Table 3.2. Public access and parking, Surf City, July 2008

Access points	Parking spaces			Access points	Parking spaces		
	Lot	Row	Total		Lot	ROW	Total
2111 N. Shore	8	0	8	Roland/Central	15	8	23
9th St.	0	10	10	Kinston	15	20	35
2001 N. Shore	9	9	18	High Point	8	3	11
5th St.	9	9	18	Raleigh	6	2	8
1719 N. Shore	5	28	33	Durham	9	8	17
Broadway	43	7	50	Charlotte	20	19	39
Pender	6	40	46	Quarterhorse	0	37	37
Lenior	8	32	40	1140 S. Shore	0	33	33
Jones	2	34	36	Windward	0	35	35
Craven	12	42	54	Oceanair Estates	0	39	39
Mecklenburg	0	11	11	Elizabeth St.	0	6	6
Dolphin	17	34	51	Roberts St.	0	1	1
508 N. Shore	15	5	20	Pirates Cove	0	0	0
Wilmington	10	16	26	Abigail Place	0	4	4
New Bern	12	15	27	Bland Shores	0	2	2
Goldsboro	10	12	22	Hispanola	0	6	6
Greensboro	6	13	19				
Total							785

Table 3.3. Public access and parking, North Topsail Beach, July 2008

Access points	Parking spaces			Access points	Parking spaces		
	Lot	row	Total		Lot	Row	Total
Myrtle	32	67	99	14th Ave	0	27	27
2nd Ave	0	39	39	15th Ave	0	34	34
4th Ave	0	32	32	18th Ave	0	41	41
5th Ave	0	19	19	20th Ave	0	13	13
6th Ave	0	23	23	21st Ave	12	51	63
7th Ave	0	15	15	OCBA #4	400	34	434
9th Ave	0	43	43	Chestnut St	12	30	42
10th Ave	0	27	27	Gray St	12	23	35
11th Ave	0	16	16	Green St	6	0	6
12th Ave	0	23	23	Reeves	0	83	83
13th Ave	0	22	22	Sea Shore Dr	6	65	71
Total							1,207

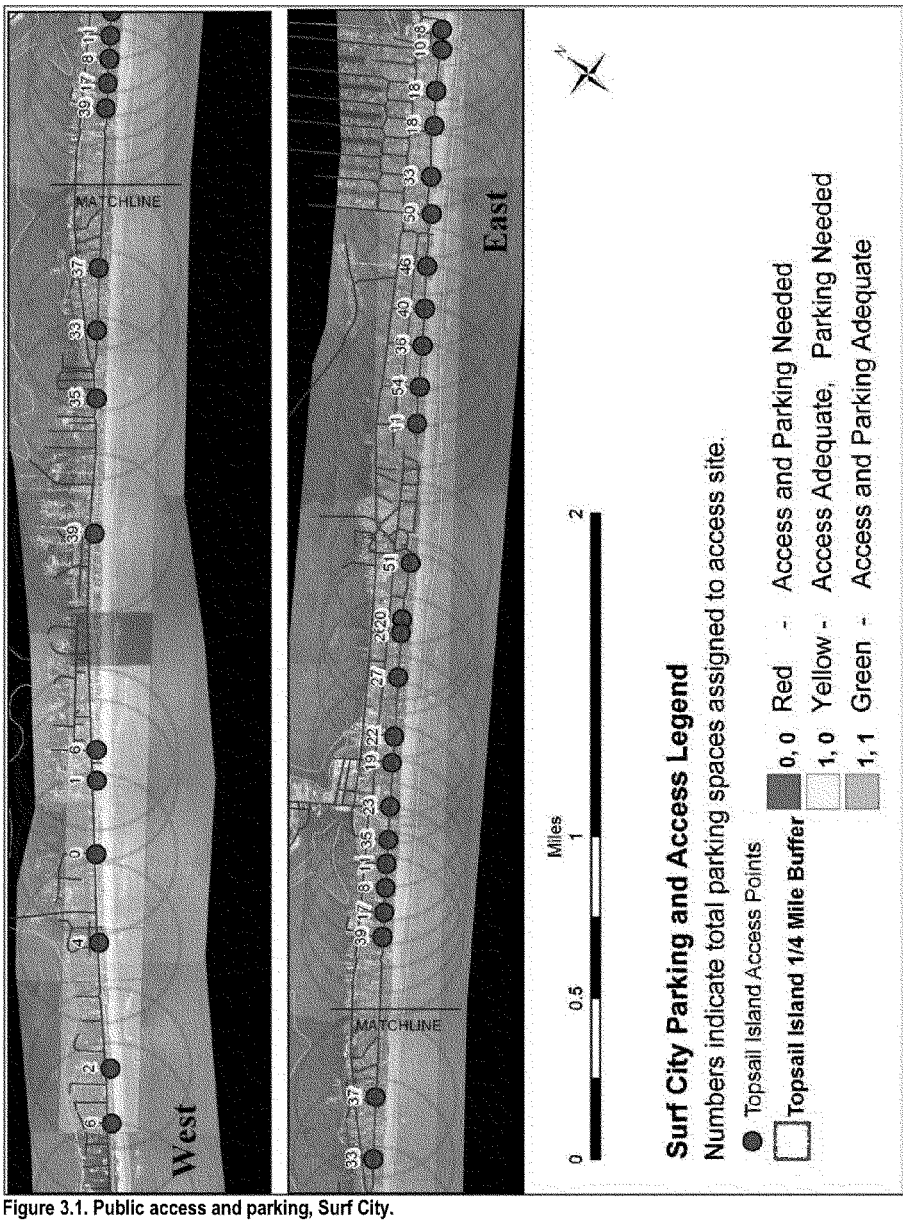


Figure 3.1. Public access and parking, Surf City.

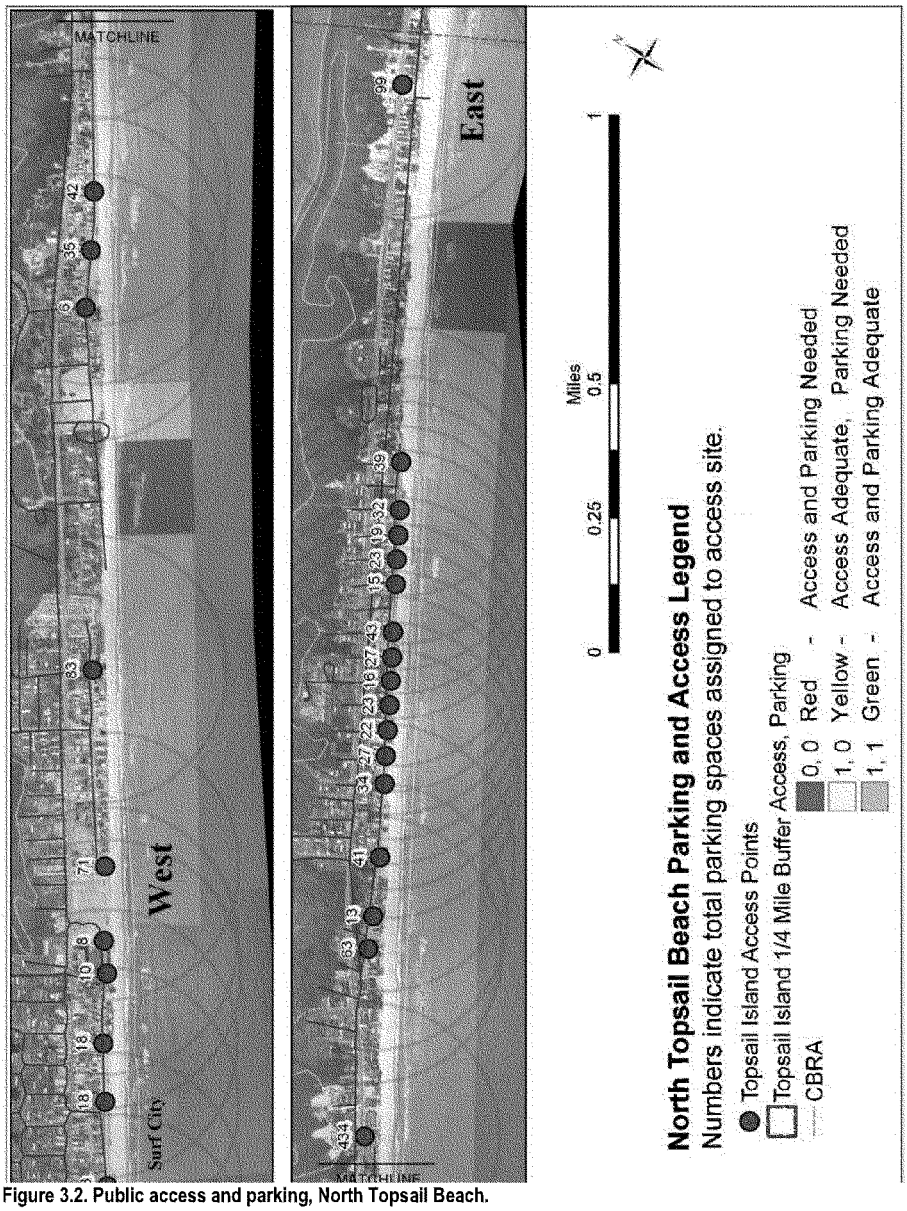


Figure 3.2. Public access and parking, North Topsail Beach.

3.05 Loss of Sea Turtle Nesting Habitat

A shoreface composed of beach, berm, and dune components can provide valuable nesting habitat for sea turtles. The loggerhead and green sea turtles, which are on the federal list of T&E species, have been documented to nest in the study area on Topsail Island. However, long-term shoreline erosion processes coupled with historical short-term hurricane events have led to significant sediment losses from the shoreface. As a result of those existing erosional activities, substantial portions of the berm and dune system have been lost as the shoreline is being squeezed between the ocean and adjacent development. That puts nesting sea turtles at risk because limited, high-quality nesting habitat remains in the eroded areas. Turtle monitoring efforts from 1990 to 2008 show significant declines over the previous year in nesting numbers following hurricanes in the 1990s: 91 to 53 from 1992 to 1993 (Hurricane Emily), 102 to 61 from 1996-97 (hurricanes Bertha and Fran) and 152 to 87 from 1999 to 2000 (Hurricane Floyd). Also, a comparison between the average number of annual turtle nests between 1990–1999 and 2000–2008 indicates a decline from 88 to 65 nests per year. In some cases, nests laid in high-erosion areas where available nesting habitat is lost need to be relocated to avoid tidal inundation (Jean Beasley, personal communication, 2004) (see Appendix I). Without beach renourishment activities, the number of nest relocations would be expected to increase. Persistent erosion along the towns of Surf City and North Topsail Beach could lead to site-specific loss of nesting habitat. Additionally, as short-term erosional processes scour the existing shoreface and the nesting beach environment slowly erodes away, large scarps may form at the toe of the primary dune, thus, preventing a turtle from encountering suitable nesting habitat above the mean high tide line. Reestablishing a berm and dune system with a gradual slope can enhance nesting success of sea turtles by providing suitable nest sites without escarpment obstacles and away from tidal inundation.

3.06 Existing Shore Condition

In March 2002, beach profile surveys were taken along Topsail Island at 1,000-ft. intervals to determine existing conditions of the project shoreline. Of the 56 shoreline profiles in the study area, 16 were selected as representative of the existing condition and used for analysis. The selection of the representative profiles was based on important features such as dune height, berm and nearshore profile. The typical profiles are shown in Figures 3.3 and 3.4 and in Appendix D.

The existing condition includes a fairly substantial constructed dune that was rebuilt following the decimation of the existing dune by Hurricane Fran in 1996. The dune was rebuilt using sand recovered from the landward side of the beach (from roads and drives) that was sifted and used for dune repair. The existing dune varies in height from 15 to 20 ft. along most of the study area; however, the dune has very little crest width, if any, and very steep side slopes. At the time of the surveys, the dry beach width from the base of the dune (at about elevation 7 ft. NGVD) out to the MHW line (at elevation 2.1 ft. NGVD) was rather narrow, generally averaging only about 60 ft. No well-defined berm feature existed either, with the beachface generally sloping directly from the base of the dune seaward. It is believed that the profiles are continuing to show effects from the

active storm seasons in the 1990's.

Over the past 25 to 30 years, material resulting from maintenance dredging of New River, the AIWW, and connecting channels has been placed on the northernmost mile of the study area in the vicinity of New River Inlet. Records from FY1998 through FY2007 show that the total placement of 680,000 cubic yards has occurred on an irregular basis, generally every 1 to 3 years, with dredging quantities varying from 70,000 to 170,000 cubic yards and averaging about 110,000 cubic yards per event.

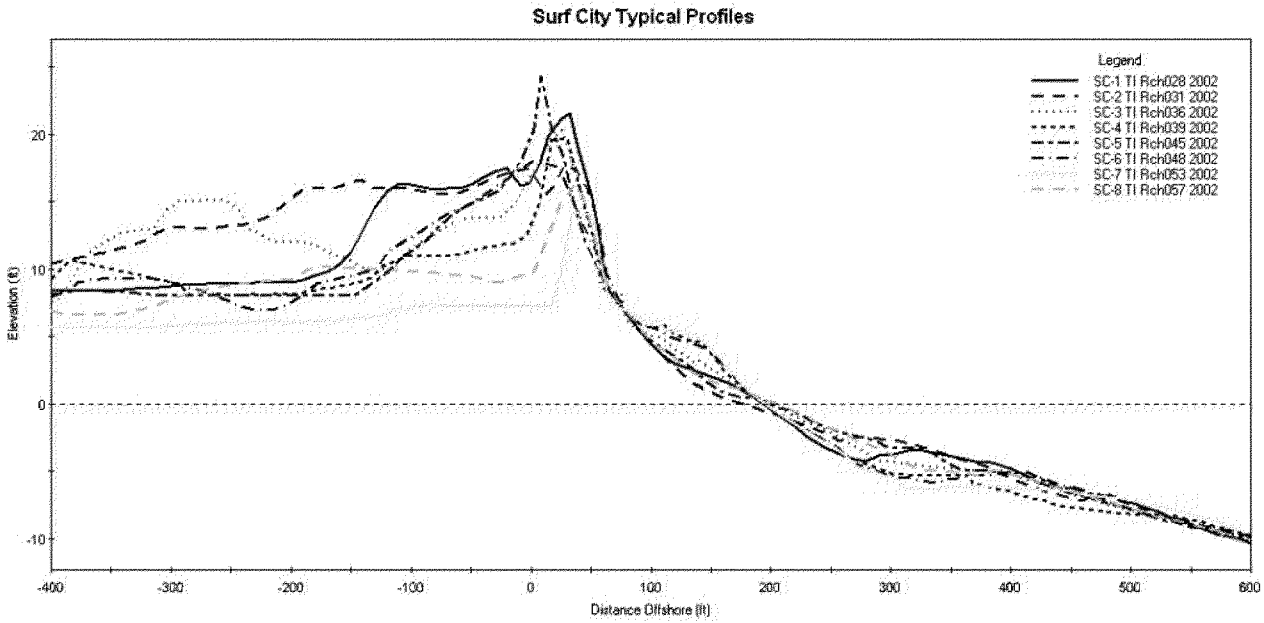


Figure 3.3. Surf City, typical profiles.

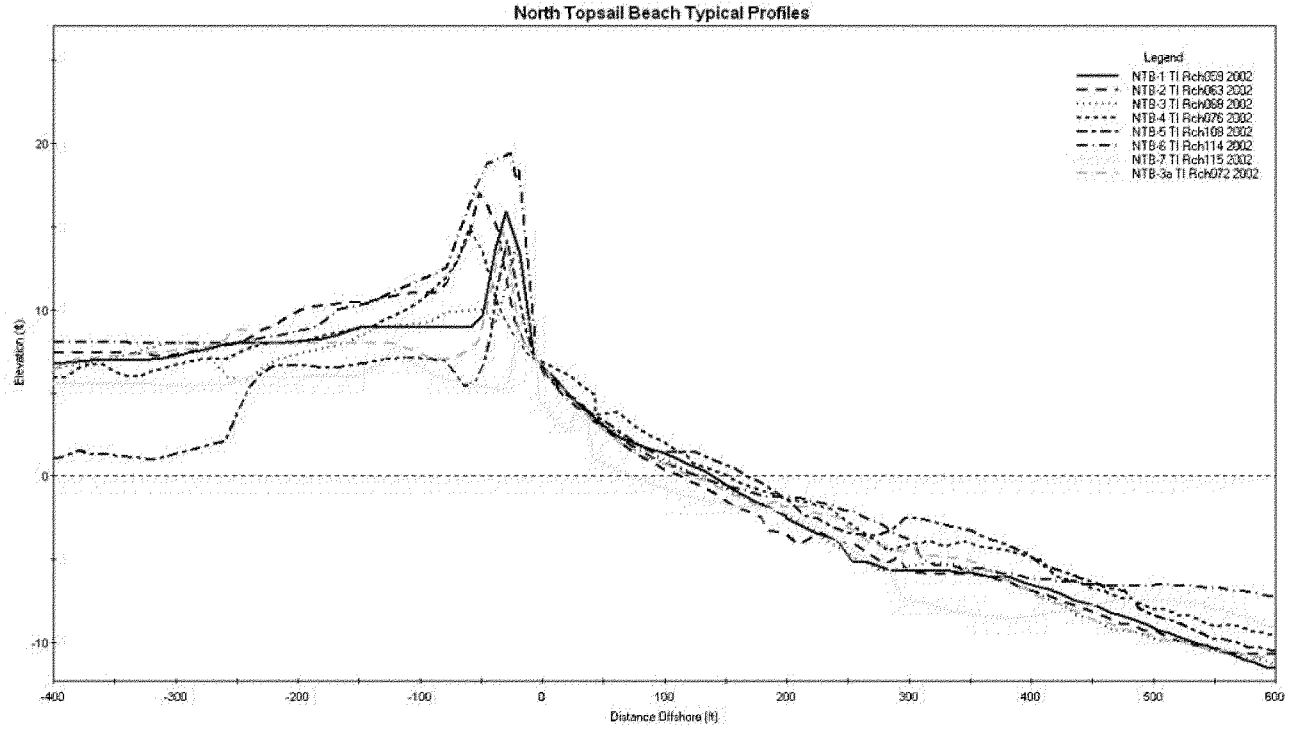


Figure 3.4. North Topsail Beach, typical profiles.

3.07 Without-Project Hydraulic Analysis

The without-project condition was analyzed using the Generalized Risk AND Uncertainty—Coastal (GRANDUC) model to establish the base condition for alternative evaluation. A range of storm responses (e.g., erosion distance, water level, volume lost) was determined for each of the typical existing profiles. The study area was subdivided into reaches of approximately 1,000 ft. each. Reach 27 is located near the Topsail Beach–Surf City town boundary and reach 117 is near New River Inlet. On the basis of 1,000 different 50-year storm simulations, in conjunction with existing long-term erosion rates, average land losses and structure damages for each reach were computed to allow for comparative economic analysis of alternatives. No allowance was made for future placement of maintenance dredging material because of the sporadic and variable nature of such work.

3.08 Without-Project Economic Analysis

The without-project condition displays the implication of storm damage and erosion if a federal project is not constructed in the study area. The base year for the without-project condition is the same year that construction of an authorized federal project would be completed. Construction is estimated to begin in December 2014 with completion 4 years later in March 2018, making the base year 2018.

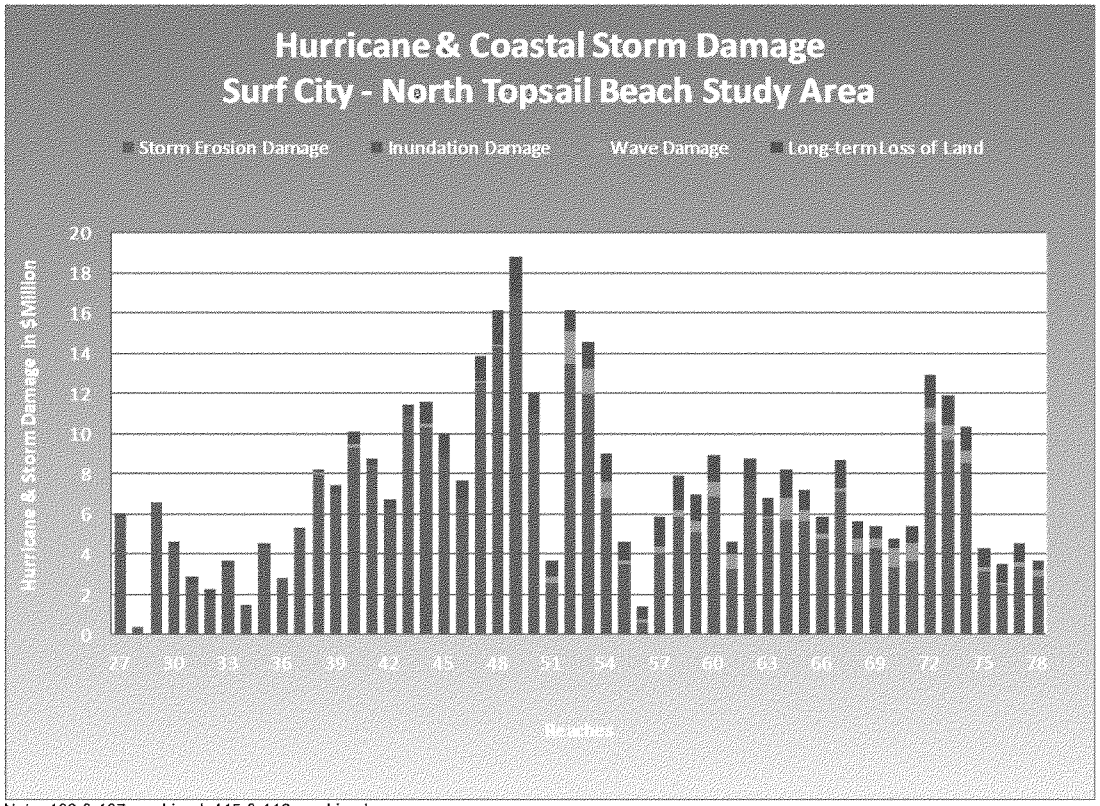
On the basis of historical building patterns, it is assumed that the study area will be fully developed by the base year. Although vacant lots exist, it is assumed that those lots will be built on by the base year, because the infrastructure (electricity, sewer, and such) is already available. Growth has occurred rapidly in the past, especially when the economy has been robust. For instance, in 2004, 174 building permits were issued in the two towns, and in 2006, more than 200 permits were issued. New structures built on vacant lots or replacing existing structures would be required to meet certain building codes for reducing storm damages. A horizontal setback is 60 ft. landward from the established line of stable vegetation. Vertically, the first living floor would be elevated on pilings, above the minimum Federal Flood Insurance elevation. Additionally, pilings for all first row replacement structures would be 16 ft. below grade or 5 ft. below mean sea level. Even with those building codes applied to new structures, the potential for hurricane-wave damage would increase without a project because of the weakened natural dune system in the area. Unlike long-term erosion, which can be predicted to some extent, on the basis of past trends and observed shore processes, damages from hurricane wave attack can occur in any year and can be predicted only as a mathematical probability.

Coastal storm damages in the study area include damages to structures and contents and to transportation infrastructure. Average annual coastal storm damages for the study area were computed using the Corps Wilmington District's computer models. The models integrate coastal engineering data—including storm frequency, storm surge, and long-term erosion rates—with economic data, including the values of structures that could be damaged or destroyed and the value of land that could be lost to erosion. That subject is addressed in greater detail in Appendix D, Coastal Engineering.

When evaluated at an interest rate of 4.125 percent over the 50-year period of analysis, the present worth (October 2010 price levels) of the expected damages totals $442.2 million; equivalent average annual damages are $21.0 million. For the continuous group of reaches 27 through 78, the present worth of the expected damages totals $400.9 million; equivalent average annual damages are $19.1 million. The storm and erosion damages calculated for the without-project condition are presented in Table 3.4 and illustrated in Figure 3.5. The vast majority of damage is categorized as storm erosion, which is the loss of structures from undermining as the supporting ground is eroded away during hurricanes and severe tropical storms. Flood damages are limited because most structures in the study area are now elevated. Wave damages are caused by the impact of waves on the structures. Finally, land damages are losses in the acreage of land.

Table 3.4. Estimated value of damages, without-project conditions, October 2010 price levels, 4.125% interest rate

	Damages					
	Present Value					
Reach	Erosion	Flood	Wave	Land	Total Damage	Annual Total
27	$ 5,952,000	$ 2,000	$ -	$ 220,000	$ 6,174,000	$ 294,000
28	$ 282,000	$ -	$ -	$ 110,000	$ 392,000	$ 19,000
29	$ 6,688,000	$ 2,000	$ -	$ 134,000	$ 6,823,000	$ 324,000
30	$ 4,531,000	$ 6,000	$ -	$ 223,000	$ 4,760,000	$ 226,000
31	$ 2,627,000	$ 1,000	$ -	$ 410,000	$ 3,038,000	$ 144,000
32	$ 1,827,000	$ 28,000	$ -	$ 671,000	$ 2,526,000	$ 120,000
33	$ 3,539,000	$ 25,000	$ -	$ 315,000	$ 3,880,000	$ 184,000
34	$ 1,473,000	$ 32,000	$ -	$ 118,000	$ 1,624,000	$ 77,000
35	$ 4,431,000	$ 58,000	$ -	$ 118,000	$ 4,607,000	$ 219,000
36	$ 2,784,000	$ 28,000	$ 1,000	$ 118,000	$ 2,931,000	$ 139,000
37	$ 5,341,000	$ 22,000	$ -	$ 126,000	$ 5,489,000	$ 261,000
38	$ 8,291,000	$ 27,000	$ 83,000	$ 137,000	$ 8,539,000	$ 406,000
39	$ 7,195,000	$ 74,000	$ 32,000	$ 402,000	$ 7,703,000	$ 366,000
40	$ 9,579,000	$ 64,000	$ 196,000	$ 581,000	$ 10,419,000	$ 495,000
41	$ 8,679,000	$ 18,000	$ 10,000	$ 402,000	$ 9,109,000	$ 433,000
42	$ 6,479,000	$ 7,000	$ 4,000	$ 406,000	$ 6,896,000	$ 328,000
43	$ 11,281,000	$ 16,000	$ 39,000	$ 477,000	$ 11,814,000	$ 562,000
44	$ 10,592,000	$ 112,000	$ 225,000	$ 1,181,000	$ 12,110,000	$ 576,000
45	$ 9,217,000	$ 171,000	$ 1,000	$ 1,065,000	$ 10,454,000	$ 497,000
46	$ 6,893,000	$ 154,000	$ 5,000	$ 1,071,000	$ 8,124,000	$ 386,000
47	$ 12,860,000	$ 179,000	$ 129,000	$ 1,411,000	$ 14,578,000	$ 693,000
48	$ 14,691,000	$ 170,000	$ 78,000	$ 1,785,000	$ 16,724,000	$ 795,000
49	$ 17,408,000	$ 51,000	$ 18,000	$ 1,995,000	$ 19,472,000	$ 926,000
50	$ 11,500,000	$ 41,000	$ -	$ 1,142,000	$ 12,683,000	$ 603,000
51	$ 2,563,000	$ 144,000	$ 260,000	$ 848,000	$ 3,815,000	$ 181,000
52	$ 13,934,000	$ 73,000	$ 1,632,000	$ 1,007,000	$ 16,646,000	$ 792,000
53	$ 12,409,000	$ 38,000	$ 1,250,000	$ 1,461,000	$ 15,157,000	$ 721,000
54	$ 7,088,000	$ 11,000	$ 858,000	$ 1,421,000	$ 9,377,000	$ 446,000
55	$ 3,554,000	$ 65,000	$ 170,000	$ 913,000	$ 4,702,000	$ 224,000
56	$ 669,000	$ 50,000	$ 216,000	$ 626,000	$ 1,561,000	$ 74,000
57	$ 4,216,000	$ 46,000	$ 266,000	$ 1,556,000	$ 6,083,000	$ 289,000
58	$ 6,044,000	$ 54,000	$ 282,000	$ 1,750,000	$ 8,131,000	$ 387,000
59	$ 5,261,000	$ 41,000	$ 542,000	$ 1,511,000	$ 7,355,000	$ 350,000
60	$ 7,129,000	$ 28,000	$ 723,000	$ 1,327,000	$ 9,207,000	$ 438,000
61	$ 3,374,000	$ 70,000	$ 710,000	$ 673,000	$ 4,827,000	$ 230,000
62	$ 7,823,000	$ 13,000	$ 34,000	$ 1,254,000	$ 9,123,000	$ 434,000
63	$ 6,000,000	$ 72,000	$ 131,000	$ 939,000	$ 7,141,000	$ 340,000
64	$ 5,880,000	$ 108,000	$ 1,115,000	$ 1,425,000	$ 8,528,000	$ 406,000
65	$ 5,728,000	$ 97,000	$ 596,000	$ 1,080,000	$ 7,501,000	$ 357,000
66	$ 5,092,000	$ 46,000	$ 241,000	$ 884,000	$ 6,262,000	$ 298,000
67	$ 7,372,000	$ 9,000	$ 218,000	$ 1,482,000	$ 9,082,000	$ 432,000
68	$ 4,133,000	$ 138,000	$ 685,000	$ 854,000	$ 5,811,000	$ 276,000
69	$ 4,181,000	$ 343,000	$ 544,000	$ 645,000	$ 5,714,000	$ 272,000
70	$ 3,384,000	$ 136,000	$ 893,000	$ 565,000	$ 4,978,000	$ 237,000
71	$ 3,826,000	$ 15,000	$ 816,000	$ 914,000	$ 5,570,000	$ 265,000
72	$ 11,061,000	$ 1,000	$ 769,000	$ 1,640,000	$ 13,470,000	$ 641,000
73	$ 10,119,000	$ 1,000	$ 757,000	$ 1,522,000	$ 12,398,000	$ 590,000
74	$ 8,862,000	$ 4,000	$ 705,000	$ 1,141,000	$ 10,712,000	$ 509,000
75	$ 3,145,000	$ 76,000	$ 307,000	$ 987,000	$ 4,514,000	$ 215,000
76	$ 2,626,000	$ 36,000	$ 144,000	$ 962,000	$ 3,767,000	$ 179,000
77	$ 3,418,000	$ 119,000	$ 223,000	$ 922,000	$ 4,682,000	$ 223,000
78	$ 3,031,000	$ 38,000	$ 267,000	$ 531,000	$ 3,867,000	$ 184,000
Subtotal	$ 336,062,000	$ 3,160,000	$ 16,175,000	$ 45,458,000	$ 400,850,000	$ 19,061,000
107	$ 3,743,000	$ 15,000	$ 802,000	$ 900,000	$ 5,460,000	$ 260,000
108	$ 10,867,000	$ 1,000	$ 748,000	$ 1,614,000	$ 13,230,000	$ 629,000
114	$ 9,920,000	$ 1,000	$ 738,000	$ 1,495,000	$ 12,154,000	$ 578,000
115	$ 8,704,000	$ 3,000	$ 686,000	$ 1,125,000	$ 10,518,000	$ 500,000
Total	$ 369,296,000	$ 3,180,000	$ 19,149,000	$ 50,592,000	$ 442,212,000	$ 21,028,000



Note: 106 & 107 combined, 115 & 116 combined

Figure 3.5 Estimated damages by reach, present value.

3.09 Without-Project Environmental Analysis

Only those resources that have the potential to be affected by the No Action Alternative are included in the analysis, below.

Sea Turtles. No nesting attempts of hawksbill, leatherback, and Kemp's ridley sea turtles are documented on Topsail Island. However, in regard to loggerhead and green sea turtles, Topsail Island is considered to be one of the more heavily nested areas along the North Carolina coast. Without implementing the proposed project, continued erosion of the beach would be expected to result in losses of sea turtle nesting habitat and possible poor nest site selection by females. That would put nesting sea turtles at risk because limited, high-quality nesting habitat remains in the eroded areas. Turtle monitoring efforts from 1990 to 2008 show declines over the previous year in nesting numbers following hurricanes in the 1990s: 91 to 53 from 1992 to 1993 (Hurricane Emily), 102 to 61 from 1996-97 (hurricanes Bertha and Fran) and 152 to 87 from 1999 to 2000 (Hurricane Floyd). Also, a comparison between the average number of annual turtle nests between 1990–1999 and 2000–2008 indicates a decline from 88 to 65 nests per year. In some cases, nests laid in high-erosion areas where available nesting habitat is lost must be relocated to avoid tidal inundation (Jean Beasley, personal communication, 2004) (see Appendix I). Without beach renourishment activities, the number of nest relocations would be expected to increase.

Seabeach Amaranth. Since 1992 the Corps has surveyed Topsail Island for seabeach amaranth. From 1992 to 2008, the average number of plants found on Topsail Island during any given year was 1,433. However, the number of plants varies along the project area and by year. In the Surf City and North Topsail Beach project area, the number of plants declined immediately following hurricane events as evidenced by the fluctuating numbers between 1996 and 2001 (Appendix I, Table 4). The maximum number of plants was 11,129 in 1995, and the minimum was 13 in 2006. When separated into incremental averages, it is apparent that the total number of plants from 1992 to 2008 have declined considerably. From 1992 to 1997 the average number of plants was 2,854; from 1998 to 2003 the average number of plants was 1,042; and from 2004 to 2008 the average number was 207. Although hurricane events result in a reduction in plant numbers immediately following the event, long-term beach erosion is probably the primary threat to the continued presence of seabeach amaranth in the area as evidenced by the consistent decline in plant numbers since 2001. Failure to construct the proposed project could result in continued loss of seabeach amaranth habitat. In the event that the beach and dune erode back to the infrastructure, it is possible that no seabeach amaranth habitat would be available in the developed portion of the project area.

Water Resources. Natural sedimentation and turbidity rates would continue to vary depending on storm activity, rainfall, currents, and other natural phenomenon. As the beach and dune erodes back under into the infrastructure, there is a potential for significant amount of debris and associated water pollution (i.e., septic tanks, sewer) from the compromised structures.

Aesthetic and Recreational Resources. Continued erosion of the beach would result in a continually narrowing beach front that is squeezed between the ocean

and existing development, thus adversely affecting the recreation experience and aesthetics of the study area on Topsail Island.

Community Cohesion, public facilities and services. Ongoing erosion of the beach and degradation of the dune system by erosion and storms could result in damage to public facilities, such as roads and utilities, and threats to human lives, all of which would adversely affect services and community cohesion. Highway 50 is especially important because it is the only road to Topsail Beach to the south.

Beach and Dune. The Surf City and North Topsail Beach shoreline change rates average between 2–5 ft. per year depending on location in the study area (Appendix D; Figure D-5). Therefore, the beach would continue to erode from the existing condition back into the dune. Once the beach has eroded back into the dune, escarpments would likely occur resulting in wave reflection off the escarpment with subsequent increased erosion, scouring, and loss of intertidal beach habitat. As the beach and dune complex erode back, public infrastructure, public and private property, human lives, and important habitat for a variety of plants and animals would be endangered including loss of the dune grasses and associated fauna. The intertidal beach habitat and benthic invertebrate community is a significant resource for feeding shorebirds and surf zone fishes. Additionally, beach habitat for loafing and nesting shorebirds as well as nesting sea turtles would be degraded or lost as the beach and dune are eroded into the coastal infrastructure.

Floodplains. The floodplain in the study area is being adversely affected by erosion and the continued deterioration of the beach and dune complex. Those effects would become more pronounced as the beach continues to erode and future storms encroach on the area.

4. PLANNING OBJECTIVES

4.01 Goals and Objectives

The overall goal of the study is to reduce the adverse economic effects of coastal storms at Surf City and North Topsail Beach. Identifying and considering the problems, needs, and opportunities of the study area in the context of federal authorities, policies, and guidelines resulted in the establishment of the following specific objective:

Objective: Over a 50-year period of analysis, provide coastal storm damage reduction (as measured by increases in NED benefits) to the shoreline in Surf City and North Topsail Beach, while minimizing or avoiding impacts to natural resources.

Although achieving that objective would likely also have positive environmental effects and benefits to recreation, those benefits are considered incidental to the objective of providing coastal storm damage reduction benefits.

4.02 Constraints

The planning process is subject to the limitations imposed by the following constraints:

a. Geographic limits of the study authority but including the affected area of the environment

b. Applicable federal and state laws

c. Current limits of knowledge, information, and predictive ability

d. The CBRA zone in North Topsail Beach would be excluded from any proposed federal project

5. PLAN FORMULATION AND EVALUATION OF ALTERNATIVES

After identifying existing conditions, problems, needs, opportunities, planning goals, and planning constraints, this section describes the plan formulation process. A number of alternatives are usually identified early in the planning process, and their number is reduced by screening, evaluation, and comparison in an iterative sequence in increasing levels of detail to finally identify the selected plan.

Plan formulation for this study consisted of the following: (1) establishing criteria by which alternatives would be evaluated; (2) identifying, analyzing, and screening of measures; (3) identifying alternative plans; (4) screening of alternative plans; and (5) evaluating alternative plans. Each of those steps is discussed below.

5.01 Formulation and Evaluation Criteria

Alternative plans are evaluated by applying numerous, rigorous criteria. Those include basic, general criteria and four categories of technical criteria, including (1) engineering, (2) economic, (3) environmental, and (4) institutional items. They are as follows:

General Criteria

- The plan must comply with applicable federal laws and regulations.
- The plan must comply with applicable state and local laws and regulations, to the maximum extent practicable.
- The plan must comply with Corps regulations.

Engineering Criteria

- The plan must represent a sound, acceptable, and safe engineering solution.

Economic Criteria

- The plan must contribute benefits to NED.
- Tangible benefits of a plan must exceed economic costs.
- Each separable unit of improvement must provide benefits at least equal to costs.
- Recreation benefits may not be more than 50 percent of the total benefits required for economic justification.
- Plan implementation may not preclude development of more economical means of accomplishing the same purpose.

Environmental Criteria

- The plan would fully comply with all relevant environmental laws, regulations, policies, executive orders.
- The plan would represent an appropriate balance between economic benefits and environmental sustainability.
- The plan would be developed in a manner that is consistent with the Corps' Environmental Operating Principles (EOPs).
- Adverse impacts to the environment would be avoided. In cases where adverse effects cannot be avoided, mitigation must be provided to minimize impacts to at least a level of insignificance.

Institutional Criteria

- The plan must satisfactorily address the identified needs and concerns of the public.
- The plan must be implementable with respect to financial and institutional capabilities.
- The plan must be implementable with regard to public support.

5.02 Identification, Examination, and Screening of Measures

An extremely large variety of potential measures can be considered and combined when formulating plans. The measures generally are categorized as either structural or nonstructural. Structural measures are those that directly affect conditions that cause storm damage and erosion. The nonstructural measures are those taken to reduce damages without directly affecting those conditions. Finally, there is the No Action Alternative where no institutional or structural measure is applied.

A wide variety of structural measures are possible, such as beachfills, breakwaters, seawalls, and groins.

- Beachfill measures consist of berms, dunes, and terminal sections. The beachfill measures are considered some of the most appropriate, because they mimic the natural environment and can be shaped to maximize net storm damage reduction benefits.
- Groins can be a terminal groin near an inlet or can be installed as a repetitive groin field throughout the project length. Groin fields can be used to prolong the life of a beach nourishment project. However, groin fields create the risk of potential adverse effects on adjacent shorelines because of trapping or shunting sand offshore. Groin fields have high initial costs, do not provide storm damage reduction, have the potential to negatively affect turtles seeking beach nesting sites, and would require an extensive monitoring program with triggers that would initiate remediation. Some situations warrant the acceptance of the risk that accompanies the use of a groin field. Those situations include short beachfills, hot spots, areas adjacent to sediment sinks, and offset or convex shorelines. The study area does not include any of the situations that warrant the use of a groin field.
- Seawalls, bulkheads, and revetments are appropriate for reducing structural damage; however, they do not meet the goal of preserving the

environmental value of the beach and would reduce the usable recreation area of the beach at high tide.

- Breakwaters can be used in erosional hotspots where it is difficult to maintain a beachfill; however, no such condition appropriate for breakwaters was found in the project area. Moreover, while offshore breakwaters may reduce erosion in their lee, the benefits may be offset by accelerated erosion of the downdrift shoreline because of interruption of the littoral drift.
- Vegetation and sand fencing help retain windblown sand but do not provide adequate storm damage reduction for moderate to severe storms.

Nonstructural measures considered are changes in regulations and physical modifications to reduce damages.

- *Regulatory measures.* Some regulatory measures are coastal building codes, building construction setbacks, and floodplain regulations. Most regulatory measures are no longer considered in the alternative plans because these measures have already been implemented, they do not affect older structures, and there are few buildable, vacant lots remaining that would benefit. These measures are considered as part of the existing conditions. They have reduced damages from past events, and as older structures are replaced, would help to reduce future damages.
- *Removal.* Another category of nonstructural measures is reduction of the damage threat by removing beachfront structures from the threat. The three removal measures are retreat, relocation, and demolition. Retreat is moving an existing structure away from the shoreline a short distance within the same property parcel. Relocation is moving an existing structure away from the shoreline a longer distance to a vacant property. Acquisition of the property and demolition of the structure is a third measure where retreat or relocation is not feasible. Those three removal measures were retained for consideration in the nonstructural alternative.

The selected structural measure for detailed evaluation and consideration is beachfill. The selected nonstructural measures for detailed evaluation and consideration are retreat, relocation, and demolition. The measures can be applied independently and in combinations with each other to develop alternative plans.

5.03 Identification of Initial Alternative Plans

Beachfill plans were initially developed to extend the entire study area, including the two, separate, short groups of reaches in the non-CBRA area in the north end of North Topsail Beach. The two basic types of beachfills are a berm only and a berm and dune together. For all plans the berm elevation is 7 ft., the locally natural berm elevation for this coast. That selection of 7 ft-NGVD was made because of concerns that the artificially high berm would result in persistent scarping along the beach face.

The ends of typical beachfill plans have tapered transition sections. For Surf City and North Topsail Beach, the ends of the project would abut other beachfill projects planned to the south and north of the study area. Either the transition section would not be needed or would be a smaller transition between the two

projects' cross sections. Plan formulation was conducted assuming a full cross section for each reach.

The nonstructural plans consist of retreats, relocations, and demolitions applied to threatened structures on an individual case basis.

The No Action Alternative remains in the list of alternative plans.

5.04 Screening of Alternative Plans

All but one of the initial alternative plans developed using the selected measures were considered to have sufficient potential for feasibility to be continued into economic evaluations of costs and benefits. The No Action Alternative did not undergo further economic evaluation because both costs and benefits of the plan are zero.

5.05 Evaluation of Alternative Plans

The remaining alternative plans were evaluated on the basis of costs, benefits, and net benefits. Benefits of all the plans were evaluated using the GRANDUC program. The program estimates the present worth of storm damages for the without project condition and the various alternative plans, including the nonstructural plan. Sea-level rise is factored into the analysis of both structural and non-structural alternatives, as GRANDUC is able to incorporate sea-level rise into its life cycle analysis. The analysis of alternatives was based on a historical sea level rise rate of 0.008 ft/yr, which is factored into both the future with- and without project conditions

5.05.1 Nonstructural Evaluation

The structures included in the analysis are those in the first row from the ocean. Those structures further landward from the shoreline are not likely to be severely threatened for a few decades and, therefore, are not included in the plan. Of the 1,815 structures in the study area, 904 were considered for the nonstructural alternative. Costs for moving structures are very specific and vary greatly depending on site conditions, travel route, and on structure size and construction. Several broad assumptions were necessary to make a manageable evaluation of the plan. Structures were categorized as one of three general relocation types, plus large, commercial structures such as hotels. Because of the rapid rate of development on Topsail Island, only one-third of the existing vacant lots were assumed available for relocation. Costs for each relocation type of structure were estimated for each of the three measures—retreat, relocation, and demolition. Costs were based solely on construction and acquisition costs for each measure. The costs for each structure were subtotaled by project reach and for the entire project area. More detailed discussion of the nonstructural plan is in Appendix P, Nonstructural Alternatives.

The GRANDUC program was also used to evaluate benefits of the nonstructural plan. The structure database was modified to delete all first row structures, whether actually planned for retreat or for removal. The without-project condition damages were recomputed on the basis of the revised database to estimate residual damages for the nonstructural plan. The difference in residual damages

represented the present worth of average annual storm damage reduction benefits. Recreation benefits were not calculated for the nonstructural plan. There could be an increase in recreational benefits from the nonstructural alternative over the No Action Alternative because the nonstructural alternative can lead to an improved beach condition that users might value more (Daniel 2001; Kriesel, et al. 2005; Landry, et al. 2003). However, those benefits would likely be less than those accruing from a beachfill alternative, and recreation benefits from a nonstructural alternative would decrease as the beach continues to erode. The nonstructural plan does not benefit highway 50 where it is threatened by erosion at the south end of Surf City.

The present value economics of the nonstructural plan are given in Table 5.1. The overall net benefits are less than zero with a benefit to cost ratio of 0.26 and is not economically feasible. Combination plans of nonstructural measures in some reaches with beachfill in other reaches were also considered, but no applicable reach was found in the project area. On the basis of the nonstructural analysis that was performed, two reaches were found to have positive net benefits from a nonstructural plan. One of those, reach 44, had average annual net benefits of about $11,000. However, because beach fill is being proposed for reaches on either side, a transitional zone beach fill would still need to be placed through the nonstructural reach. The cost of the transitional zone was not determined; however, it would far exceed $11,000 per year. Therefore, that reach would not end up being economically feasible for a nonstructural plan. Another reach, reach 107 at the northern end of the study area, was found to have positive net average annual benefits of about $44,000 (benefit to cost ratio of 1.1). Beach fill is not being proposed for the adjacent reaches, so the cost of a transitional zone is not an issue. However, because of the coarser nature of the nonstructural analysis (i.e., costs were based on structure type, rather than a detailed assessment of the particular structure) and the benefit to cost ratio being barely over 1.0, it could be very likely that the reach was in fact not economically feasible from a nonstructural standpoint if a more detailed analysis was performed. Additionally, the benefits are assuming a 100 percent compliance rate by property owners. That is very highly unlikely because property owners would more than likely want to keep their beachfront property. Therefore, any combination plans were screened from further consideration. Because the nonstructural plan is not economically feasible, it was not further evaluated for technical feasibility or for acceptability.

Table 5.1. Nonstructural plan economics, present worth, October 2004 levels, 5.375% interest rate

Items	Amount
Cost, Demolition cost and value lost, 615 structures	$96,200,000
Cost, Relocation and retreat, 289 structures	$34,500,000
Cost, Purchase of lots, demolition and relocation, 739 lots	$389,500,000
Cost, Total, Nonstructural Plan	$520,200,000
Benefits, Total, Nonstructural Plan	$135,000,000
Net Benefits, Total, Nonstructural Plan	($385,000,000)

5.05.2 Beachfill Evaluations

As explained previously, the GRANDUC program is used to estimate benefits of alternative plans. To evaluate alternative plan storm damage reduction benefits, a comparison was made of without-project damages with the with-project, residual damages. That difference defines the storm damage reduction benefits. The benefits were determined for each reach and for each alternative. Recreation benefits were not included at this level of plan evaluation.

GRANDUC also estimates present worth costs for the alternative beachfill plans on the basis of initial sand volumes and renourishment sand volumes needed to replenish sand lost because of long-term and storm erosion. GRANDUC applies unit costs for dredging such sand volumes and applies mobilization and demobilization costs for each job. Other estimated costs included are engineering and design costs and contract supervision and administration. Other minor costs for tilling, vegetation, and walkover structures were omitted from the beachfill formulation process because the incremental differences between plans are negligible. Those costs would later be included in the evaluation of the final plans.

A common assumption of all beachfill plans was regarding borrow material. While geotechnical, environmental, and cultural resource surveys of the borrow sites were conducted, beachfill plans were being simultaneously evaluated. It was assumed that sufficient quantity of offshore sand was available for the project within 6 miles and that both initial construction and following renourishments would be performed by hopper dredges. Costs for all beachfill alternatives used the same mobilization costs and unit costs per cubic yard of dredging. A common loss factor between volume dredged and volume placed was used for all beachfill plans.

To assist in incremental analysis of the beachfill plans, costs and benefits of the beachfill plans were estimated for each reach. The process of identifying potentially feasible reaches was called scoping. A mid-range dune and berm cross section was selected as being representative for reach scoping. For the project, the representative cross section selected had a dune with a 25-ft. top width at elevation 13 ft. NGVD fronted by a 50-ft.-wide berm at elevation 7 ft. NGVD.

The results of the scoping showed most reaches had relatively good net benefits, some had very high net benefits, and a few had negative net benefits. The set of continuous reaches, 27–78, in Surf City and the non-CBRA portions of North Topsail Beach were all found to be economically feasible for beachfill. From a coastal morphodynamic perspective (difference in erosion rates, potential for a sediment transport reversal point – discussed in more detail in Appendix D), these reaches could be divided into segments A (reaches 27-44) and B (45-78). However, these erosion rates and their effects on the associated economic features were used in the alternative analysis on the 1,000 ft economic reaches, and consideration for differences in these segments was accounted for in this manner. Therefore, this difference in segments would not affect the scope of the overall plan. The two separate, short groups of reaches, 104–106 and 115–117, in the non-CBRA areas in the north end of North Topsail Beach were not found to be economically feasible for beachfill. Those were the only reaches excluded by the

scoping analysis.

5.06 Optimization and Comparison of Beachfill Alternative Plans

Evaluation of plans at this point has narrowed the alternatives to beachfills in reaches 27 through 78. Cost estimates were developed using construction quantities produced from the GRANDUC evaluations. Additional information regarding surveyed profiles and nearshore bathymetry is in Appendix D.

5.06.1 Cross Sections

Plans were designated in the format, Plan DDBB, where DD represents the dune elevation in ft. NGVD datum, and BB represent the berm width from the seaward toe of dune to the top of the foreshore slope. For example, a plan with a 12-ft elevation dune and a 25-ft-wide berm is named Plan 1225. Table 5.2 presents the beachfill plan naming system.

Table 5.2 Beachfill plan names

Dune elevation (ft. NGVD)	Berm widths (ft.)				
	25	50	75	100	150
11	1125	1150	1175	--	--
13	1325	1350	1375	--	--
14	--	1450	--	--	--
15	1525	1550	1575	--	--
16	--	1650	--	--	--
17	--	1750	--	--	--
No dune, berm only	--	750	--	7100	7150

Higher storm dunes and wider berms result in both higher benefits and higher costs. Initially, dune elevations of 11, 13, and 15 ft. were evaluated for berm widths of 25, 50, and 75 ft. That analysis was based on using identical unit construction costs across all plans. Although the initial analysis indicated that 25-ft. plans on average had the highest net benefits (about 2 percent higher on average than 50-ft. plans), it was determined that borrow unit costs for implementing a 25-ft. plan were underestimated by at least 8 percent as compared to 50-ft. and greater width plans. One of the primary reasons for the greater unit cost with a 25-ft. plan is the additional equipment that would be needed to move pipe along the beach as the dredge is pumping, because the narrow berm width does not allow pumping at one location for as long. Therefore, on the basis of that reassessment of unit costs, the 50–ft. berm plans had the highest net benefits. Next, various dune elevations were evaluated with the preferred 50-ft. berm width. Dune elevations between 11 and 17 ft. were all found to be economically feasible. Plan 1550 was found to have the maximum net benefits.

5.06.1.1 Berm-Only Cross Sections

The berm-only plan is a fill extending seaward from the existing profile, with an elevation of 7 ft. NGVD, approximately the elevation of the existing berm along the study area beaches. Berm width is measured seaward along the top of the berm from the point where the top of proposed berm intersects the natural profile. Seaward of the designed berm width, the with-project profile parallels the existing

profile out to the closure depth of –23 ft. NGVD. The widths included in preliminary plan screening of berm-only plans were 50, 100, and 150 ft. Berm-only plans with widths less than 50 ft. were not analyzed because they were not considered constructible or maintainable, particularly because no advance maintenance is added to the design berm width. Beach berm construction requires a sufficient width platform to construct the required longitudinal dikes, stage and advance pipeline, shape the pipeline effluent (both before and after dewatering) and minimize loss of material during construction. For 25-ft., berm-only plans, that becomes an issue particularly during the renourishment cycles. Also, because there is no advance maintenance, a 0-ft. hold the line, berm-only alternative is not considered constructible because in many areas, there is minimal existing berm width. In spite of a fairly substantial existing dune, the 50-, 100- and 150-ft. berm-only plans did not provide the level of coastal storm damage risk reduction as did the dune-and-berm plans, resulting in significantly lower total net benefits. Therefore, they did not warrant further consideration.

5.06.1.2 Dune and Berm Combination Cross Sections

Existing dunes were assumed to remain in place, with the designed dunes abutting them. Designed dune templates were tied to a construction line, which is based on both the existing shoreline and the existing development. The construction line is landward of the 7-ft. contour of the existing profile. The landward slope of the dune template is 5 horizontal to 1 vertical, the top of the dune is 25-ft. wide, and the seaward slope is 10 horizontal to 1 vertical. The berm elevation is 7 ft. NGVD, with berm width measured from the toe of the constructed dune. Seaward of the designed berm width, the with-project profile parallels the existing profile out to a closure depth of –23 ft. NGVD. Historical projects in place along the North Carolina coast have dune heights of about 13-ft. above NGVD with a berm width of about 50 ft. Therefore, in addition to the 13-ft dune with a 50-ft. berm, a higher 15-ft. and lower 11-ft. dune, each with a 25-, 50-, and 75-ft. berm at 7 ft-NGVD, were selected for initial screening.

5.06.2 Economic Comparisons

Table 5.3 presents the economic comparisons of the plans as described in Section 5.06.1 and subsections 5.06.1.1 and 5.06.1.2. All values are shown as average annual equivalent value discounted at the FY2005 federal water resources interest rate of 5.375 percent over a 50-year project life. More detailed evaluations of the selected plan are given later at current interest rates and price levels. The GRANDUC model estimates damages in three categories and selects the greatest of the three for both the with-project and without-project conditions, preventing the double counting of benefits in the analysis. Recreation benefits would be included as incidental benefits in the total benefit accounting, but they are not included in Table 5.3 in the formulation of the project with respect to size and scope.

All beachfill plan cross sections have average annual Storm Damage Reduction net benefits of more than $7 million, indicating economic feasibility. Of those plans, the plan with the greatest net benefits is defined as the NED plan. The NED plan is Plan 1550.

No specific modification to the NED plan is proposed. Any recommended plan would include a complete dune and berm section for the entire project length. During Pre-Construction Engineering and Design (PED) phase of the project, the endpoints of the project may be modified to transition to conditions outside of the project limits.

Table 5.3 Dune and berm plans, alternative screening, reaches 27 to 78*

Plan	Annual costs	Annual CSDR benefits	Annual net CSDR benefits
750 (berm only)	$4.3	$11.2	$6.9
7100 (berm only)	$4.8	$12.7	$7.9
7150 (berm only)	$5.0	$13.2	$8.2
1150	$5.7	$13.5	$7.8
1350	$6.1	$15.3	$9.2
1450	$6.5	$15.8	$9.3
1550	$6.7	$16.2	$9.6
1650	$7.0	$16.3	$9.2
1750	$7.3	$16.6	$9.3
1575	$7.3	$16.5	$9.2
Nonstructural	$30.2	$7.8	($22.4)

* Net annual benefits, without recreation, in millions. October 2004 cost levels, FY2005 interest rate 5.375%

5.06.3 Borrow Site Comparisons

The preliminary identification of borrow areas for the project included New River Inlet and ocean waters off Topsail Island in water depths greater than 30 ft. below NGVD. The results of a geophysical investigation conducted by OSI were used to define the boundaries of the offshore borrow areas. The AIWW was ruled out as borrow source because the compatible material obtained from maintenance dredging is already designated for another area, is relatively small, and its distance from the project would not make it a cost-effective source

As identified in Section 2 (b) of the Coastal Barrier Resources Act CBRA, P.L. 97-348 (96 Stat. 1653; 16 U.S.C. 3501 *et seq.*), the purpose of CBRA is to, "minimize the loss of human life, wasteful expenditure of federal revenues, and the damage to fish, wildlife, and other natural resources associated with the coastal barriers along the Atlantic and Gulf coasts by restricting future federal expenditures and financial assistance which have the effect of encouraging development of coastal barriers, by establishing a Coastal Barrier Resources System, and by considering the means and measures by which the long-term conservation of these fish, wildlife, and other natural resources may be achieved."

The CBRA designates various undeveloped coastal barrier islands, depicted by specific maps, for inclusion in the Coastal Barrier Resources System (CBRS). Areas so designated were made ineligible for direct or indirect federal financial assistance that might support development, including flood insurance, except for emergency life-saving activities. Those areas included in the system are to be reviewed by the Secretary of the Interior, "at least once every five years in order to make minor and technical modifications to the boundaries of system units as

are necessary solely to reflect changes that have occurred in the size or location of any system units as a result of natural forces." The last such boundary modification occurred in 1990, and at the time included New River Inlet. New reviews of the CBRS boundaries are underway; however, it is unclear how those boundaries would be adjusted.

In general, no federal funding may be used for physical or planning activities conducted in a CBRS area. However, exceptions for certain activities identified in Section 6 of the CBRA allow federal expenditures or financial assistance within the CBRS. Specifically, "the maintenance of existing channel improvements and related structures, such as jetties, and including the disposal of dredge materials related to such improvements...scientific research, including but not limited to aeronautical, atmospheric, space, geologic, marine, fish and wildlife and other research, development, and applications...[and] nonstructural projects for shoreline stabilization that are designed to mimic, enhance, or restore natural stabilization systems" are exempt from CBRA restrictions. As such, Corps geological studies of the area are authorized, as is maintenance dredging of the existing navigational channel within New Topsail Inlet and New River Inlet. The Department of the Interior, however, reads CBRA to prohibit the transfer of sand from within a CBRS to a location outside the CBRS. Wilmington District does not necessarily agree with that interpretation, and indeed, material from the navigation channels has been used as borrow in other projects. However, the amount of borrow material available from New Topsail Inlet/Banks Channel is relatively small (< 94,000 cubic yards available) compared to what would be needed for a renourishment cycle (2.6 million cubic yards). A study of borrow volume available at New River Inlet was not conducted; however, it is expected that the available amount from maintenance dredging would be less than that in New Topsail Inlet. A qualitative assessment also indicates that it would not be cost-effective to use material from the inlets, on the basis of the distance required to move the material from the channels to the project area. Although a nonfederal project by the town of North Topsail Beach is proposing to use additional material that would be made available from a New River Inlet realignment, it would be inconsistent with the CBRA to use this new material on the federal project. Those factors, in addition to the availability of offshore borrow material, and other environmental factors that include the constituent elements of piping plover habitat and other estuarine resources, led to the screening out of the navigational channels as a potential borrow area for the project.

After completing the archeological resources survey, 10 offshore borrow areas were identified for the further evaluation as potential borrow sources for Surf City and North Topsail Beach. On the basis of the results of the compatibility analysis, the total estimated volume in those 10 borrow areas is insufficient to meet the required project volume over a 50-year project life. As a result, the excess amount of material identified in six offshore borrow areas for the Topsail Beach Federal Coastal Storm Damage Reduction project (USACE, 2009) have been included with the aforementioned 10 borrow areas to meet the project requirements for the Surf City/North Topsail Beach project. The offshore borrow areas were assumed to be the source of material in evaluation of the alternative plans. The borrow areas are discussed in more detail in Section 7.04.

5.06.4 Environmental Comparisons of Plans

In addition to the economic comparison, the effects of the major categories of plans on the resources described in Section 2.00 are considered. Table 5.4 presents the comparative effects on those resources. Only effects on areas that are of greater concern are listed in the table. The No Action Alternative is defined as no action by the federal government on this proposed coastal storm damage reduction project. It should be noted that categories of plans were not screened out on the basis of environmental effects. As mentioned earlier in the report, the No Action Alternative was screened out because it does not provide any NED benefits, and the nonstructural alternative was screened out because the benefit to cost ratio was < 1. However, an environmental comparison of plans was still done to show if categories of plans are consistent with protecting the nation's environment.

Table 5.4. Comparative impacts of the proposed plan to the Nonstructural and No Action alternatives, (part 1 of 5)

Resource Alternative →	Beachfill Alternatives[a]	Nonstructural Alternative	No Action
Socioeconomic Resources	1. Improved recreational quality on expanded beach 2. Greater damage reduction of oceanfront land, roads/utilities, structures, and personal property 3. Economically justified	1. More remote, undisturbed beach 2. Eliminates need for future damage reduction of structures, land loss continues 3. Displaces beachfront homeowners and businesses. Reduced tax base. Expected cost exceeds benefits	1. Continued deterioration of the existing beach 2. Continued threat to oceanfront land, roads/utilities, structures, and personal property 3. NED benefits foregone
Recreational and Aesthetic Resources	1. Improved appearance of beach would enhance recreational experience. Wider berm would increase recreation area. 2. Temporary inconvenience to beach users during initial construction and future maintenance.	1. More natural appearance along the beach that may be valued more by users. Recreation capacity would decrease as the beach erodes. 2. Temporary inconvenience to beach users during demolition or removal of structures.	1. Continued deterioration of beach appearance and berm width 2. Status quo maintained

Table 5.4. (continued) part 2 of 5

Resource Alternative	Beachfill Alternatives[a]	Nonstructural Alternative	No Action
Marine Resources	1. Benthic organisms in borrow areas would be removed but would be recolonized by opportunistic species 2. Temporary effects on intertidal microfauna in the immediate vicinity of the beach nourishment 3. Reduces needs for bulldozing, beach scraping, and sand bags 4. Short-term, recurring impacts to fishing areas 5. Temporary impacts to adult, larval, and juvenile fish because of turbidity and reduced benthic food in dredging and renourishment areas.	1. Status quo maintained 2. Status quo maintained 3. Eliminates needs for bulldozing, beach scraping, and sand bags. Eliminates reoccurring loss of invertebrates along beach. 4. Temporary inconvenience to beach fishermen during demolition or removal of structures. Status quo maintained in nearshore waters. 5. Status quo maintained.	1 to 5 Status quo maintained
Natural Communities	1. The berm would be reestablished, resulting in an extended shoreline. In the case of a dune and berm plan, the dune would also be revegetated. 2. Bottom substrate and bathymetry within 4,210 acres of nearshore ocean would be modified.	1. The beach would continue to erode, existing overwash areas would expand and new overwash areas would form. 2. Status quo maintained	1. The beach would continue to erode, existing overwash areas would expand and new overwash areas would form. 2. Status quo maintained

Table 5.4. (continued) part 3 of 5

Resource Alternative	Beachfill Alternatives[a]	Nonstructural Alternative	No Action
Threatened and Endangered Species	1. Placement of fill would increase nesting habitat for sea turtles. 2. Placement of fill may increase beach hardness and alter other physical characteristics of the beach that may affect the nesting environment of sea turtles. 3. May adversely affect loggerhead, green, and Kemp's Ridley sea turtle species through lethal entrainment within hopper dredge dragheads. 4. May affect piping plover foraging, sheltering, and roosting areas. 5. Placement of fill would increase seabeach amaranth habitat. 6. Minimal threat of collision with whales during dredging operations.	1. Conditions for loggerhead and green sea turtle nesting would be improved by reduced disturbance and artificial lighting 2. Status quo maintained 3. Status quo maintained 4. Conditions for piping plover may be improved by reduced disturbance and new overwash areas. 5. Conditions for seabeach amaranth may be improved by reduced disturbance 6. Status quo maintained	1. Continued erosion of the beach would result in losses of sea turtle nesting habitat and possible poor site selection by females. 2. Status quo maintained 3. Status quo maintained 4. Status quo maintained 5. Continued erosion of beaches would result in loss of seabeach amaranth habitat 6. Status quo maintained
Water Quality	1. Temporary elevated turbidities over existing conditions during initial construction and nourishment in nearshore areas and offshore borrow areas.	1. Status quo maintained	1. Status quo maintained

Table 5.4 . (continued) part 4 of 5

Resource Alternative	Beachfill Alternatives[a]	Nonstructural Alternative	No Action
Cultural Resources	1. No effects	1. Potential resource affected by natural processes or storms. Relocation could affect any historic structures.	1. Potential resource affected by natural processes or storms.
Contaminated Sediments	1. Remote possibility exists that OEW (anti-aircraft ammunition) could be present in the material to be dredged from offshore borrow areas and placed on the beach. The only ordnance that would be expected to be encountered would be spent shells from anti-aircraft target practice. In 1994, inspectors surveyed the beach area to the water's edge and did not find evidence of ordnance. Offshore areas were not surveyed. 2. Remote possibility that dredging in offshore borrow areas could encounter a missile (no OEW) and place it on beach. The missiles that were tested during Operation Bumblebee contained no OEW and were fired approximately 40 miles offshore, well beyond the project area, so the likelihood of encountering them in an offshore borrow area is remote.	1. Status quo maintained 2. Status quo maintained	1. Status quo maintained 2. Status quo maintained

Table 5.4. (continued) part 5 of 5.

Resource Alternative →	Beachfill Alternatives[2]	Nonstructural Alternative	No Action
Other significant resources	1. Temporary noise increases during construction and maintenance events 2. Minor, short-term increases in boat/floating plant traffic 3. Beneficial effects of the storm damage reduction project on community cohesion, public facilities (including roads and utilities) and services.	1. Temporary noise increases during demolition or removal of structures 2. Status quo maintained 3. Initially detrimental to community cohesion, public facilities (near beach) and some services.	1 and 2 Status quo maintained 3. Continued erosion of beaches would be detrimental to community cohesion and public facilities.

[a]. This column addresses the effects that are generally relevant to any beachfill alternative. There may be some differences in effects with regard to different beachfill plans (i.e., berm and dune vs. berm-only alternatives, different berm widths); however, those differences are minor and would not affect plan selection.

6. PLAN SELECTION

6.01 National Economic Development Plan

The NED Plan is the alternative among plans with the greatest net economic benefits. The dune and berm plan, named Plan 1550, having the greatest net economic benefits, is the NED plan. Plan 1550 consists of a 52,150-ft-long dune and berm system to be constructed to a height of 15 ft. NGVD fronted by a 7-foot NGVD (50-ft-wide) beach berm.

6.02 Locally Preferred Plan (LPP)

Surf City and North Topsail Beach have indicated that they approve of the NED Plan. There is no Locally Preferred Plan.

6.03 Other Plans

No other plan has been proposed as being the selected plan.

6.04 Selected Plan

The NED Plan, Plan 1550, is the plan recommended for federal action. Average annual storm damage reduction benefits as shown in Table 5.3 are $16.2 million for the NED Plan. Average annual costs of shown in Table 5.3 are $6.7 million for the NED Plan. Annual Net CSDR Benefits for Plan 1550 are $9.6 million. The costs and benefits described in this section and in Table 5.3 were developed during FY2005 and use October 2004 costs and prices and the Federal Water Resources FY2005 interest rate of 5.375 percent. This concludes comparative evaluations of the alternatives. From this point forward in the Feasibility Report, costs and benefits for the NED Plan are reported at October 2010 costs and prices and the FY2011 interest rate of 4.125 percent.

7. THE SELECTED PLAN

The purpose of this report section is to centralize information concerning the Selected Plan. The Selected Plan is discussed in terms of features, construction, maintenance, real estate requirements, accomplishments, and economic feasibility.

7.01 Plan Description and Components

The Selected Plan is Plan 1550, which is the NED Plan. Plan 1550 consists of a 52,150-foot long dune and berm system. Sand for the beachfill would be delivered from offshore borrow areas by dredge. A cross section is shown in Figure 7.1, and a plan view is shown in Figure 7.2, and in more detail in Appendix A, Project Maps.

7.01.1 Main fill

The plan has a main fill length of 52,150 ft., from the Surf City town boundary in reach 27 to reach 78 in North Topsail Beach at the CBRA zone boundary. The two essential features of the selected plan are the dune and the berm.

The plan has a dune at an elevation of 15 ft. NGVD and with a crest width of 25 ft. The side slopes of the dune are 5H:1V on the landward side and 10H:1V on the seaward side to the berm.

The plan includes a berm seaward of the dune. The berm has a flat, level section with an elevation of 7 ft. NGVD and an optimum width of 50 ft. The seaward slope of the berm extends the beachfill approximately another 100 ft. at a slope of approximately 15H:1V down to mean low water elevation (-1.9 ft. NGVD), below which the with-project profile parallels the existing profile out to a closure depth of 23 ft.. A construction berm at elevation 7 ft. NGVD and varying width supplies sufficient volume to allow for the redistribution of material within the active profile while maintaining the optimum NED Plan berm width of 50 ft.

The landward construction line for the project is placed to minimize effects on existing structures, to parallel the existing shoreline, to allow the Perpetual Beach Storm Damage Reduction Easement to extend about 20 ft. landward of the dune toe, and to tie the fill into a minimum elevation of 7 ft. NGVD.

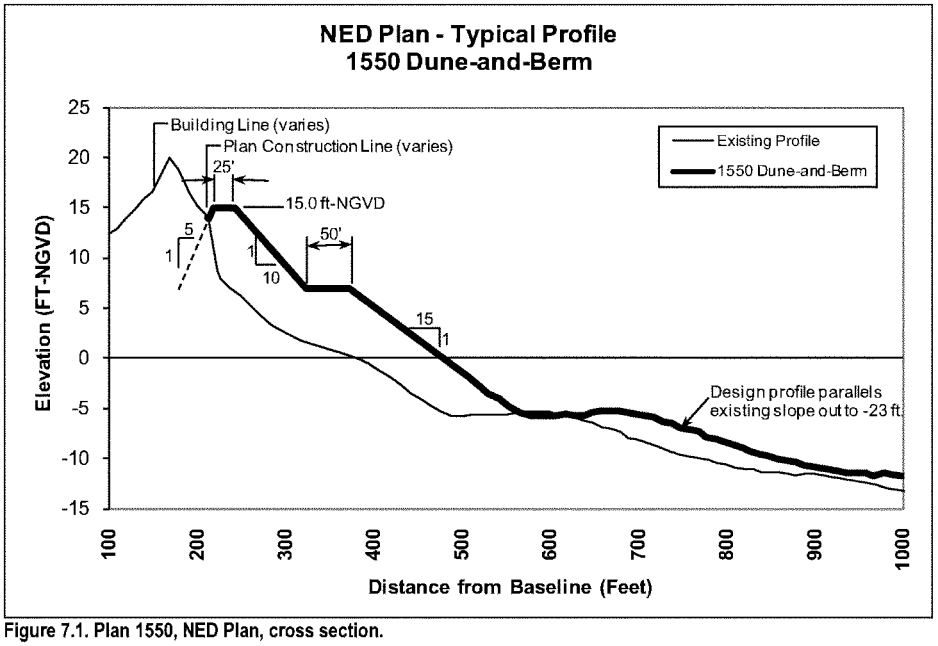


Figure 7.1. Plan 1550, NED Plan, cross section.

7.01.2 Transition Sections

The Selected Plan includes the complete berm and dune cross section for the entire project length. Depending on endpoint conditions found at construction, up to 2,000 ft. of each of the project endpoints may be replaced with transitions sections. The transition sections at both ends of the main fill are necessary to improve project stability and reduce end losses. If no adjacent beachfill project occurs, the plan would include a transition consisting of a tapered berm only, starting with a transition berm width of 200 ft. that uniformly tapers to zero. If an adjacent beachfill project occurs, any transition would be shorter and designed to fit the adjacent project.

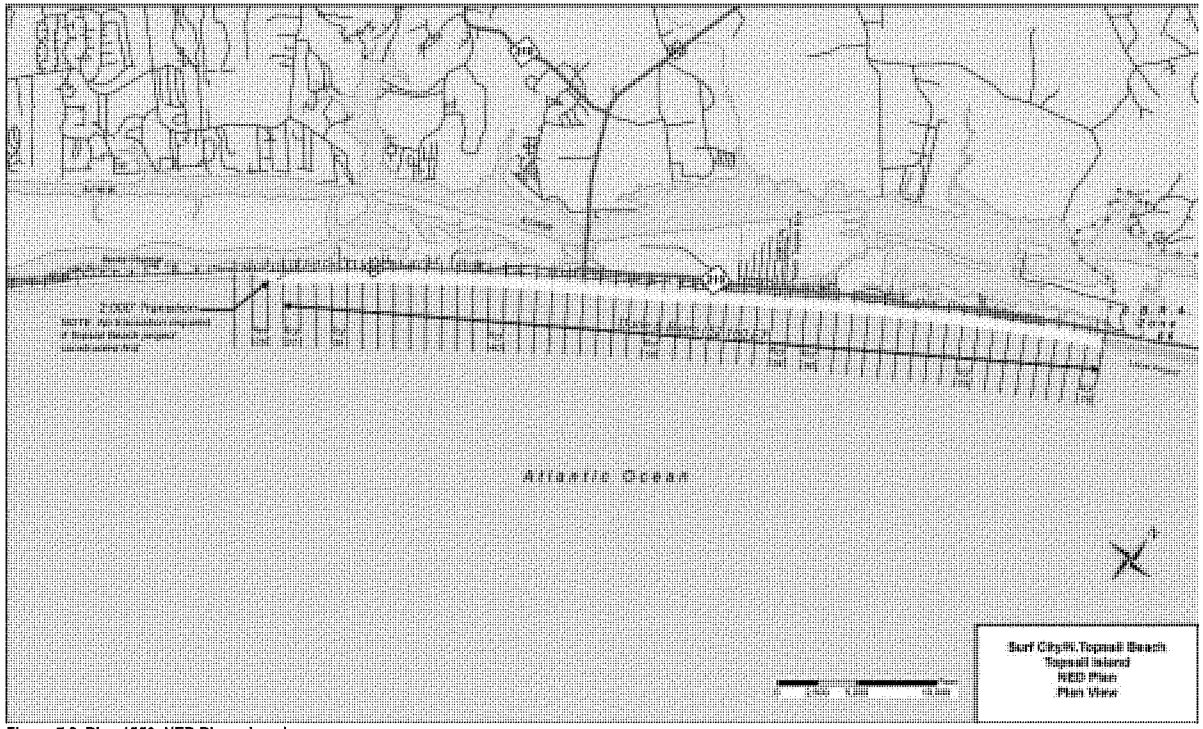


Figure 7.2. Plan 1550, NED Plan, plan view.

7.02 Rationale for Support of the Locally Preferred Plan

Surf City and North Topsail Beach have indicated that they approve of the NED plan. There is no Locally Preferred Plan.

7.03 Design and Construction Considerations

7.03.1 Initial Construction and Renourishment

The selected plan requires about 11.86 million cubic yards of borrow material during initial construction, averaging 197 cubic yard per linear ft (in place). Project renourishment requirements for the 6-year renourishment cycle are about 2.64 million cubic yards of borrow material. In total, about 32.3 million cubic yards of borrow material would be required for the 50-year project. Those borrow volume quantities are actually 15 percent greater for initial construction and 21 percent greater for renourishment than the desired volumes to account for placement losses during construction, which equates to an average loss factor of 1.15 and 1.21. Placement losses are defined as the extra volume of material that must be removed from the borrow area to realize the required in-place volume of material on the beach.

The material would be pumped to the beach from hopper dredges and shaped on the beach by earth-moving equipment. The initial construction profile would extend seaward of the final design berm profile a variable distance to cover anticipated sand movement during and immediately after construction. This variable distance would generally range from 100 to 200 ft. along the project depending on foreshore slopes established by the fill material. Once sand redistribution along the foreshore occurs, the adjusted profile should resemble the design berm profile. The anticipated construction plan is to use two hopper dredges during four separate construction seasons to complete the initial project. Environmental windows limit the construction season to mostly the winter months from December 1 to March 31.

Renourishment is estimated to require 2,642,000 cubic yards of sand by two hopper dredges in one construction season. Renourishment would be repeated on a 6-year cycle. Because of the long initial construction period, the first renourishment would occur only two years after the most recently completed construction and 6 years after the sections of the project completed first. Therefore, the first renourishment volume would be estimated to be 75 percent of the volume compared to a project completed all within one year. The estimated volume for the first renourishment is 1,982,000 cubic yards. The seventh and last renourishment will occur at year 42 of the project and is estimated to require 3,523,000 cubic yards.

Delivery of sand could occur by hauling filled scows to a pumping station buoy or by hopper dredge hauling sand to the pipeline buoy. In both initial construction and during renourishment, material between the toe of dune and mean high water line would be tilled to prevent compaction.

7.03.2 Dune Vegetation

The dune portion of the project would be stabilized against wind losses by planting appropriate native beach grasses. Dune stabilization would be accomplished by planting vegetation on the dune during the optimum planting seasons and following the berm and dune construction. Planting stocks would consist of a variety of native dune plants including sea oats (*Uniola paniculata*), American beachgrass (*Ammophila breviligulata*), panic grass (*Panicum amarum*), and seaside little bluestem (*Littoralis variety*). The vegetative cover would extend from the landward toe of the dune to the seaward intersection with the storm berm for the length of the dune. Plant spacing guidelines would follow the recommendations provided by the North Carolina Sea Grant publication, *The Dune Book* (Nash and Rogers, 2003). Sea oats would be the predominant plant with American beach grass and panic grass as a supplemental plant. Seaside little bluestem would be planted on the backside of the dune away from the most extreme environment. The total area for dune plantings is estimated to be 165 acres.

7.03.3 Construction Access and Public Access

Surf City has 33 public beach access points in the project limits, and North Topsail has 22. Most access sites have wooden dune walkovers. Both Surf City and North Topsail Beach each have a vehicle crossover in the project limits for beach maintenance and emergency access. The drive-over sites would provide access during construction of the beachfill for delivery and removal of the dredge pipeline and for other construction equipment.

Most of the existing public dune walkovers would be totally or partially removed before beachfill construction. After the beachfill is completed, new walkovers would be built, and remaining walkovers would be extended over the dune. Including 5 new proposed public access sites, the total number of walkovers required is estimated to be 60. Of those, approximately 12 would be constructed to allow wheelchairs to cross the dune. The walkovers are to be constructed as a shared project construction cost. The real estate cost of providing the public access locations is not part of the project cost and is not creditable.

7.03.4 Renourishment Interval

An analysis of various renourishment intervals from 2 to 7 years was conducted in the GRANDUC model. Longer renourishment intervals increase the risks between renourishment events of allowing accumulated erosion to create escarpments (for instance, it is projected that the escarpment would be nearly two miles longer under a 7 versus a 4 year renourishment cycle), narrow the non-dune portion of the beachfill, erode the toe of the dune, and damage dune vegetation, resulting in an unnatural beach profile. Large scarps also create potential safety hazards (Figure 7.3). For renourishment cycles beyond 4 years, an additional hopper dredge would be needed in order to complete dredging during the environmental hopper dredging window of December 1 to March 31.

Net benefits increase as a function of renourishment interval from 2 to 4 years (Table 7.1). Beyond 4 years, the differences in benefits are insignificant. Therefore, the 6 year

renourishment interval, which had the lowest cost, was selected.



Figure 7.3. Example of escarped dune and eroded berm.

Table 7.1. Summary of total costs and net benefits used for the selection of the project renourishment interval.

Renourishment interval (years)	Total cost ($)	Total net benefit ($)
2	129,594,587	158,481,504
3	115,058,012	165,298,498
4	111,479,241	168,712,045
5	111,931,664	167,731,332
6	109,549,340	169,771,051
7	109,637,064	169,032,905

7.03.5 Beachfill Monitoring

A comprehensive monitoring program in accordance with Corps guidance (CEM Part V, Chapter 4 and CHETN II-35) is planned for the Surf City and North Topsail Beach

project to assess and ensure project functionality throughout its design lifetime. Such monitoring supports the design efforts for periodic renourishment and is cost shared 50 percent federal and 50 percent nonfederal. Estimated annual costs for beachfill monitoring are $483,000. The annual monitoring plan would consist of (1) semiannual beach profile surveys, $362,000, (2) New River Inlet monitoring, $6,000, (3) annual aerial photography of New River Inlet and the beach (cost included in the inlet hydrographic survey), (4) an annual monitoring report, $100,000, and (5) monitoring program coordination, $15,000. Beach profile surveys would allow assessment of anticipated beachfill performance and determination of renourishment volume requirements. An aerial photographic record of the beach would further facilitate assessment of the beachfill performance. An annual monitoring report would be prepared that presents the data collected and the corresponding analysis of project performance, including recommendations on renourishment requirements.

7.03.6 Environmental Monitoring and Other Commitments.

The environmental goal of the project is to avoid and minimize adverse impacts to the maximum extent practicable. Table 7.2 is a summary of environmental commitments to protect species and habitat types related to the construction and maintenance of the proposed project. This summary includes commitments to federally listed T&E species as identified in Appendix I. The table also lists other commitments to support coastal management plans and floodplain management.

Environmental monitoring costs associated with hopper dredging and beach tilling are estimated to be $31,050 for initial construction and $10,000 for each periodic nourishment. The environmental monitoring costs are included in the construction management costs and include only costs that are known at this time. It is anticipated that post-construction monitoring would be required, described as follows. Monitoring of sea turtle nesting activities in beach nourishment areas, item (10) is estimated to have an effective average cost of about $68,000 per year. That is an item occurring as part of the without-project condition and is not included as part of the project OMRR&R costs. Monitoring sea turtle nest temperature on the nourished beach, item (16) is estimated to cost about $10,000 during the nesting season following initial construction. Satellite tracking of sea turtle distribution in the project area, item (17) is estimated to cost about $25,000. Seabeach amaranth survey, item (18) is estimated to cost about $6,000 during the growing season following initial construction. Benthic Invertebrate Monitoring, part of item (19), of initial construction is estimated to cost $120,000. Physical monitoring of potential sedimentation impacts to hard bottom from initial construction dredging activities, item (23) is estimated to cost $300,000. When evaluated over the 50-year project life at 4.125 percent discount rate, the present value equivalent of environmental monitoring is estimated at $461,000 with an equivalent annual value of $22,000.

Table 7.2. Project commitments

Species, habitat, other	**Commitments to reduce environmental impacts and other impacts**
Sediment Compatibility	(1) Only beach compatible sediment (i.e., in accordance with North Carolina Sediment Criteria Rule Language) would be placed on the beach as a component of this project (Sections 10.06.1 and 11.02) (2) During the PED phase of this project, additional borings or geophysical surveys or both would be performed to better delineate the borrow area boundaries and material types (Section 7.04.3). (3) If the dredging operations encounter sand deemed non-compatible with native grain size or sorting characteristics of the native beach, the Wilmington District would make the decision on a suitable contingency measure that may include moving the dredge to another site in the borrow area or to another borrow area and would notify the NCDCM and other resource agencies of such a contingency measure (Section 7.04.4).
Piping Plover and Other Shorebirds	(4) The Corps would adhere to appropriate environmental windows to the maximum extent practicable (Appendix I and Section 10.06.1). (5) All staging areas, pipeline routes, and associated construction activities would avoid high value piping plover and shorebird habitat, located within the vicinity of New River Inlet, to the maximum extent practicable (Appendix I and Sections 10.06.1 and 11.02).
Manatee	(6) The Corps would implement precautionary measures for avoiding impacts to manatees during construction activities as detailed in the *Guidelines for Avoiding Impacts to the West Indian Manatee in North Carolina Waters* established by the USFWS (Appendix I and Section 10.06.1).

Table 7.2. (*continued*)

Species, habitat, other	**Commitments to reduce environmental impacts and other impacts**
Large Whales	(7) Endangered species observers would be on board all hopper dredges and would record all large whale sightings and note any potential behavioral effects. The Corps and the contractor would keep the date, time, and approximate location of all marine mammal sightings. They would take care not to closely approach (within 300 ft.) any whales, manatees, or other marine mammals during dredging operations or transport of dredged material. An observer would serve as a lookout to alert the dredge operator or vessel pilot or both of the occurrence of such animals. If any marine mammals are observed during other dredging operations, including vessel movements and transit to the dredged material disposal site, collisions would be avoided either through reduced vessel speed, course alteration, or both.
Sea Turtles	(8) The Corps would strictly adhere to all conditions outlined in the most current NMFS Regional Biological Opinion (RBO) for dredging of channels and borrow areas in the southeastern United States. Furthermore, as a component of this project, hopper dredging activities for both initial construction and each nourishment interval would adhere, to the maximum extent practicable, to a dredging window of December 1 to March 31 to avoid periods of peak sea turtle abundance. Turtle-deflecting dragheads, inflow or overflow screening, or both would be used, and NMFS-certified turtle and whale observers would also be implemented (Appendix I and Section 10.06.1). (9) To determine the potential taking of whales, turtles, and other species by hopper dredges, NMFS-certified observers would be on board during all hopper dredging activities. Recording and reporting procedures would be followed in accordance with the conditions of the current NMFS RBO (Appendix I and Section 10.06.1). (10) The Corps would avoid the sea turtle nesting season during initial construction and each nourishment interval. If, because of unforeseen circumstances, construction extends into the nesting season, the Corps would implement a sea turtle nest monitoring and avoidance/relocation plan through coordination with USFWS and NCWRC (Appendix I and Section 10.06.1).

Table 7.2. (*continued*)

Species, habitat, other	Commitments to reduce environmental impacts and other impacts
Sea Turtles (continued)	(11) Sea turtle nesting monitoring activities in beach nourishment areas would be required to assess post-nourishment nesting activity. That would include daily surveys beginning at sunrise from May 1 until September 15. Information on false crawl location, nest location, and hatching success of all nests would be recorded and provided to NCWRC (Appendix I and Section 10.06.1). (12) The beach would be monitored for escarpment formation by the contractor before completion of beach construction activities associated with initial construction and each nourishment interval. Additionally, the local sponsor would monitor the beach for escarpment formation before each turtle nesting season every year between nourishment events. Escarpments that exceed 18 inches in height for a distance of 100 ft. would be leveled by the contractor or the local sponsor accordingly. If it is determined that escarpment leveling is required during the nesting or hatching season, leveling actions should be directed by the USFWS (Appendix I and Section 10.06.1). (13) Only beach-compatible sediment would be placed on the beach as a component of the project. The Corps would, in coordination with the NCWRC and USFWS, evaluate post-nourishment beach compaction (hardness)would using qualitative assessment techniques to assure that impacts to nesting and incubating sea turtles are minimized and, if necessary, identify appropriate mitigation responses (Appendix I and Section 10.06.1). (14) Local lighting ordinances would be encouraged to the maximum extent practicable to reduce lighting impacts to nesting females and hatchlings. The local sponsors would be encouraged to work with the USFWS, local monitoring groups, and other concerned organizations to develop the best plan for Surf City and North Topsail Beach (Appendix I and Section 10.06.1).

Table 7.2. (*continued*)

Species, habitat, other	**Commitments to reduce environmental impacts and other impacts**
Sea Turtles (continued)	(15) Throughout the duration of each nourishment event, both initial construction and periodic nourishment, the contractor would be required to monitor for the presence of stranded sea turtles, live or dead. If a stranded sea turtle is identified, the contractor would immediately notify the NCWRC of the stranding and implement the appropriate measures, as directed by the NCWRC. Construction activities would be modified appropriately as not to interfere with stranded animals, live or dead (Appendix I and Section 10.06.1). (16) To better understand the threshold of sediment color change and resultant heat conduction from nourishment on temperature-dependent sex determination of sea turtles, the Corps would monitor nest temperatures in the project area during the nesting season following initial construction. That data would be compared to non-nourished native sediment temperatures to support development of management criteria for sediment color guidelines (Appendix I and Section 10.06.1). (17) To assess the abundance of sea turtles, and potential risk of hopper dredge take, within the proposed borrow areas for the project, the Corps would participate in the NCWRC's current satellite telemetry efforts to track the distribution and habitat usage of sea turtles in North Carolina offshore waters (Appendix I and Section 10.06.1).

Errata – page changed on 8/9/2010

Table 7.2. (*continued*)

Species, habitat, other	Commitments to reduce environmental impacts and other impacts
Seabeach Amaranth	(18) Monitoring for seabeach amaranth on Surf City and North Topsail Beaches would be implemented in the growing season following initial construction to assess the post-nourishment presence of plants. The survey would be broken down into survey reaches for each town in accordance with the designated Corps sea beach amaranth survey reaches from 1991 to 2008 to maintain consistent data and survey techniques over time, and results would be provided to USFWS (Appendix I and Section 10.06.1).
Benthic Invertebrates	(19) The anticipated construction time frame for initial and periodic nourishment events would avoid peak recruitment and abundance time period for surf zone fishes and benthic invertebrates (Section 8.01.6 and NCDCM consistency condition). (20) Before initiating any land disturbing activities related to the initial construction period, the Corps would develop Monitoring Plan, in coordination with the resource agencies, to assess project impacts on fisheries and fish prey habitat that outlines: (1) the methodologies for evaluating for hard bottom and intertidal beach habitat impacts, (2) the criteria for determining whether significant, adverse impacts to these habitats have occurred, (3) implementation of the monitoring plan. Though unlikely, based on the avoidance measures incorporated in the study design, should the Monitoring Plan document that a significant adverse impact to habitat has occurred, a Mitigation Plan would be developed outlining the appropriate actions that would be implemented in cooperation with state and federal agencies to rectify the adverse impacts to a level of insignificance. (Section 8.01.6 and NCDCM consistency condition). (21) Initial construction would be completed over the course of four construction stages, each stage entailing a full constructed template. Such a staged initial construction approach would increase the speed of benthic invertebrate recovery for affected areas by allowing for recruitment from adjacent unaffected areas of the beach (Section 8.01.6 and NCDCM consistency condition).

Table 7.2. (*continued*)

Species, habitat, other	Commitments to reduce environmental impacts and other impacts
Hard Bottom Monitoring	(22) To (1) ensure that required buffer distances are adhered to, (2) avoid physical impacts to hard-bottom resources, and (3) monitor the potential for leakage of sediment, the Corps would require all dredges to implement the Silent Inspector automated dredge plant monitoring system (Section 8.01.8.2). (23) Considering the ephemeral nature of the low-relief, hard-bottom features in the nearshore environment and the potential for low-lying outcrops to occur in the pipeline corridor distance requirements and associated dredge and pipeline anchor points, the Corps intends to survey all areas associated with potential pumpout and pipeline corridor requirements before construction to avoid potential impacts to hard-bottom features. All information associated with the surveys, data analysis, identification and mapping of pipeline corridors, appropriate buffers, and such, and subsequent measures developed to avoid resource impacts would be coordinated with the resource agencies before construction (Section 8.01.8.2) (24) If a physical impact by the hopper dredge dragheads to previously unexposed hard-bottom occurs, the incident would be thoroughly documented and coordinated with the appropriate state and federal resource agencies. On the basis of the outcome of such coordination, appropriate action would be taken to investigate and mitigate potential effects (Section 8.01.8.2). (25) Project monitoring of sedimentation effects from dredging activities in the proposed 122-m (400-ft.) buffer would be implemented when appropriate. Sediment monitoring at select offshore transects, including controls, would occur before, during, and, if necessary, after construction and would include installing sediment traps (collectors) and in-situ sediment depth measurements. If sediment accumulation at the compliance transects is > 10% of the sediment accumulated on average per day at the three control sites, the Corps would direct the contractor to stop dredging operations within the 122-m (400-ft.) buffer and move to another area 500-m (1,640-ft.) from the identified hard-bottom sites (Section 8.01.8.2).
Shellfishing	(26) The Corps would contact the North Carolina Shellfish Sanitation and Recreational Water Quality Section before start of work, so the project area may be posted as required.

Table 7.2. (*continued*)

Species, habitat, other	Commitments to reduce environmental impacts and other impacts
Erosion/Sediment Control	(27) Before initiating any land-disturbing activities, the Corps would obtain the approval of the North Carolina Division of Land Resources of an erosion and sedimentation control plan. The Corps would comply with the requirements of the approved erosion and sedimentation control plan. A copy of the plan approval will be forwarded to NCDCM (NCDCM consistency condition).
Water Quality	(28) Before construction, the Corps would obtain a Section 401 Water Quality Certification from the NCDWQ for the proposed project. The Corps would comply with the requirements of the Section 401 Water Quality Certification. A copy of the certification would be forwarded to NCDCM (NCDCM consistency condition). (29) Temporary dikes would be used to retain and direct flow of material parallel to the shoreline to minimize surf zone turbidities. The temporary dikes would be removed and the beach graded in accordance with approved profiles on completion of pumping activities in that section of beach (NCDCM consistency condition).
Terrestrial Impacts	(30) Land-based equipment necessary for beach nourishment work would be brought to the site through existing accesses. If the work results in any damage to existing accesses, the accesses would be restored to pre-project conditions immediately on project completion (NCDCM consistency condition). (31) Dune disturbance would be kept to a minimum. Any alteration of existing dunes would be coordinated with NCDCM and the appropriate property owner(s). All disturbed areas would be restored to original contours and configuration with reference to the surveyed normal high water line and would be revegetated immediately after project completion in that area (NCDCM consistency condition). (32) To prevent leakage, dredge pipes would be routinely inspected. If leakage is found and repairs cannot be made immediately, pumping of material must stop until such leaks are fixed (NCDCM consistency condition).

Table 7.2. (*continued*)

Species, habitat, other	Commitments to reduce environmental impacts and other impacts
Other Commitments	(33) Before construction the existing MHW line would be surveyed, and a copy provided to the NCDCM. If construction is not initiated within 60 days or there is a major shoreline change before beginning beach nourishment (or both), a new survey would be conducted (NCDCM consistency condition). (34) Before initiating any beach nourishment activity, the Corps would coordinate with NCDCM to determine the static vegetation line to be used as the reference point for measuring future oceanfront setbacks. That static vegetation line would then be marked, and a survey depicting the static vegetation line would be submitted to NCDCM before any beach nourishment activities (NCDCM consistency condition). (35) After the post-construction beach profile surveys are completed, the Corps would coordinate with the North Carolina Floodplain Mapping Program to support revisions to the Digital Flood Insurance Rate Maps (DFIRMs). As part of such coordination, the Corps would provide a Letter of Map Revision. (36) No sand would be placed on any sandbags that have been determined by NCDCM to be subject to removal under 15A NCAC 07H .0308(a)(2). To ensure compliance with that condition, NCDCM would be contacted before project initiation so that NCDCM staff may meet on-site with the Corps or the contractor or both (NCDCM consistency condition). (37) To mitigate the very remote chance of encountering ordnance, the beach would be inspected daily, and any ordnance discovered would be handled in accordance with the Military Munitions Rule, Title 40 of the *Code of Federal Regulations* (CFR) Parts 260-270. The Marine Corps Base Explosive Ordnance Disposal Team would be available (on call) during the dredging process. Additionally, the contract specifications for the proposed project would direct the contractor to immediately stop dredging or disposal. Additional measures would then be implemented, as necessary, including inspection of dredged material on the beach and installing outflow screens on the dredge pipeline. Any unexploded ordnance found on the beach would be promptly removed (Section 8.08.3).

Table 7.2. (*continued*)

Species, habitat, other	**Commitments to reduce environmental impacts and other impacts**
Other Commitments (continued)	(38) To assure the risk of potential impacts to cultural resources within inshore areas subject to pumpout activities are avoided, specific pumpout locations would identified, surveyed, and investigated for cultural resources in conjunction with hard-bottom surveys before beginning nourishment activities (Section 8.06). (39) If, during dredging activities, any previously unidentified or unanticipated historical, archaeological, and cultural resources are discovered in the inflow screening of the dredge or in the beach placement area, all activities that could damage or alter such resources would be temporarily suspended. If such a discovery or find is made, the Corps' Contracting Officer would be immediately notified so that the appropriate authorities, including the MMS, may be notified in accordance with Corps policy and 30 CFR 250.194(c) and a determination made as to their significance and what, if any, special disposition of the finds should be made (Section 8.06).

7.04 Borrow Areas

Sixteen borrow areas have been identified for the Surf City/North Topsail Beach Coastal Storm Damage Reduction Project. Those borrow areas include 10 identified for the Surf City/North Topsail Beach project and the excess amount from 6 borrow areas identified for the Topsail Beach Federal project (USACE, 2009). Those areas are typically between 1 and 6 miles offshore and have pre-dredge bottom depths between 35 and 50 ft. Material from the borrow areas were classified in accordance with the Unified Soil Classification System. The material classification (EM 1110-1-1906) types for the material identified as compatible from the borrow areas consisted of poorly graded clean sand (SP) or gravelly sand (SP-SM). Borrow areas in the project area were identified on the basis of material characteristics and depth of suitable material. For more information on the borrow areas, see Appendices C and E. Borrow area characteristics are summarized in Table 7.3.

Table 7.3. Topsail Island borrow area characteristics

Borrow area	Mean grain size	Estimated volume (million cubic yards)	Distance offshore (miles)	Surface elevation (ft. MLLW)
A	2.36 phi (0.20 mm)	*	1 to 3	–38.5 to –49.0
B	2.17 phi (0.22 mm)	*	1.5 to 2.5	–42.2 to –43.2
C	2.32 phi (0.20 mm)	*	4 to 5.5	–45.5 to –47.7
D	2.13 phi (0.23 mm)	*	3.5 to 4.5	–43.5 to –46.9
E	2.15 phi (0.23 mm)	*	4.5 to 5.5	–49 to –50
F	1.09 phi (0.47 mm)	*	4.5 to 5.5	–47.2 to –48
G	2.05 phi (0.24 mm)	2.41	4 to 5.5	–46.5 to –49
H	2.21 phi (0.22 mm)	0.72	3.5 to 4.5	–44.4 to –45.2
J	2.12 phi (0.23 mm)	3.67	3 to 4.5	–42 to –47.4
L	2.05 phi (0.24 mm)	6.13	3 to 5.5	–42.3 to –47
N	1.86 phi (0.28 mm)	5.64	4 to 6	–43.6 to –46.7
O	2.12 phi (0.23 mm)	3.85	1.5 to 4	–40.6 to –43.9
P	2.01 phi (0.25 mm)	2.73	2 to 3.5	–39.5 to –40.5
Q	2.30 phi (0.20 mm)	0.73	1 to 1.5	–35.2 to –35.4
S	1.62 phi (0.32 mm)	1.46	3.5 to 4.5	–43.8 to –44.8
T	1.78 phi (0.29 mm)	0.25	2 to 4	–37.2 to –42

* These borrow areas are planned to be used for the Topsail Beach federal and nonfederal projects (USACE, 2009). The excess material not used for those projects would be expected to be available for the Surf City/North Topsail Beach project. That amount is approximately 9.68 million cubic yards.

As discussed in Section 2.01.10, an extensive geophysical investigation was conducted to identify hard bottom presence and delineate hard bottom that was identified in and near several borrow areas. Hard-bottom buffers of 500 meters (1,640 ft.) were established for high- and moderate-relief hard bottom and 122 meters (400 ft.) were established for low-

relief hard bottom. The Corps, Wilmington District, proposed such buffers, and several state and federal resource agencies concurred. For more specific information regarding impacts to hard bottoms, see section 8.01.8.2 f.

7.04.1 Borrow Area Material Compatibility

The compatibility analysis compares the grain size of the *native beach* or the *reference beach* with the material in the proposed borrow material. The overfill ratio is the primary indicator of the compatibility of the borrow material to the beach material, with a value of 1.00 indicating that one cubic yard of borrow material is needed to match one cubic yard of beach material. An overfill ratio of up to 1.5 is generally considered acceptable as a match of compatibility. Table 7.4 illustrates the overfill ratios for potential borrow areas for the Surf City/North Topsail Beach project. The overfill ratios for the borrow areas are all below 1.5 with the exception of borrow area C, which is 1.56. Because the overfill ratio for borrow area C was only slightly above 1.5, it has been retained for further evaluation when additional characterization is conducted during the design phase.

North Carolina implemented new beachfill standards in 2007, which require compatibility of the native beach with borrow sources in regards to the percentage of silt (< 0.062 mm), granular sediment, (< 4.76 mm and ≥ 2.0 mm), gravel (≥ 4.76 mm), and calcium carbonate. The state still needs to gain approval from NOAA to add the new standards to their Coastal Zone Management Program. If NOAA approves the changes, then the new criteria would need to be met in order for the project to be consistent with the Coastal Zone Management Act. A visual estimate of shell content can be used in lieu of carbonate weight percent for samples collected before the effective date of beachfill rules that applies to the Surf City/North Topsail Beach project. The standards require that percent silt, granular sediment, and gravel in borrow material not exceed the amount found in the native beach plus 5 percent, and the percent carbonate in borrow material not exceed the amount found in the native beach plus 15 percent. Those characteristics for the native beach and borrow material are given in Table 7.4. The analysis for the native beach material indicates the silt, granular sediment, and gravel content are 1.2, 1.1, and 0.5 percent, respectively. The visual shell content for the native beach is 9 percent. After incorporating the tolerance permitted by the beachfill standards, the silt, granular sediment, gravel, and shell content permitted for borrow areas to be used for Surf City/North Topsail Beach are 6.2, 6.1, 5.5, and 24 percent, respectively.

As shown in Table 7.4, all the borrow areas comply with the beachfill standards regarding the percentage of silt with the exception of borrow areas A (6.6 percent) and L (6.3 percent). Both of those borrow areas exceed the standard slightly by 0.4 and 0.1 percent, respectively. All the borrow areas comply with the beachfill standards regarding the percentage of granular sediment with the exception of borrow areas F (7.0 percent) and S (6.6 percent), which exceed the standard by 0.9 and 0.5 percent, respectively. All the borrow areas comply with the beachfill standards regarding the percentage of gravel sediment with the exception of borrow areas F (8.5 percent) and P (6.6 percent), which exceed the standard by 3.0 and 1.1 percent, respectively. All the borrow areas comply with the beachfill standards regarding the percentage of shell content (carbonate). The borrow areas in which the standards are exceeded for the various characteristic (A, F, L,

S, and P) have been retained because all borrow areas would be further characterized during the design phase of the project. Additional vibracores would be performed to comply with the beachfill standards of 1 core/acre or 1,000 foot spacing. Vibracores would be performed to produce a density of 1,000 foot spacing in a borrow area before its use as a borrow source. For more information on borrow material compatibility, see Appendix E.

Table 7.4. Surf City/North Topsail Beach compatibility table

Native Beach	Mean (phi)	Mean (mm)	Std Dev (phi)	Std Dev (mm)	% Silt (0.062 mm)	% Granular (2 - 4.76 mm)	% Gravel (4.76 mm)	% Shell
Surf City/North Topsail Beach	2.15	0.23	0.71	0.61	1.2	1.1	0.5	9

Borrow Site	Mean (phi)	Mean (mm)	Std Dev (phi)	Std Dev (mm)	% Silt (0.062 mm)	% Granular (2 - 4.76 mm)	% Gravel (4.76 mm)	% Shell	Overfill Ratio	Silt Correction Factor	Final Overfill Ratios Corrected for Silt Content[1]
A ^	2.36	0.20	0.88	0.54	6.6	3.4	2.2	11	1.29	1.07	1.38
B ^	2.17	0.22	0.99	0.50	4.0	1.7	0.8	13	1.18	1.04	1.23
C ^	2.32	0.20	0.63	0.64	3.9	1.7	2.6	9	1.50	1.04	1.56
D ^	2.13	0.23	0.99	0.50	5.2	4.6	2.2	10	1.15	1.06	1.21
E ^	2.15	0.23	0.69	0.62	3.2	0.9	1.2	5	1.02	1.03	1.15
F ^	1.09	0.47	1.78	0.23	3.8	7.0	8.5	10	1.14	1.04	1.19
G	2.05	0.24	0.98	0.51	5.2	2.7	5.2	10	1.11	1.05	1.17
H	2.21	0.22	0.65	0.64	2.6	1.6	2.0	7	1.16	1.03	1.19
J	2.12	0.23	0.75	0.60	4.5	2.3	1.1	10	1.01	1.05	1.15
L	2.05	0.24	0.94	0.52	6.3	2.8	3.1	10	1.09	1.07	1.16
N	1.86	0.28	0.96	0.51	3.6	3.2	4.8	9	1.05	1.04	1.15
O	2.12	0.23	0.86	0.55	6.2	2.0	4.7	9	1.08	1.07	1.15
P	2.01	0.25	0.96	0.52	5.5	2.4	6.6	7	1.09	1.06	1.15
Q	2.30	0.20	0.66	0.63	5.9	2.4	2.3	10	1.37	1.06	1.46
S	1.62	0.32	1.12	0.46	3.3	6.6	4.1	21	1.06	1.03	1.15
T	1.78	0.29	0.95	0.52	2.8	3.0	3.9	17	1.03	1.03	1.15

^ These borrow areas have been identified for the Topsail Beach Federal project. The excess material not used for these projects is planned to be available for the Surf City/North Topsail Beach Federal project. This amount is approximately 9.68 million cubic yards.

[1] In order to account for placement losses, borrow areas were assigned a minimum overfill ratio of 1.15

7.04.2 Regional Sand Requirements

Four beachfill projects are planned or being planned for Topsail Island as shown in Figure 7.4. Those projects consist of the Surf City/North Topsail Beach Federal Coastal Storm Damage Reduction Project, the North Topsail Beach non-Federal Project, the West Onslow Beach and New River Inlet (Topsail Beach) Federal Coastal Storm Damage Reduction Project, and the Topsail Beach non-Federal Project. The two federal projects and the North Topsail Beach non-Federal project are planning to use material from offshore borrow areas identified for the federal projects. However, the Topsail Beach nonfederal project is not proposing to use material from those borrow areas. The estimated volume requirements for 50-year period of analysis of the projects are shown in Table 7.5.

By evaluating all Topsail Island offshore borrow areas together, the 16 borrow areas contain approximately 50.5 million cubic yards of borrow material. The four Topsail Island project volume requirements from these areas are approximately 46.2 million cubic yards or about 91 percent of the available borrow material in all the borrow areas evaluated for the federal projects.

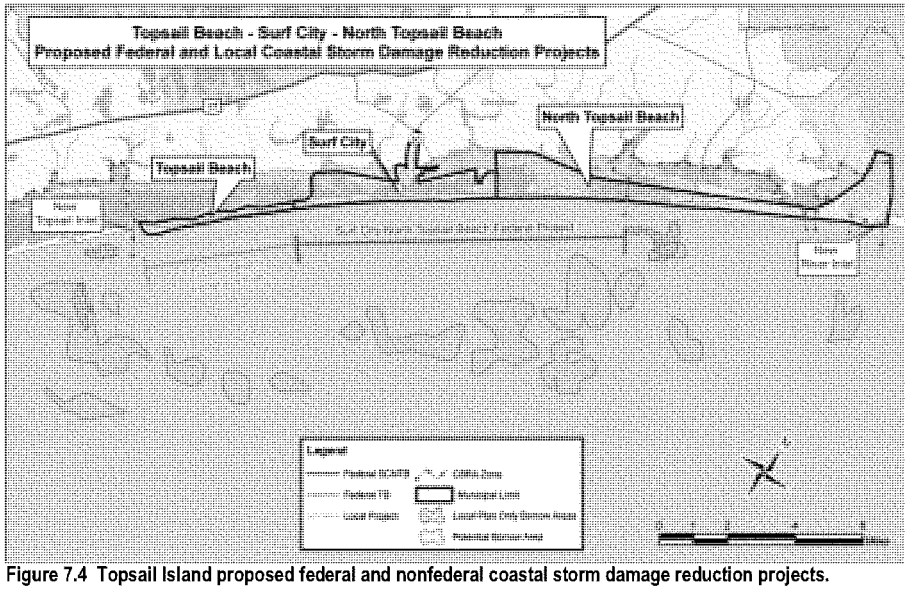


Figure 7.4 Topsail Island proposed federal and nonfederal coastal storm damage reduction projects.

Table 7.5. Lifetime borrow requirements, Topsail Island

Project	Volume (million cubic yards)
Surf City/North Topsail Beach federal[a]	32.3
North Topsail Beach nonfederal	0.34[b]
Topsail Beach federal	13.6
Topsail Beach nonfederal	0[c]
Total, required	46.2
Total, available	50.5

[a] brought back from NED plan identification.

[b] The amount estimated for the project is approximately 4 million cubic yards. However, only 340,000 cubic yards would be required from the borrow areas identified for the federal project.

[c]The amount estimated for the project is approximately 1.3 million cubic yards. However, none of this material is coming from the borrow areas identified for the federal project.

7.04.3 Borrow Area Use Plan

Many possible sequences and methods can be used for placing available material on the beach for the project. The purpose of this plan is to discuss the subjects of borrow area characteristics, dredging specifics, project construction plan, project sand requirements, and borrow area use. The economic optimization of using the borrow areas for the life of the project would be further evaluated when the final borrow area data has been collected and fully analyzed during the PED phase. Additional vibracore boring data would be collected and made a part of the final borrow area use plan, but for now, the defined borrow areas would be used. In addition to borrow area parameters (material quantities and location), the dredging production rates and dredging window are critical to selecting optimum borrow use plan.

The offshore borrow areas beyond 3 nautical miles offshore would be subject to federal mining requirements of the MMS. The borrow areas have been configured on the basis of a geotechnical evaluation (Appendix C, Geotechnical Analysis) and results of the compatibility analysis (Appendix E, Sand Compatibility Analysis).

Areas to be used for borrow would be further defined during the PED phase of the project. Additional borings or geophysical surveys or both would be performed to better delineate the borrow area boundaries and material types. Vibracore borings would be performed in a grid pattern, on a 500-ft to 1,000-ft spacing, in any area before its use as a borrow source.

7.04.4 Borrow Area Contingency Plan

Borrow area compatibility is determined on the basis of grain size analyses from borings taken before construction, during both the feasibility study and PED phase. The borings conducted during the PED phase would provide any additional data necessary to help further refine the borrow area to comply with the North Carolina beachfill standard of 1 core/acre or 1,000-ft spacing when combined with the borings conducted during the feasibility study. Such additional characterization of the borrow material would increase the level of confidence for borrow material compatibility and decrease the degree of

interpolation between boring locations. Qualitative visual characterizations of the in-place material would be made by representatives of the Corps construction and environmental offices throughout the project construction.

Furthermore, dredging production rates are specific to each dredge and its operation and can be quantified. The recommended construction plan identified in Section 7.04.1.4 discusses the use of hopper dredges during initial construction and each periodic nourishment event. Hopper dredges would use pumpout facilities for each dredged hopper load. Because hopper dredges have a maximum capacity per load and are self-propelled, the Corps can feasibly manage potential incompatible material.

Federal and state environmental agencies would be notified if, and how much, potentially incompatible material is encountered during dredging operations. If necessary, the Wilmington District would make the decision on a suitable contingency measure that could include moving the dredge to another site in the borrow area or to another borrow area, depending on availability of sediment, and would notify the agencies of the contingency measure.

7.05 Dredging and Material Shaping

The following discussion describes the dredging and construction plan.

7.05.1 Dredging Production

Dredging production refers to the average volume transported per day and relates to factors such as plant, material, distance, and weather. This information is used to estimate project cost and construction time. Production rates are estimated to average 14,000 cubic yards/day for each hopper dredge for initial construction and for periodic nourishment.

7.05.2 Dredging Window

In determining the optimum borrow use plan, the hopper dredging window restriction was evaluated, with respect to sea turtles, using a December 1 to March 31 dredging window. The plan considers that to work within the hopper dredging window, the initial construction would take four seasons to complete.

A 6-year periodic nourishment cycle using hopper dredges is considered for the 50-year life of the project. Hopper dredging operations for the project would work in accordance with the *1997 National Marine Fisheries Service (NMFS) South Atlantic Regional Biological Opinion (SARBO) for the continued hopper dredging of channels and borrow areas in the Southeastern United States* or any superseding SARBO that is prepared by NMFS. Although, under the 1997 SARBO, the NMFS does not cover window hopper dredging operations from Pawley's Island, South Carolina, through North Carolina, both the Corps South Atlantic Division (SAD) office and South Atlantic Wilmington (SAW) District office recommend implementing a December 1 to March 31 dredging window, to the extent practicable, to minimize impacts to sea turtles in the offshore environment. A summary for the recommended construction plan follows with a brief discussion of start-

stop times, number of contracts required, type and number of dredges required, and dredging presence in the project area during the life of the project.

7.05.3 Recommended Construction Plan

Initial construction would begin after December 1 of project year 1. The initial construction would consist of hopper dredging one or more of the offshore borrow areas and proceed until sea turtle activity resumes about March 31 of the following year. The process would continue each winter for 4 years until the full project length is completed in project year 4. To meet that schedule, two hopper dredges would be used in each season. Because of the relatively thin sand layer in the borrow areas, a cutterhead-pipeline dredge is unlikely to be effective.

Periodic nourishment would begin in project year 7 and consist of hopper dredging because of limited thickness of available material in the borrow areas and long haul distances. Periodic nourishment for the project would use a combination of offshore borrow areas. Renourishment would adhere to the hopper-dredging window and begin December 1 for each cycle and proceed until completion before March 31 of the following year. In summary, every 6 years two hopper dredges would be expected to complete the renourishment within the designated hopper-dredging window. The plan would require separate contracts for initial construction and for each periodic nourishment cycle. The first renourishment would apply the most material in reaches constructed in project year 1 and smaller volumes in reaches constructed in project year 4. The overall volume to be placed in the first renourishment would therefore be only about 75 percent of the volume required in each following renourishment.

7.06 Real Estate Considerations

Real estate requirements for the Selected Plan include lands, easements, rights-of-way and relocations, and disposal/borrow areas, which are referred to as LERRD. Real estate requirements in each of those categories are discussed and followed by a summary of estimated real estate costs. There would be no utility relocations. No existing federal project is within the acquisition area. Further details are provided in the Real Estate Appendix (Appendix M).

7.06.1 Borrow Areas

Proposed borrow areas are offshore. On final selection of borrow areas to be used for the project, coordination and concurrence for the sand removal from the offshore borrow areas would be required from appropriate state or federal agencies or both.

7.06.2 Pipeline

Material for initial project construction and beach nourishment would be dredged by hopper dredge from the offshore borrow areas, and then moved by pipeline to the beach. The pipeline would be routed along the ocean shoreline, where it would be placed either below Mean High Water or in the acquired Perpetual Beach Storm Damage Reduction Easements.

7.06.3 Construction Area

The project limits extend along the shoreline of Surf City and North Topsail Beach northward to reach 78, a total length of 52,150 ft. The estate to be acquired for the project would be a Perpetual Beach Storm Damage Reduction Easement for approximately 828 easements. According to project maps and ground examination, three parcels have structures so far seaward that it would be necessary to acquire the parcel and structures in fee. Another two parcels would be used temporarily as construction staging areas. No relocation of landowners would occur. Improvements (other than the pier) within the project include walkover structures that allow beach access from private and public property. The easement specifies that construction of walkover structures must not violate the integrity of the constructed dune. Approval of PED for construction of new walkover structures must be obtained from the project sponsor.

7.06.4 Real Estate Costs

Estimated real estate costs for the Selected Plan of Improvement are shown in Table 7.6. The land value for the Perpetual Beach Storm Damage Reduction Easements is $0. As *offsetting benefits* applies, a determination is made that the project would not reduce the value of the land. Rather, it would remain the same or increase after construction of the project.

Table 7.6. Real estate estimate (2010 price level), beachfill plan

a. Lands (two temporary staging areas)	$58,000
b. Improvements (three residences)	$1,158,300
c. Mineral rights	$0
d. Damages	$0
e. P.L. 91-646 Relocation costs	$4,000
f. Acquisition administrative costs (three parcels in fee, 828 easements)	$2,825,400
Federal	$332,400
Nonfederal	$2,493,000
Subtotal	$4,182,888
Contingencies, 25%	$1,045,722
Total, rounded	$5,229,000

7.07 Operation and Maintenance Considerations

Operation, maintenance, repair, replacement, and rehabilitation (OMRR&R) requirements of the sponsors would consist of project inspections and maintenance. The beachfill monitoring actions are different from the nonfederal sponsors' OMRR&R project inspections and surveillance, which consist of assessing dune vegetation, access facilities, dune crest erosion, trash and debris, and unusual conditions such as escarpment formation or excessive erosion. Periodic renourishment and beachfill monitoring (including the semiannual beach profile surveys) are classified as continuing construction, not as OMRR&R. Dune vegetation maintenance includes watering, fertilizing, and replacing dune plantings as needed. Other maintenance is reshaping of any minor dune damage, repairs to walkover structures and vehicle accesses, and grading any large escarpments. Estimated OMRR&R annual costs are $52,000.

7.08 Plan Accomplishments

The Selected Plan would significantly reduce expected annual damages to structures and roads from coastal storm damages along the project reaches 27 though 78. It also would significantly reduce damages from long-term progressive erosion.

The Selected Plan would reduce, but not entirely eliminate, damages due to short term erosion, inundation, and wave overwash during storms. Although the Selected Plan would substantially reduce damages due to hurricane-wave overwash, note that the plan provides for storm damage reduction only in terms of reducing damage to development from the action of ocean storm surge and wave action. No provisions are in the project to reduce damages to the area against storm-tide flooding occurring from increased water levels in the sounds landward of Topsail Island.

The Selected Plan would reduce emergency costs and other damages and would increase the width of beach available for recreation and for beach habitat, providing incidental benefits. Topsail Island was included in a study of recreation demand and benefits to four barrier islands on the North Carolina coast. Details of the analysis are in the Recreation Appendix (Appendix O). To summarize, the study reports willingness to pay for a beach day for the average visitor within a travel cost method (TCM) framework. The TCM makes use of the basic idea that the time and money that households expend in traveling to beaches provide a signal of the value of such resources. The TCM relies on the assumption that, although access to a recreational site has a minimal price or no explicit price, an individual's travel cost, including transportation, accommodation, and lost wages, can be used as surrogate prices to approximate the nonexplicit prices for their recreational experiences. The basic premise is that visitors perceive and respond to changes in travel cost to the site in the same way they would respond to changes in an entry fee, so the number of trips to a recreation site should decrease with increases in distance traveled and other factors increasing the total travel cost.

Socioeconomic characteristics of the individuals and information concerning substitute sites and environmental quality indicators can also be included. On-site visitation data for 17 North Carolina beaches were collected between July and August 2003. A telephone survey was conducted in May 2004, with a target population based on the results of the on-site survey conducted in 2003. Results from the TCM measure the incremental value of having access to a beach when other substitute beaches are available, and the value of changes in beach characteristics, such as beach width. Additionally, the data were used to predict annual and peak visitation at the subject beaches and parking and access requirements to handle projected visitation. Finally, the NED benefits for the with-project conditions for the subject beaches were estimated. The expected average annual benefit for Surf City and North Topsail beaches for increases in beach width resulting from the selected 1550 alternative plan are approximately $12,709,000 and $7,796,000, respectively, for a total of $20,505,000 in average annual benefits for the entire project. Note that average annual recreation benefits for all North Topsail Beach actually amounts to $23,376,000; however, benefits were applied only for the portion of beach that is in the

project area, which is approximately one-third of the total. The 1550 plan would add an additional beach width of 65 and 73 ft. for Surf City and North Topsail beaches, respectively. Table 7.7 summarizes expected peak visitation and the amount of parking required to satisfy peak visitation on 95 percent of peak days with a project in place. Peak visitation was defined as the average estimated number of visitors in the project area beaches at 1 p.m. on July 4, 5, 12, 13 and Aug 2, 3, 9, 10, 30, and 31. On the basis of a 2008 count, more than enough parking spaces exist (1,992) to accommodate peak visitation; however, the current distribution of parking spaces is inadequate, as is discussed in section 3.04.

Table 7.7. Peak visitation and parking required and available at the SCNTB project area

Peak visitors[a]	Parking spaces required[a]	Parking spaces available[b]
3,358	1,679	1,992

a. Projected 2012 peak visitation and parking requirements, with project

b. 2008 count of spaces

7.09 Economics of the Selected Plan

Many suitable plans were identified that have benefits that exceed costs. The Selected Plan is the NED Plan, having the greatest net benefits. Benefits and costs of the Selected Plan are presented in this section at October 2010 price levels. The Water Resources Interest Rate for FY 2011 of 4.125 percent is used to develop present values and annual values for benefits, costs, and net benefits.

7.09.1 Selected Plan—Benefits

The total expected annual benefits for the Selected Plan are estimated at $40,129,000. An itemized listing of expected annual benefits is presented in Table 7.8. Regarding the increase in flood damages, as storm erosion and long-term land losses are reduced, flood damages begin to become the dominant category. Also, structures that might have otherwise been taken out by storm and wave damage without a project would then be subject to residual flood damages.

Table 7.8. Expected annual benefits, October 2010 levels, 4.125% interest rate

Benefit category	Expected annual benefit
	Selected Plan, NED
Hurricane and Storm Damage Reduction	
Storm Erosion	$14,352,000
Flood	$(98,000)
Wave	$404,000
Land and Long-Term Erosion	$2,162,000
Subtotal, rounded	$16,820,000
Recreation	$ 20,505,000
Benefits During Construction	$ 2,804,000
Total expected annual benefits	$40,129,000

7.09.2 Selected Plan—Costs

Determining the economic costs of the Selected Plan consists of four basic steps. First, project First Costs are computed. First Costs include expenditures for project design and

initial construction and related costs of supervision and administration. First Costs also include the lands, easements, and rights-of-way for initial project construction and periodic nourishment. Total First Costs are estimated to be $123,135,000 at October 2010 price levels as presented in Table 7.9.

Table 7.9. Project first costs, Plan 1550 NED (October 2010 price levels)

FIRST COST							
ACCT. CODE	ITEM	QUANTITY	UNIT	UNIT PRICE	AMOUNT	CONTIN-GENCY	TOTAL COST
1	LANDS AND DAMAGES						
	Lands				$1,216,00	$305,00	$1,521,00
	Improvement				$137,00	$34,00	$171,00
	PL 91-646				$4,00	$1,00	$5,000
	Acquisition Cost, Federal				$332,00	$83,00	$415,00
	Acquisition Cost, Non-				$2,493,00	$624,00	$3,117,00
	Subtota				$4,182,00	$1,047,00	$5,228,00
17	BEACH REPLENISHMENT						
	Mobilizati n Demobili atio	1	JOB	LS	$7,600,00	$1,596,00	$9,196,00
	Dredging and Fill	11,855,17	CY	$6.9	$82,102,00	$17,241,00	$99,344,00
	Dune Vegetatio	165	AC	$10,00	$1,650,00	$347,00	$1,997,00
	Beac Tillin	150	AC	$750	$113,00	$24,00	$137,00
	Public Walkovers	35	EA	$48,16	$1,866,00	$392,00	$2,258,00
	Subtota				$93,331,00	$19,600,00	$112,932,00
30	PLANNING, ENGINEERING, AND DESIGN				$2,454,00	$614,00	$3,068,00
31	CONSTRUCTION MANAGEMENT				$1,527,00	$382,00	$1,909,00
	TOTAL FIRST COST				$101,494,00	$21,640,00	$123,135,00

Second, Interest during Construction is added to the project First Cost. Interest during Construction is computed from the start of PED through the 4-year initial construction period. Interest during Construction for the Selected Plan is estimated to be $9,513,000. The project First Cost plus Interest during Construction represents the Total Investment Cost required to place the project into operation. Total Investment Cost for the Selected Plan is estimated to be $132,648,000 as shown in Table 7.10.

Table 7.10. Total investment cost, Plan 1550 NED (October 2010 price levels)

Item	Amount
Total First Cost	$123,135,000
Interest During Construction	$9,513,000
Total Investment Cost	$132,648,000

Third, Scheduled Renourishment Costs are computed. Those costs are incurred in the future for each renourishment. Neither discounting to present value, nor escalation for anticipated inflation is included.

Renourishments would be repeated on a 6-year cycle. There are three different renourishment volumes and costs. As explained in Section 7.03.1, the first renourishment would require less volume and the last renourishment would require additional volume. At October 2010 price levels the renourishment costs including non-contract costs, and other support costs are estimated to be $20,866,000 for the first event, $27,724,000 for events two through six, and $46,053,000 for the final renourishment. Details are shown in Tables 7.11, 7.12, and 7.13.

Table 7.11. Project renourishment costs, Plan 1550 NED (October 2010 price levels): First event

Acct. code	Item	Quantity	Unit	Unit price	Amount	Contingency	Total cost
17	Beach Replenishment						
	Mobilization and Demobilization	1	JOB		$1,900,000	$399,000	$2,299,000
	Dredging and Beachfill	1,981,670	CY	$7.17	$14,202,000	$2,982,000	$17,184,000
	Beach Tilling	66	AC	$753	$50,000	$10,000	$60,000
	Subtotal				$16,152,000	$3,391,000	$19,543,000
30	Planning, Engineering, And Design				$658,000	$165,000	$823,000
31	Construction Management				$400,000	$100,000	$500,000
	Total First Cost				$17,210,000	$3,656,000	$20,866,000

Table 7.12. Project renourishment costs, Plan 1550 NED (October 2010 price levels): Second through sixth events

Acct. code	Item	Quantity	Unit	Unit price	Amount	Contingency	Total cost
17	Beach Replenishment						
	Mobilization and Demobilization	1	JOB	LS	$1,901,000	$399,000	$2,300,000
	Dredging and Beachfill	2,642,225	CY	$7.57	19,870,000	$4,173,000	$24,042,000
	Beach Tilling	66	AC	$792	$50,000	$10,000	$60,000
	Subtotal				$21,820,000	$4,582,000	$26,402,000
30	Planning, Engineering, And Design				$658,000	$165,000	$823,000
31	Construction Management				$400,000	$100,000	$500,000
	Total First Cost				$22,878,000	$4,857,000	$27,724,000

Table 7.13. Project renourishment costs, Plan 1550 NED (October 2010 price levels): Final (seventh) event.

Acct. code	Item	Quantity	Unit	Unit price	Amount	Contingency	Total cost
17	Beach Replenishment						
	Mobilization and Demobilization	1	JOB	LS	$2,728,000	$573,000	$3,301,000
	Dredging and Beachfill	3,523,000	CY	$9.70	34,173,000	$7,176,000	$41,349,000
	Beach Tilling	66	AC	$792	$66,000	$13,000	$79,000
	Subtotal				$36,967,000	$7,762,000	$44,729,000
30	Planning, Engineering, And Design				$658,000	$165,000	$823,000
31	Construction Management				$400,000	$100,000	$500,000
	Total First Cost				$38,025,000	$8,027,000	$46,053,000

Fourth, Expected Annual Costs are computed. Those costs consist of interest and amortization of the Total Investment Cost and the equivalent annual cost of project OMRR&R. The Expected Annual Costs provide a basis for comparing project costs to expected annual benefits. Expected Annual Costs for the Selected Plan are estimated to be $10,702,000. A summary of the computations involved in each of these four steps is presented in Table 7.14.

Table 7.14. Project annual costs, Plan 1550 NED (October 2010 price levels)

interest rate =	4.125%	years of analysis =	50
ITEM	**YEAR**	**AMOUNT**	**PRESENT VALUE, 2014**
Total Investment Cost	2014	$132,648,000	$132,648,000
Renourishment	2020	$20,866,000	$16,372,000
Renourishment	2026	$27,724,000	$17,069,000
Renourishment	2032	$27,724,000	$13,393,000
Renourishment	2038	$27,724,000	$10,508,000
Renourishment	2044	$27,724,000	$8,245,000
Renourishment	2050	$27,724,000	$6,470,000
Renourishment	2056	$46,053,000	$8,639,000
Total Investment Cost, Present Value			$213,344,000
Annual Costs			
Interest & Amortization @ 4-1/8%			$10,145,000
Monitoring			$505,000
OMRR&R			$52,000
Total Annual Cost			$10,702,000
Cost level	Oct-10		

7.09.3 Benefit to Cost Ratio

With expected annual benefits of $40,129,000 and average annual costs of $10,702,000, the benefit to cost ratio for the Selected Plan, Plan 1550, is 3.7 to 1. The annual net benefits are $29,427,000. Because the project is justified solely on the basis of coastal storm damage reduction benefits, all incidental recreation benefits are being claimed in the benefit cost ratio.

7.09.4 Incremental Analysis

Incremental costs and benefits by reach are shown in Table 7.15 and graphically in Figure 7.5. For the incremental feasibility test, allowable recreation benefits cannot exceed hurricane and storm damage reduction benefits. Four reaches are shown with negative net benefits—reaches 28, 31, 34 and 56. Those reaches are included within the selected plan because a transition across the reaches would be required if they were omitted. The costs of the transitions would be close to the costs of the full dune and berm cross section. Therefore, omitting those sections does not actually omit the full cost of that reach as indicated in the table.

Table 7.15. Incremental analysis

Incremental Analysis of Typical Plan, 1550, by Reach, Annual Value 2010 Costs and Benefits, 4.125% interest rate

REACH	1550 CSDR Benefits	1550 Costs	1550 Net CSDR Benefits	1550 Recreation Benefits	1550 Allowable Recreation Benefits	1550 Total Benefits	1550 Total Net Benefits
27	$282,000	$262,000	$20,000	$387,500	$282,000	$564,000	$302,000
28	$17,000	$217,000	($200,000)	$387,500	$17,000	$34,000	($183,000)
29	$302,000	$247,000	$55,000	$387,500	$302,000	$604,000	$357,000
30	$153,000	$196,000	($43,000)	$387,500	$153,000	$306,000	$110,000
31	$62,000	$196,000	($135,000)	$387,500	$62,000	$124,000	($72,000)
32	$93,000	$197,000	($104,000)	$387,500	$93,000	$186,000	($11,000)
33	$136,000	$194,000	($58,000)	$387,500	$136,000	$272,000	$78,000
34	$30,000	$193,000	($163,000)	$387,500	$30,000	$60,000	($133,000)
35	$198,000	$184,000	$14,000	$387,500	$198,000	$396,000	$212,000
36	$123,000	$184,000	($61,000)	$387,500	$123,000	$246,000	$62,000
37	$237,000	$185,000	$53,000	$387,500	$237,000	$474,000	$289,000
38	$375,000	$217,000	$158,000	$387,500	$375,000	$750,000	$533,000
39	$336,000	$215,000	$121,000	$387,500	$336,000	$672,000	$457,000
40	$467,000	$215,000	$252,000	$387,500	$387,500	$854,500	$639,500
41	$388,000	$215,000	$173,000	$387,500	$387,500	$775,500	$560,500
42	$267,000	$215,000	$53,000	$387,500	$267,000	$534,000	$319,000
43	$499,000	$215,000	$284,000	$387,500	$387,500	$886,500	$671,500
44	$522,000	$215,000	$308,000	$387,500	$387,500	$909,500	$694,500
45	$476,000	$157,000	$319,000	$387,500	$387,500	$863,500	$706,500
46	$368,000	$158,000	$210,000	$387,500	$368,000	$736,000	$578,000
47	$649,000	$202,000	$447,000	$387,500	$387,500	$1,036,500	$834,500
48	$739,000	$202,000	$537,000	$387,500	$387,500	$1,126,500	$924,500
49	$886,000	$202,000	$684,000	$387,500	$387,500	$1,273,500	$1,071,500
50	$590,000	$157,000	$432,000	$387,500	$387,500	$977,500	$820,500
51	$150,000	$234,000	($84,000)	$387,500	$150,000	$300,000	$66,000
52	$648,000	$267,000	$381,000	$387,500	$387,500	$1,035,500	$768,500
53	$636,000	$268,000	$368,000	$387,500	$387,500	$1,023,500	$755,500
54	$390,000	$267,000	$123,000	$387,500	$387,500	$777,500	$510,500
55	$201,000	$234,000	($33,000)	$387,500	$201,000	$402,000	$168,000
56	$61,000	$234,000	($173,000)	$387,500	$61,000	$122,000	($112,000)
57	$254,000	$208,000	$46,000	$387,500	$254,000	$508,000	$300,000
58	$348,000	$208,000	$140,000	$387,500	$348,000	$696,000	$488,000
59	$315,000	$188,000	$127,000	$380,000	$315,000	$630,000	$442,000
60	$384,000	$188,000	$196,000	$380,000	$380,000	$764,000	$576,000
61	$198,000	$188,000	$10,000	$380,000	$198,000	$396,000	$208,000
62	$383,000	$175,000	$208,000	$380,000	$380,000	$763,000	$588,000
63	$316,000	$191,000	$125,000	$380,000	$316,000	$632,000	$441,000
64	$358,000	$208,000	$149,000	$380,000	$358,000	$716,000	$508,000
65	$307,000	$208,000	$99,000	$380,000	$307,000	$614,000	$406,000
66	$258,000	$208,000	$50,000	$380,000	$258,000	$516,000	$308,000
67	$345,000	$208,000	$138,000	$380,000	$345,000	$690,000	$482,000
68	$235,000	$207,000	$28,000	$380,000	$235,000	$470,000	$263,000
69	$201,000	$192,000	$9,000	$380,000	$201,000	$402,000	$210,000
70	$186,000	$192,000	($6,000)	$380,000	$186,000	$372,000	$180,000
71	$215,000	$203,000	$13,000	$380,000	$215,000	$430,000	$227,000
72	$576,000	$191,000	$385,000	$380,000	$380,000	$956,000	$765,000
73	$531,000	$191,000	$339,000	$380,000	$380,000	$911,000	$720,000
74	$462,000	$191,000	$270,000	$380,000	$380,000	$842,000	$651,000
75	$197,000	$190,000	$7,000	$380,000	$197,000	$394,000	$204,000
76	$162,000	$190,000	($28,000)	$380,000	$162,000	$324,000	$134,000
77	$194,000	$191,000	$3,000	$380,000	$194,000	$388,000	$197,000
78	$146,000	$163,000	($17,000)	$380,000	$146,000	$292,000	$129,000
27 to 78	$17,275,000	$11,025,000	$6,250,000	$20,505,000	$14,602,000	$35,107,000	$24,082,000

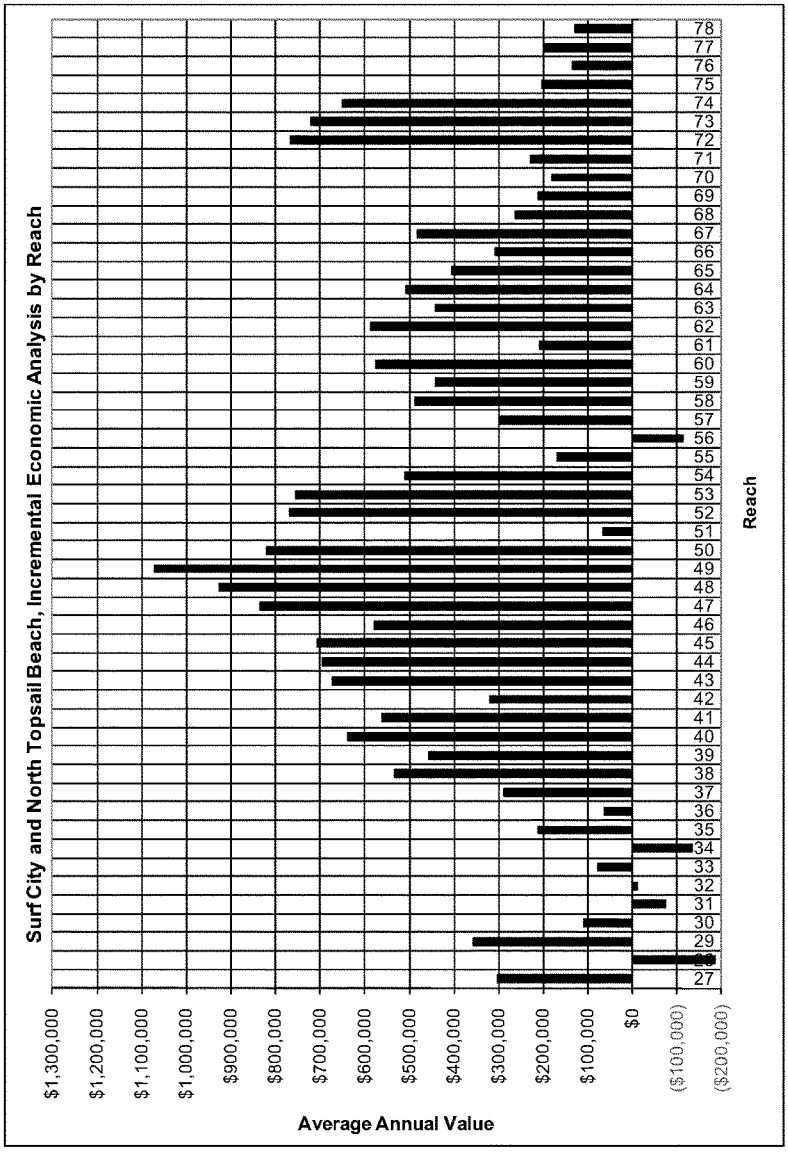


Figure 7.5. Net benefits by project reach.

7.10 Evaluation of Risk and Uncertainty

7.10.1 Residual Risks

The proposed beachfill plan would greatly reduce average annual storm damages. The selected plan, Plan 1550 would reduce combined wave and erosion damages by 88 percent. Some wave and erosion damages would still occur, estimated to average $2,241,000 per year over the 50-year period of analysis (Table 7.16). The project is designed to reduce damages mainly from storm waves and storm-induced erosion, two major categories of storm damage. The project would not prevent any damage from back bay flooding; therefore, any ground-level floors of structures, ground-level floor contents, vehicles, landscaping, and property stored outdoors on the ground would still be subject to saltwater flooding that flows in through New Topsail Inlet and New River Inlet and the back bay channels. However, flooding is a relatively minor issue in the first three rows of the island, which is where the benefits of the project are being measured. Flooding from all sources (back bay and ocean side) accounts for less than 1 percent of total expected damages to the first three rows in the without-project condition. Because the project is not claiming any benefits beyond the third row of the island, damages from flooding to structures past the third row have not been calculated. However, in major storm events, those structures could be subject to back bay flooding. Structures would also continue to be subject to damage from hurricane winds and windblown debris. Damages from flooding and winds would decrease as older structures are replaced with those meeting floodplain ordinances and wind hazard building construction standards. But even new construction is not immune to damage, especially from severe storm events. Also, the condition of the CSDR project at the time of storm occurrence can affect the performance of the project for that event.

The proposed beachfill would reduce damages but does not have a specific design level. In other words, the project is not designed to fully withstand a certain category of hurricane or a certain frequency storm event. The project purpose is storm damage reduction, and the berm-and-dune is not designed to prevent loss of life. Loss of life is prevented by the existing procedures of evacuating the barrier island completely, well before expected hurricane landfall and removing the residents from harm's way. The erratic nature and unpredictability of hurricane path and intensity require early and safe evacuation. That policy should be continued both with and without the storm damage reduction project.

Table 7.16. Residual risks, average annual values, 50-year period of analysis, 4.125% interest rate, October 2010 price level

Plan	Residual damages	CSDR benefits
No Action	$19,061,000	$0
Plan 1550, NED	$2,241,000	$16,820,000

7.10.2 Risk and Uncertainty in Economics

GRANDUC's life cycle approach to plan formulation explicitly incorporates risk and uncertainty into the formulation process. Three significant variables in GRANDUC are programmed to incorporate uncertainty, namely the following:

- erosion distance – plus or minus 5.0 ft.
- structure distance – plus or minus 2.0 ft.
- structure elevation – plus or minus 0.1 ft.

Given the probabilistic nature of the analysis, the dune-and-berm alternatives were evaluated to determine the percent chance that the alternative would have positive net benefits, or conversely, the risk of having negative net benefits. On the basis of analysis of 1,000 life cycles, the Selected Plan (15-ft. dune elevation with 50-ft. berm) has a 99.8 percent chance of having positive net benefits (i.e., less than a 0.2 percent risk of negative net benefits in any given year).

7.10.3 Risk and Uncertainty in Borrow Availability

Enough material has been identified in the borrow areas to supply the initial construction and periodic renourishments over the 50-year life of the project, although the measured surplus of material is a relatively low percentage of the estimated total. However, a risk exists that during the latter renourishment cycles of the project, no more material would be available in the designated borrow areas. For example, factors such as accelerated rates of sea level rise (SLR) and higher storm frequencies could lead to a more than anticipated volume of borrow material being required during the renourishment cycles. Also, refining the borrow area boundaries during the PED stage of the study could indicate that less volume is available in the areas then originally estimated. If borrow material from the designated areas were to run out, additional borrow material would need to come from a different site or sites, at a potentially higher cost. If that scenario begins to develop, a Limited Reevaluation Report on borrow sources would be initiated. The scope of the Limited Reevaluation Report would be to identify additional suitable borrow sources and to conduct a feasibility analysis of remaining costs and remaining benefits over the expected life of the project. A strong possibility exists that additional borrow material is available and accessible both in the designated sites and further offshore. For example, in the current sites, beach quality material may be available at greater volume than anticipated from the investigation because of densification of sand material during the vibracore sampling process. Also, because borrow area boundaries were interpolated on the basis of a limited amount of vibracores, a possibility exists that during the PED phase when additional vibracores are taken additional borrow material might be available adjacent to the defined boundaries. One specific area of note is borrow area C, where the ancestral New Topsail River channel (fluvial paleochannel) cuts as deep as 60 ft. into the underlying lithology (Greenhorne and O'Mara 2004) and extends throughout the 1- to 5-mile investigation boundary, intersecting borrow areas A, B, and C. The cores conducted in the paleochannel (TI-V-132, 185, 186, 187, 188, 189, 197)

indicate beach quality material is present at varying thickness (4 to 9 ft.) throughout the paleochannel.

For economic purposes in calculating project benefits, investigating the identified borrow areas was limited to about a 5.5 miles offshore boundary. No data exist as to the availability of borrow material beyond 5.5 miles; however, existing data from within the investigation boundaries indicate that the potential for additional sand resources exists beyond the 5.5 mile boundary. For example, cores that were taken in borrow areas C, E, F, G, and N that coincide with the 5.5-mile boundary indicate beach quality material. The cores include the following:

Borrow Area C

- TI-V-03-186: 3.3 ft. thick with an average silt content below 3.5 percent. 6.2 ft. thick with an average silt content of 5.5 percent
- TI-V-03-198: 3 ft. thick with an average silt content of 1.7 percent
- TI-V-03-199: 3 ft. thick with an average silt content of 1.4 percent

Between Borrow Area C and E

- TI-V-03-212A: 1.5 ft. thick with an average silt content of 1.8 percent
- TI-V-03-232: 1.8 ft. thick with an average silt content of 2.7 percent
- TI-V-03-239: 1.5 ft. thick with an average silt content of 3.6 percent

Borrow Area E

- TI-V-03-240: 2.8 ft. thick with an average silt content of 2.3 percent

Borrow Area F

- TI-V-03-245: 2.5 ft. thick with an average silt content of 1.6 percent
- TI-V-03-369: 3 ft. thick with an average silt content of 5.6 percent

Outside and within Borrow Area G

- TI-V-03-248: 1.4 ft. thick with an average silt content of 1.5 percent
- TI-V-03-255: 1.2 ft. thick with an average silt content of 0.7 percent
- TI-V-03-256: 2 ft. thick with an average silt content of 1.1 percent

Outside and within Borrow Area N

- TI-V-03-64: 1.5 ft. thick with an average silt content of 0.4 percent
- TI-V-03-63: 3 ft. thick with an average silt content of 1.2 percent

As illustrated by the data, the potential for additional beach quality material exists beyond the boundaries of the investigation. In terms of costs, going an additional mile offshore is estimated to increase unit costs by 4 percent, going 2 extra miles would increase costs by 9.7 percent, and going 3 extra miles would increase costs by 15.5 percent. The benefit-cost ratio of the project is high enough that going to an additional

borrow area several miles further offshore should not affect the economic feasibility of the plan.

The towns of Topsail Beach and North Topsail Beach have also identified other offshore borrow areas, containing approximately 8 million cubic yards of sand, that they intend to use for their own, nonfederally funded beachfill projects. They are known borrow areas from which remaining material could be used, if necessary, for the federal projects.

On the basis of all the factors outlined above, it is unlikely that the project would encounter a situation where no more sand could be reasonably obtained. Therefore, the risk to the project from potentially not having enough suitable material in the defined borrow areas is considered to be minimal.

7.10.4 Risk and Uncertainty in Sea Level Rise Assumptions

Sea-level change can cause a number of effects on coastal in estuarine zones, including changes in shoreline erosion and changes in storm and flood damages. SLR rates over time are the subject of many predictions. Historical trends in Mean Sea Level (MSL) are determined using measurement data from tide gauge records. Tidal records from nearby National Ocean Service tidal station in Wilmington, North Carolina (No. 865810) show a historical trend of 0.008 ft. per year from 1953 to 1993. This feasibility study uses that historical SLR rate to formulate the NED plan. Climate research has documented global warming during the 20th Century and has predicted continued or accelerated global warming ultimately resulting in continued or accelerated rise in sea level. Corps, Engineering Circular EC 1165-2-211 provides the guidance for considerations of accelerated SLR for federal civil works projects. The guidance uses the updated National Research Council projections (updated from 1987) as well as using the Intergovernmental Panel on Climate Change (IPCC 2007b) Fourth Assessment Report guidelines. The guidelines were used to bracket a range of possible SLR for the Surf City and North Topsail Beach area. The modified National Research Council SLR projections include three scenarios resulting in three curves of SLR thru 2100. The curves represent global eustatic sea-level rise values of 0.5 m and 1.5 m over the next 125 years. To investigate the sensitivity of the NED Plan to SLR, Curves 1 and 3 were used to bracket estimates in SLR. The Curve 1 projection indicates an SLR of 0.8 ft. 50 years after construction (year 2064), while Curve 3 indicates 2.2 ft. of SLR in 2064. For comparison, the historic SLR rate projects about 0.4 ft. of SLR in 2064 (see Figure 7.6).

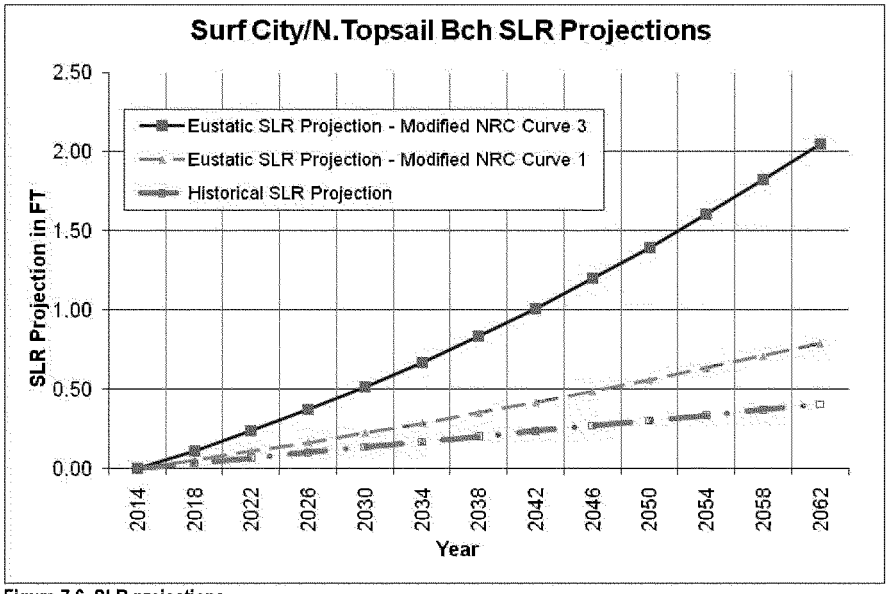


Figure 7.6. SLR projections

A sensitivity analysis of SLR effects on the NED Plan was conducted to estimate the with-project and without-project damages, benefits, and costs. The purpose of the sensitivity analysis was to determine if the project would still be economically feasible (greater benefits then costs) under higher rates of SLR, and not to provide project equivalent costs and benefits under the different scenarios. Note that the GRANDUC life cycle model does not allow a gradually occurring SLR, and therefore the sensitivity analysis represents a worst-case scenario in which total projected SLR over 50 years is immediately applied at year 1 of the modeling process. Full details of the analysis are included in Appendix D, Coastal Engineering. In summary, with accelerated SLR scenarios, the without-project damages are about six times greater than the with-project damages. Total project costs would increase 24 percent from additional erosion (using the most extreme estimate of 2.2 ft. of SLR over 50 years [NRC Curve 3] and worst case modeling scenario of it being applied all at the start of the project), but the project provides an additional 115 percent of damage reduction benefits. Realistically, since an immediate SLR of 2.2 ft is not possible, the actual increase in project costs would be much less than 24 percent, and therefore the chance of the project exceeding section 902 limits on the basis of accelerated sea level rise is extremely unlikely. A summary graph of the SLR scenarios analyzed and resulting modeling output is provided in Figure 7.7.

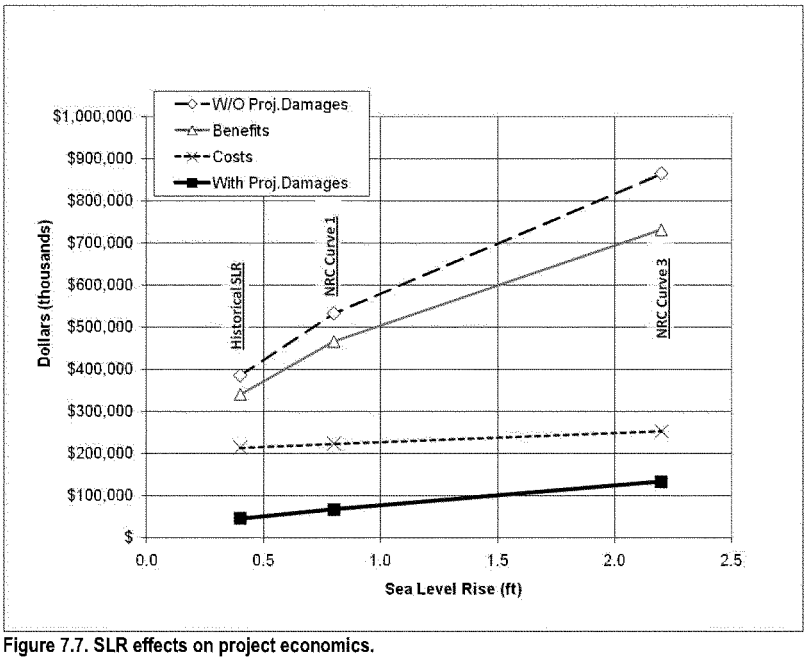


Figure 7.7. SLR effects on project economics.

The proposed beach nourishment project is not a hard structure and adjusts to natural forces. Regardless of the rate of SLR, the beach fill project would be monitored annually and renourished every 6 years. Monitoring data provides input to determining the details of each renourishment of the beach. If an accelerated SLR occurs, erosion volumes increase and renourishment volumes would increase, shortening the life of designated borrow areas. Under SLR Curves 1 and 3, approximately 1.4 million and 5.5 million extra cubic yards of material would be needed, respectively, over the life of the project (for more detail see Appendix D). If necessary, a Limited Reevaluation Report on borrow sources would be conducted to investigate additional borrow sources (see Section 7.10.3). All alternative plans contain a 7-ft. elevation berm, and all would be affected similarly by accelerated SLR. Therefore, no change to the Selected Plan by accelerated SLR would be expected other than minor modification of the berm elevation and possibly the dune elevation. There is no expectation that accelerated SLR would result in selection of other major categories of alternative plans such as the nonstructural plan or hard structure plans.

7.11 System of Accounts Evaluation

The plan selected for recommendation, Plan 1550, was based on the NED account alone. The plan is compared to the Nonstructural Plan and the No Action Alternative in Table 7.17. The plans are compared quantitatively in the NED account and qualitatively in the other three accounts—Regional Economic Development, Environmental Quality and Other Social Effects, as well in terms of risk.

Table 7.17. (1 of 7). System of Accounts, NED

Item	Beachfill	Nonstructural	No Action
Plan Description	Vegetated dune (elevation varies) fronted by nonvegetated, sandy beach berm at elevation 7 ft. NGVD, with beach then sloping to approximate natural slope. Includes NED Plan 15-ft elevation dune with 50-ft-wide berm. Specific amounts are shown for Plan 1550 at Oct. 2010 level of 4.125%.	Combinations of relocating existing beach structures either demolition, removal to new tract, or moving in same tract away from shoreline. Allow natural revegetation to occur on vacated lands on and landward of existing dune. Amounts for nonstructural plan shown for Oct. 2004 level at 5.375%.	No federal action, nor significant changes to existing nonfederal actions.
a. Damages Prevented (see Figure 7.8)	$16,820,000	$7,800,000	$0
b. Recreation Benefits	$20,505,000	$0	$0
c. Ben. During Construction	$2,804,000	$0	$0
d. Total Benefits	$40,129,000	$7,800,000	$0
e. Costs	$10,702,000	$30,200,000	$0
f. Net Benefits	$29,427,000	($22,400,000)	$0
g. Residual Damages	$2,241,000	$11,400,000	$19,061,000

Table 7.17. (*continued*) 2 of 7. System of Accounts, Regional Economic Development

Item	Beachfill Alternatives	Nonstructural Alternative	No Action
a. Sales Volume	Preserves rental sales and tourism markets.	Reduces rental market and tourism market.	Occasionally changes from tourism to reconstruction.
b. Income	Increased recreation visitation may improve the income of service industries.	Decreased recreation visitation may reduce the income of service industries.	Occasional loss of tourism income.
c. Employment	Preserves seasonal employment. Project construction employment increases during winter dredging months and when walkovers and dune vegetation are installed.	Minor reduction in employment related to maintaining structures and serving tourists. Increase in project construction employment during relocations and demolition.	Occasionally changes from tourism services to reconstruction.
d. Tax Changes	Tax base and property values preserved.	Moderate loss to tax base as front row structures and property are removed from property tax base and rental market.	Continued occasional storm losses to revenues, tax base and buildable lots.

Table 7.17. (*continued*) 3 of 7. System of Accounts, Other Social Effects, Part 1

Item	Beachfill Alternatives	Nonstructural Alternative	No Action
a. Security of Life, Health and Safety	Significant reduction in stress related to concern of amount of damage and recovery. Significant reduction in hazards associated with post-storm recovery and reconstruction.	Moderate reduction in stress related to concern of amount of damage and recovery. Moderate reduction in hazards associated with post-storm recovery and reconstruction.	No change. Continued stress during damaging storms.
b. Preservation of Life	No change. Evacuation required before storm landfall.	No change. Evacuation required before storm landfall.	No change. Evacuation required before storm landfall.
c. Community Cohesion	Reduces displacements of all permanent residents.	Permanently displaces oceanfront residents/visitors. Periodic displacement of other residents. Continued threat to Highway 50.	Occasional displacement of all permanent residents. Continued threat to Highway 50.
d. Community Growth	Growth trends in population and recreation visitation would continue.	No significant net change.	Occasional reductions in population and recreation visitation trends.

Table 7.17. (*continued*) 4 of 7. System of Accounts, Other Social Effects, Part 2

Item	Beachfill Alternatives	Nonstructural Alternative	No Action
e. Man-made Resources	Reduces risks to buildings, houses, and other structures.	Eliminates erosion risks to structures relocated. Demolishes those not suitable for relocation.	Continued erosion risks to buildings, houses, and other structures. Occasional replacement of heavily damaged structures.
f. Public Facilities	Reduces erosion and wave damages to streets and utilities nearest the shoreline.	Continued threat to streets and utilities near shoreline.	Continued threat to streets and utilities near shoreline.
g. Displacement of business	Reduces displacement of business.	Continued occasional disruption.	Continued occasional disruption.
h. Recreation and public access.	Improved appearance and utility of beach for recreation and requirement to maintain access for public. Infrequent storm litter.	Reduced lodging available for visitors. Continued narrowing of beach width. Infrequent storm litter.	Continued narrowing of beach width. Occasional littering of beach with storm debris.
i. Traffic and transportation	Prevents damage to streets and sole highway to Topsail Beach.	Continued risk to streets and highways. Major disruptions during house relocations.	Continued risk to streets and highways.

Table 7.17. (*continued*) 5 of 7. System of Accounts, Risk Evaluation

Item	Beachfill Alternatives	Nonstructural Alternative	No Action
a. Risk of Failure (risk that the project would not provide stated benefits)	Low. If renourishments occur on schedule, a beachfill plan should continue to provide reduction in damages. The selected plan has a 99.8% chance of having positive net benefits. There is also risk that borrow material from identified sources would run out in the future; however, additional nearby sources could be identified and used.	High. The benefits for this plan assume a high compliance rate, which is unlikely for beachfront properties.	N/A
b. Residual Risk (risk to structures and population once the plan is implemented)	Damages to structures would still occur from soundside flooding. In storms of greater intensity. Some wave and erosion damage would still occur. Structures are not protected from wind or windblown debris. There is still risk to loss of life if hurricane evacuation procedures are not followed.	Damages would still occur to structures from soundside flooding. Remaining structures would still be subject to wave and erosion damage, as well as wind damage. There is still risk to loss of life if hurricane evacuation procedures are not followed.	Damages to structures would not be reduced. There is still risk to loss of life if hurricane evacuation procedures are not followed.
c. Risk from accelerated SLR	Accelerated rates of SLR would increase project costs, but also increase project net benefits. Material running out in the identified borrow areas would be more likely to occur.	Accelerated rates of SLR would increase damages to remaining structures from waves, and erosion.	Accelerated rates of SLR would increase damages to all structures from waves and erosion.

Table 7.17. (*continued*) 6 of 7. System of Accounts, Environmental Quality, Part 1

Item	Beachfill Alternatives	Nonstructural Alternative	No Action
a. Ecosystem Restoration	Indirectly only, not an authorized project purpose.	Indirectly only, not an authorized project purpose.	No change.
b. Natural Resources	Increase in vegetated primary dune and upper beach habitat area.	Increase in undeveloped natural primary dune habitat.	Reduction of upper beach, dune, and upland habitat areas.
c. Biological Resources	Bottom substrate and bathymetry of nearshore ocean would be modified. Benthic organisms in borrow areas during dredging would be temporarily lost; however, recovery would be expectedwould be expected to occur within 1–2 years. Beach bulldozing very infrequently.	Occasional beach bulldozing and scraping would result in temporary losses to intertidal habitat and biota.	Occasional beach bulldozing and scraping would result in temporary losses to intertidal habitat and biota.
d. Threatened and Endangered Species	Reestablishment of beach and dune would benefit sea turtle nesting suitability and seabeach amaranth habitat. Hopper dredging offshore may increase risk of sea turtle take. Temporary loss to piping plover foraging habitat during construction.	Sea turtle nesting suitability would be reduced by continued erosion of beach, but improved by reduction of artificial lighting. No risk of incidental sea turtle take from hopper dredging. Improved piping plover conditions from reduced disturbance.	Continued erosion of beach would impact suitability and success of sea turtle nesting. No risk of incidental sea turtle take from hopper dredging. Continued loss of seabeach amaranth habitat. Piping plover foraging reduced occasionally by beach bulldozing.

Table 7.17. (*continued*) 7 of 7. System of Accounts, Environmental Quality, Part 2

Item	Beachfill Alternatives	Nonstructural Alternative	No Action
e. Water Quality	Temporary elevated turbidity during construction and renourishment in nearshore area and in off-shore borrow areas. Temporary impacts to benthic invertebrates feeding activities of shorebird and surf zone fish species.	No change.	No change.
f. Air Quality	Reduction offshore from dredging operations and onshore from earthmoving equipment.	Reduction during relocation and during demolition and hauling.	Occasional reduction during hauling of debris and reconstruction.
g. Noise Level Changes	Noise from mobilization/de-mobilization of equipment and pipeline. Noise from earthmoving equipment.	Noise during relocations, demolitions, and hauling.	Occasional noise from storm recovery and reconstruction.
h. Aesthetic Values	Improve appearance of beach and enhanced recreational quality. Temporary inconvenience during construction and renourishments, winter only.	More natural appearance of landscape immediately landward of dune on vacated properties. Continued deterioration of dune and beach appearance.	Continued deterioration of dune and beach appearance.
i. Cultural and Historical Preservation	No change, no such objects found in beach construction or borrow sites.	No change.	No change.
j. Total Quality of the Environment	Improvement of beach and dune. Temporary reduction during construction.	Short-term and long-term degradation of the beach and dune would continue. Increase habitat areas created landward of dune.	Short-term and long-term degradation of the beach and dune would continue.

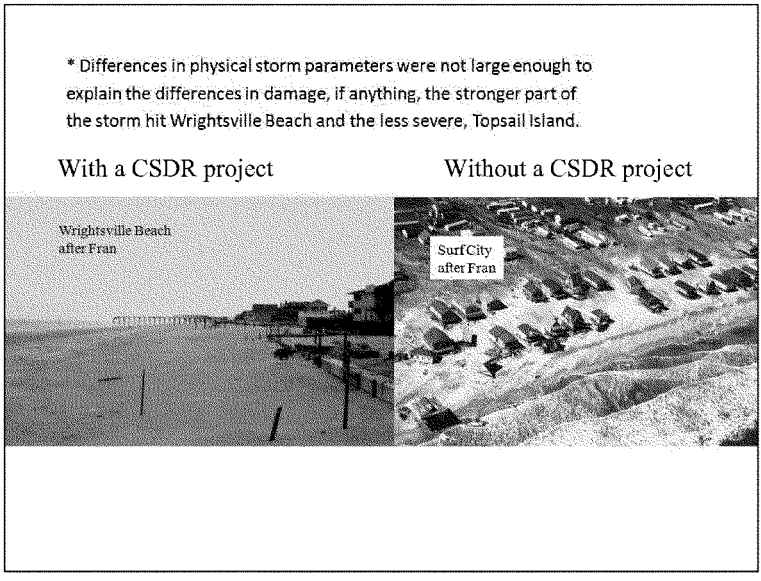


Figure 7.8. Example of differences in damages sustained in an area with and without a storm damage reduction project in place. (From USACE 2000).

8. ENVIRONMENTAL EFFECTS

The selected plan consists of a sand dune constructed to an elevation of 15 ft. NGVD, fronted by a 50-ft-wide beach berm constructed to an elevation of 7 ft. NGVD. The berm and dune project extends along a reach of 52,150 ft. Depending on endpoint conditions at the time of construction, up to 2,000 ft. of the berm and dune on the ends of the project could be replaced with a tapered transition section.

The proposed borrow sites are between 1 and 6 miles offshore at depths of 35 to 50 ft. MLLW. Initial construction would require 11.86 million cubic yards of borrow material. Renourishment would require 2.64 million cubic yards of borrow material at 6-year intervals. In total, about 32.3 million cubic yards of borrow material would be required for the 50-year project.

This section describes the probable consequences (impacts and effects) of the selected alternative on significant environmental resources in the project area. Natural communities that would be affected by the proposed action include the beach and dune and nearshore ocean as described below. Effects on wetlands and floodplains, inlets, flats, sounds and maritime shrub habitat would not be expected.

8.01 Marine Environment

8.01.1 Wetlands and Floodplains

The proposed borrow areas for the project are between 1 and 6 miles offshore; therefore, dredging operations would not be expected to adversely affect wetlands and floodplains of Surf City or North Topsail Beach. Nourishment operations would not be expected to adversely affect wetlands and floodplains. Section 10 includes additional discussion of wetlands and floodplains pursuant to Executive Order 11988 (Floodplain Management) and Executive Order 11990 (Protection of Wetlands).

8.01.2 Inlet, Flats, and Sounds

The proposed borrow areas for the project are between 1 and 6 miles offshore and would not be expected to adversely affect the inlet, flats, and sound of Surf City or North Topsail Beach. Because no sediment would be removed from the inlet complex for beach nourishment, impacts to inlet dynamics would not be expected. Although large quantities of sediment would be added to Surf City and North Topsail Beach to construct and maintain the project, the total volume of sediment added to the littoral system would not be expected to be significantly more than pre-project conditions. Furthermore, the southern and northern limits of the project are approximately 5 and 7 miles from New Topsail and New River inlets, respectively. Therefore, placing additional sediment on the beach would not significantly affect sand flat and shoal development in the inlet systems. The additional material would only accentuate the natural dynamics of the sand sharing system that exists. Therefore, nourishment operations would not be expected to adversely affect the inlet, flats, and sounds.

8.01.3 Surf Zone Fishes

The surf zone is a dynamic environment, and the community structure of organisms that inhabit it (e.g., surf zone fishes and invertebrates) is complex. Representative organisms of both finfish and the invertebrate inhabitants they consume exhibit similar recruitment periods. In North Carolina, the majority of invertebrate species recruit between May and September (Hackney et al., 1996; Diaz, 1980; Reilly and Bellis, 1978), and surf zone fish species recruit from March through September (Hackney et al., 1996). The anticipated construction time frame for the project is from December 1 to March 31 and would avoid a majority of the peak recruitment and abundance periods of surf zone fishes and their benthic invertebrate prey source.

The surf zone represents HAPC for some species, including adult bluefish and red drum, which feed extensively in that portion of the ocean. The surf zone is suggested to be an important migratory area for larval/juvenile fish moving in and out of inlets and estuarine nurseries (Hackney et al., 1996). Disposal operations along the beach can result in increased turbidity and mortality of intertidal macrofauna, which serves as food sources for those and other species. Therefore, feeding activities of the species could be interrupted in the immediate area of beach sand placement. Those mobile species are expected to temporarily relocate to other areas as the project proceeds along the beach. However, some species like Florida pompano and Gulf kingfish exhibit strong site fidelity during the middle portion (summer) of the nursery period (Ross and Lancaster, 2002) and might not avoid secondary effects (turbidity) of disposal. Because the project would avoid impacts to the surf zone during the summer months, it is expected that the project would not affect this period of strong site fidelity. Although a short-term reduction in prey availability could occur in the immediate disposal area, only a small area is affected at a time, and once complete, organisms can recruit into the nourished area. Such a recovery would begin immediately after disposal activity if the material is similar to the native beach (see Benthic Resources—Beach and Surf Zone Section 8.01.6).

According to Ross (1996) some surf zone fishes exhibit prey switching in relation to prey availability. Therefore, during periods of low prey availability, as a result of short-term impacts to the benthic invertebrate population during beach disposal activities, surf zone fishes may temporarily use alternative food sources. Considering the dynamic nature of the surf zone, such opportunistic behavior of avoidance and prey switching might enable some surf zone fishes to adapt to disturbances such as beach nourishment. A combination of short-term prey switching and temporary relocation capabilities may help mitigate short-term prey reductions during beach disposal operations. Once the placement operation is finished, physical conditions in the impact zone quickly recover and biological recovery soon follows. Surf-feeding fish can then resume their normal activities in the areas. That is supported in Ross and Lancaster's (2002) study in which Florida pompano and Gulf kingfish appeared to remain as long near a recently nourished beach as a beach that was not recently nourished.

Disposal and subsequent turbidity increases may have short-term effects on surf zone fishes and prey availability. However, the opportunistic behavior of the organisms within

the dynamic surf zone environment enables them to adapt to short-term disturbances. Because of the adaptive ability of representative organisms in the area and the avoidance of peak recruitment and abundance time frames with a December 1 to March 31 construction time frame, such effects would be expected to be temporary and minor.

8.01.4 Larval Entrainment

For many marine fishes, spawning grounds are believed to occur on the continental shelf with immigration to estuaries during the juvenile stage through active or passive transport. According to Hettler and Hare (1998), research suggests two bottlenecks that occur for offshore-spawning fishes with estuarine juveniles: the transport of larvae into the nearshore zone and the transport of larvae into the estuary from the nearshore zone. During that immigration period from offshore to inshore environments, the highest concentration of larvae generally occurs in the inlets as the larvae approach the second bottleneck into the estuary. Once through the inlet, the shelter provided by the marsh and creek systems in the sound serve as nursery habitat where young fish undergo rapid growth before returning to the offshore environment.

Those free floating planktonic larvae lack efficient swimming abilities and are, therefore, susceptible to entrainment by an operating hydraulic or hopper dredge as they immigrate from offshore to inshore waters. However, all the proposed borrow areas are between 1 and 6 miles offshore, and none of the borrow areas are in the vicinity of the New River Inlet or New Topsail Inlet complexes. Therefore, though concentrations of larvae would likely be present within offshore borrow areas, dredging activities would not occur in the highest concentration *inlet bottleneck* areas.

Susceptibility to this effect of entrainment is largely dependent on proximity to the cutter-head or drag-head and the pumping rate of the dredge. Those larvae present near the bottom would be closer to the dredge area and would, therefore, be subject to higher risk of entrainment. Assessment of the significance of the entrainment is difficult. Assuming the very small volumes of water pumped by dredges relative to the total amount of water in the dredging vicinity, a small proportion of organisms are presumed to be affected. Potential reasons for low levels of impact include the extremely large numbers of larvae produced by most estuarine-dependent species and the extremely high natural mortality rate for early life stages of many fish species. Because natural larval mortalities might approach 99 percent (Dew and Hecht, 1994; Cushing, 1988), entrainment by a hydraulic dredge would not be expected to pose a significant additional risk in most circumstances.

An assessment of potential entrainment effects of the proposed dredging action may be viewed in a more site-specific context by comparing the pumping rate of a dredge with the amount of water present in the affected waterbody. For the purposes of this assessment, assumptions would be made that inlet bottlenecks would have the highest concentrations of larvae as they are transported into the estuarine environment from the nearshore zone. Larval effects of dredging in this *high-concentration* system would be significantly greater than the entrainment risk of dredging in offshore borrow areas. The larval fish distribution, abundance seasonality, transport, and ingress at Beaufort Inlet,

North Carolina, has been extensively studied (Blanton et al., 1999; Churchill et al., 1999; Hettler and Barker, 1993; Hettler and Chester, 1990; Hettler and Hare, 1998). Therefore, it represents a good case study site for assessing larval entrainment of a hydraulic dredge. The largest hydraulic dredge likely to work in offshore borrow areas would have a discharge pipe about 30 inches in diameter and would be capable of transporting about 30,600 m^3 of sand per day if operated 24 hours (because of breakdown, weather, and the like, dredges generally do not work 24 hours a day, 7 days a week). The dredged sediment would be pumped as slurry containing about 15 percent sand and about 85 percent water by volume. The volume of water discharged would, thus, be about 173,000 m^3 per day, or about 2.0 m^3 per second. In contrast, the calculated spring tide flow through Beaufort Inlet (a representative North Carolina inlet) is approximately 142,000,000 $m^3 \times 2 = 284,000,000$ m^3 (i.e., two tides a day) of water and 264,000,000 m^3 during neap tide. Thus, the dredge would entrain only 0.06 to 0.07 percent of the daily volume flux through the inlet. According to Larry Settle (2002), the percentage of the daily flux of larvae entrained during a spring and neap tide is very low regardless of larval concentration and the distribution of larvae within the channel. Under the worst-case scenario with the highest concentrations of larvae possible based on spatial and temporal distribution patterns, the maximum percentage entrained barely exceeds 0.1 percent per day (for a more detailed analysis conducted by Larry Settle, see Appendix Q). Although any larvae entrained (calculations indicate 914 to 1.8 million depending on the initial concentration in the tidal prism) would likely be killed, the effect at the population level would be expected to be insignificant. On the basis of those calculations indicating an *insignificant* larval entrainment impact, at the population level, from hydraulic dredging activities within a representative high concentration *inlet bottleneck* at Beaufort Inlet, North Carolina, the risk of larval entrainment from dredging activities in the offshore borrow areas associated with this project would likely be even less and would not be expected to adversely affect marine fish larvae.

8.01.5 Nekton

Oceanic nekton are active swimmers, not at the mercy of the currents, and are distributed in the relatively shallow oceanic zone. They are composed of three phyla-chordates, mollusks, and arthropods, with chordates (i.e., fish species) forming the largest portion. Any entrainment of adult fish, and other motile animals in the vicinity of the borrow area during dredging would be expected to be minor because of their ability to actively avoid the disturbed areas. Fish species are expected to leave the area temporarily during the dredging operations and return when dredging ceases (Pullen and Naqvi, 1983). Larvae and early juvenile stages of many species pose a greater concern than adults because their powers of mobility are either absent or poorly developed, leaving them subject to transport by tides and currents. That physical limitation makes them potentially more susceptible to entrainment by an operating hydraulic dredge (see Section 8.01.4, Larval Entrainment). Benthic-oriented organisms close to the dredge draghead could be captured by the effects of its suction field and entrained in the flow of dredged sediment and water. As a worst-case, it could be assumed that entrained animals experience 100 percent mortality, although some small number might survive. Susceptibility to this effect depends on avoidance reactions of the organism, the efficiency of its swimming ability, its proximity to the draghead, the pumping rate of the dredge, and possibly other factors.

Behavioral characteristics of different species in response to factors such as salinity, current, and diurnal phase (daylight versus darkness) are also believed to affect their concentrations in particular locations or strata of the water column. Any benthic oriented organisms present near the ocean bottom (i.e., calico scallops and spiney dogfish (SAFMC-managed species) would be closer to the dredge draghead and, therefore, subject to higher risk of entrainment.

The biological effect of hydraulic entrainment has been a subject of concern for more than a decade, and numerous studies have been conducted nationwide to assess its effect on early life stages of marine resources, including larval oysters (Carriker et al., 1986), post-larval brown shrimp (Van Dolah et al., 1994), striped bass eggs and larvae (Burton et al., 1992), juvenile salmonid fishes (Buell, 1992), and Dungeness crabs (Armstrong et al., 1982). The studies indicate that the primary organisms subject to entrainment by hydraulic dredges are bottom-oriented fishes and shellfishes. The significance of entrainment effects depends on the species present; the number of organisms entrained; the relationship of the number entrained to local, regional, and total population numbers; and the natural mortality rate for the various life stages of a species. Assessing the significance of entrainment is difficult, but most studies indicate that the significance of impact is low. Effects of dredging activities on marine mammals and sea turtles are addressed in the biological assessment (Appendix I). Although entrainment of benthic oriented organisms would be expected from the proposed dredging activities, a hydraulic dredge operating in the open ocean would pump such a small amount of water in proportion to the surrounding water volume that any entrainment effects associated with dredging of borrow material for the project are not expected to adversely affect species at the population level. In accordance with T&E species observer requirements for hopper dredging activities (See appendix I), inflow screening, as well as observation of dredged material is required to assure accountability of species entrained by the draghead. As a component of hopper dredge observer requirements, all other biota (i.e., fish, bivalves) captured by the inflow screening are recorded and submitted to the Corps for incorporation into a historic entrainment database.

8.01.6 Benthic Resources—Beach and Surf Zone

Beach nourishment may have negative effects on intertidal macrofauna through direct burial, increased turbidity in the surf zone, or changes in the sand grain size or beach profile. Literature dating back to the early 1970s along the southeast coast indicate that opportunistic infauna species (e.g., *Emerita* and *Donax*) found in the nourished areas are subject to direct mortality from burial; however, recovery often occurs within one year (Hayden and Dolan, 1974; Saloman, 1984; Van Dolah et al., 1992; Van Dolah et al., 1993; Jutte et al., 1999) especially if compatible material is placed on the beach (Hayden and Dolan, 1974; Reilly and Bellis, 1978; Saloman, 1984; Nelson, 1989; Van Dolah et al., 1992; Van Dolah et al., 1993; Hackney et al., 1996; Jutte, P.C. et al., 1999; Peterson et al., 2000). In North Carolina, post-nourishment studies have documented similar reductions in abundance of coquina clams (*Donax* spp.), mole crabs (*E. talpoida*), and amphipods (*Haustoriid* spp.) immediately following disposal with recovery times persisting between one and three seasons after project construction depending on

sediment compatibility (Reilly and Bellis 1983; Peterson et al., 2000; and Coastal Science Associates, Inc., 2002).

Reilly and Bellis (1978) state, "Beach nourishment virtually destroys existing intertidal macrofauna; however, recovery is rapid once the pumping operation ceases. In most cases, recovery should occur within one or two seasons following the project completion." Similar findings were reached by Van Dolah (1992) in a study of the effects of a beach nourishment project in South Carolina. A study by Dolan et al. (1992) of the effects of beachfill activities on mole crabs at the Pea Island National Wildlife Refuge, Dare County, North Carolina, indicates that while nourishment has a dramatic effect on mole crabs in the area where beachfill is placed, mole crabs returned to the beach areas that were nourished soon after pumping stopped.

While beach nourishment may produce negative effects on intertidal macrofauna, they would be localized in the vicinity of the nourishment operation. Beach nourishment conducted as a component of the proposed action would be expected to move along the beach at a relatively slow rate (i.e., about a mile per month or about 200 ft. per day). Such a rate of progress is slow enough that surf-feeding fishes and shorebirds can move to other areas that are not affected by the nourishment operation. As the dredging operation passes by a section of beach, that area is soon available for recolonization by invertebrates.

In a 1999 Environmental Report on the use of federal offshore sand resources for beach and coastal restoration, U.S. Department of Interior, MMS provided the following assessment of potential effects on beach fauna from beach nourishment.

> Because benthic organisms living in beach habitats are adapted to living in high energy environments, they are able to quickly recover to original levels following beach nourishment events; sometimes in as little as three months (Van Dolah et al. 1994; Levisen and Van Dolah, 1996). This is again attributed to the fact that intertidal organisms are living in high energy habitats where disturbances are more common. Because of a lower diversity of species compared to other intertidal and shallow subtidal habitats (Hackney et al. 1996), the vast majority of beach habitats are re-colonized by the same species that existed before nourishment (Van Dolah et al. 1992; Nelson 1985; Levisen and Van Dolah, 1996; Hackney et al. 1996).

As a component of their review of the potential effects of beach nourishment on surf zone fishes and invertebrates in the South Atlantic Bight, Hackney et al. (1996) identified nine fish species and five invertebrate species/groups that are important inhabitants of the intertidal and subtidal beach environment. According to their literature review of associated impacts to these species and how best to protect the natural resources associated with beach nourishment, they identified four management questions to address for each nourishment project: (1) project timing, (2) sediment compatibility, (3) nourishment duration, and (4) innovative ways to minimize effects (i.e., staging nourishment events). Those questions were considered during planning efforts associated with the proposed dredging and beach construction efforts for this project. The proposed

dredging window of December 1 through March 31 for initial construction and each nourishment event avoids the identified peak recruitment periods for surf zone fish (March through September [Hackney et al., 1996]) and invertebrate species (May through September [Hackney et al., 1996; Diaz, 1980; Reilly and Bellis, 1978]) in North Carolina. Beach nourishment would therefore be completed before the onshore recruitment of most surf zone fishes and invertebrate species. Furthermore, to complete the full initial construction template, while adhering to the December 1 to March 31 dredging window, the construction effort would occur over a 4-year period. Therefore, the duration of each initial construction effort and each subsequent renourishment effort would be limited so that it does not preclude recruitment for any species during its entire recruitment period. Additionally, in accordance with recommendations provided by Hackney et al. (1996), the four initial construction events would occur in stages along the beach, with the full template being constructed for each stage, instead of the entire beach being affected within each construction event. This approach would also increase the speed of recovery for affected areas by allowing for recruitment from adjacent unaffected areas of the beach. To assure compatibility of nourishment material with native sediment characteristics and minimize impacts to benthic invertebrates from the placement of *incompatible* sediment, all sediment identified for use for the project would meet the *Technical Standards for Beachfill Projects* (15A NCAC 07H.0312) identified in the NCDCM rule language. During each renourishment interval, any loss of intertidal organisms would be temporary, as repopulation would be expected to begin as soon as the renourishment operation ends with recolonization of the beach by organisms from adjacent unaffected areas and offshore.

In summary, temporary effects on intertidal macrofauna in the immediate vicinity of the beach nourishment project would be expected as a result of discharges of nourishment material on the beach. While the proposed beach nourishment may adversely affect intertidal macrofauna, with the implementation of environmental measures discussed above, such effects would be expected to be localized, short-term, and reversible. Any reduction in the numbers or biomass (or both) of intertidal macrofauna present immediately after beach nourishment may have localized limiting effects on surf-feeding fishes and shorebirds because of a reduced food supply. In such instances, those animals may be temporarily displaced to other locations.

8.01.7 Benthic Resources—Nearshore Ocean

Individual borrow areas, or a combination of borrow areas, could be used for each construction event throughout the 50-year duration of the project. All the borrow areas are offshore of Topsail Island between 1 and 6 miles offshore. The offshore borrow areas beyond 3 nautical miles offshore would be subject to federal mining requirements of the MMS. Multiple dredging areas within a given borrow site may be used to reduce material transport or allow for concurrent operation of more than one dredge in an area. Considering the distance offshore and the shallow volumes of sediment within the borrow areas, it is anticipated that all dredging activities associated with initial construction and each renourishment interval would be conducted using a hopper dredge. Hopper dredges are mobile and are most productive dredging smaller depths of cut of approximately 3 ft. over larger areas rather than dredging to larger depths of cut over

smaller areas, as is the case with hydraulic cutterhead dredges. The depth of hopper dredge cut would vary depending on the availability of suitable sandy material within each borrow area and dredge plant capabilities. On the basis of existing vibracore data, the anticipated average dredging depths for all borrow areas off of Topsail Island are provided in Table 8.1.

Table 8.1. Anticipated dredge cut depths and subsequent post-dredge surface elevations for borrow areas located offshore of Topsail Island based on vibracore data

Borrow area	Pre-dredge surface elevation (MLLW)	Post-dredge surface elevation (MLLW)	Thickness range	Average thickness
A	–38.5 to –49	–40.5 to –54.8	2 to 9.3	4.4
B	–42.2 to –43.2	–45.2 to –47.6	2 to 5.4	3.7
C	–45.5 to –47.7	–48 to –51	2 to 4.5	2.8
D	–43.5 to –46.9	–46.5 to –53.6	2 to 6.7	3.9
E	–49 to –50	–52.8 to –53	2.8 to 4	3.4
F	–47.2 to –48	–49.7 to –51	2.5 to 3	2.8
G	–46.5 to –49	–49.3 to –54	2 to 5.5	3.7
H	–44.4 to –45.2	–46.6 to –50	2.2 to 4.8	3.5
J	–42 to –47.4	–45.6 to –55	2 to 8.3	3.7
L	–42.3 to –47	–45.3 to –60.8	2 to 13.8	4.2
N	–43.6 to –46.7	–46.4 to –59.1	2.3 to 14.8	5.1
O	–40.6 to –43.9	–44.7 to –55	2 to 12.7	6.4
P	–39.5 to –40.5	–42.5 to –51	2 to 10.5	5.7
Q	–35.2 to –35.4	–39.6 to –41.2	4.2 to 6	5.1
S	–43.8 to –44.8	–46.1 to –47.7	2.2 to 3.5	2.6
T	–37.2 to –42	–40.4 to –49.2	2.2 to 8.6	4.2

A few outlier vibracores with compatible sediment thicknesses of 10.5, 12.7, 14.8, and 13.8 ft. were identified in borrow areas P, O, N, and L, respectively; however, insufficient vibracore data exists to assume that dredging depths significantly greater than the identified averages would be achieved. According to the existing pre-dredge depths and the anticipated average depths of material removed, post-project borrow area depressions would likely not exceed about 50 to 60 ft. of depth.

Because all proposed offshore borrow areas are beyond the –35-ft. contour and the proposed depth of closure for this project is –23 ft, significant infilling of the borrow areas as a result of longshore sediment transport processes would not be expected to occur. However, considering the shallow dredge volumes of material to be removed from the borrow areas, some infilling of sediments could still occur from other storm- and current-driven processes. Monitoring studies of post-construction borrow areas in the southeast indicated that borrow areas can fill in and return to near pre-dredging conditions when there is adequate transport of sediment under the influence of strong currents in the area (Bowen and Marsh, 1988). Although, some infilling of the borrow areas is anticipated from sedimentation and side sloughing, as well as wind- and tidal-driven currents, the bathymetric feature of the post-dredging borrow area would be expected to persist.

The post-dredge infilling rate and quality and type of the material are contributing factors to the recovery of the area dredged. Data collected by Saloman (1974) indicate that low densities and diversities of benthic fauna within the borrow area compared to control sites can be attributed to thick deposits of gelatinous, organic-rich sediments that lead to low dissolved oxygen concentrations. The MMS (1999) indicates that the bottom substrate at and near a borrow area can be modified in several ways. A change in bottom contour could be evident throughout the project life and post-construction populations can differ from pre-construction conditions. A change in the hydrologic regime as a consequence of altered bathymetry may result in the deposition or scour of fine sediments, which may result in a layer of sediment that differs from the existing substrate. Also, once material in the borrow areas is dredged, it is possible that different post-dredging underlying sediment types would be exposed and would be different from pre-dredging sediment types.

Benthic organisms within the defined borrow areas dredged for construction and periodic nourishment would be lost. However, recolonization by opportunistic species would be expected to begin soon after the dredging activity stops. Because of the opportunistic nature of the species that inhabit the soft-bottom benthic habitats, recovery would be expected to occur within 1–2 years. Rapid recovery would be expected from recolonization from the migration of benthic organisms from adjacent areas and by larval transport. Monitoring studies of post-dredging effects and recovery rates of borrow areas indicates that most borrow areas usually show significant recovery by benthic organisms approximately 1 to 2 years after dredging (Naqvi and Pullen, 1982; Bowen and Marsh, 1988; Johnson and Nelson, 1985; Saloman et al., 1982; Van Dolah et al., 1984; and Van Dolah et al. 1992). According to Posey and Alphin (2000), benthic fauna associated with sediment removal from borrow areas off of Carolina Beach recovered quickly with greater inter-annual variability than differences from the effects of direct sediment removal. However, a potential change in species composition, population, and community structure may occur from the initial sediment removal impact and the change in surficial sediment characteristics, resulting in the potential for longer recovery times (2–3 years) (Johnson and Nelson, 1985; Van Dolah et al., 1984). Differences in community structure may occur that may last 2–3 years after initial density and diversity levels recover (Wilber and Stern, 1992). Specifically, large, deeper-burrowing infauna can require as long as 3 years to reach pre-disturbance abundance. According to Turbeville and Marsh (1982), long-term effects of a borrow site at Hillsboro Beach, Florida, indicated that species diversity was higher at the borrow site than at the control site. Jutte et al. (1999 and 2001) evaluated recovery rates of post-hopper dredged borrow areas and found that hopper dredging creates a series of ridges and furrows, with the ridges representing areas missed by the hopper dredge. Rapid recolonization rates were documented because of the dredge's inability to completely remove all the sediment. Furthermore, Jutte et al. (2002) documented that dredging to shallower depths is less likely to modify wave energy and currents at a borrow site; thus, reducing the likelihood of infilling of fine-grained sediment.

According to Cahoon et al. (1990 and 1992), primary production in Onslow Bay is characterized as being dominated by benthic microalgae, rather than phytoplankton. Therefore, Onslow Bay food web interactions with demersal zooplankton grazers are significant. However, on the basis of existing depths of the proposed borrow areas, the maximum post-dredging depth would likely not exceed about 60 ft. According to Dr. Cahoon (Larry Cahoon, personal communication, October 24, 2006), although a direct, short-term dredging impact would occur, benthic microalgae are very adaptable to disturbance, and the effects of dredging would likely be no more significant than large storm events. The chlorophyll *a* concentrations decrease as depth increases; however, solar irradiance at 60 ft. is not a limiting factor, and recruitment of benthic microalgae at the proposed post-dredging depths (maximum of ~60 ft.) would be expected to occur fairly quickly (about 4–6 weeks). Furthermore, microalgae biomass is less in the winter; thus, because the dredging window for initial construction and each nourishment interval is December 1 through March 31, biomass would be low during periods of impact and when the dredging window ends, spring time recruitment would begin (Larry Cahoon, personal communication, October 24, 2006)).

As identified in Section 8.01.8.2, dredging in the selected borrow areas would not be expected to have an adverse physical effect on any hard bottom in the area. Though secondary sedimentation effects could occur from dredging operations, they would likely not exceed natural sedimentation and burial levels, provided strict adherence to buffer requirements for all offshore activities. However, strong trophic linkages exist between hard-bottom communities and adjacent soft-bottom habitat. Though hard-bottom communities have been considered highly productive, self-sustaining habitats, the primary food resource of reef associated fishes is not solely supported by attached or associated motile benthic organisms. Data collected off North Carolina's Onslow Bay hard-bottom communities suggest that benthic microalgae are an important source of soft-bottom primary production supporting reef fishes (Lindquist et al., 1994). Benthic microalgae are concentrated at the sediment-water interface and are grazed by demersal zooplankton, meiobenthos, and many macrofaunal sand-bottom animals (Cahoon et al., 1990). According to Lindquist et al. (1994), gut content analysis of reef fishes indicated that an important benthic food chain connection between benthic microalgae concentrations, associated demersal zooplankton, and infaunal macroinvertebrates from sand substrata adjacent to hard-bottom communities are important to the diet of reef fishes. Therefore, rather than hard bottoms being self-sustaining communities, reef-associated predators depend adjacent soft-bottom communities for food. According to Posey and Ambrose (1994), benthic macrofaunal abundances near a rock ledge near Wrightsville Beach, North Carolina, indicated significantly higher abundances of total infauna, and of polychaetes, bivalves, isopods, and scaphopods, at a distance of 75 m (225 ft) from the rock ledge. Those data, suggesting a zone of decreased prey abundance (i.e., *halo*) adjacent to predator refugia, provide support for a trophic link between hard bottom ledges and soft bottom communities. On the basis of the proposed hard-bottom dredging buffer distances discussed in Section 8.01.8.2, dredging of sediment within the vicinity of hard-bottom resources (moderate and high relief – 500 m (1,640 ft.) buffer; low relief – 400 ft. (122 m)) would not be expected to directly affect this documented tropic link within the 75-m (225-ft) halo from the hard-bottom ledge.

Effects on estuarine-dependent organisms are not expected to be significant because construction-related activities in the offshore borrow areas and on beaches proposed for nourishment would be localized. A study of nearshore borrow areas after dredging offshore of South Carolina revealed no long-term effects on fishery and planktonic organisms, as a result of the dredging (Van Dolah et al., 1992). In a 1999 Environmental Report on the use of federal offshore sand resources for beach and coastal restoration, the U.S. Department of Interior MMS provided the following assessment of potential turbidity impacts.

> The impacts from turbidity on benthic organisms during dredging operations were reviewed in detail by Pequegnat et al. (1978) and Stern and Stickle (1978). Both studies concluded that impacts to the benthic populations of the marine ecosystem from turbidity are local and temporary but not permanent. Similarly, recent studies show that benthic impacts may be limited to the immediate vicinity of dredging operations (e.g., Hitchcock et al. 1998; MMS 1996).

8.01.8 Essential Fish Habitat

The FMP amendments of the SAFMC identify more than 30 categories of EFH and HAPC, which are listed in Table 8.2. Fish species managed by the SAFMC and their association with those categories of EFH and HAPC are identified in Table 8.2. While all those habitat categories occur in waters of the southeastern United States, only a few occur in the immediate project vicinity or the project impact zone. The proposed project would avoid direct effects on estuarine areas; therefore, only identified EFH and HAPC in marine areas might be directly affected. Effects on habitat categories potentially present in the project vicinity are discussed in the following subsections.

Table 8.2. Categories of EFH and HAPC and potential impacts

Essential Fish Habitat	Potential presence		Potential impacts	
Estuarine areas	**In/near project vicinity**	**Project impact area**	**Dredge plant operation**	**Sediment disposal activities**
Estuarine Emergent Wetlands	no	no	no	no
Estuarine Scrub/Shrub Mangroves	no	no	no	no
Submerged Aquatic Vegetation (SAV)	no	no	no	no
Oyster Reefs & Shell Banks	no	no	no	no
Intertidal Flats	no	no	no	no
Palustrine Emergent & Forested Wetlands	no	no	no	no
Aquatic Beds	no	no	no	no
Estuarine Water Column	Yes	no	no	no
Seagrass	no	no	no	no
Creeks	no	no	no	no
Mud Bottom	no	no	no	no
Marine areas				
Live/Hard Bottoms	Yes	Yes	W/in Acceptable Limits	no
Coral and Coral Reefs	no	no	no	no
Artificial/Man-made Reefs	Yes	no	no	no
Sargassum	offshore	no	no	no
Water Column	Yes	yes	W/in Acceptable Limits	W/in Acceptable Limits

Table 8.2. (*continued*)

Geographically Defined HAPC

Area-wide				
Council-designated Artificial Reef Special Management Zones	no	no	no	no
Hermatypie (reef-forming) Coral Habitat and Reefs	offshore	no	no	no
Hard Bottoms	Yes	Yes	W/in Acceptable Limits	no
Hoyt Hills	no	no	no	no
Sargassum Habitat	offshore	no	W/in Acceptable Limits	no
State-designated Areas of Importance of Managed Species (PNAs)	yes	no	no	W/in Acceptable Limits
Submerged Aquatic Vegetation (SAV)	no	no	no	no
North Carolina				
Big Rock	distant offshore	no	no	no
Bogue Sound	no	no	no	no
Pamlico Sound at Hatteras/Ocracoke islands	no	no	no	no
Cape Fear sandy shoals	No	no	no	no
Cape Hatteras sandy shoals	No	no	no	no
Cape Lookout sandy shoals	No	no	no	no
New River	Yes	no	no	no
The Ten Fathom Ledge	distant offshore	no	no	no
The Point	distant offshore	no	no	no

194

8.01.8.1 Effects on the Estuarine Water Column

All proposed borrow areas are approximately 1 to 6 miles offshore beyond 35-ft. MLLW; thus, dredging operations would not be expected to directly affect the estuarine water column, and therefore, would not be expected to directly affect estuarine life cycle requirements of managed species in the South Atlantic Region. However, the selected 1550 beach nourishment plan consists of a berm and dune project along a reach of 52,150 ft. Short-term, elevated turbidity levels could occur during the nourishment operation and could be transported outside the immediate disposal area via longshore and tidal currents. However, the nearest inlet (New River Inlet) is more than 7 miles to the north of the northern terminus of the project. Therefore, turbidity associated with the beach nourishment operation could extend into the New River Inlet vicinity and the estuarine water column from longshore currents and tidal influx; however, the associated effects would not be expected to be significant.

8.01.8.2 Effects on Hard Bottoms

Background

Hard-bottom communities are within state waters throughout the North Carolina coast, including the vicinity of the proposed SCNTB coastal storm damage reduction project. Depending on the location of these hard-bottom communities to the proposed project site, they could be vulnerable to shoreline alterations or dredging operations or both (Moser and Taylor, 1995). However, as discussed in Section 2.01.10 to develop a detailed understanding of the existing hard-bottom resources both in the nearshore and offshore environments of the project area, multiple contracts including remote sensing and in-situ ground-truth dive operations were implemented. That detailed hard-bottom resource data provided a better understanding of location and characterization of the sites relative to available sand resources. Thus, they enable the Corps to refine the limits of the identified borrow areas to avoid effects on the resources. To guide the decision process for collecting hard-bottom resource data, a PDT was developed to specifically discuss hard-bottom issues as a component of the project. The PDT consisted of state and federal resource agency representatives with an interest or expertise in hard-bottom communities. Also, concurrent with the resource evaluations being developed for the project, the town of North Topsail Beach and its consultant CPE were performing hard-bottom resource evaluations as a component of a separate nonfederal coastal storm damage reduction project for North Topsail Beach. To ensure consistency in the collection of resource data and avoid duplication of data-collection efforts, representatives of CPE were also included in the PDT. Members of the team provided comment on the development of scopes of work for each field investigation contract to ensure that all concerns for the data-collection procedures were addressed before task completion. On completion of each consecutive contract, the PDT was briefed of the results, and comments were solicited to identify what data gaps still existed and what actions were still necessary to assure avoidance of hard-bottom resource effects in both the nearshore and offshore environment as a component of the beach profile equilibration and dredging processes, respectively. The consistent coordination of hard-bottom resource evaluations among the PDT throughout the planning process of the project ensured team concurrence on what steps were necessary to fulfill critical data gaps and

resulted in a detailed understanding of hard-bottom resource location and characterization throughout the project area.

On the basis of the hard-bottom resource evaluations completed in both the nearshore and offshore areas of Surf City and North Topsail Beach, actions associated with both the nearshore beachfill template construction (including hopper dredge pumpout stations and associated pipeline routes), and the associated offshore dredging operations, were refined to avoid effects on identified hard-bottom communities. Therefore, no direct effects associated with the physical dredging operation or associated construction activities (i.e., pipeline route) would be expected to occur. Potential project effects relative to the beachfill construction and associated equilibration process in the nearshore environment and the dredging and associated sedimentation and turbidity in the offshore environment are discussed below.

Nearshore (< –7 m [–23 ft.] NGVD)
The long-term and short-term limits of cross-shore sediment transport are important in engineering and environmental considerations of beach profile response. Significant quantities of sand-sized sediments can be transported and deposited seaward as a result of short-term erosional events and the equilibration of a constructed beach profile. Over time, the evolving profile advances seaward into deeper water until it approaches equilibrium; however, sediment particles can be in motion at greater depths than those at which profile readjustment occurs. The seaward limit of effective profile fluctuation over long-term time scales is referred to the *closure depth*. On the basis of calculations derived from the Corps Coastal Engineering Manual (2002), the calculated Depth of Closure for this study is –7 m (–23 ft.) NGVD. On the basis of the remote sensing data collected in the –7 m (–23 ft.) contour and the in-situ diver ground-truth investigations of identified anomalies from the remote sensing data, no hard-bottom features were identified in the calculated depth of closure for the study. The anomalies identified from the side-scan and multibeam survey results were not hard-bottom resources but regions of course gravel and shell hash that extend as shallow, depressional features perpendicular to shore. Ground truth dive investigation transects were specifically in traverse transitional areas identified in the side-scan sonar data. Divers were able to capture video of the transitional regions of sediment grain size, and sediment samples were gathered both in and outside the features to confirm that the side-scan sonar acoustic signature documented a transition from fine- to course-grained sediment, not consolidated, hard-bottom features. Such RSDs, RCDs, and sorted bedform features are common throughout North Carolina and are thought to be the result of a feedback mechanism whereby an existing deposit of coarse shell hash and gravel material is built on and segregated from fine material because of wave motion interacting with the enhanced roughness of the seafloor bed around those patches of coarse material (Cacchione et al., 1984; Thieler et al., 1999; Thieler et al., 2001; Murray and Thieler, 2004).

On the Pacific Coast, Cacchione et al. (1984) identified surficial sedimentary features of the shoreface and inner shelf environments with slight topographic expressions (~1 m (3.28 ft.) total relief) about 100–200 m (328–656 ft.) wide and extending hundreds to thousands of meters in the cross-shore direction. Those features were composed of course

sand (in some cases shell hash and gravel) and arranged into large wave-generated ripples. Termed, RSDs the features are attributed to areas of intensified cross-shore flow that preferentially winnow fine material, leaving a course lag parallel to flow. Similar geologic features were later identified throughout the Atlantic Coast, including off the coast of North Carolina and South Carolina (McQuarrie, 1998; Thieler et al., 1999; Thieler et al., 2001).

According to McQuarrie (1998), an approximately 102 square km area was surveyed using side-scan sonar, high-resolution seismic, and vibracores on the shoreface and inner shelf of Onslow Bay. The study characterized the inner shelf off Topsail Island as Tertiary and Pleistocene outcrops with a thin, discontinuous, loose surficial sheet of sediment. In addition to continuous quaternary fluvial channels traced shore perpendicular across the shore face, wave and current action on the shoreface generates RCDs on the shoreface. Vibracore and surface sediment samples in and outside the features were consistent with RSD sediment data identified in other studies (Cacchionne et al., 1984; Thieler et al., 1999; Thieler et al., 2001).

Side scan imagery from Theiler et al. (1999) identified subtle shore oblique bathymetric expressions of high acoustic reflectivity dominating the shoreface and inner shelf of Wrightsville Beach, North Carolina, and Folly Beach, South Carolina. The depressional features had 1-m (3.28-ft.) vertical relief across widths of hundreds of meters and were associated with RSDs as defined by Cacchione et al. (1984). According to Thieler (1999), individual RSDs were approximately 40–100 m (131–328 ft.) wide on Wrightsville Beach, North Carolina, and Folly Beach, South Carolina, and are up to 1-m (3.28-ft.) deep on the upper shoreface, but have a much more subdued (~50 cm (~1.6 ft.)) bathymetric expression further offshore. Most depressions develop just outside the surf zone at 3–4 m (9.8–13.1 ft.) water depth and extend into the inner shelf at 15 m (49.2 ft.). Vibracore data from Thieler et al. (2001) indicate that these RSD features are floored by course sand, shell hash, and quartz gravel and are surrounded by areas of fine sand. The study sites appear to be relatively stable or represent a recurring, preferential morphologic state to which the seafloor returns after storm-induced perturbations. The apparent stability is interpreted to be the result of interactions at several scales that contribute to a repeating, self-reinforcing pattern of forcing and sedimentary response that ultimately causes the RSDs to be maintained as bedforms responding to both along and across shore flows. According to Dr. Bill Cleary (personal communication), the presence of RSDs/RCDs/sorted bedforms as identified through side-scan imagery off Topsail Beach are ubiquitous from Topsail Beach through Wrightsville Beach. Side-scan sonar imagery identifying the same features exists for Figure Eight Island and Lee/Hutaff Island.

Murray and Thieler (2004) reviewed data within Wrightsville Beach, North Carolina, RSDs and did not find any significant offshore-directed currents as identified by Cacchione et al. (1984), suggesting the dominance of along-shelf transport rather than cross-shelf flow. The depressional features are independent of geologic factors and are a result of oceanographic process such as the interaction of waves, mean currents, and poorly sorted bed material in a moderately high-energy environment. Because their

observations suggested the dominance of along-shelf transport rather than cross-shelf flow and transport, Murray and Thieler (2004) adopted the term *sorted bedforms* to describe the features off Wrightsville Beach and elsewhere.

The North Carolina Marine Fisheries, Environmental Management, and Coastal Resources Commissions adopted the *North Carolina Coastal Habitat Protection Plan* (CHPP) was adopted by in December 2004. The CHPP identifies six types of habitats that produce North Carolina's coastal fisheries resources consisting of shell bottom, sea grasses, wetlands, hard bottoms, soft bottoms, and the water column. RSDs are identified as soft-bottom habitat in chapter 6 of the CHPP under the subsection titled Ocean Intertidal Beaches and Subtidal bottom:

> The surf zone is the shallow subtidal area of breaking waves seaward of the intertidal beach. Within the surf zone, longshore sandbars frequently develop and shift seasonally in response to wave energy. Seaward of the surf zone, the subtidal bottom consists of a series of minor ridges and swales. Ripple scour depressions, ranging from 40–100 m (130–330 ft) in width and up to 1 m (3 ft) in depth, occur along the southern portion of the coast and are perpendicularly oriented to the beach, extending to the base of the shoreface (Thieler et al. 1995; Reed and Wells 2000). These features are located adjacent to areas experiencing chronic severe beach erosion, and may be indicative of rapid offshore transport of sand during storms (Thieler et al. 1995).

According to the CHPP, RSDs are not considered EFH, HAPC, PNA or Strategic Habitat Area. Though soft-bottom habitat is probably the most resilient to physical alterations because of its lack of structure and dynamic nature, it plays a vital role as nursery and foraging grounds for fish and invertebrate species. During the equilibration process, nourished sediment from the constructed berm could gradually move within the RSD/RCD/Sorted Bedform features; however, it is likely that the features would be maintained as a preferential morphologic state through the repeating, self-reinforcing pattern of forcing and sedimentary response, which causes the features to be maintained as sediment starved bedforms responding to both along- and across-shore flows (Thieler et al., 2001). Therefore, it is expected that benthic organisms normally associated with soft- and coarse-grained sediments in the nearshore environment would not be significantly altered by the project. The RSD/RCD/Sorted Bedform data collected off of Wrightsville Beach, North Carolina, a beach with a long nourishment history, further suggests that those features are self-reinforcing, independent of beach construction activities. Additionally, a significant amount of historic side-scan data has been collected offshore of Topsail Island (1992, 1994, and 1996) (Rob Thieler, personal communication, March 1, 2007; McQuarrie, 1998). This historic data matches well with the 2006 side-scan data collected by Geodynamics, providing some additional insight to the offshore extent and stability of these features. Because the data are spread over a 15-year time frame and imagery still matches well, it appears that the features are fairly stable, at least over a decadal time frame (Rob Thieler; personal communication, March 1, 2007); thus, further suggesting that the features are maintained by the localized interaction of oceanographic processes and poorly sorted bed material.

Though, according to Thieler et al. (1999) it is possible that sedimentation occurs beyond the –7-m (–23-ft.) depth of closure calculated for SCNTB, the available information of hard bottom off the coast of Topsail Island indicate that the hard-bottom areas of influence are low lying and ephemeral (USACE, 2008, 2004a, 2003; Moser and Taylor, 1995) and associated sedimentation would not affect high-relief, significant hard bottom. Biological characterization of low-relief, hard-bottom habitats in the nearshore and offshore environment of SCNTB confirmed that the species associated with low-lying features are more adapted to sediment loading associated with the ephemeral nature of such systems, and, therefore, would not experience effects greater than existing natural conditions. Therefore, no burial of exposed hard bottom features would be expected to occur in the nearshore environment as a result of the constructed beachfill template and associated beach profile equilibration process. Though surveys and diver ground truth efforts did not identify hard bottom within the –23-ft. depth contour, it is anticipated that any selected pipeline corridor and associated pumpout anchor point features could extend approximately 2,500 to 3,000 ft. offshore into areas that were not surveyed. Therefore, because of ephemeral nature of the low-relief, hard bottom features in the nearshore environment and that pipeline corridors and pumpout stations may be outside the surveyed areas, the Corps intends to survey all potential pipeline corridor routes before construction to avoid potential hard-bottom features.

Offshore (> –7 m (–23 ft.) NGVD)

As identified in Section 2.01.10, preliminary investigations of hard-bottom communities throughout each proposed borrow area were identified using high-resolution, side-scan sonar and delineated as *low-*, *moderate-*, and *high*-relief, in accordance with Moser and Taylor (1995) and Moser et al. (1995). Follow-up diver ground-truth efforts confirmed their presence and characterized the associated biota. To ensure protection of the hard-bottom resources from the physical dredging operation and the associated sedimentation and turbidity, the contractor applied a conservative approach when delineating hard-bottom features from the side-scan sonar acoustic signature data. For example, areas where hard bottom was interspersed with large areas of sediment, a line was drawn around the entire area to define the limits of the hard-bottom feature instead of delineating each individual feature. It is important for reviewers of those hard-bottom data to be aware of that conservative methodology and not assume that all the delineated features are large, consistently exposed hard-bottom platforms. In some instances, the delineated limits of a hard bottom area could consist of several very small pinnacles of low-relief and highly ephemeral outcroppings rather than a persistent hard-bottom platform. Furthermore, although the delineation of hard-bottom resources from the acoustic signature data incorporated high-, medium-, and low-relief classification, ground truth diver verification of the sites confirmed that no high-relief hard bottom was identified, and most of the mapped areas consist of low-relief hard bottom. As a component of the ground-truth effort, transect locations were specifically placed to traverse predefined areas of medium and high relief; however, divers confirmed that the areas were predominantly low-relief systems.

Biological characterization data of offshore hard-bottom resources were evaluated using the Benthic Ecological Assessment for Marginal Reefs (BEAMR) model developed by CPE. That methodology for characterizing benthic communities has been implemented throughout Florida and for the nonfederal North Topsail Beach coastal storm damage reduction project. The BEAMR methodology samples three core characteristics in each sample quadrant: (1) physical characteristics (including maximum sediment depth), (2) abiotic and biotic percent cover, (3) and coral density. During BEAMR surveys, biologists look for indications of natural sediment movement stress. Visual inspections include indentifying whether benthic organisms are being, or have recently been, stressed. Visual inspections include observations and evaluation of stress indicators such as standing sediment not removed by normal currents or wave actions. As identified in Table 8.3, sediment loading was evident in all sampled transects.

Table 8.3. Physical characteristics of hard bottom at each transect

	Transect										
Physical Parameters	**G1**	**G3**	**J2**	**L1**	**L2**	**O1**	**O3**	**O4**	**T1**	**T3**	**T4**
Number of Quadrants Surveyed	10	10	9	10	10	10	10	10	14	10	10
Number of 100% Sediment Quadrants	0	5	6	1	2	4	3	7	0	2	4
Percent Sediment Cover	27.4	60	90	33	35	43	46	30	46	55	48
Average Sediment Depth (cm)	4.7	6.8	8.3	3.3	2.1	4.5	4.3	6	2	4.5	6.2

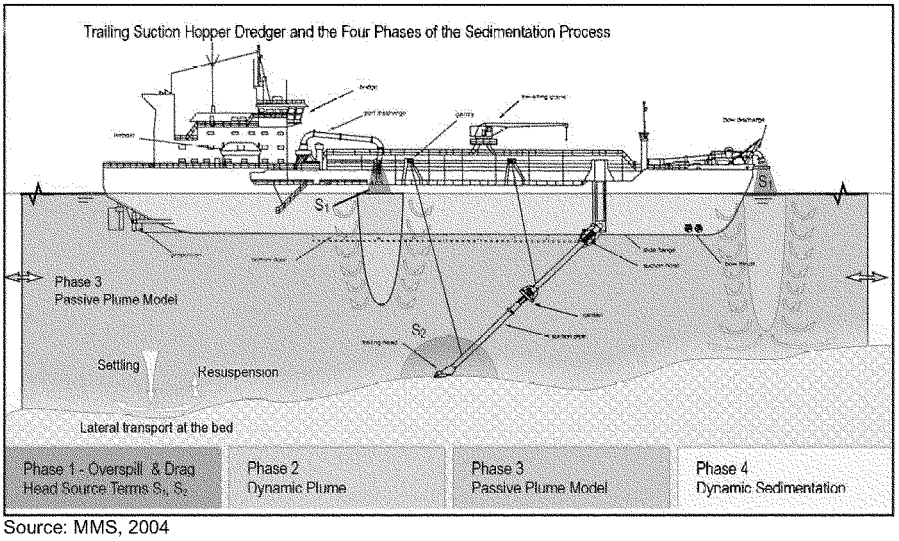
Overall, most hard-bottom areas investigated in the proposed borrow areas of the study were characterized by a combination of moderate- and low-relief habitats. Most areas included some regions of relatively moderate-relief rock outcroppings or ledges that were able to support adult *Oculina* sp. colonies and high cover by tunicates and sponges, and other areas of lower relief that were subject to more frequent burial and were characterized by low stony coral cover and higher cover by fast growing corals. The lower relief areas identified in each borrow area appeared to be more ephemeral. The increased benthic diversity and high numbers of adult *Oculina* sp. found on ledges and crevices are likely the result of protection from ambient sedimentation offered by the vertical and overhanging surfaces. The persistent growth of organisms on those protected surfaces compared to the flat surfaces suggests a natural environment with high sedimentation. Details of the results are in Attachment 4 of Appendix R.

Additional benthic characterization data of the nearshore and offshore environment collected by CPE in 2005 and 2006, for the adjacent non-Federal North Topsail Beach Coastal Storm Damage Reduction Project, also suggest a high-sedimentation environment. In some instances, heavy sediment and particulate loading observed in the water column during summer and fall sampling periods prevented divers from

completing flora and fauna surveys. Furthermore, in June 2005 CPE marine biologists confirmed hard bottom at two sites that were later found covered with more than 60 cm (1.9 ft.) of mud during subsequent October 2005 dives. The ephemeral nature of many of the sites was also confirmed through a comparison of side-scan sonar, hard-bottom edge digitization from 2005 to 2006, which indicated a change in exposed hard bottom by as much as 3 acres.

Hopper Dredge—Sedimentation and Turbidity

During dredging operations, hard bottom within the vicinity of offshore borrow areas can be affected by turbidity and sediment plumes generated from filling and overflow of the hopper dredge depending on the characteristics and suspension time of the sediment being dredged. Because of the distance offshore and the limited thickness of available sediment in the proposed borrow areas for the project, all dredging activities are expected to be performed using hopper dredge. Hopper dredge suction dragheads hydraulically remove sediment from the sand bottom and discharge the material into the storage hoppers on the dredge. The screened sandy material fills the hopper until an economic load is achieved for transit and subsequent pumpout to the beach placement location. As illustrated in Figure 8.1, the operation has two types of sedimentation and turbidity sources: S1 from the overflow (which for most U.S. dredges now is through the bottom of the hull) and S2 associated with suspension of sediment at the draghead. During filling of the hopper, any fine sediments (primarily silt, clays, and fine-sands) are washed overboard through *overflow* ports (i.e., S1) either over the side of the vessel or through *weirs* that release the slurry through the hull of the vessel. Such *washing* of the dredged material is the predominant source of turbidity plumes and sedimentation generated by the hopper dredge. Some turbidity would be expected from the physical interaction of the draghead with the bottom substrate (i.e., S2) during the dredging operation; however, it would not be expected to be significant considering most of the disturbed sediments would be confined to the suction field of the hopper dredge dragheads and would be dredged and disposed into the hopper. Sediment discharged overboard from the hopper overflow moves faster than would be anticipated from simple Gaussian models because of the settlement velocity of component particles. That is because of high sediment concentration and discharge rate of the overflowed material, factors that lead to the development of a density current that moves through the water column in a *dynamic phase* of settlement, at least initially. Sediment is stripped away as the dynamic plume moves through the water column forming a passive plume that is advected and dispersed by ambient currents, with the particles settling according to Gaussian models (MMS, 2004).



Source: MMS, 2004

Note: This figure shows two S1 sources at overflows from a screening operation; in almost all U.S. dredges, the S1 source is through the bottom of the hull.

Figure 8.1. Hopper dredge sedimentation processes..

Hitchcock and Drucker (1996) summarized values for material lost through the overflow process on a typical 4,500 ton hopper dredge operating in U.K. waters. Results from the study indicate that during an average loading time of 290 minutes, 4,185 tons of dry solids are retained as cargo, while 7,973 tons of dry solids are returned overboard from overflow. Sand-sized particles fall directly to the seabed and are reduced to background levels over a distance of 200–500 m (656–1,640 ft.) and smaller, silt-sized particles have a typical settling velocity of 0.1 to 1.0 mm/s and are reduced to background values of 2–5 milligrams per liter (mg/L) over a similar distance. According to Neff (1981, 1985), concentrations of 1,000 mg/L immediately after discharge decreased to 10 mg/L within one hour. The minimal effect of settling particles from hopper dredge turbidity plumes was further supported by a study from Poopetch (1982), which found that the initial hopper dredge overflow concentrations of 3,500 mg/L were reduced to 500 mg/L within 50 m (164 ft.).

The distance that sediment plumes can extend depends on the type of dredge, how it is operated, currents, and the nature of the sediments in the dredged area. As discussed in Section 7.03.6, only beach-compatible, sandy sediments would be used for this project in accordance with the North Carolina sediment compatibility rules. Dredging of sandy sediments would minimize the amount of turbidity and sedimentation associated with the dredging operation and would reduce the suspension time and advection distance of overflow sediments. A study performed by Newell and Siederer (2003) in the U.K. (high-current velocities) showed that, in most cases, coarse material up to sand-size particles settles within 200 m (656 ft.) to 600 m (1,968 ft.) of the point source of discharge, depending on depth of water, tidal velocity, and the velocity of flow from the discharge

pipe. During hopper dredging operations in the Baltics, Gajewski and Uscinowicz (1993) noted that the main deposition of sand from hopper dredge overflow was confined to distances within 150 m (492 ft.) on each side of the dredge. The study further supported that the initial sedimentation associated with overflow material behaves like a density current where particles are held together by cohesion during the initial phase of the sedimentation process and are mainly confined to a zone of a few hundred meters from the discharge chutes. According to a plume dispersion model developed by Whiteside et al. (1995) (based on field study measurements obtained while hopper dredging in Hong Kong waters), the contours for sediment deposition remain as a narrow band extending for approximately 100 m (328 ft.) on each side of the vessel, consistent with that recorded by Gajewski and Uscinowicz. As a component of the sedimentation associated impacts to hard bottom from hopper dredging in adjacent borrow areas offshore of Bal Harbor, Florida, Blair et al. (1990) recorded elevated sediment levels at about 335 m (1,100 ft) from the borrow area when dredged sediment had a higher silt/clay composition.

Though elevated turbidity levels could occur from hopper dredging overflow, the overflow process occurs only during the physical dredging operation. Because maximum load efficiency would be attained before transit to the pumpout location, overflow of material would not be expected to occur once the dredging process is complete. Therefore, although the hopper dredge might transit over hard-bottom locations in route to the beach, no significant turbidity or sedimentation would be expected to occur during the process. Once at the pumpout location, all turbid water generated by the hopper dredge slurry for pumpout would be retained in the hopper.

Hard-Bottom Buffer

As discussed in Section 2.01.10, the North Carolina hard-bottom buffer rule language (NCAC 07H. 0208(b) (12)(A)(iv)) states, "Mining activities shall not be conducted on or within 500 meters of significant biological communities, such as high relief hard bottom areas. High relief is defined for this standard as relief greater than or equal to one-half meter per five meters of horizontal distance." Adherence to a 500-m (1,640-ft.) buffer for high-relief hard bottom, as defined in the North Carolina state rule language (NCAC 07H. 0208(b) (12)(A)(iv)), would be adhered to. However, implementing a 500-m (1,640-ft.) buffer for all delineated hard bottom (i.e., including low and medium relief) would result in a reduction of available sediment to a volume that is less than that required for the 50-year life of the project. To provide sufficient compatible sand resources for the 50-year project while minimizing impacts to hard bottom resources, a 122 m (400 ft.) dredging buffer around the low relief hard bottom (< 0.5 m [1.6 ft.]) in the offshore borrow sites would be implemented; while still adhering to the 500-m (1,640-ft.) buffer for moderate- and high-relief hard bottom (as defined by MATER report [Appendix U]). State and federal resource agency representatives from the NCWRC, NCDMF, and NMFS concurred with that dredging buffer proposal on the basis of an evaluation of all the Surf City and North Topsail Beach hard-bottom resource data collected by the Corps. Furthermore, implementing a 122-m (400-ft.) buffer around low relief is consistent with the recommended buffer distances in Florida, which recommends a 122-m (400-ft.) dredging buffer around all hard bottom, including coral reefs, in its state dredging permit conditions. Additionally, that buffer recommendation is consistent

with the decision made by the PDT for the non-federal North Topsail Beach Coastal Storm Damage Reduction project, which allowed dredging within 122 m (400 ft.) of all identified hard-bottom resources. A discussion of Florida's buffer recommendation and associated project specific monitoring results are provided below:

Florida's 122-m (400-ft.) Dredging Buffer
Beach nourishment in southeast Florida is commonly accomplished by dredging sand deposits from between offshore coral reefs and moving the sand to shore. As a component of Florida Department of Environmental Protection (FLDEP) permit process for coastal storm damage reduction and dredging projects, a 122 m (400 ft.) buffer distance for hopper dredging in the vicinity of coral reef and hard-bottom communities is recommended as a guideline in the permit conditions for dredging projects. However, site-specific and project specific circumstances are considered for each permit request and expansions of the recommended buffer distances are considered on the basis of the site context (i.e., 183-m (600-ft.) buffer recommendation for projects with high silt content). The establishment of that buffer distance recommendation by FLDEP is based on a history of lessons learned from previous projects with myriad different buffer distances and associated monitoring of sedimentation impacts. Historically, 46-m (150-ft.) dredging buffer distances from hard bottom were considered adequate for cutterhead dredging operations. However, for hopper dredge operations, buffer recommendations ranged from 46 m (150 ft.) to 76 m (250 ft.) with site-specific effects ranging from no effect to significant effect depending on the site and the project. In 1998 significant effects were documented for the Bal Harbor (Miami-Dade county) dredging project, which resulted in a reconsideration of the recommended buffer distance and the development of improved techniques for monitoring coral sedimentation stress by developing a visual stress index (Vargas-Angel et al., 2006). On the basis of lessons learned from previous projects, FLDEP later implemented a 122-m (400-ft.) dredging buffer distance from hard-bottom communities, and the state monitoring of coral stress now incorporates histological and visual investigations of coral response to dredging associated sedimentation. Modifications to that buffer recommendation are pursued for individual projects depending on habitat quality and site- and project-specific conditions (i.e., currents, sediment quality) of the project area.

As a component of the Town of Reach 7, Phipps Ocean Park Beach Restoration project (Lybolt and Tate, 2003; Delaney et al., 2006)), pre-, during-, and post-construction biological monitoring was required to assess dredging impacts to adjacent coral reef. Project permits mandated to Palm Beach implement a program to monitor sedimentation rates, baseline biological conditions of live organisms, and coral stress associated with hopper dredging within 122 m (400 ft.) of barrier coral reef formations. Analysis of the collected data demonstrated that project associated turbidity, sedimentation, and coral stress did not exceed previously defined threshold criteria used to assess impacts to offshore hard-bottom resources (Delaney et al., 2006). In 2005 Broward County, Florida, constructed 10.9 km of beach using a hopper-dredge and moving 1.9 million cubic yards of sand from five different sand borrow areas as close as 122 m (400 ft.) from offshore coral reefs. A visual stress index was developed for three coral species to monitor a real-time response of stony corals to potentially increased sediment-induced stress

environment during the dredging process. An average stress index threshold was developed to allow for cessation of dredging at specific borrow areas if the stress threshold is exceeded. However, the threshold shutdown criteria were not exceeded throughout the project (Lou Fisher, personal communication, July 24, 2008). As a component of the Boca Raton Beach Restoration Project conducted in 1988, a 3-year environmental monitoring program was implemented to monitor potential impacts to the surrounding hard-bottom habitats. On the basis of the data collected, the environmental conditions at the offshore hard-bottom monitoring stations did not appear to be affected by the dredging efforts associated with the restoration project. The borrow areas were between two offshore hard-bottom zones and associated dredging was separated from the patch hard-bottom zone by a minimum of 122 m (400 ft.) and from the barrier hard-bottom zone by 305 m (1,000 ft.) The average sedimentation rates recorded during the construction and post-construction phases were less than the background, or pre-construction sedimentation rate.

Summary

As identified through the myriad investigative studies discussed in Section 2.01.10 to identify and avoid nearshore and offshore hard-bottom resources, the Corps has demonstrated a commitment to avoidance and minimization of impacts to hard-bottom communities. Early in the planning process, a PDT composed of state and federal resource agency representatives was developed to identify and discuss key concerns specific to hard-bottom resource concerns and develop appropriate avoidance and minimization guidelines. These avoidance efforts include eliminating three borrow areas, I, K, and M, from the project design because of the discovery of significant hard-bottom resources within and adjacent to the proposed borrow areas. Furthermore, in coordination with the PDT, specific dredging buffer guidelines were developed and incorporated into the borrow area design providing appropriate buffer distances from the dredging and associated overflow activities to the varying hard-bottom resource areas. Specific buffer requirements include adherence to a 500-meter, hard-bottom buffer around high- and moderate-relief hard bottom, as defined in NCAC 07H. 0208(b)(12)(A)(iv)), while implementing a 122-m (400-ft.) buffer around low-relief hard bottom (based on hard-bottom mapping data provided by MATER [Appendix U]).

Recognizing that it is too costly to ground truth, delineate, and map all hard-bottom resources throughout each borrow area, the Corps requested mapping of low-, moderate-, and high-relief hard bottom from the side-scan sonar data collected by the MATER contract. A conservative approach to mapping the resources was used to limit the amount of dredging activities in and around patchy hard-bottom resources. For example, if multiple anomalies were identified to be hard bottom throughout an area, the entire feature was identified instead of separating each individual anomaly. Furthermore, although the best effort was made to differentiate low-, moderate-, and high-relief hard bottom from the remote sensing data, the exact relief patterns were not revealed until ground-truth efforts were pursued. As a component of the ground-truth effort, transect locations were carefully selected to traverse the transition areas of previously identified by MATER as low-, moderate-, and high-relief hard bottom. In some instances, the ground-truth efforts did not support the moderate- to high-relief classifications defined by

MATER, but rather site-specific maximum relief points of low to moderate relief with an average of low-relief features throughout the study area. Therefore, when adding the additional data from the ground-truth efforts of the offshore hard-bottom communities to the previously mapped hard-bottom features on the basis of side-scan interpretation, it becomes apparent that the hard-bottom mapping provided by MATER using side-scan sonar is a very conservative effort.

Although in-situ dive efforts confirmed that areas previously defined as high-relief hard bottom were actually moderate or low relief, for those areas that have not been ground truthed, the North Carolina 500-m (1,640-ft.) buffer requirement is still included to offer sufficient protection of potentially more stable hard-bottom resources associated with higher relief systems. However, a buffer distance of 122 m (400 ft.) for hopper dredging within the vicinity of lower relief systems throughout all borrow areas associated with this project would be implemented. The plan is consistent with that developed by the PDT, and addressed in the EIS, for the adjacent nonfederal coastal storm damage reduction project proposed for North Topsail Beach, North Carolina (USACE, 2007). The rationale for establishing a buffer zone limit of 122 m (400 ft.) for low–relief, hard-bottom resources in the project area instead of the state standard of 500 m (1,640 ft.) (15A NCAC 07H.0208(b)(12)(A)(iv)) is based on lessons learned from 40 years of dredging experience in less turbid south-Florida waters adjacent to sensitive coral reef systems where site-specific borrow area buffer zones ranging from 76 m (250 ft.) to 122 m (400 ft.) have proven effective in protecting hard bottom and coral reef habitats. On the basis of the species list provided from the in-situ dive investigations offshore of Surf City and North Topsail Beach, North Carolina, and the natural sediment loaded nature of this hard bottom system, it is apparent that the species are more adapted to sedimentation than the reef-building coral species of Florida. The potential turbidity and sedimentation effects associated with proposed activities are not expected to significantly different than those associated with disturbances from natural storm events.

On the basis of the available information pertaining to the dredged sediments, hopper dredge overflow activities, and associated potential turbidity plumes, and implementing a 122-m (400-ft.) to 500-m. (1,640-ft.) buffer distance depending on relief, no significant impacts would be expected from the sedimentation and turbidity associated with the proposed dredging activities. The potential impacts to the hard-bottom communities would not be expected to exceed the natural sedimentation and turbidity conditions of the project area.

Monitoring

Silent Inspector (SI)—Automated Dredge Plant Monitoring System

To ensure that the dredgers adhere to the required buffer distance and to avoid physical impacts to hard-bottom resources, the Corps would require all dredges to implement the SI automated dredge plant monitoring system. The SI Program is a Corps-dredging industry partnership for automated dredging monitoring of Corps dredging projects. Onboard sensors monitor dredge activities, operations, and efficiency. Data are routed to the SI Support Center for data retrieval and storage; contract managers, dredge inspectors, biologists, and others can use Corps-provided software to monitor

performance and ensure environmental compliance. SI produces many different reports including dredge location history, volume history, disposal location history, and operational status. It also helps monitor all aspects of dredge operations from contract compliance to assurance that the operation is being performed in an environmentally safe manner. In addition to providing detailed tracking information of dredge location, SI also tracks the hopper dredge displacement status throughout the entire dredging operation, including hopper filling, transit, and pumpout. Therefore, the potential for any leakage of sediment through the hopper during transit can be tracked to assure accountability of any misplaced material. If material is misplaced, the Corps would take appropriate coordination and mitigative action. Additional information and specifications regarding the SI is at: http://si.wes.army.mil/.

Although it is unlikely, if a physical impact by the hopper dredge dragheads on previously unexposed hard bottom occurs, the exact location of impact would be recorded using SI. The Corps would direct the dredge to move to a new borrow area or different portion of the existing borrow area to avoid additional risk of impact. The incident would be thoroughly documented and coordinated with the appropriate state and federal resource agencies. On the basis of the outcome of such coordination, appropriate action would be taken to investigate and mitigate potential impacts.

Nearshore Hard Bottom Monitoring—Pipeline Corridor
As discussed in Section 8.01.8.2 and Appendix R, Attachments 2-4, significant of remote sensing and ground truth diver survey efforts were conducted between the shoreface and –23 ft., and no hard-bottom resources were identified. It is anticipated that any selected pipeline corridor for hopper dredge pumpout during construction could extend from the shoreface to approximately 2,500 to 3,000 ft. offshore. Considering the ephemeral nature of the low-relief, hard-bottom features in the nearshore environment and the potential for low-lying outcrops to occur within the pipeline corridor distance requirements and associated dredge and pipeline anchor points, the Corps intends to survey all areas associated with potential pumpout and pipeline corridor requirements before construction to avoid impacts to hard-bottom features. All existing remote-sensing and ground-truth data would be used in combination with the new survey data. All information associated with the surveys, data analysis, identification and mapping of pipeline corridors, appropriate buffers, and such, and subsequent measures developed to avoid resource impacts would be coordinated with the resource agencies before construction.

Offshore Hard-Bottom Sedimentation Monitoring
As a component of the November 2007 EIS for the permitted non-federal North Topsail Beach Coastal Storm Damage Reduction Project, prepared by CPE for North Topsail Beach, an agency-approved sedimentation monitoring plan was provided. Detailed methodologies for documenting potential sedimentation impacts from the dredging operation on offshore hard bottom were discussed. As a component of the agency coordination for the federal coastal storm damage reduction project (August 28, 2008, PDT meeting), agency representatives requested that similar sedimentation monitoring methodologies be applied for the federal project in the event that monitoring for the nonfederal project is not completed before beginning the federal project. If monitoring

for the nonfederal project is completed before beginning the federal project and no sedimentation impacts are documented from dredging with a 122 m (400 ft.) buffer, no additional monitoring as a component of the federal project would be implemented. Because multiple borrow areas would be used throughout the 50-year project and dredging would not occur within the vicinity of hard-bottom communities at all times, during-project monitoring of sedimentation impacts from dredging activities would not occur until dredging within the proposed 122-m (400-ft.) buffer would be required. Details of the proposed sedimentation monitoring plan, based on methodologies developed by CPE (USACE, 2007b), are provided below. Specific contract monitoring requirements and subsequent scope of work would be circulated for agency concurrence before implementation.

Marine resource investigations of the offshore communities conducted by ANAMAR and CPE in March 2007 included establishing 12 temporary transects throughout five borrow areas (G=2; J=2; L=2; O=3; and T=3). A representative sample of those 12 sites would be established as permanent transects before construction. Additional control transects would be established before construction for comparison purposes to determine changes in community cover or possible sedimentation effects from dredging activities on proximate hard bottom. Monitoring stations would include stainless steel pins that would be installed into the hard bottom using a hammer or drill at 5.0 m (16.4 ft) spacing along each of the permanent transects.

Sediment monitoring at the offshore transects would occur before, during, and, if necessary, after construction and would include (1) installing sediment traps (collectors) (Figure 8.2) and (2) in-situ sediment depth measurements. Sediment collectors would be installed on both ends of the transects and could consist of a replaceable 2–liter, high-density polypropylene (HDPE) bottle with a triple PVC tube lid, installed in a permanent housing. The three-tube lid is screwed onto the top of the bottle for collecting settling particles. The collector design allows sediment from the water column to enter through the open tubes and accumulate in the collector.



Figure 8.2. Sediment trap permanently installed at each end of a monitoring transect.

During each monitoring event, the HDPE bottle is removed and replaced with empty bottles, and the lid is checked for biofouling and replaced or cleaned if blocked. The contents in each of the sediment bottles would be combined to produce a composite sample in the lab. Each composite sample would be dried and mechanically sieved to determine both the dry weight of the sample (in milligrams) and the silt/clay fraction (the material that passed through a No. 200 U.S. standard sieve). The resulting weights are divided by the area of the tubes open to the water column and the number of days the trap was in place. The area of the tubes used to calculate the sedimentation rates would be adjusted if one or more of the sediment traps is lost or if debris/organism growth is observed in the collector tubes preventing unrestricted access to the collection jar. The offshore monitoring transects adjacent to the borrow area would be installed and sampled for sedimentation biweekly for 2 months before construction (weather and sea state conditions permitting) and once every 2 weeks for the initial 2 months of construction. If sediment accumulation at the compliance transects is > 10 percent of the sediment accumulated on average per day at the three control sites, the Corps would direct the contractor to stop dredging operations within the 122-m (400-ft.) buffer and move to another area 500-m (1,640-ft.) from the identified hard-bottom sites. Dredging would not be allowed to resume within the 500-m (1,640-ft.) buffer until measures can be implemented to reduce sedimentation impacts to adjacent hard bottom resources, such as no hopper dredge overflow within 500 m (1,640 ft.) from hard bottom. All monitoring

data would be coordinated with appropriate state and federal resource agencies throughout the construction process, and all proposed modifications of the dredging operation to minimize sedimentation impacts would be coordinated before implementation.

8.01.8.3 Effects on Reef-forming Corals

Hermatypic, or reef-forming, corals consist of anemone-like polyps occurring in colonies united by calcium encrustations. Reef-forming corals are characterized by the presence of symbiotic, unicellular algae called zooxanthellae, which impart a greenish or brown color. Because those corals derive a very large percentage of their energy from the algae, they require strong sunlight and are, therefore, generally found in depths of less than 150 ft. They require warm water temperatures (68 °F to 82 °F) and generally occur between 30° N and 30° S latitudes. Off the East Coast of the United States, that northern limit roughly coincides with northern Florida; however, they can occur off the North Carolina coast. As identified in Section 2.01.10, extensive limestone and siltstone hard-bottom communities have been identified in the offshore borrow areas of the proposed action. As a component of the in-water diver benthic characterization of the communities, *Oculina* sp. were identified in each surveyed transect. However, the percentage of *Oculina* sp. relative to other functional groups identified along the transects ranged from 0.3 to 3.7 percent. *Oculina* colonies identified were predominantly small recruits (1 cm); however, some of the higher-relief outcroppings or ledges supported larger adult colonies.

Oculina sp. range from Cape Hatteras, North Carolina, through the Gulf of Mexico and Caribbean. Oculina Banks, off east-central Florida, are the area of main concern and have been identified as an HAPC. Colonies are semi-isolated, patchy, and low growing in shallow water; however, they form larger, massive coalescing aggregates with substantial topographic relief in 160 to 330 ft. (50-100 m) depth (http://www.nmfs.noaa.gov/pr/pdfs/species/ivorytreecoral_detailed.pdf). Though *Oculina* colonies were identified in the project area, as discussed in section 8.01.8.2, buffers would be incorporated to avoid sedimentation and turbidity effects associated with hopper dredging activities. Therefore, though *Oculina* sp. are present in the project vicinity, appropriate buffers have been incorporated into the project design to avoid impacts to the species.

8.01.8.4 Effects on Artificial/Manmade Reefs

North Carolina, Department of Environment and Natural Resources, NCDMF Artificial Reef Program manages six reefs that are offshore of Topsail Island. They are AR 355, AR 360, AR 362, AR 364, AR 366, and AR 368. With the exception of AR 360, which is offshore of Topsail Beach about 2.5 nautical miles from the New Topsail Inlet sea buoy, all those sites are offshore of the proposed borrow sites and are not within the immediate project area. Therefore, dredging and placement of material associated with the Surf City and North Topsail Beach Coastal Storm Damage Reduction Project would not be expected to adversely affect artificial reef sites managed by the Artificial Reef Program.

8.01.8.5 Effects on Sargassum

Benthic and pelagic *Sargassum* sp. are found within the vicinity of the proposed project area. *Sargassum filipendula* is a benthic species of *Sargassum* and is often the predominant macrophyte in nearshore areas where *Sargassum* beds grow subtidally in moderately exposed or sheltered rocky or pebble areas near hard bottom or coral reef communities (Schneider et al., 1991). Pelagic *Sargassum* sp. occur in large floating mats on the continental shelf, in the Sargasso Sea, and in the Gulf Stream. Most pelagic *Sargassum* circulates between 20° N and 40° N latitudes and 30° W longitude and the western edge of the Florida Current/Gulf Stream and forms a dynamic structural habitat with a diverse assemblage of marine organisms including fungi, micro- and macro-epiphytes, at least 145 species of invertebrates, 100 species of fishes, four species of sea turtle, and numerous marine birds. It is a major source of productivity in a nutrient-poor part of the ocean. Unregulated commercial harvest of *Sargassum* for fertilizer and livestock feed has prompted concerns over the potential loss of this important resource.

As discussed in Section 2.01.10, in-water benthic characterization surveys (i.e., BEAMR) of offshore, hard-bottom communities were completed by ANAMAR Environmental Consulting, Inc., and CPE in March 2008. In-situ dives were conducted along 12 representative transects throughout the proposed offshore borrow areas. Benthic *Sargassum* sp. were identified as a dominant macroalgae in almost all surveyed transects. Though benthic *Sargassum* sp. are dominant macroalgal species in vicinity of the dredging operation, their presence is associated with the hard-bottom attachment substrate. Because dredging buffers have been incorporated into the project plan to avoid impacts to hard-bottom communities, dredging operations would be expected to avoid direct and indirect impacts to benthic *Sargassum* sp.

Pelagic *Sargassum* is positively buoyant and, depending on the prevailing surface currents, would remain on the continental shelf for extended periods or be cast ashore. Therefore, pelagic *Sargassum* species could be transported inshore from the Gulfstream and drift through the vicinity of the dredge plant operation. Because it occurs in the upper few feet of the water column, it is not subject to effects from dredging or sediment disposal activities associated with the proposed action (SAFMC, 1998.); thus, effects from the dredging or disposal operations would not be expected to be significant.

8.01.8.6 Effects on the Marine Water Column

The potential water quality effects of dredging and beachfill placement are addressed in Section 8.07.2. Dredging and beachfill placement conducted during project construction and periodic nourishment could create effects in the marine water column in the immediate vicinity of the activity potentially affecting the surf zone and nearshore ocean. Such effects could include minor and short-term suspended sediment plumes and related turbidity, and the release of soluble trace constituents from the sediment. In the case of overflowing hopper dredges or scows to obtain economic loading, sediment that is more than 90 percent sand is not likely to produce significant turbidity or other water quality impacts (USACE, 1997) (for sedimentation and turbidity associated with hopper dredges, see section 8.01.8.2). Overall water quality impacts of the proposed action would be expected to be short-term and minor. The various life stages of fish species associated with

marine and estuarine resources dependent on good water quality would not be expected to experience significant adverse effects from water quality changes.

Scientific data are very limited with regard to the effects of beach nourishment on fishery resources. The effects could be similar, on a smaller scale, to the effects of storms; storm effects could include increased turbidity and sediment load in the water column and, in some cases, changes in fish community structure (Hackney et al., 1996). Storms of great severity, such as hurricanes, have been documented to create conditions resulting in fish kills, but such situations are not usually associated with beach nourishment.

In a 1999 Environmental Report on the use of federal offshore sand resources for beach and coastal restoration, the U.S. Department of Interior MMS provided the following assessment.

> In order to assess if turbidity causes an impact to the ecosystem, it is essential that the predicted turbidity levels be evaluated in light of conditions such as during storms. Storms on the Mid-Atlantic shelf may generate suspended matter concentrations of several hundred mg/L (e.g., Styles and Glenn 1999). Concentrations in plumes decrease rapidly during dispersion. Neff (1981, 1985) reported that solids concentrations of 1000 ppm two minutes after discharge decreased to 10 ppm within one hour. Poopetch (1982) showed that the initial concentration in the hopper overflow of 3,500 mg/L decreased rapidly to 500 mg/L within 50 m. For this reason, the impact of the settling particles from the turbidity plume are expected to be minimal beyond the immediate zone of dredging.

Beach nourishment can affect fishery resources and EFH through increases in turbidity and sedimentation that, in turn, can create localized stressful habitat conditions, and can result in temporary displacement of fish and other biota. However, the sediment proposed for beach placement on Surf City and North Topsail Beach would average 90 percent or more sand (see Appendix C, Geotechnical Analysis). Because of the low silt/clay content, water column effects would be expected to be localized, short-term, and minor. Furthermore, the beach nourishment operation would be expected to proceed at a slow rate. Mobile biota, including juvenile and adult fish, should be able to relocate outside the more stressful conditions of the immediate nourishment operation. Cumulative effects of multiple, simultaneous beach nourishment operations could be harmful to fishes of the surf zone. Because of the high quality of the sediment selected for beachfill and the small amount of beach affected at any time, the proposed activity would not be expected to pose a significant threat.

8.01.8.7 Effects on State-Designated Areas Important for Managed Species

PNAs are designated by the North Carolina Marine Fisheries Commission and are defined by North Carolina as tidal saltwaters that provide essential habitat for the early development of commercially important fish and shellfish (http://www.ncfisheries.net/rules.htm; 15 NC Administrative Code 3B .1405). Many fish species undergo initial post-larval development in the areas. PNAs would not be expected

to be directly affected by implementing the proposed project. However, PNAs adjacent to the New River Inlet vicinity could experience indirect and short-term elevated turbidity levels from the nourishment operation on the shoreface. Such turbidity effects are dependent on the location of the outflow pipe and the direction of longshore and tidal currents. Because the elevated turbidity levels would be short-term and within the range of elevated turbidity from natural storm events, the impacts to state-designated PNAs would be expected to be insignificant.

8.01.8.8 Effects on New River

New River Inlet is approximately 7 miles north of the northern terminus of the project. No direct impacts associated with dredging or beach placement of sediment would be expected to occur within New River Inlet. However, short-term elevated turbidity levels could occur during the nourishment operation and could be transported outside the immediate disposal area via longshore and tidal currents. Such elevated turbidity levels could extend into the New River Inlet vicinity; however, the associated effects would not be expected to be significant and likely would not affect HAPC for managed fish species.

8.01.8.9 Effects on Big Rock and Ten Fathom Ledge

Big Rock and the Ten Fathom Ledge are south of Cape Lookout, North Carolina. Ten Fathom Ledge is at 95–120 m (312–394 ft.) depth on the Continental Shelf in Onslow Bay, North Carolina, and consists of 136 square miles of ocean floor containing patch reefs and rock outcroppings. Big Rock is approximately 36 miles south of Cape Lookout at about 50–100 m (164–328 ft.) of water. Hard substrate consists of algal limestone and calcareous sandstone. Both sites are offshore of the proposed borrow areas and would not be expected to be affected by implementing the proposed project (SAFMC, 1998).

8.01.8.10 Effects on The Point

The Point is near Cape Hatteras near the 200-m (656-ft.) contour and is a confluence zone of six major water masses including the Gulf Stream, Western Boundary Under Current (WBUC), Mid-Atlantic Shelf Water (MASW), Slope Sea Water (SSW), Carolina Capes Water (CCW), and the Virginia Coastal water. A result of the convergence of the currents is a dynamic and highly productive environment. The area is well offshore of the proposed project, and no effects would be expected (SAFMC, 1998).

8.01.8.11 Impact Summary for Essential Fish Habitat

The proposed action would not be expected to cause any significant adverse impacts to EFH or HAPC for those species managed by the SAFMC and MAFMC. Effects would be expected to be minor on an individual and cumulative effects basis.

8.02 Terrestrial Environment

8.02.1 Maritime Shrub Thicket

The maritime shrub thicket community occurs sporadically throughout Surf City and North Topsail Beach, occurring on the backside of the island, west of the highway, and interspersed with marsh areas, which border the sound. Because the community is

landward of the proposed project construction limits, no significant effects would be expected.

8.02.2 Beach and Dune

Under the proposed plan, approximately 52,150 ft. of beach berm and dune would be constructed. Constructed dunes would be waterward of the first line of stable vegetation, would tie into existing dunes where practical, and be revegetated with native dune grasses to minimize effects. That would result in a seaward movement of the shoreline.

Project construction and periodic nourishment would not be expected to have an adverse effect on wildlife found along the beach or that uses the dune areas. However, short-term transient effects could occur to mammalian species using the dune and fore-dune habitat, but those species are mobile and would be expected to move to other, undisturbed areas of habitat during construction and periodic nourishment events. Revegetation of dune areas would be expected to increase the amount and quality of habitat available to mammal and avian species dependent on those areas.

Project construction would result in disturbance and removal of some of the existing vegetation along the seaward side of the existing dune. However, construction would be followed by measures designed to stabilize the constructed dunes. Dune stabilization would be accomplished by planting vegetation on the dune during the optimum planting seasons and after the berm and dune construction. Planting stocks would consist of sea oats (*Uniola paniculata*), American beachgrass (*Ammophila breviligulata*), panic grass (*Panicum amarum*), and seaside little bluestem (*Littoralis* variety). The vegetative cover would extend from the landward toe of the dune to the seaward intersection with the storm berm for the length of the dune. Sea oats would be the predominant plant with American beach grass and panic grass as a supplemental plant. Seaside little bluestem would be planted on the backside of the dune away from the most extreme environment. Planting would be accomplished during the season best suited for the particular plant. Periodic nourishment of the project would involve placing material along the berm. Therefore, minimal impacts to dune vegetation would be expected from implementing the project.

Nourishment operation at Surf City and North Topsail Beach would be expected to directly affect ghost crabs through burial (USACE, 2004b; Lindquist and Manning, 2001; Peterson et al., 2000; Reilly and Bellis, 1983). Because ghost crabs are vulnerable to changes in sand compaction, short-term effects could occur from changes in sediment compaction and grain size. According to Hackney et al. (1996), management strategies are recommended to enhance recovery after beach nourishment are (1) timing activities so that they occur before recruitment and, (2) providing beach sediment that favors prey species and burrow construction. Ghost crabs are present on the project beach year-round (Hackney et al., 1996); therefore, direct effects from burial could occur during the proposed construction time frame of December 1 to March 31. However, the peak larval recruitment time frame would be avoided and, because only compatible borrow material would be used, it is expected that ghost crab populations would recover within one year post-construction (USACE, 2004b; Lindquist and Manning, 2001; Peterson et al., 2000;

Reilly and Bellis, 1983). Because ghost crabs recover from short-term effects and because recommended management strategies to avoid long-term effects would be followed, no significant long-term impacts to the ghost crab population would be expected.

8.02.3 Birds

The waters off of Topsail Island and Onslow Beach are very important to migrating and wintering northern gannets, loons, and grebes because of the abundant hard-bottom habitat. It has been suggested that migrating and wintering birds key on the hard-bottom areas (Sue Cameron, personal communication, September 8, 2004) because such habitat supports significant prey species for the birds. However, appropriate dredging buffers have been incorporated into the project design so disturbance of birds using those areas for feeding would be expected to be minimal. Nonetheless, distribution patterns of sea ducks or other birds using the offshore environment in the project vicinity could be affected during dredging operations for construction and periodic nourishment. Congregation or rafting of sea ducks in the areas is primarily for loafing. Because of the depth in the areas (greater than 30 ft.), they would not be expected to provide a benthic food source for sea ducks. Because the area of ocean disturbed is small when compared to available loafing or foraging areas, it is expected that any effects would be minor.

The identified project limits avoid important shorebird habitat in the New River and New Topsail Inlet complexes. Although the project area is heavily developed and sustains heavy recreational use, migratory shorebirds could still use the project area for foraging and roosting habitat. As mentioned in Section 2.02.3 of this report, beach nourishment activities could temporarily affect the roosting and intertidal macro-fauna foraging habitat; however, recovery often occurs within one year if nourishment material is compatible with native sediments. A recent 2-year study in Brunswick County, North Carolina (USACE, 2004b) indicated that beach nourishment had no measurable impact to shorebird use. Additionally, to complete the full initial construction template while still adhering to the December 1 to March 31 dredging window, initial construction would be staged in four intervals. Although temporary impacts to the shorebird prey base could occur in the affected areas, the staggering of the initial construction effort would allow for availability of adjacent unaffected foraging habitat. Because (1) areas of diminished prey base are temporary and isolated, (2) recovery occurs within one year if material is compatible, and (3) adjacent unaffected foraging and roosting habitat would be available throughout the project, it would not be expected that foraging and roosting habitat would be significantly affected by implementing the proposed action.

Although it is possible that shorebird nesting could occur in the project area during the spring and summer months (April 1–August 31), most of the bird species have been displaced by development pressures and heavy recreational use along the beach; thus, traditional nesting areas on the project beach have been lost. Many of the bird species have retreated to the relatively undisturbed dredged material disposal islands that border the navigation channels in the area. Nonetheless, it is possible that shorebird species would still attempt to nest in the project area (Sue Cameron, personal communication, September 8, 2004). To protect bird nesting, the NCWRC discourages beach work

between April 1 and August 31. All work is proposed to be accomplished by hopper dredges within the hopper dredging window of December 1 to March 31, thus avoiding the bird nesting window. Additionally, as discussed in Section 2.02.3, a significant amount of shorebird activity occurs year-round on the north end of North Topsail Beach and in the New River Inlet complex. To avoid disturbance to this important shorebird habitat, all associated construction activities for this project would avoid those areas to the maximum extent practicable.

Undeveloped and undisturbed barrier island systems with associated saltmarsh, beach, and adjacent sand flats offer ideal migratory shorebird and waterbird microhabitats. Specifically, the undeveloped islands are dominated by overwash processes and the formation of bare sand habitats that offer prime nesting habitat for some shorebird species. Undeveloped barrier islands to the north (Onslow Beach and Bear Island) and south (Lea Island) of the project area are overwash-dominated systems and support thousands of shorebirds during migration and during winter, hundreds of beach-nesting seabirds and shorebirds, wading birds, waterfowl and marsh birds. However, the project limits in Surf City and North Topsail Beach are heavily developed on both the ocean and sound sides of the island; thus, limiting the opportunity for overwash fan formation. The Corps recognizes that natural barrier island overwash processes are an important factor in the creating and maintaining shorebird nesting habitat and that creating a constructed dune as a component of the project would further inhibit natural overwash processes. However, the without-project condition in the project area is not an undisturbed barrier system that is supportive of those habitat features. Rather, it is a continued developed shoreline. As identified in Section 3.08 of the report, the Corps' without-project future economic condition assumes that all structures affected by hurricane and storm erosion damages would be replaced to a level similar to the existing distribution of residential and commercial use. Thus, if an existing structure is replaced by an overwash fan as a result of a significant storm event, the home would likely be rebuilt on top of the overwash fan. That process of structural loss and redevelopment on top of overwash features was experienced in North Topsail Beach in the years after Hurricane Fran in 1996. Furthermore, it is assumed that residential structures removed by long-term erosion would not be replaced during the 50-year period of analysis; however, the second row structures would become first row structures. Therefore, in regards to the Corps evaluation of without-project conditions relative to economics, post-storm structural losses would be replaced and any washover fan formation that occurs within property limits that are deemed rebuildable by the state would have a new structure rather than offering new bird habitat. The project area is, and would continue to be, a highly developed beach whose residential and commercial development practices have led to the degradation of available washover habitat before the construction of a coastal storm damage reduction project.

On the basis of the following considerations, the proposed construction activities would not be expected to significantly affect breeding and nesting shorebirds or colonial waterbirds in the project area: (1) contractors would adhere to the April 1 to August 31 bird-nesting window when timing the initial construction activities and periodic renourishments, (2) beach nourishment and construction activities would not occur in the

New River and New Topsail Inlet complexes, which most likely support foraging, loafing, roosting, and nesting shorebirds, and (3) project construction timing and planning would allow for rapid recovery of intertidal foraging habitat in the project area.

8.02.4 Endangered and Threatened Species

In accordance with section 7 (a)(2) of the ESA of 1973, as amended, the Corps initiated consultation with both the USFWS and NMFS for the proposed project. A biological assessment (Appendix I) was prepared to evaluate effects of the proposed action on listed T&E species and their designated critical habitat in the project area. A summary of effect determinations for all listed species identified in the project area relative to both the beach placement and in-water related activities for the project are provided in Table 8.4. All commitments to reduce impacts to listed species are provided in Section 5.0 of Appendix I and Table 7.2 and Section 10.06.1 of the main report.

Table 8.4. T&E species effects determination for beach placement and dredging activities associated with the proposed project area

Listed species w/in the project area		Effects determination	
		Beach placement activities (USFWS)	In-water dredging activities (NMFS)
Sea turtles	*Leatherback*	MANLAA	MANLAA
	Loggerhead	MANLAA	MALAA
	Green	MANLAA	MALAA
	Kemp's Ridley	NE	MALAA
	Hawksbill	NE	MALAA
Large whales	*Blue, finback, sei, and sperm*	NE	NE
	NARW	NE	MANLAA
	Humpback	NE	MANLAA
West Indian manatee		NE	MANLAA
American alligator		NE	NE
Piping plover		MANLAA	NE
Red-cockaded woodpecker		NE	NE
Shortnose sturgeon		NE	NE
Smalltooth sawfish		NE	NE
Seabeach amaranth		MANLAA	NE
Golden sedge		NE	NE
Chaffseed		NE	NE
Cooley's meadowrue		NE	NE
Rough-leaved loosestrife		NE	NE

Notes: No Effect (NE = green); May Affect Not Likely to Adversely Affect (MANLAA = orange); and May Affect Likely to Adversely Affect (MALAA = red)

Summary of Effects Determinations

American Alligator, Red-cockaded Woodpecker, Golden Sedge, Chaffseed, Cooley's Meadowrue, and Rough-leaved Loosestrife.

These are all terrestrial, freshwater, woodland, or savanna species. Because the habitat type is not present in the areas that would be affected by the proposed action, those species are unlikely to occur. Therefore, implementing the proposed action would not be expected to adversely affect any of those species or their habitat.

Large Whales—Blue Whale, Finback Whale, Humpback Whale, North Atlantic Right Whale (NARW), Sei Whale, and Sperm Whale

Of the six species of whales being considered, only the NARW and humpback whale would normally be expected to occur in the project area during the project construction period. Therefore, the proposed project would not be expected to adversely affect the blue whale, finback whale, sei whale, and sperm whale. Conditions outlined in previous NMFS consultations to reduce the potential for accidental collision (i.e., contractor pre-project briefings, large whale observers, slow down and course alteration procedures) would be implemented as a component of the project. Because of such implementation measures, dredging activities associated with the proposed project may affect but are not likely to adversely affect the NARW and humpback whale species.

West Indian Manatee

Since the habitat and food supply of the manatee would not be significantly impacted, overall occurrence of manatees in the project vicinity is infrequent, all hopper dredging would occur in the offshore environment, and precautionary measures for avoiding impacts to manatees, as established by USFWS, would be implemented for transiting vessels associated with the project, the proposed action may affect by is not likely to adversely affect the manatee.

Sea Turtles—Loggerhead, Hawksbill, Kemp's Ridley, Green, and Leatherback

All five species are known to occur within oceanic waters of the proposed project borrow areas; however, only the loggerhead, green, and leatherback sea turtles are known to nest within the limits of the project beach placement area. Therefore, species-specific impacts could occur from both the beach placement and dredging operations. Considering the proposed dredging window to avoid the sea turtle nesting season to the maximum extent practicable, the proposed project may affect but is not likely to adversely affect nesting loggerhead, green, and leatherback sea turtles by altering nesting habitat. Though significant alterations in beach substrate properties may occur with the input of sediment types from other sources, reestablishing a berm and dune system with a gradual slope can enhance nesting success of sea turtles by expanding the available nesting habitat beyond erosion- and inundation-prone areas. As previously stated, in regards to suitability for nesting, turtles continue to nest on disposal beaches of Topsail Island with hatch rate successes similar to non-disposal beaches (Jean Beasley, personal communication, 2004).

The proposed hopper dredging activities for initial construction, and each nourishment interval, could occur in areas used by migrating turtles. Hopper dredges pose risk to

benthic-oriented sea turtles through physical injury or death by entrainment. Although the December 1 to March 31 dredging window would avoid periods of peak turtle abundance during the warm water months, the risk of lethal effects still exist because some sea turtle species can be found year-round in the offshore area. Therefore, the proposed hopper dredging activities would be expected to adversely affect loggerhead, green, hawksbill, and Kemp's ridley sea turtles. On the basis of historic hopper dredging take data, leatherback sea turtles are not known to be impacted by hopper dredging operations.

Shortnose Sturgeon
Although hopper dredges have been known to affect shortnose sturgeons, dredging for the project would occur in offshore environments, outside its habitat range. Therefore, impacts from dredges would not be expected. Because of the unlikelihood of shortnose sturgeon being present in the project area (Fritz Rhode, personal communication, August 9, 2008) and because dredging would occur in the offshore environment, the actions of the proposed project are not likely to adversely affect the shortnose sturgeon.

Seabeach Amaranth
Beach nourishment would restore much of the existing habitat lost to erosion and would be expected to provide long-term benefits to seabeach amaranth; however, construction and deep burial of seeds on a portion of the beaches during project construction could slow germination and population recovery over the short term. Therefore, the project may affect, but is not likely to adversely affect seabeach amaranth.

Piping Plover
The long-term effects of the project may restore lost roosting and nesting habitat through the addition of beachfill; however, short-term impacts to foraging, sheltering, roosting habitat may occur during project construction. Therefore, it has been determined that the project may affect, but is not likely to adversely affect the piping plover.

Smalltooth Sawfish
On the basis of the South Atlantic distribution of smalltooth sawfish and only one sighting in North Carolina since 1999, hopper dredge impacts to smalltooth sawfish in the project area are unlikely. Additionally, the take of a smalltooth sawfish by a hopper dredge is unlikely considering the smalltooth sawfishes affinity for shallow, estuarine systems as well as the fact that there has never been a reported take of a smalltooth sawfish by a hopper dredge. Therefore, hopper dredge activities associated with this project are not likely to adversely affect smalltooth sawfish.

Consultation Summary—NMFS
On April 30, 2007, the Corps formally reinitiated consultation under section7 of the ESA in regard to the NMFS South Atlantic Regional Biological Opinion (SARBO), dated September 25, 1997. The SARBO was issued to the Corps' South Atlantic Division for "the continued hopper dredging of channels and borrow areas in the Southeastern United States." On September 12, 2008, SAD provided NMFS with the Corps' South Atlantic Regional Biological Assessment (SARBA). The SARBA addresses federal, federally permitted, or federally sponsored (funded or partially funded) dredging activities (i.e.,

hopper, cutterhead, mechanical, bed leveling, and side cast) in the coastal waters, navigation channels (including designated Ocean Dredged Material Disposal Sites), and sand mining areas in the South Atlantic Ocean (including OCS sand resources under MMS jurisdiction) from the North Carolina/Virginia Border through and including Key West, Florida and the Islands of Puerto Rico and the U.S. Virgin Islands. As noted in the September 12, 2008, transmittal letter, the U.S. Department of Interior, MMS, has agreed to a joint consultation with the Corps as the lead agency. In May 2007 during a SARBA scoping meeting at the NMFS Southeast Regional Office in St. Petersburg, Florida, Corps and NMFS representatives agreed that all dredging activities in the South Atlantic would continue to work under the 1997 SARBO until the new SARBO was developed and finalized. Therefore, all dredging actions associated with the proposed project would work under the Reasonable and Prudent Measures (RPMs), Terms and Conditions (T&Cs), and Incidental Take Statement (ITS) of the 1997 SARBO until a superseding SARBO is completed. When the NMFS completes the new SARBO, all new RPMs, T&Cs, and ITS would be adhered to as a component of this project.

On January 13, 2010, the Corps provided a letter to the NMFS requesting concurrence that operating under the 1997 and superseding SARBO, for the purposes of this project, would satisfy section 7 requirements of the ESA. In an e-mail from Erick Hawk (NMFS-SERO) dated January 19, 2010, NMFS provided the following determination:

> NMFS agrees with the [Corps'] determination that the proposed beach renourishment action, consisting (in part) of utilizing hopper dredges to mine offshore sand sources for deposition of sand onto North Carolina beaches (a 17-mile section extending from Topsail Beach/Surf City town limits to the northern end of Topsail Island) falls under the authority of the current NMFS South Atlantic regional biological opinion on hopper dredging of navigation channels and borrow areas in the southeastern United States, dated September 25, 1997 (i.e., SARBO). The SARBO is in the process of being revised and will eventually supersede the current opinion. The [Corps] will abide by the revised SARBO when it is ultimately issued. Sea turtle or shortnose sturgeon takes resulting from the proposed dredging action when conducted under the RPMs and T&Cs of the SARBO are authorized and would be counted against the ITS take limit as set forth in the SARBO.

Consultation Summary—USFWS

On January 13, 2010 the Corps provided a letter to the USFWS requesting review and concurrence of the Corps effect determination of project related impacts to listed species in the project area. Specifically, the letter states that proposed project could affect but would not be likely to adversely affect the West Indian manatee (*Trichechus manatus)*, seabeach amaranth (*Amaranthus pumilus)*, piping plover *(Charadrius melodus)*, and nesting loggerhead (*Caretta caretta*), green (*Chelonia mydas*), and leatherback (*Dermochelys coriacea*) sea turtles.

In a letter dated April 30, 2010, the USFWS provided the following determination:

> The USFWS believes that the proposed action is not likely to adversely affect federally listed species or their critical habitat as defined by the Endangered Species Act (ESA) of 1973, as amended (16 U.S.C. 1531-1543). Therefore, the requirements of section 7 (a)(2) of the ESA have been satisfied for this project. However, the Corps' obligations under the ESA must be reconsidered if: (1) new information identifies impacts of this action that may affect listed species or critical habitat in a manner not previously considered; (2) this action is modified in a manner that was not considered in this review; or, (3) a new species is listed or critical habitat determined that may be affected by the identified action.

Upon further consultation following modifications made to monitoring commitments, the USFWS established that their concurrence is for initial construction only and consultation will need to be re-initiated prior to the first renourishment. A USFWS letter in regards to this is contained in Appendix L.

8.03 Physical Resources

8.03.1 Wave Conditions

Localized deepening of offshore borrow areas is the only potential source of effects on wave conditions, however, those changes would not be expected to be significant. The borrow area use plan identifies 16 borrow areas 1.2 to 5.5 miles offshore scattered across approximately 24 miles in water depths of 35 to 50 ft. MLLW, which should have less impact on wave conditions than dredging a large, contiguous area. The anticipated average dredging depths for the majority of the borrow areas range from 2.8 to 4.4 ft. with the exception of borrow areas N, O, P, and Q, where the average dredging depth ranges from approximately 5.1 to 6.4 ft. Specific locations in borrow areas A, J, L, N, O, P, and T indicate isolated locations of compatible material at depths ranging from 8.3 to almost 15 ft. The potential to dredge those borrow areas to the deeper depths would be dependent on additional investigation conducted during the design phase to comply with the North Carolina beachfill standards. Simplified, irregular wave transformation calculations were made to look at the sensitivity of deepening the ocean floor by 5 ft. (to simulate excavating borrow) on wave heights. Findings indicate absolute wave height differences of less than 0.1 ft. because of deepening for a range of the most commonly occurring wave heights and periods. Even considering the greater depths up to 15 ft. in the borrow areas, negligible changes in wave conditions would be expected along the project shoreline because of pre-dredge water depths at the borrow areas ranging from 38 to 48 ft. MLLW.

8.03.2 Shoreline and Sand Transport

Existing water depths in the borrow areas range from 35 to 50 ft. MLLW, which is substantially deeper than the estimated active profile depth of 23 ft. NGVD. Therefore no impacts to the active profile would be expected as a result of borrow area dredging.

Planform evolution indicates that without-project erosion rates of 0 to 3 ft. per year would increase to 2 to 13 ft. per year with a beachfill project in place, with rates increasing toward the ends of the project. Renourishment would take place every 6 years

to replenish the losses, unless project monitoring indicates that renourishment could be reasonably delayed. Net movement of the material would be predominantly to the north on the basis of transport analysis, with northerly sediment transport being roughly twice that of southerly transport on average.

8.03.3 Geology and Sediments

8.03.3.1 Borrow Area Dredging

About 11.5 square miles of sandy ocean bottom would be affected over the 50-year economic life of the project. Within the borrow areas (Figures A-1 and A-6, in Appendix A) existing water depths (greater than –35-foot MLLW) would be deepened, and recolonization of affected areas would be expected within 1–3 years. As discussed in Section 2.01.10, an extensive geophysical investigation was conducted to identify hard bottom presence and delineate hard bottom that was identified in and near several borrow areas. Hard-bottom buffers of 500 meters (1,640 ft.) were established for high- and moderate-relief hard bottom, and 122 meters (400 ft.) were established for low-relief hard bottom. The buffers were proposed by the Corps, Wilmington District and agreed to by several state and federal resource agencies. For more specific information regarding impacts to hard bottoms, see Section 8.01.8.2.

8.03.3.2 Beachfill Construction

Hopper dredging would be the anticipated method used during the construction and renourishment phases. Adverse effects during the construction phase would be minor and temporary. Potential effects associated with this type of operation include the following:

- Increased turbidity in the surf zone
- Sedimentation of nearshore and offshore hard bottoms

Impacts should be insignificant considering turbidity and sedimentation plumes would be confined to the offshore borrow areas during hopper dredging operations, and hard bottoms were identified within only the vicinity of eight of the offshore borrow areas. For more information, see Section 8.01.8.2.

During nourishment operations, there would be an increase in the turbidity in the surf zone in the immediate area of sand deposition. Deposition and subsequent turbidity increases may have short-term effects on surf zone fishes and prey availability. The anticipated hopper dredging time frame for the project is from December 1 to March 31 and avoids the peak recruitment and abundance timeframe of the surf zone fishes. Because of the construction time frame and the adaptive availability of representative organisms, the impacts should be temporary and minor. For more information, see Section 8.01.3.

8.03.3.3 Sediment Compatibility

The compatibility analysis compared the grain size of the *native beach* or the *reference beach* with the material in the proposed borrow areas. The overfill ratio is the primary indicator of the compatibility of the borrow material to the beach material, with a value of 1.00 indicating that one cubic yard of borrow material is needed to match one cubic

yard of beach material. The procedure for calculating the overfill ratio for borrow areas in relation to the reference beach was performed in accordance with the Corps Coastal and Hydraulics Laboratory Automated Coastal Engineering System (ACES) software version 4.01. That procedure is discussed in section V-4-1.e.(2)i. of the Corps' Engineer Manual (EM) 1110-2-1100, part V, titled *Coastal Engineering Manual.* An overfill ratio of up to 1.5 is generally considered acceptable as a match of compatibility. Although no studies have been conducted concerning overfill ratios and post-project water quality, post-construction studies conducted for beach erosion control projects have concluded the effects of beachfill operations on short-term turbidity appeared to be limited to the immediate area of the operation. Total suspended sediment concentrations outside the swash zone seldom exceed 25 mg/L, a value comparable to concentrations many species experience in estuaries or during storms (USACE New York District, 2001). Because the project borrow area sediment generally consists of a low percentage of silt, post-project impacts to water quality would be expected to be minimal.

Table 7.4 illustrates the overfill ratios for potential borrow areas for the Surf City/North Topsail Beach project. The overfill ratios for the borrow areas are all below 1.5 with the exception of borrow area C, which is 1.56. Because the overfill ratio for borrow area C is only slightly above 1.5, it has been retained for further evaluation when additional characterization is conducted during the design phase.

As stated in Section 7.04.1, North Carolina implemented new beachfill standards in 2007, which require compatibility of the native beach with borrow sources in regards to the percentage of silt, granular sediment, gravel, and calcium carbonate (or shell content for projects initiated before implementation of the rules). The standards require that percent silt, granular sediment, and gravel in borrow material not exceed the amount found in the native beach plus 5 percent and the percent carbonate in borrow material not exceed the amount found in the native beach plus 15 percent. As illustrated in Table 7.3, the silt, granular sediment, gravel content, and visual shell content for the Surf City/North Topsail Beach project are 1.2, 1.1, 0.5, and 9 percent respectively. Incorporating the tolerance permitted by the beachfill standards results in the following criteria silt (6.2 percent), granular sediment (6.1 percent), gravel (5.5 percent), and calcium carbonate (24 percent).

As shown in Table 7.4, all the borrow areas comply with the beachfill standards in regards to the percentage of silt with the exception of borrow areas A (6.6 percent) and L (6.3 percent). Both of these borrow areas exceed the standard slightly by 0.4 and 0.1 percent respectively. All the borrow areas comply with the beachfill standards in regards to the percentage of granular sediment with the exception of borrow areas F (7.0 percent) and S (6.6 percent), which exceed the standard by 0.9 and 0.5 percent respectively. All the borrow areas comply with the beachfill standards in regards to the percentage of gravel sediment with the exception of borrow areas F (8.5 percent) and P (6.6 percent), which exceed the standard by 3.0 and 1.1 percent respectively. All the borrow areas comply with the beachfill standards in regards to the percentage of shell content (carbonate). The borrow areas in which the standards were exceeded for the various characteristic (A, F, L, S, and P) have been retained because all borrow areas would be

further characterized during the design phase of the project. Additional vibracores would be performed to comply with the beachfill standards of 1 core/acre or 1,000-ft spacing. Vibracores would be performed to produce a density of 1,000-ft spacing in a borrow area before its use as a borrow source. For more information on borrow material and sediment compatibility, see Appendix E.

8.04 Socioeconomic Resources

8.04.1 Commercial and Recreational Fisheries

The economic effects of the NED plan or other nourishment plans during construction would not be expected to be significant. Effects on shore fishing would be limited to the area where material is being placed on the beach. Such localized temporary impact can easily be avoided by anglers in the area. Nearshore fishing boats can operate around the dredging equipment operating in the area. The beach nourishment plan would not be expected to affect inside fishing or the operation of commercial fishing boats operating in or going through New Topsail Inlet or New River Inlet. Unless there is extreme weather, the ocean going dredge would operate continuously. Therefore, the economic impact of commercial and recreational fishing would not be expected to change with the project construction.

8.05 Recreation and Aesthetic Resources

Overall, short-term minor adverse and long-term minor beneficial effects would be expected on aesthetic and recreational resources. Implementing the proposed action could cause temporary reduction of aesthetic appeal and interference with recreational activities in the areas of project construction. However, because project construction would be conducted in relatively small areas at a time, recreational and aesthetic impacts would be localized. Also, construction and maintenance would be done between December 1 and March 31, thereby avoiding the peak summer tourist season. When work activities in any area are completed, aesthetic values and recreational opportunities would be restored or enhanced as construction equipment is moved away.

The ocean and navigable waters in the vicinity of Surf City and North Topsail Beach would be affected to only a minor extent in that dredges, barges, and other watercraft associated with the work would be on-site for several months during construction and during renourishment events. However, that is judged to be an insignificant effect.

Placement of beachfill would result in temporary use of dredge pipeline, bulldozers, and other equipment on the beach, and these objects would detract from the normal appearance of the beach. Also, recreational activities on beaches may experience some interruption or interference during work periods, but the degenerated, eroded conditions of the beaches already present recreational constraints. After work is completed on a beach and the heavy equipment is removed, the resulting wider beach would be expected to represent an aesthetic enhancement and an improvement for recreation.

One ocean pier, the Surf City Ocean Pier, is within the construction area. The placement of beachfill under this pier could temporarily reduce the area available for fishing. Beach

nourishment during the fishing season could also affect the recreational catch. During past projects at Wrightsville Beach and Carolina Beach, no special provisions were made during placement of beach-fill around the piers and no major objections were raised during the process. However, for Atlantic Beach, during the pumpout of Brandt Island, the beachfill was wider than usual, thus raising concerns from fishing interests. The Surf City and North Topsail Beach project is similar to the Wrightsville and Carolina Beach projects. In the vicinity of the pier, immediately after construction, the shoreline could extend out approximately 300 ft. from its present position. However, natural forces would reshape the beach area and within a few months, beachfill material would be more evenly distributed throughout the nearshore zone. After that redistribution of material, it is expected that the new beach profile would extend out approximately 150 ft. beyond its current position, thus having minimal impact on the 937-foot pier. Any turbidity that would occur during placement would be dissipated during several tidal cycles and should have no significant long-term impact on fishing from either the piers or the surf zone. Such impacts are not expected to significantly reduce public use at the pier.

8.06 Cultural Resources

The Coastal Plain remains the least known archaeological region in North Carolina (Phelps, 1983; Science Applications, Inc., 1981; Ward and Davis, 1999). While there has been some success developing upland-offshore site location correlations in Florida and perhaps elsewhere, the methodology is not very well developed for sites in the Carolinas region. There are not a significant number of known upland locations that could be used to model settlement in now inundated areas (Ward and Davis, 1999). Scientific Applications, Inc. (1981) noted the paucity of archaeological data in its study area along the Atlantic coast from North Carolina to Florida, and its need to use data from outside the study area to develop a model for predicting the location of archaeological sites on the submerged continental shelf. Anderson (1996) also found a low site incidence for Early, Middle, and Late Archaic Period sites for the coastal area of North Carolina when examining Archaic settlement in the Southeast.

Five chronological cultural units, Pre-Paleoindian, Paleindian to Early Archaic (early), Early Archaic (late) to Middle Archaic, Late Archaic to Woodland, and Woodland were used for assembling the data for modeling. Pre-Paleoindian sites are assumed to date before 11,500 B.P. and represent transient camps of a low density population (Scientific Applications, Inc., 1981). Paleoindian and Early Archaic sites tend to be clustered along major drainages and sources of knappable stone (Anderson and Faught, 2000; Ward and Davis, 1999). These sites are likely to be associated with paleochannels; however, these sites are very rare in the North Carolina coastal region and consist only of single point (Science Applications, Inc., 1981). Terminal Early through Middle Archaic sites are also associated with riverine settings and upland swamps, with base camps located on terraces of major rivers, and specialized sites occurring in throughout interfluvial areas (Blanton, 1996; Sassaman, 1996; Scientific Applications, Inc., 1981; Ward and Davis, 1999). Settlement during the Late Archaic and Early Woodland appears to have shifted to the mouths of major rivers, and by the Woodland period, sites are in most estuarine settings (Scientific Applications, Inc., 1981; Ward and Davis, 1999). Base camps, especially shell

middens, tend to be in the most productive estuaries and adjacent landforms (Scientific Applications, Inc., 1981). However, Anderson (1996) noted the lower Coastal Plain and coastal areas of North Carolina appear to have been of limited use during the Late Archaic.

The Science Applications, Inc., model uses three sensitivity zones, with zone 1 having the highest probability of containing archaeological sites, and zone 3 having the least probability. Zone 1 includes areas from the present day shoreline to the 8,000 B.P. shoreline (circa the 39-foot-depth contour). Zone 2 extends outward from the 8,000 B.P. shoreline to the 12,000 B.P. shoreline (circa the 75-foot-depth contour). Zone 3 continues outward from the 12,000 B.P. shoreline to the 16,000 B.P. shoreline (circa 200-foot-depth contour). The paleoshorelines for the above zones are based on the sea level curve proposed in the same study (Science Applications, Inc., 1981).

The proposed borrow areas are in water depths ranging from 28 to 52 ft. Those depths would correlate to roughly the 9,000 B.P. to 6,000 B.P. shorelines proposed by Science Applications, Inc. (1981). Early- to Middle-Archaic base camps could exist along major inundated channels, with specialized sites in most riverine settings. Pump-out locations closer to shore could contain Late Archaic and Woodland period sites. Significant sites of those periods tend to be larger than earlier base camps and contain shell middens in estuarine environments. The proposed project is also within zone 1, the highest probability zone; however, the North Carolina coastline is considered a high-energy, wave-dominated zone because of the narrow and steep nature of the continental shelf. Most of the North Carolina continental shelf is believed to have been dominated by erosional transgression and have a low preservation potential (Scientific Applications, Inc., 1981).

In its reviews of this project, the Underwater Archaeology Branch (UAB) of the North Carolina Office of State Archaeology has not mentioned prehistoric sites or impacts to other types of sites; shipwrecks have been the major concern. The North Carolina State Historic Preservation Officer (NC SHPO) letter accepting the final report of investigations is dated March 1, 2005, and is included in Appendix H of the FEIS. Although all literature reviews, surveys, coordination efforts, and the like, have not identified any cultural resource concerns to date, to further minimize the risk of resource impacts before and during construction, the following commitments would be implemented: (1) To assure the risk of potential impacts to cultural resources within inshore areas subject to pump-out activities are avoided, specific pump-out locations would identified, surveyed, and investigated for cultural resources in conjunction with hard bottom surveys before commencement of nourishment activities. (2) If, during dredging activities, any previously unidentified or unanticipated historical, archaeological, and cultural resources are discovered or found within the inflow screening of the dredge or within the beach placement area, all activities that may damage or alter such resources would be temporarily suspended. Resources of interest include any human skeletal remains or burials; artifacts; shell, midden, bone, charcoal, or other deposits; shipwrecks; rock or coral alignments, pavings, wall or other constructed features; and any indication of agricultural or other human activities. If such a discovery

or find is made, the Corps' Contracting Officer would be immediately notified so that the appropriate authorities, including the MMS, can be notified in accordance with Corps policy and 30 CFR 250.194(c) and a determination made as to their significance and what, if any, special disposition of the finds should be made. All activities that could result in effects on or the destruction of those resources would cease. The area would be secured to prevent employees or other persons from trespassing on, removing, or otherwise disturbing such resources until the sites potential historic significance can be assessed and protected.

Whereas the Topsail Island vicinity is known to have had an active historical maritime trade, the Corps Wilmington District, in consultation with the North Carolina Division of Archives and History, undertook contracted remote sensing survey designed to meet the intent of the National Historic Preservation Act and the Abandoned Shipwreck Act. During summer and fall of 2004, Mid-Atlantic Technology and Environmental Research, Inc., conducted a magnetometer and side-scan sonar survey of the 10 proposed borrow areas. The results of that survey are reported in *Archaeological Remote Sensing Survey of Topsail and West Onslow Beaches Offshore Borrow Areas (*Contract DACW54-03-D-0002, Order 0003, Wes Hall, Principal Investigator, December 2004). Data were collected along parallel lines spaced at 65-ft (20-m) intervals. Magnetic data, along with corresponding positioning data, were recorded at one-second sample intervals (or approximately every 8 ft. along a track line at 5 knots).

Note that seven potential offshore borrow areas (extending from the Topsail Beach/Surf City town limit to New River Inlet) were originally identified at the time the cultural resources survey was conducted. After completion of the survey, hard bottom was identified in several borrow areas, which required modification to the boundaries of several borrow areas and elimination of three borrow areas (now identified as I, K, and M). Consequently, the remaining viable borrow areas were renamed and reconfigured into 10 borrow areas. The boundaries of those reconfigured borrow areas are completely contained within the boundaries of the original seven borrow areas.

No single, isolated magnetic anomalies or acoustic targets were identified during the survey of the 10 borrow areas. A low potential exists for encountering submerged prehistoric sites according to proposed borrow areas and material type, preservation potential, and current data on North Carolina prehistoric sites in coastal/submerged settings. No further cultural resources studies are anticipated for the project within the proposed borrow areas. By letter of November 2, 2004, the NC SHPO concurred with the reported findings. The Corps must, pursuant to 36 CFR 800.13(b), immediately secure the jobsite, suspend work in the vicinity of the affected resource, and consult with the NC SHPO and MMS if previously unidentified culture resources are discovered during the execution of the project.

8.07 Water Resources

8.07.1 Hydrology

Marine waters of the project area display considerable daily variation in current and salinity conditions due to fresh water inflow, tides, and wind. Within the ocean environment, any project-induced changes in the vicinity of the proposed work would be very small (if any) in comparison and would, therefore, considered to be insignificant.

8.07.2 Water Quality

Dredging in the selected borrow areas would involve mechanical disturbance of the bottom substrate and subsequent redeposition of suspended sediment and turbidity generated during dredging. Factors that are known to influence sediment spread and turbidities are grain size, water currents and depths. Monitoring studies done on the impacts of offshore dredging indicate that sediments suspended during offshore are generally localized and rapidly dissipate when dredging ceases (Naqvi and Pullen, 1983; Bowen and Marsh, 1988; Van Dolah et al., 1992). Some infilling of the borrow area after dredging would be expected from side sloughing of native bottom sediments, which consist of predominately sandy material with a small amount of fine or organic material.

During construction, there would be elevated turbidity and suspended solids in the immediate area of sand deposition when compared to the existing non-storm conditions of the surf zone. Significant increases in turbidity are not expected to occur outside the immediate construction/maintenance area (turbidity increases of 25 nephelometric turbidity units [NTUs]) or less are not considered significant). Turbid waters (increased turbidity relative to background levels but not necessarily above 25 NTUs) would hug the shore and be transported with waves either northeast or southwest depending on wind conditions. Because of the low percentage of silt and clay in the borrow areas (less than 10 percent), turbidity impacts would not be expected to be greater than the natural increase in turbidity and suspended material that occurs during storm events. Any increases in turbidity in the borrow areas during project construction and maintenance would be expected to be temporary and limited to the area surrounding the dredging. Turbidity levels would be expected to return to background levels in the surf zone when dredging ends.

Overall water quality impacts of the proposed action would be expected to be short-term and minor. Living marine resources dependent on good water quality should not experience significant adverse effects from water quality changes.

A section 401 Water Quality Certificate under the Clean Water Act of 1977 (P.L. 95-217), as amended, is required for the proposed project and would be obtained from the NCDWQ before construction begins.

Pursuant to section 404 of the Clean Water Act, the impacts associated with the discharge of fill material into waters of the United States are discussed in the Section 404(b)(1) (P.L. 95-217) Guidelines Analysis in Appendix G. Discharges associated with dredging in the offshore borrow areas are considered incidental to the dredging operation, and

therefore, are not being considered as being a discharge addressed under the *Section 404(b)(1) Guidelines Analysis.*

8.07.3 Groundwater

Dredging with beach placement of material would not be expected to adversely affect groundwater of the area. Groundwater in the area moves generally east and southeast along a regional gradient of about 8 ft. per mile. The potential for saltwater intrusion into groundwater does not exist unless a reversal of hydrologic gradient occurs from excessive groundwater pumping. Water supplies of nearby communities would not be expected to be affected by the proposed action.

8.08 Other Significant Resources (P.L. 91-611, Section 122)

8.08.1 Air, Noise, and Water Pollution

Temporary increases in exhaust emissions from construction equipment are expected during the construction and periodic renourishment of the SCNTB project; however, the pollution produced would be similar to that produced by other large pieces of machinery and should be readily dispersed. All dredges must comply with the applicable EPA standards. Additionally, ozone is North Carolina's most widespread air quality problem, particularly during the warmer months. High ozone levels generally occur on hot sunny days with little wind, when pollutants such as nitrogen oxides and hydrocarbons react in the air. High levels of fine particles are more of a problem in the western Piedmont region but can occur throughout the year, particularly during episodes of stagnant air and wildfires. The project would be constructed outside the ozone season. The air quality in Pender and Onslow counties, North Carolina, is designated as an attainment area. North Carolina has a State Implementation Plan (SIP) approved or promulgated under section 110 of the Clean Air Act (CAA), however, for the following reasons; a conformity determination is not required.

a. 40 CFR 93.153 (b), "For Federal actions not covered by paragraph (a) of this section, a conformity determination is required for each pollutant where the total of direct and indirect emissions in a nonattainment or maintenance area caused by a federal action would equal or exceed any of the rates in paragraphs (b) (1) or (2) of this section." North Carolina has designated Pender and Onslow counties as an attainment area.

b. The direct and indirect emissions from the project fall below the prescribed deminimus levels (58 *Fed. Reg.* 93.153(c)(1)) and, therefore, no conformity determination would be required.

c. The project is within the jurisdiction for air quality of the Wilmington Regional Office of the NCDENR. The ambient air quality for Pender and Onslow counties has been determined to be in compliance with the National Ambient Air Quality Standards. Furthermore, Table 8.5 includes an analysis of total emissions for the proposed dredging and land-based operations associated with the project as well as a comparison of the project calculated emissions to EPA's NEI data for Onslow County.

To provide additional verification that the proposed project would not adversely impact air quality in these attainment areas, air emissions of the various pieces of equipment used in beach nourishment project were estimated. The following assumptions were made when calculating the emissions outputs for the dredging and beach placement equipment:

1. Hopper Dredge emissions calculations were based on representative hopper dredge (i.e., RN Weeks) emissions calculated by MMS for the Sandbridge Beach Restoration project in Virginia. MMS made the following assumptions:

a. Hopper Dredge (with pump ashore capability) is working 120 days and pumps 2,000,000 cubic yards of material to the beach.

b. The following equipment is part of the in-water dredging operation:
1) 2 tender tugs
2) 1 derrick barge
3) 2 work barges
4) 1 bulldozer

c. The following equipment is part of the beach placement operation:
1) 2 bull dozers (215 horsepower)
2) 1 flat bed truck

2. Initial SCNTB Project Construction Requirements: Two hopper dredges would be working for about 120 days each year or from December 1 to March 31 for 4 years. The two hopper dredges would pump about 3,000,000 cubic yards each year for a total of about 12,000,000 cubic yards of material (after 4 years).

a. The following equipment is part of the in-water dredging operation:
1) 2 tender tugs
2) 1 derrick barge
3) 2 work barges
4) 1 bulldozer

b. The following equipment is part of the beach placement operation:
1) 2 bull dozers (215 horsepower)
2) 1 flat bed truck

3. Renourishment Maintenance Interval for the SCNTB project: Once every 6 years after initial construction, two hopper dredges working about 120 days or from December 1 to March 31 and would place about 2.6 million cubic yards of material on the beach.

a. The following equipment is part of the in-water dredging operation:
1) 2 tender tugs
2) 1 derrick barge
3) 2 work barges

4) 1 bulldozer

b. The following equipment is part of the beach placement operation:
1) 2 bull dozers (215 horsepower)
2) 1 flat bed truck

3. Equation used: From EPA: VOC= 1.005 × HC.

Table 8.5 below indicates that the percentage of the monthly emission rate (tons/month) for all construction equipment (i.e., hoppers, tugs, barges, bulldozers, and trucks) for the SCNTB project compared to the monthly emissions (tons/month) in EPA's NEI Data for Onslow County is 3.3 percent for NO_2, 0.08 percent for CO, 0.08 percent for HC, 0.17 percent for PM_{10}, and 1.20 percent for SO_2.

On the basis of the analysis provided in Table 8.5, the project would not be expected to create any adverse effects on the air quality in the attainment area, and the project would be in compliance with section 176 (c) of the Clean Air Act, as amended. Additionally, the analysis provided in Table 8.5 is considered conservative for the following reason: vessels powered by Category 2 engines (i.e., hopper dredges, tugs, crew boats) use non-road diesel fuel, which is subject to a 500 ppm (0.05 percent) sulfur level. Starting in 2012, the diesel fuel sulfur limit for locomotive and marine diesel fuel will be reduced to 15 ppm (0.0015 percent) (Penny Carey, personal communication, EPA, March 23, 2010).

Table 8.5. Project emissions analysis

Initial Construction	NOX	CO	HC	PM10	SO2
Two Hopper Dredges	113.10	30.04	3.17	3.53	10.71
2 Tender Tugs	0.72	0.17	0.02	0.02	0.10
1 Derrick Barge	1.80	0.41	0.05	0.05	0.24
2 Work Barges	1.44	0.33	0.04	0.04	0.19
Dozer	0.14	0.03	0.01	0.01	0.01
Sub-Total	117.20	30.98	3.29	3.66	11.25
*Land Based Equipment					
Sub-Total	19.24	4.20	1.56	1.37	1.28
TOTALS	136.44	35.18	4.85	5.03	12.54
Emissions (tons/month)	11.37	2.93	0.40	0.42	1.04
** Initial Construction Total	545.75	140.72	19.40	20.13	50.14
Maintenance Interval (Every 6 years)***					
Two Hopper Dredge	113.10	30.04	3.17	3.53	10.71
2 Tender Tugs	0.72	0.17	0.02	0.02	0.10
1 Derrick Barge	1.80	0.41	0.05	0.05	0.24
2 Work Barges	1.44	0.33	0.04	0.04	0.19
Dozer	0.14	0.03	0.01	0.01	0.01
Sub-Total	117.20	30.98	3.29	3.66	11.25
*Land Based Equipment					
Sub-Total	19.24	4.20	1.56	1.37	1.28
Renourishment Total	136.44	35.18	4.85	5.03	12.54

* Land based Equipment includes 2 dozers and 1 flatbed truck
** Initial Construction takes 2 Hoppers (includes land based equipment) for 4 years.
Total of about 12 million yards for initial construction.
*** Maintenance Interval is every 6 years at about 3 million yards

Water quality impacts are discussed in Section 8.07.2 and in the Section 404(b)(1) (P.L. 95-217) evaluation included with this document as Appendix G. Noise in the outside environment associated with beach construction activities would be expected to minimally exceed normal ambient noise in the project area; however, construction noise would be attenuated by background sounds from wind and surf. In-water noise would be expected in association with the dredging activities for this project. Specifically, noise associated with dredging could occur from (1) ship/machinery noise—noise associated with onboard machinery and propeller and thruster noise, (2) pump noise—noise associated with pump driving the suction through the pipe, (3) collection noise—noise associated with the operation and collection of material on the sea floor, (4) deposition noise—noise associated with the placement of the material within the barge or hopper,

and (5) transport noise—noise associated with transport of material up the suction pipe. The limited available data indicate that dredging is not as noisy as seismic surveys, pile driving and sonar; but it is louder than for example most shipping, operating offshore wind turbines and drilling (Thomsen et al., 2009).

Dredging produces broadband and continuous, low-frequency sound (below 1 kHz) and estimated source sound pressure levels range between 168 and 186 dB re 1 µPa at 1 m, which can trigger avoidance reaction in marine mammals and marine fish. In some instances, physical auditory damage can occur. Auditory damage is the physical reduction in hearing sensitivity due to exposure to high-intensity sound and can be either temporary (temporary threshold shift) or permanent (permanent threshold Shift) depending on the exposure level and duration. Other than physical damage, the key auditory effect is the increase in background noise levels, such that the ability of an animal to detect a relevant sound signal is diminished, which is known as *auditory masking*. Masking marine mammal vocalizations used for finding prey, navigation and social cohesion could compromise the ecological fitness of populations (Compton et al., 2008).

According to Richardson et al. (1995) the following noise levels could be detrimental to marine mammals:

Prolonged exposure of 140 dB re 1 µPa/m (continuous man-made noise), at 1 km can cause permanent hearing loss.

Prolonged exposure of 195 to 225 dB re 1 µPa/m (intermittent noise), at a few meters or tens of meters, can cause immediate hearing damage.

According to Richardson et al. (1995), "Many marine mammals would avoid these noisy locations, although it is not certain that all would do so." In a study evaluating specific reaction of bowhead whales to underwater drilling and dredge noise, Richardson et al. (1990) also noted that bowhead whales often move away when exposed to drillship and dredge sound; however, the reactions are quite variable and can be dependent on habituation and sensitivity of individual animals. According to Richardson et al (1995), received noise levels diminish by about 60 dB between the noise source and a radius of 1 km. For marine mammals to be exposed to a received level of 140 dB at 1-km radius, the source level would have to be about 200 dB re 1 µPa/m. Furthermore, few human activities emit continuous sounds at source levels greater than or equal to 200 dB re 1 µPa/m; however, supertankers and icebreakers can exceed the 195 dB noise levels.

According to Clarke et al. (2002), hopper dredge operations had the highest sustained pressure levels of 120–140 dB among the three measured dredge types; however, the measurement was taken at 40 m from the operating vessel and would likely attenuate significantly with increased distance from the dredge. On the basis of (1) the predicted noise effect thresholds noted by Richardson et al. (1995), (2) the background noise that already exists in the marine environment, and (3) the ability of marine mammals to move away from the immediate noise source, noise generated by bucket, cutterhead, and

hopper dredge activities would not be expected to affect the migration, nursing/breeding, feeding/sheltering or communication of large whales. Although behavioral effects are possible (i.e., a whale changing course to move away from a vessel), the number and frequency of vessels present in a given project area is would be small, and any behavioral impacts would be expected to be minor. Furthermore, for hopper dredging activities, endangered species observers would be on board and would record all large whale sightings and note any potential behavioral impacts. Per the standard Corps specifications for all dredging projects, the Corps and the contractor would keep the date, time, and approximate location of all marine mammal sightings. Care would be taken not to closely approach (within 300 ft.) any whales, manatees, or other marine mammals during dredging operations or transportation of dredged material. An observer would serve as a lookout to alert the dredge operator or vessel pilot or both of the occurrence of the animals. If any marine mammals are observed during other dredging operations, including vessel movements and transit to the dredged material disposal site, collisions must be avoided either through reduced vessel speed, course alteration, or both. During the evening hours, when there is limited visibility from fog, or when there are sea states of greater than Beaufort 3, the dredge must slow down to 5 knots or less when transiting between areas if whales have been spotted within 15 nautical miles of the vessel's path in the previous 24 hours. Sightings of whales or manatees (alive, injured, or dead) in the work area must be reported to NMFS Whale Stranding Network.

Similar to conclusions made regarding effects of sound on marine mammals, non-injurious impacts to sea turtles may also occur because of acoustic annoyance or discomfort. It has been hypothesized, on the basis of anatomical studies that sea turtle hearing range centers around low-frequency sounds. Ridgeway et al. (1969, 1970) evaluated the frequency sensitivity of green sea turtles and found that green turtles detect limited sound frequencies (200–700 Hz) and display high level of sensitivity at the low-tone region (approx 400 Hz). According to Bartol et al. (1999), the most sensitive threshold for loggerhead sea turtles is 250–750 Hz with the most sensitive threshold at 250 Hz. Though noise generated from dredging equipment is within the hearing range of sea turtles, no injurious effects would be expected because sea turtles can move from the area, and the significance of the noise generated by the dredging equipment dissipates with an increasing distance from the noise source.

8.08.2 Man-made and Natural Resources, Aesthetic Values, Community Cohesion, and the Availability of Public Facilities and Services

Beach nourishment would require the extension of dune crossover structures along the beach. Dredging in the offshore borrow areas would not be expected to cause significant interference with commercial and recreational boat traffic. The mobility of a hopper dredge would preclude any interference with regular commercial ship traffic as a result of travel to and from the borrow areas.

Impacts to aesthetic values are discussed in Section 8.05. Impacts to natural resources are discussed previously throughout Sections 8.01 and 8.02. Impacts to cultural resources are discussed in Section 8.06. Coastal storm damage risk reduction would benefit numerous roads, business, and residences. Implementing the NED alternative would be expected to

have beneficial effects on community cohesion and would reduce damages to many public facilities and services (i.e., roads and utilities) from storm events.

8.08.3 Hazardous, Toxic and Radioactive Wastes (HTRW)

The Corps' standard tiered approach for analyzing the potential for encountering contaminated sediments in the potential borrow areas was used to assess the potential borrow areas for HTRW. According to that analysis, before any chemical or physical testing of sediments would be conducted, a reason to believe that the sediments could be contaminated must be established. The sources of the sediments in the selected borrow areas are derived from sediment transport and deposition by ocean currents. The probability of the areas being contaminated by pollutants is low; however, the beach front (potential nourishment area) and the potential borrow areas are in areas that were affected by the operations of Camp Davis and the Navy's Operation Bumblebee.

Because of the project area's location relative to Camp Davis operations, a very remote possibility exists that OEW could be present in the material to be dredged from offshore borrow areas. However, the only ordnance that would be expected to be encountered would be spent shells from anti-aircraft target practice. The missiles that were tested during Operation Bumblebee contained no OEW and were fired approximately 40 miles offshore, well beyond the project area, and the likelihood of encountering them in an offshore borrow area would be remote.

As described in Section 2.07, the anti-aircraft shells that were fired from the beach during WWII were presumed to range in size from 37 mm (1.46 inches) to 155 mm (6.10 inches). A cultural resources survey, which used magnetometer and side-scan sonar, was completed for all proposed offshore borrow areas. Survey line spacing was 20 meters, and no anomalies were found in the areas surveyed (for a cultural resources summary, see Section 8.06). Although the cultural resources survey would have identified large anomalies, it was not intended to identify, nor was it capable of identifying, smaller anomalies, such as anti-aircraft shells. Because the survey did not identify any anomalies, it is presumed that any materials found offshore would be small and therefore would not impede the dredging and disposal operations and would not present a safety hazard to workers on the dredge or to anyone on the beach. However, to mitigate the very remote chance of encountering ordnance, the beach would be inspected daily, and any ordnance discovered would be handled in accordance with the Military Munitions Rule, 40 CFR 260-270. The Marine Corps Base Explosive Ordnance Disposal Team would be available (on call) during the dredging process. Additionally, the contract specifications for the proposed project would direct the contractor to immediately stop work and inform the contracting officer if unexploded ordnance is encountered during dredging or disposal. At that time, additional measures would be implemented, as necessary, including inspecting dredged material on the beach and installing outflow screens on the dredge pipeline. Any unexploded ordnance found on the beach would be promptly removed.

The bottom sediments that would be dredged from the borrow areas and placed on the beach would consist of predominately fine- to medium-grain size with some shell. Therefore, no further analyses or physical and chemical testing of the sediments is

recommended. It would not be expected that any hazardous and toxic waste sites would be encountered during construction or periodic nourishment. However, if any hazardous and toxic waste sites are identified, response plans and remedial actions would be the responsibility of the local sponsor.

8.09 Summary of Cumulative Effects

The detailed analysis of cumulative effects is included as Appendix J. The assessment of cumulative effects focused on effects of dredging from the proposed ocean borrow sites, and effects of placing sand material on the beach (whether for beach nourishment or disposal of dredge maintenance material) on significant coastal shoreline resources In completing the cumulative effects analysis, the Corps reviewed two Environmental Reports prepared for and published by the U.S. Department of the Interior, MMS, titled *Use of Federal Offshore Sand Resources for Beach and Coastal Restoration in New Jersey, Maryland, Delaware, and Virginia*, dated November 1999 (DOI 1999) and *Collection of Environmental Data Within Sand Resource Areas Offshore North Carolina and the Environmental Implications of Sand Removal for Coastal and Beach Restoration*, dated 2003 (Byrnes et al. 2003); the *U.S. Army Corps of Engineers Dare County Beaches (Bodie Island Portion) Final Feasibility Report and EIS on Hurricane Protection*, dated September 2000; the Corps' *Draft Evaluation Report and Environmental Assessment*, Morehead City Harbor Section 933, dated May 2003, and the *Final Integrated General Reevaluation Report and Environmental Impact Statement, Shore Protection, West Onslow Beach and New River Inlet (Topsail Beach)*, dated March 2008, the last three of which include comprehensive assessments of statewide cumulative effects. In discussing the potential cumulative effects of offshore borrow area dredging and beach nourishment, time-crowded perturbations, and space-crowded perturbations, as defined below, were considered to be pertinent to the action.

Time-crowded perturbations—repeated occurrence of one type of impact in the same area

Space-crowded perturbations—a concentration of a number of different impacts in the same area

For instance, as a result of dredging borrow areas for beach nourishment sand, there is concern for potential cumulative effects from repeated dredging in a borrow area within short periods of time such that the benthic community might not have time to recover. Dredging in subsequent areas close to one another could result in impacts to potential adult organism recruitment to the dredged areas, further lengthening the time for recovery in an area. However, as noted in Section 8.01.7 of the report, considering the distance offshore and the shallow volumes of sediment in the borrow areas, it is anticipated that all dredging activities associated with initial construction and each re-nourishment interval would be conducted using a hopper dredge. Recognizing the thin volumes of sediment within each borrow area, it is anticipated that all available sediment within each dredged portion of a borrow site would be fully used. Therefore, reoccurring impacts to an individual portion of a borrow area are not anticipated and full recovery of each

Relatively small portions of North Carolina beaches (approximately 12 percent) are affected by time/space crowded perturbations. With the proposed action, the impact area would not increase significantly because portions of the areas proposed for fill have previously had sand deposition. On a statewide scale, the existing and approved disposal sites are well distributed in northern, central, and southern parts of the state with undeveloped protected beaches (i.e., national/federal and state parks and estuarine reserves) in between. It is unlikely that cumulative effects from space-crowded perturbation are occurring or would occur because of the construction of this project. The analysis suggests that the potential impact area from the proposed and existing actions is small relative to the area of available similar habitat on a vicinity and statewide basis. Also, for some species such as sea turtles and seabeach amaranth, beach projects would improve habitat by replacing beach material lost to erosion. Last, all affected areas would be expected to recover invertebrates, which should continue to be available as food resources.

9. PLAN IMPLEMENTATION

9.01 Project Schedule

Table 9.1 shows the schedule through initial construction for the Selected Plan. The schedule assumes expeditious review and approval of the project through all steps, including authorization and funding. Actual project implementation could take longer. The schedule is subject to availability of funds.

Table 9.1. Project schedule

Study Authority	February 16, 2000
Reconnaissance Report, HQ Approval	June 12, 2001
Execute FCSA	February 13, 2002
Initiate Feasibility Study	February 2002
Alternative Formulation Briefing	December 2006
Complete Draft Feasibility Report & EIS	August 2009
Begin 45-day Public Review	January 2010
Begin Independent External Peer Review (IEPR)	February 2010
IEPR Certified	June 2010
Complete Final Feasibility Report & EIS	July 2010
Civil Works Review Board	August 2010
Begin 30-day Public Review	October 2010
Sign Record of Decision (ROD)	May 2011
Execute Design Agreement	October 2010
Initiate Initial Plans & Specifications	October 2010
Project Authorization (WRDA)	December 2010
Complete Initial Plans & Specifications	September 2012
Initiate Real Estate Acquisition	October 2012
Execute Project Partnership Agreement	March 2013
Initiate Final Plans & Specifications	October 2013
Complete Real Estate Acquisition	March 2014
Complete Final Plans & Specifications	June 2014
Advertise Initial Construction Contract	July 2014
Open Bids	August 2014
Award Initial Construction Contract	September 2014
Begin Initial Construction, Season 1 of 4	November 2014
Begin Initial Construction, Season 2 of 4	November 2015
Begin Initial Construction, Season 3 of 4	November 2016
Begin Initial Construction, Season 4 of 4	November 2017
Complete Initial Beachfill Construction	April 2018
Complete Remaining Construction Items	June 2018
Begin First Renourishment	November 2020
Complete First Renourishment	February 2021
Begin Second Renourishment	November 2026
Complete Second Renourishment	April 2027

9.02 Division of Plan Responsibilities

9.02.1 General

Federal policy requires that costs for water resources projects be assigned to the various purposes served by the project. These costs are then apportioned between the federal government and the nonfederal sponsor according to percentages specified in section 103 of the Water Resources Development Act (WRDA) of 1986 (P.L. 99-662). For projects that provide damage reduction to publicly owned shores, the purposes are usually (1) coastal storm damage reduction and (2) separable recreation. For the Surf City and North Topsail Beach project, there is no separable recreation component.

9.02.2 Cost Sharing

Cost sharing for initial construction of the Selected Plan would be consistent with that specified in section 103(c)(5) of WRDA 1986 as amended by WRDA 1996 (generally 65 percent federal and 35 percent nonfederal). Nonfederal interests are required to provide all lands, easements, rights-of-way, and dredged material disposal areas and perform all necessary relocations (LERRD) necessary for the project. The value of the nonfederal portion of the LERRD is $4,814,000 and is included in the nonfederal share of initial project construction costs. The remainder of the nonfederal share of initial project construction costs consists of $38,283,000 cash contribution.

Cost sharing for periodic nourishment (continuing construction) would be consistent with Section 215 of WRDA 99, which requires that such costs be shared 50 percent federal and 50 percent nonfederal.

Annual OMRR&R costs, such as inspection costs and dune vegetation maintenance costs, are 100 percent nonfederal responsibility. The federal government is responsible for preparing and providing an OMRR&R manual to the sponsor.

As noted previously, current federal policy requires that, unless there are other, overriding considerations, the plan that produces the maximum net benefits, the (NED) plan, would be the selected plan recommended for implementation. In this case, the selected plan recommended for implementation is the NED plan. Cost sharing for the selected plan is shown in Table 9.2 at October 2010 price levels.

The sponsor is in the process of obtaining the required public access sites and public parking to meet the definition of a public shoreline. The cost apportionment is computed to assume that 100 percent of the project would be a public shoreline by the time the PPA is executed. All project costs are allocated to the purpose of hurricane and storm damage reduction.

Table 9.2. Cost allocation and apportionment, October 2010 price levels

Initial project construction costs					
	Project	Apportionment %		Apportionment $	
Project purpose	first cost	Nonfederal	Federal	Nonfederal	Federal
Coastal storm damage reduction	$123,135,000	35%	65%	$43,097,000	$80,038,000
LERRD credit				$4,814,000	
Cash portion				$38,283,000	$80,038,000
Total financial initial project construction costs					
	Project	Apportionment %		Apportionment $	
Project purpose	first cost	Nonfederal	Federal	Nonfederal	Federal
Coastal storm damage reduction	$123,135,000	35%	65%	$43,097,000	$80,038,000
sunk feasibility phase costs	$4,240,000	50%	50%	$2,120,000	$2,120,000
Total financial cost	$127,375,000	35%	65%	$45,217,000	$82,158,000
Total renourishment costs					
	Total Cost	Apportionment %		Apportionment $	
Project purpose	(7 renourishments)	Nonfederal	Federal	Nonfederal	Federal
Coastal storm damage reduction	$205,539,000	50%	50%	$102,769,500	$102,769,500
	Cost per	Apportionment %		Apportionment $	
	Year	Nonfederal	Federal	Nonfederal	Federal
Monitoring	$505,000	50%	50%	$252,500	$252,500
Annual OMRR&R costs					
	Cost per	Apportionment %		Apportionment $	
	year	Nonfederal	Federal	Nonfederal	Federal
General repair, maintenance, inspection	$52,000	100%	0%	$52,000	$0

If parking and access minimums are not met, public use requirements for those areas would not be met and they would not be eligible for federal cost sharing. As described in Section 3.04, there are three areas totaling 2,800 ft. that do not meet shoreline access requirements to be considered as a public use shoreline. Two adjacent areas, totaling 8,200 ft., although having access, do not meet the criterion of having at least 10 public parking spaces within one-quarter mile, and so do not meet requirements. Those areas have a total length of 11,000 ft. and include both the 2,800 ft. without access and the 8,200 ft. lacking sufficient parking. Those reaches not meeting federal cost-sharing requirements represent 21 percent of the 52,150-ft total project length. The cost sharing percentage effects of the present categorization of the project shorelines are shown in Table 9.3. Table 9.3 is based on Appendix C, of ER 1165-2-130, *Federal Participation in Shore Protection*. Without the required access, the federal cost sharing decreases from 65 to 61.5 percent for initial construction and decreases from 50 to 47.3 percent for renourishment. Without both the required access and parking, the federal cost sharing decreases from 65 to 51.3 percent for initial construction and decreases from 50 to 39.5

percent for renourishment. As stated previously the towns of Surf City and North Topsail Beach intend to provide access and parking along the entire shoreline.

Table 9.3. Cost sharing based on shoreline category

Shore ownership	Public or private shores		Private shores	
	Developed public use	Developed no public use	Not developed	Total project requirements
Federal participation, construction	65%	0%	0%	
Length, ft (based on access)	49,350	2,800	0	52,150
Federal Cost Share	61.5%	0.0%	0.0%	**61.5%**
Federal participation, renourishment	50%	0%	0%	
Length, ft (based on access)	49,350	2,800	0	52,150
Federal cost share	47.3%	0.0%	0.0%	**47.3%**
Federal participation, construction	65%	0%	0%	
Length, ft (based on parking)	41,150	11,000	0	52,150
Federal cost share	51.3%	0.0%	0.0%	**51.3%**
Federal participation, renourishment	50%	0%	0%	
Length, ft (based on parking)	41,150	11,000	0	52,150
Federal cost share	39.5%	0.0%	0.0%	**39.5%**

The given cost sharing percentages assume that there would be no vacant first-row lots when construction begins. Vacant lots would be considered undeveloped, and the cost allocation for these lots would be 100 percent nonfederal. The number of undeveloped first-row lots would be reassessed before the signing of the PPA, and the cost sharing would be recalculated at that time to reflect any remaining undeveloped lots.

9.02.3 Financial Analysis

The nonfederal sponsors have submitted financial plans and statements of financial capability and have requested a letter from North Carolina, which declares the state's financial capability and financing plan relative to a Surf City and North Topsail Beach, North Carolina, Coastal Storm Damage Reduction project. Preliminary documentation of the sponsors' financial capability is to be provided in Appendix H.

9.02.4 Project Partnership Agreement

The model Project Partnership Agreement (PPA), based on the selected plan, was fully discussed with the nonfederal sponsors. The nonfederal sponsors have a clear understanding of the type of agreement that must be signed before the start of project construction. The terms of local cooperation to be required in the PPA are described in Section 13.0, Recommendations. Letters of intent from the nonfederal sponsors are to be provided in Appendix H.

Federal commitments regarding a construction schedule or specific provisions of the PPA cannot be made to the nonfederal sponsors on any aspect of the recommended plan or separable element until the following are true:

- The recommended plan is authorized by Congress
- Construction funds are provided by Congress, apportioned by the OMB, and their allocation is approved by the Assistant Secretary of the Army for Civil Works (ASA [CW])
- The draft PPA has been reviewed and approved by the ASA (CW)

The PPA would not be executed nor would construction be initiated on the project or any separable element until compliance requirements have been met for applicable federal and state statutes. Compliance is met once the Final EIS has been fully coordinated and a Record of Decision has been signed.

After this report is approved and the project budgeted for construction, Wilmington District can conduct negotiations with the nonfederal sponsors regarding the PPA, and submit a draft PPA package to higher authority for review and approval by the ASA (CW). The PPA would be executed only after approval of this report and enactment into law of an Appropriations Bill providing funds for the project. Federal construction funds for the project would not allocated by the Chief of Engineers until the ASA (CW) approves the nonfederal sponsors' financing plans and the PPA has been executed.

9.03 Views of the Nonfederal Sponsor

The Selected Plan of Improvement is acceptable to the nonfederal sponsors. Letters of support from the towns of Surf City and North Topsail Beach are to be provided in Appendix H.

9.04 Views of North Carolina

North Carolina, Department of Environment and Natural Resources, Division of Water Resources has indicated support for implementation of the Selected Plan.

9.05 Views of the U.S. Fish & Wildlife Service

Views of the USFWS are provided in the attached Fish and Wildlife Coordination Act Report in Appendix L. The recommendations of the USFWS and responses by Corps are presented in Section 11.02, Fish & Wildlife Coordination, of this report.

10. COMPLIANCE WITH ENVIRONMENTAL REQUIREMENTS

10.01 General

The following paragraphs summarize the relationship of the proposed action to the most pertinent federal, state, and local requirements. Table 10.1 lists the compliance status of all federal laws and policies that were considered for the proposed Surf City and North Topsail Beach project.

10.02 Water Quality

10.02.1 Section 401 of Clean Water Act of 1977

A section 401 Water Quality Certificate under the Clean Water Act of 1977 (P.L. 95-217), as amended, would be required for the proposed project and would be obtained from the NCDWQ before construction begins. Work would not proceed until the certificate is received.

10.02.2 Section 404 of Clean Water Act of 1977

Pursuant to section 404 of the Clean Water Act, the effects associated with the discharge of fill material into waters of the United States are discussed in the section 404(b)(1) (P.L. 95-217) evaluation in Appendix G. Discharges associated with dredging in the offshore borrow areas are considered incidental to the dredging operation, and therefore, are not being considered as being a discharge addressed under the section 404 (b)(1) Guidelines Analysis.

10.03 Marine, Protection, Research, and Sanctuaries Act

In 1972 Congress enacted the Marine Protection, Research and Sanctuaries Act, declaring that it is the policy of the United States to regulate the dumping of all types of materials into ocean waters. The act is designed to prevent or strictly limit the dumping into ocean waters of any material that would adversely affect human health, welfare, or amenities, or the marine environment, ecological systems, or economic potentialities. The proposed coastal storm damage reduction project does not involve ocean disposal of dredged material. Therefore, the project would be considered to be in compliance with the requirements of the Marine Protection, Research and Sanctuaries Act.

10.04 Essential Fish Habitat

Potential project effects on EFH species and their habitats have been evaluated and are addressed in Section 8.01.8 of this document. It has been determined that the proposed action would not have a significant adverse effect on such resources. By coordination of this document with the NMFS, consultation is officially initiated and concurrence with the Corps findings is requested. Compliance obligations related to EFH provisions of the 1996 congressional amendments to the MSFCMA (P.L. 94-265) would be fulfilled before initiation of the proposed action.

10.05 Fish and Wildlife Resources

The Fish and Wildlife Coordination Act, as amended (16 U.S.C. 661, *et seq*), requires that the Corps coordinate and obtain comments from the USFWS, the NMFS, where applicable, and appropriate state fish and wildlife agencies, including the NCDMF and the North Carolina Wildlife Resources Commission. A Fish and Wildlife Coordination Act Report (Appendix L) has been provided by the USFWS under the Fish and Wildlife Coordination Act.

10.06 Endangered and Threatened Species

A biological assessment evaluating the potential effects of the proposed action on T&E species has been prepared (Appendix I) and is being coordinated with the USFWS (jurisdiction over the Florida manatee, nesting sea turtles, piping plovers, and seabeach amaranth) and NMFS (jurisdiction over other protected marine and aquatic species which can occur in the project vicinity) pursuant to section 7 of the ESA of 1973 (P.L. 93-205), as amended. All compliance obligations under section 7 would be satisfied before the proposed action is implemented.

10.06.1 Commitments to Reduce Impacts to Listed Species

The following list is a summary of environmental commitments to protect listed species related to the construction and maintenance of the proposed project. The commitments address agreements with agencies, mitigation measures, and construction practices and should be considered preliminary. The list of commitments may be modified pending new information acquired through the public and agency review process.

1. The Corps will strictly adhere to all conditions outlined in the most current National Marine Fisheries Service RBO for dredging of channels and borrow areas in the southeastern United States. Furthermore, as a component of this project, hopper dredging activities for both initial construction and each nourishment interval will adhere, to the maximum extent practicable, to a dredging window of 1 December to 31 March in order to avoid periods of peak sea turtle abundance. The use of turtle deflecting dragheads, inflow and/or overflow screening, and NMFS certified turtle and whale observers will also be implemented.

2. In order to determine the potential taking of whales, turtles and other species by hopper dredges, NMFS certified observers will be on board during all hopper dredging activities. Recording and reporting procedures will be in accordance with the conditions of the current NMFS RBO.

3. Endangered species observers (ESOs) will be on board all hopper dredges and will record all large whale sightings and note any potential behavioral impacts. The Corps and the Contractor will keep the date, time, and approximate location of all marine mammal sightings. Care will be taken not to closely approach (within 300 feet) any whales, manatees, or other marine mammals during dredging operations or transportation of dredged material. An observer will serve as a lookout to alert the dredge operator and/or vessel pilot of the occurrence of these animals. If any marine mammals are

observed during other dredging operations, including vessel movements and transit to the dredged material disposal site, collisions shall be avoided either through reduced vessel speed, course alteration, or both.

4. The Corps will avoid the sea turtle nesting season during initial construction and each nourishment interval. If, due to unforeseen circumstances, construction extends into the nesting season, the Corps will implement a sea turtle nest monitoring and avoidance/relocation plan through coordination with USFWS and NCWRC.

5. Monitoring of sea turtle nesting activities in beach nourishment areas will be required to assess post nourishment nesting activity. This will include daily surveys beginning at sunrise from May 1 until September 15. Information on false crawl location, nest location, and hatching success of all nests will be recorded and provided to NCWRC.

6. The beach will be monitored for escarpment formation by the Contractor prior to completion of beach construction activities associated with initial construction and each nourishment interval. Additionally, the beach will be monitored by the local sponsor for escarpment formation prior to each turtle nesting season every year between nourishment events. Escarpments which exceed 18 inches in height for a distance of 100 ft. will be leveled by the Contractor or local sponsor accordingly. If it is determined that escarpment leveling is required during the nesting or hatching season, leveling actions should be directed by the USFWS

7. Only beach compatible sediment will be placed on the beach as a component of this project. Post nourishment beach compaction (hardness) will be evaluated by the Corps, in coordination with the NCWRC and USFWS, using qualitative assessment techniques to assure that impacts to nesting and incubating sea turtles are minimized and, if necessary, identify appropriate mitigation responses.

8. Local lighting ordinances will be encouraged to the maximum extent practicable in order to reduce lighting impacts to nesting females and hatchlings. The local sponsors will be encouraged to work with the USFWS, local monitoring groups, and other concerned organizations to develop the best plan for the Towns of Surf City and North Topsail Beach.

9. Throughout the duration of each nourishment event, both initial construction and periodic nourishment, the Contractor will be required to monitor for the presence of stranded sea turtles, live or dead. If a stranded sea turtle is identified, the Contractor will immediately notify the NCWRC of the stranding and implement the appropriate measures, as directed by the NCWRC. Construction activities will be modified appropriately as not to interfere with stranded animals, live or dead.

10. In order to better understand the threshold of sediment color change and resultant heat conduction from nourishment on temperature dependent sex determination of sea turtles, the Corps will monitor nest temperatures in the project area during the nesting

season following initial construction. This data will be compared to non-nourished native sediment temperatures in order to support development of management criteria for sediment color guidelines.

11. In order to assess the abundance of sea turtles, and potential risk of hopper dredge take, within the proposed borrow areas for this project, the Corps will participate in the NCWRC's current satellite telemetry efforts to track the distribution and habitat usage of sea turtles in NC offshore waters.

12. Monitoring for seabeach amaranth on Surf City and North Topsail Beaches will be implemented in the growing season following initial construction to assess the post nourishment presence of plants. This survey will broken down into survey reaches for each town in accordance with the designated USACE sea beach amaranth survey reaches from 1991-2008 in order to maintain consistent data and survey techniques over time and results will be provided to USFWS.

13. The Corps will implement precautionary measures for avoiding impacts to manatees during construction activities as detailed in the "Guidelines for Avoiding Impacts to the West Indian Manatee in North Carolina Waters" established by the USFWS.

14. The Corps will adhere to appropriate environmental windows for piping plovers and other shorebirds to the maximum extent practicable.

15. All staging areas, pipeline routes, and associated construction activities will avoid high value piping plover and shorebird habitat, located within the vicinity of New River Inlet, to the maximum extent practicable.

10.07 Cultural Resources

Significant impacts to known archaeological or historic resources are not anticipated due to the proposed work. No cultural resources were identified in the study area. Project-specific historic survey data have been coordinated with the NC SHPO, and concurrence has been obtained that the proposed action would not cause significant adverse impacts to submerged cultural resources.

The SHPO letter accepting the final report of investigations is dated March 1, 2005, and is included in Appendix H.

10.08 Executive Order 11988 (Flood Plain Management)

Executive Order 11988 requires federal agencies to avoid to the extent possible the long and short-term adverse impacts associated with the occupancy and modification of flood plains and to avoid direct and indirect support of floodplain development wherever there is a practicable alternative. In accomplishing this objective, "each agency shall provide leadership and shall take action to reduce the risk of flood loss, to minimize the impact of

floods on human safety, health, and welfare, and to restore and preserve the natural and beneficial values served by flood plains in carrying out its responsibilities." The Water Resources Council Floodplain Management Guidelines for implementation of EO 11988, as referenced in the Corps' ER 1165-2-26, require an eight-step process that agencies should carry out as part of their decision-making on projects that have potential impacts to or within the floodplain. The eight steps reflect the decision-making process required in Section 2(a) of the Order. The eight steps and responses to them are summarized below.

1. Determine if the proposed action is in the base flood plain.

Yes, the project is a Coastal Storm Damage Reduction project located on portions of the ocean shoreline of the communities of Surf City and North Topsail Beaches, which are within the 100-year floodplain.

2. If the action is in the base flood plain, identify and evaluate practicable alternatives to the action or to location of the action in the base flood plain.

Chapter 5 of this document has an analysis of practicable alternatives and Chapter 8 evaluates the environmental impacts of the selected alternative.

3. If the action must be in the flood plain, advise the general public in the affected area and obtain their views and comments.

The general public and other interested stakeholder's including State, Federal, and Non-Governmental (NGO) resource agencies have been a part of the planning process for this study. Specifically, the integrated Feasbility Report and EIS was circulated for a 45 day Public review in January 2010. All comments have been reviewed and integrated into the report where appropriate. Also, the towns of Surf City and North Topsail Beach, as the non-federal sponsors, have been engaged throughout the planning process.

4. Identify beneficial and adverse impacts due to the action and any expected losses of natural and beneficial flood plain values. Where actions proposed to be located outside the base flood plain will affect the base flood plain, impacts resulting from these actions should also be identified.

Potential impacts associated with the proposed alternative are identified in Chapter 8, "Environmental Effects," of the report. No project components would be located outside of the base flood plain.

5. If the action is likely to induce development in the base flood plain, determine if apracticable non-flood plain alternative for the development exists.

In their Draft Fish and Wildlife Coordination Act report, the USFWS suggested that most of Topsail Island is in the 100-year floodplain and a large portion of the Surf City and North Topsail Beach project area is subject to hurricane storm surge flooding (Section

11.03). Furthermore, the USFWS has suggested that the existing structures and subsequent additional growth would be supported by the proposed federal action; thus, representing unwise development in a hazardous floodplain and incompliance with EO 11988. The Corps disagrees and believes that the proposed Coastal Storm Damage Reduction project is in full compliance with the requirements of Executive Order 11988. Specifically, IWR Report 96-PS-1, Final Report, *An Analysis of the U.S. Army Corps of Engineers Shore Protection Program*, June 1996 states the following:

> The presence of a Corps project has little effect on new housing production. The econometric results presented imply that general economic growth of inland communities is sufficient by itself to drive residential development of beachfront areas at a rapid pace. The statistical evidence indicates that the effect of the Corps on induced development is, at most, insignificant, compared to the general forces of economic growth which are stimulating development in these areas, many of which are induced through other municipal infrastructure developments such as roads, wastewater treatment facilities, etc. The results presented for beachfront housing price appreciation are consistent with the findings from the more general econometric model of real estate development in beachfront communities. The increasing demand for beachfront development can be directed related to the economic growth occurring in inland areas. There is no observable significant effect on the differential between price appreciation in inland and beachfront areas due to Corps activity. The housing price study could not demonstrate that Corps shore protection projects influence development. Corps activity typically follows significant development.

In fact, the requirements for federal participation in coastal storm damage reduction projects essentially dictate that these projects be constructed along areas that have a high degree of development. Additionally, part of the conceptual framework of the Unified National Program for Floodplain Management consists of a series of strategies and tools that can be used to manage floodplains to reduce losses to both human and natural resources. As part of the broader, national vision of floodplain management, the Water Resources Council submitted the Unified National Program for Floodplain Management to the President in 1976. That report, which updates the 1966 Unified National Program for Managing Flood Losses, reflects a shift in focus from flood damage reduction to floodplain management. Through Executive Orders and Interagency Task Forces, the 1976 report was revised and strengthened during the 1980s and 1990s and continues to serve as the focus of the national need to evaluate flood damages within the context of floodplain management. In the 1994 Unified National Program Report, four strategies for managing floodplains wisely were developed (FEMA, 1994). One of the four strategies, which is also a purpose of Executive Order 11988, is to preserve and restore the natural resources and functions of floodplains. The 1994 report further identifies beach nourishment and building sand dunes as tools to support this strategy. Clearly, beach nourishment has been accepted as a valuable tool in moderating flooding and protecting floodplains. Placement of beachfill would occur in the floodplain of area beaches. That placement would be conducted specifically for its beneficial effect in offsetting erosion and restoring damaged beaches, and therefore would be judged acceptable. The action

would be expected to have an insignificant effect on the floodplain; therefore, the proposed action is in compliance with the requirements of Executive Order 11988 and with state/local floodplain protection standards.

6. As part of the planning process under the Principles and Guidelines, determine viable methods to minimize any adverse impacts of the action including any likely induced development for which there is no practicable alternative and methods to restore and preserve the natural and beneficial flood plain values. This should include reevaluation of the "no action" alternative.

Specific "Commitments to Reduce Environmental Impacts" were identified as a part of the project planning process and are listed in Table 7.2. These identified commitments will be implemented as part of the project to minimize the project's potentially adverse impacts. The project includes some incidental environmental benefits associated with the expansion of beach habitat. The No-Action Alternative is discussed in Chapter 5 of the report, and is not considered a practicable alternative. Furthermore, the nature of the recommended project and the associated floodplain is such that the project and floodplain are able to naturally adapt and equilibrate to changes in sea level rise, and are thus sustainable during the 50 year project life.

7. If the final determination is made that no practicable alternative exists to locating the action in the flood plain, advise the general public in the affected area of the findings.

As per item 3 above, the report has been circulated for public review and directly provided to the towns of Surf City and North Topsail Beach.

8. Recommend the plan most responsive to the planning objectives established by the study and consistent with the requirements of the Executive Order.

The objective of the project is to reduce risks to public health, safety, and property on Surf City and North Topsail Beaches. The project is responsive to the EO 11988 objective of "avoidance, to the extent possible, of long- and short-term adverse impacts associated with the occupancy and modification of the base flood plain and the avoidance of direct and indirect support of development in the base flood plain wherever there is a practicable alternative" because it would not induce development in the floodplain, would reduce the hazard and risk associated with floods thereby minimizing the impacts of floods on human safety, health, and welfare, and would restore and preserve the natural and beneficial values of the base floodplain.

10.09 Executive Order 11990 (Protection of Wetlands)

Executive Order 11990 directs all federal agencies to issue or amend existing procedures to ensure consideration of wetlands protection in decision making and to ensure the evaluation of the potential effects of any new construction proposed in a wetland. The proposed action would not require filling any wetlands and would not be expected to

produce significant changes in hydrology or salinity affecting wetlands. The proposed action is in compliance with Executive Order 11990.

10.10 Executive Order 13186 (Responsibilities of Federal Agencies to Protect Migratory Birds)

Executive Order 13186 directs departments and agencies to take certain actions to further implement the Migratory Bird Treaty Act. Specifically, the executive order directs federal agencies, whose direct activities would likely result in the take of migratory birds, to develop and implement a Memorandum of Understanding with the USFWS that must promote the conservation of bird populations. As discussed in Section 8.02.3, the proposed project would not be expected to adversely affect migratory birds and therefore, is in compliance with Executive Order 13186.

10.11 Outer Continental Shelf Lands Act

The OCS law provides the Secretary of the Interior, on behalf of the federal government, with authority to manage the mineral resources, including oil and gas, on the OCS. The MMS Leasing Division is charged with environmentally responsible management of federal OCS sand and gravel resources. The OCS is a zone that generally extends from 3 nautical miles seaward of the coastal state boundaries out to 200 nautical miles. For the Surf City and North Topsail Beach project 9 of the 16 potential borrow sites are within the OCS. P.L. 102-426 (43 U.S.C. 1337(k)(2)), enacted October 31, 1994, gave MMS the authority to negotiate, on a noncompetitive basis, the rights to OCS sand, gravel, and shell resources for coastal storm damage reduction, beach or wetlands restoration projects, or for use in construction projects funded in whole or part by or authorized by the federal government.

The MMS is a cooperating agency with the Corps on the project (see correspondence in Appendix H) and coordination with MMS is ongoing. Pursuant to P.L. 103-426, which authorizes the Secretary of the Interior to negotiate agreements for the use of OCS sand, gravel, and shell resources, any federal agency that proposes to make use of sand, gravel and shell resources must enter into a Memorandum of Agreement (MOA) with the MMS concerning the potential use of those resources. Previous procedures for obtaining a noncompetitive lease for OCS sand from the MMS included execution of a MOA between the MMS and the Corps' district office making the request. Later in the process, the MMS would then complete a lease agreement with the local government entity receiving the sand. However, the MMS has changed that part of the procedure; instead of the two separate agreements, MMS now requires only one MOA signed by the local sponsor, the Corps, and the MMS. Under the new procedure, the three-party MOA becomes the lease instrument. It is developed as the required NEPA steps are completed and terms and conditions identified by the NEPA consultations with other agencies are incorporated into the MOA. The required MOA would be signed before beginning construction. The MMS would not issue a lease until all applicable federal requirements have been appropriately satisfied.

10.12 North Carolina Coastal Management Program

The proposed action would be conducted in the designated coastal zone of North Carolina. Pursuant to the federal Coastal Zone Management Act of 1972, as amended (P.L. 92-583), federal activities are required to be consistent, to the maximum extent practicable, with the federally approved coastal management program of the state in which their activities will occur. The components of the proposed action have been evaluated and determined to be consistent with the North Carolina Coastal Management Program and local land use plans. Concurrence with this determination is being requested from the North Carolina Division of Coastal Management.

10.12.1 Areas of Environmental Concern (15A NCAC 07H .0204)

The selected plan would take place in areas under the North Carolina Coastal Management Program designated as an Area of Environmental Concern (AEC) (15A NCAC 07H). Specifically, the activities could affect the following AECs: Coastal Wetlands, Estuarine Waters, Public Trust Areas, Coastal Shorelines, and Ocean Hazard Areas. The following determination has been made regarding the consistency of the proposed project with the state's management objective for each AEC affected:

Coastal Wetlands. Coastal wetlands are defined as any salt marsh or other marsh subject to regular or occasional flooding by tides, including wind tides (whether or not the tide waters reach the marshland areas through natural or artificial watercourses), provided this will not include hurricane or tropical storm tides. The highest priority of use will be allocated to the conservation of existing coastal wetlands. Second priority of coastal wetland use will be given to those types of development activities that require water access and cannot function elsewhere. Unacceptable land uses may include the following examples: restaurants and businesses; residences, apartments, motels, hotels, and trailer parks; parking lots and private roads and highways; and factories. Examples of acceptable land uses may include utility easements, fishing piers, docks, and agricultural uses, such as farming and forestry drainage, as permitted under North Carolina's Dredge and Fill Act or other applicable laws. The management objective is to conserve and manage coastal wetlands so as to safeguard and perpetuate their biological, social, economic and aesthetic values; to coordinate and establish a management system capable of conserving and using coastal wetlands as a natural resource essential to the functioning of the entire estuarine system. No dredge pipelines would cross coastal wetlands during project construction or renourishment events, therefore no impacts would be incurred, making the project consistent with the management objective for this AEC.

Estuarine Waters. Estuarine waters are defined in G.S. 113A-113(b)(2) to include all the waters of the Atlantic Ocean within the boundary of North Carolina and all the waters of the bays, sounds, rivers, and tributaries thereto seaward of the dividing line between coastal fishing waters and inland fishing waters. The highest priority of use will be allocated to the conservation of estuarine waters and their vital components. Second priority of estuarine waters use will be given to those types of development activities that require water access and use which cannot function elsewhere such as simple access channels; structures to reduce erosion; navigation channels; boat docks, marinas, piers,

wharfs, and mooring pilings. The management objective is to conserve and manage the important features of estuarine waters so as to safeguard and perpetuate their biological, social, aesthetic, and economic values; to coordinate and establish a management system capable of conserving and using estuarine waters so as to maximize their benefits to man and the estuarine and ocean system. The selected plan would not involve estuarine waters and therefore would not be detrimental to estuarine waters.

Public Trust Areas. These areas include (1) waters of the Atlantic Ocean and the lands thereunder from the mean high water mark to the 3 nautical mile limit of state jurisdiction, (2) all natural bodies of water subject to measurable lunar tides, and all lands thereunder, to the mean high water mark, and (3) all navigable natural bodies of water, and all lands thereunder, except privately owned lakes to which the public has no right of access. Acceptable uses include those that are consistent with protection of the public rights for navigation and recreation, as well as conservation and management to safeguard and perpetuate the biological, economic, and aesthetic value of these areas. The management objective is to protect public rights for navigation and recreation and to conserve and manage the public trust areas so as to safeguard and perpetuate their biological, economic and aesthetic value. Placement of beach compatible material on Surf City and North Topsail Beach would result in a wider, more stable beach, thus enhancing recreational opportunities, biological habitat and economic and aesthetic values. For a more thorough discussion of project impacts, please see Section 8 Environmental Effects, of the FEIS, specifically Sections 8.05 Recreational and Aesthetic Resources, 8.04 Socioeconomic Resources, 8.01 Marine Environment, and 8.02 Terrestrial Environment. The selected plan is an acceptable use within public trust areas and would not be detrimental to the biological and physical functions of Public Trust Areas.

Coastal Shorelines. The Coastal Shorelines category includes estuarine shorelines and public trust shorelines. Estuarine shorelines AEC are those non-ocean shorelines extending from the normal high water level or normal water level along the estuarine waters, estuaries, sounds, bays, fresh and brackish waters, and public trust areas. Acceptable uses will be limited to those types of development activities that would not be detrimental to the public trust rights and the biological and physical functions of the estuarine and ocean system. The management objective is to ensure that shoreline development is compatible with both the dynamic nature of coastal shorelines as well as the values and the management objectives of the estuarine and ocean system. Other objectives are to conserve and manage the important natural features of the estuarine and ocean system so as to safeguard and perpetuate their biological, social, aesthetic, and economic values; to coordinate and establish a management system capable of conserving and using these shorelines so as to maximize their benefits to the estuarine and ocean system and the people of North Carolina. The selected plan would not involve estuarine shorelines and therefore would not be detrimental to these areas. Please see the paragraph above regarding Public Trust Areas and the references to pertinent sections of the FEIS for information regarding public trust shorelines. Additionally, as discussed in Appendix J (Cumulative Effects) of the FEIS, on a regional basis, renourishment projects

add material to the longshore transport system, thus providing positive impacts. Although a regional sediment budget analysis has not been completed, it is expected that the proposed action and the combined effects of all other existing and proposed beach projects would have a minimal effect on shoreline and sand transport. Therefore, the proposed project would not be expected to negatively impact coastal shorelines.

Ocean Hazard Areas. These areas are considered natural hazard areas along the Atlantic Ocean shoreline where, because of their special vulnerability to erosion or other adverse effects of sand, winds, and water, uncontrolled or incompatible development could unreasonably endanger life or property. Ocean hazard areas include beaches, frontal dunes, inlet lands, and other areas in which geologic, vegetative and soil conditions indicate a substantial possibility of excessive erosion or flood damage. The specific Ocean Hazard Areas and potential project impacts are described below.

Ocean Erodible Area. This is the area in which there exists a substantial possibility of excessive erosion and significant shoreline fluctuation. The seaward boundary of this area is the mean low water line. The landward extent of this area is determined as follows:

(a) a distance landward from the first line of stable natural vegetation to the recession line that would be established by multiplying the long-term annual erosion rate times 60, provided that, where there has been no long-term erosion or the rate is less than two ft. per year, this distance will be set at 120 ft. landward from the first line of stable natural vegetation. For the purposes of this Rule, the erosion rates will be the long-term average based on available historical data. The current long-term average erosion rate data for each segment of the North Carolina coast is depicted on maps titled *Long Term Annual Shoreline Change Rates* updated through 1998 and approved by the Coastal Resources Commission on January 29th, 2004 (except as such rates may be varied in individual contested cases, declaratory or interpretive rulings). Erosion rates are variable along Surf City and North Topsail Beach. See Appendix D (Figure D-5) for a comparison of the shoreline rate change, referenced above, to recently computed erosion rates at subject beaches.

(b) a distance landward from the recession line established in Sub-Item (1)(a), above, to the recession line that would be generated by a storm having a one percent chance of being equaled or exceeded in any given year.

Construction of the proposed beach template, which consists of 15-ft elevation dune (NGVD) and 50-ft-wide berm, would result in a wider, more stable beach, thus providing significant benefits to the ocean erodible area. Beach-related work, including the discharge of dredged material, the associated temporary operation of heavy equipment, and placement of dredge pipeline, would not cause any significant adverse effects to the ocean erodible area.

High Hazard Flood Area. This is the area subject to high velocity waters (including, but not limited to, hurricane wave wash) in a storm having a one percent chance of being equaled or exceeded in any given year, as identified as zone V1-30 on the flood insurance rate maps of the Federal Insurance Administration, U.S. Department of Housing and Urban Development. Placement of beach nourishment on the beach would provide short-term damage reduction benefits for high hazard flood areas.

Inlet Hazard Area. The inlet hazard areas are natural-hazard areas that are especially vulnerable to erosion, flooding and other adverse effects of sand, wind, and water because of their proximity to dynamic ocean inlets. This area will extend landward from the mean low water line a distance sufficient to encompass that area within which the inlet would, on the basis of statistical analysis, migrate, and will consider such factors as previous inlet territory, structurally weak areas near the inlet (such as an unusually narrow barrier island, an unusually long channel feeding the inlet, or an overwash area), and external influences such as jetties and channelization. In all cases, this area will be an extension of the adjacent ocean erodible area and in no case will the width of the inlet hazard area be less than the width of the adjacent ocean erodible area. While components of the proposed action may involve the movement of equipment across these areas, no construction or periodic nourishment activities are proposed for these areas, and no adverse impacts are anticipated.

10.12.2 Use Standards (15A NCAC 07H .0208)

Primary Nursery Areas. With the exception of navigation channels, these include most estuarine waters of the project vicinity, including those bounded by New River (north), Mason Inlet (south), AIWW (west), and the landward side of Topsail Island. Protection of juvenile fish is provided in those areas through prohibition of many commercial fishing activities, including the use of trawls, seines, dredges, or any mechanical methods of harvesting clams or oysters (http://www.ncfisheries.netirules.htm; 15 NC Administrative Code 3B .1405). PNAs (Figure A-3) would not be directly affected by the project. However, PNAs adjacent to the project area may experience indirect and short-term elevated turbidity levels from the nourishment operation on the shoreface. Such turbidity effects are dependent on the location of the outflow pipe and the direction of longshore and tidal currents. Because the elevated turbidity levels would be short-term and within the range of elevated turbidity from natural storm events, the impacts to state-designated PNAs would be expected to be insignificant (FEIS Section 8.01.8.7).

Outstanding Resource Waters. Waters of the AIWW from Daybeacon 17 (between Chadwick Bay and Alligator Bay) to Morris Landing (south of Spicer Bay) and waters of Topsail Sound southward from approximately New Topsail Inlet to Middle Sound are classified as *SA ORW* (Figure A-5). As stated above, waters in the vicinity of New Topsail and New River Inlets may experience temporary elevated turbidities over existing conditions during initial construction and renourishment. Monitoring studies done on the impacts of offshore dredging indicate that sediments suspended during offshore are generally localized and rapidly dissipate when dredging ceases (Naqvi and Pullen, 1982: Bowen and Marsh, 1988; Van Dolah et al., 1992). Overall water quality impacts of the

proposed action are expected to be short-term and minor. Living marine resources dependent on good water quality should not experience significant adverse impacts due to water quality changes. Therefore, no impacts to ORW in the vicinity of the project, with the exception of minor, short-term impacts in the vicinity of New Topsail Inlet, would be expected. For more information on water quality, see Section 8.07.2 of the FEIS.

Submerged Aquatic Vegetation (SAV). As depicted in the FEIS, Table 8.2, SAV does not occur in or near the project vicinity and would not be directly or indirectly affected by the proposed project.

For compliance with 15A NCAC 07H. 0208(b)(12) Submerged Lands Mining, see Section 10.12.8.

10.12.3 Shoreline Erosion Policies (15A NCAC 07M .0202)

Pursuant to Section 5, Article 14 of the North Carolina Constitution, proposals for shoreline erosion response projects will avoid losses to North Carolina's natural heritage. All means should be taken to identify and develop response measures that would not adversely affect estuarine and marine productivity. As discussed in detail in Section 8.01 Marine Environment and Appendix J Cumulative Effects of the FEIS, the project would not be expected to result in adverse impacts to estuarine and marine productivity.

The public right to use and enjoy the ocean beaches must be protected. The protected uses include traditional recreational uses (such as walking, swimming, surf fishing, and sunbathing) as well as commercial fishing and emergency access for beach rescue services. The Corps has several requirements that must be met to fully cost share in a coastal storm damage reduction project (see ER 1105-2-100 and ER 1165-2-130). One of those requirements is that the beaches must be available for public use. As described in ER 1165-2-130 (Federal Participation in Shore Protection, paragraph 6.h.) public use implies reasonable access and parking. The Corps' Wilmington District, additionally, has developed more specific public access and parking requirements for participation in coastal storm damage reduction projects within the District's boundaries of North Carolina and Virginia. Public Access and Parking is discussed in detail in Appendix O of the FEIS.

Erosion response measures designed to minimize the loss of private and public resources to erosion should be economically, socially, and environmentally justified. The FEIS demonstrates that the proposed coastal storm damage reduction project at Topsail Beach is economically, socially and environmentally justified. Pertinent sections of the FEIS include: Section 7.08 Economics of the Selected Plan, Section 8.00 Environmental Effects, Appendix B Economic Analyses, Appendix I Biological Assessment, and Appendix J Cumulative Effects.

The following are required with state involvement (funding or sponsorship) in beach

restoration and sand renourishment projects: The entire restored portion of the beach will be in permanent public ownership and it will be a local government's responsibility to provide adequate parking, public access, and services for public recreational use of the restored beach. Public ownership of the shore in the towns of Surf City and North Topsail Beach include dedicated roads and lands below MHW owned by North Carolina. Other parcels are owned by the towns of Surf City and North Topsail Beach, including CAMA public access points and the ends of all roads. The project area includes more than 500 parcels in Surf City and nearly 350 parcels in North Topsail Beach. The primary ownership of the oceanfront parcels is private, including two fishing piers. The entire restored portion of the beach is in public ownership. Other information related to ownership of the shoreline is in Appendix M, Real Estate. Parking, public access and services for the public recreational use of the restored beach are addressed in preceding paragraphs, above. Additional details are available in Appendix O of the report.

10.12.4 Shorefront Access Policies (15A NCAC 07M .0300)

Pursuant to 15A NCAC 07M .0300, the public has traditionally and customarily had access to enjoy and freely use the ocean beaches and estuarine and public trust waters of the coastal region for recreational purposes and the state has a responsibility to provide continuous access to the resources. It is the state's policy to foster, improve, enhance and ensure optimum access to the public beaches and waters of the 20-county coastal region. Access will be consistent with rights of private property owners and the concurrent need to protect important coastal natural resources such as sand dunes and coastal marsh vegetation. Surf City and North Topsail Beach have many public ocean shoreline access sites from dedicated easements, town owned sites, and street rights of way. The availability of parking varies and includes dedicated parking lots at access sites and street right of way parking. As previously stated, the Corps has several requirements that must be met to fully cost share in a coastal storm damage reduction project (see ER 1105-2-100 and ER 1165-2-130). ER1165-2-130 stipulates that to qualify for federal cost sharing of Coastal Storm Damage Reduction projects, the local community must, at a minimum, provide public access every one half mile and parking within a one quarter mile radius of those access points. The Wilmington District has further established a minimum of ten public parking spaces be available within one-quarter mile of each required public access point (see Appendix O of the report).

10.12.5 Mitigation Policy (15A NCAC 07M .0701)

It is the policy of North Carolina to require that adverse impacts to coastal lands and waters be mitigated or minimized through proper planning, site selection, compliance with standards for development, and creation or restoration of coastal resources. Coastal ecosystems will be protected and maintained as complete and functional systems by mitigating the adverse impacts of development as much as feasible by enhancing, creating, or restoring areas with the goal of improving or maintaining ecosystem function and areal proportion. Section 7.03.6 Environmental Monitoring and Commitments of the FEIS, provides a brief summary of environmental commitments to protect listed species related to the construction and maintenance of the proposed project. Further information

on the development and details of these commitments is contained in Appendix I, Biological Assessment.

10.12.6 Coastal Water Quality Policies (15A NCAC 07M .0800)

Pursuant to 15A NCAC 07M.0800, no land or water use will cause the degradation of water quality so as to impair traditional uses of the coastal waters. Protection of water quality and the management of development within the coastal area is the responsibility of many agencies. The general welfare and public interest require that all state, federal and local agencies coordinate their activities to ensure optimal water quality. Overall water quality impacts of the proposed action would be expected to be short-term and minor. Living marine and estuarine resources dependent on good water quality are not expected to experience significant adverse impacts due to water quality changes. A Section 401 Water Quality Certificate under the Clean Water Act of 1977 (P.L. 95-217), as amended, is required for the proposed project and would be requested from the NCDWQ at the appropriate time. Project construction would not begin until a Water Quality Certification has been received. For a full discussion of water resources and potential project impacts, see Sections 2.06 and 8.07 Water Resources, of the FEIS, which address hydrology, water quality and groundwater. Pursuant to Section 404 of the Clean Water Act, the impacts associated with the discharge of fill material into waters of the United States are discussed in the Section 404(b)(1) (P.L. 95-217) Guidelines Analysis in Appendix G. Discharges associated with dredging in the offshore borrow areas are considered incidental to the dredging operation, and therefore, are not being considered as being a discharge addressed under the Section 404 (b)(1) Guidelines Analysis. Pursuant to the Sedimentation Pollution Control Act of 1973, a state-approved soil erosion and sedimentation control plan would be implemented during construction to minimize soil loss and erosion.

10.12.7 Policies on Beneficial Use and Availability of Materials Resulting From the Excavation or Maintenance of Navigational Channels (15A NCAC 07M .1100)

It is North Carolina's policy that material resulting from the excavation or maintenance of navigation channels be used in a beneficial way wherever practicable. Policy statement .1102 (a) indicates that, "clean, beach quality material dredged from navigation channels within the active nearshore, beach, or inlet shoal systems must not be removed permanently from the active nearshore, beach, or inlet shoal system unless no practicable alternative exists. Preferably, this dredged material would be disposed of on the ocean beach or shallow active nearshore area where environmentally acceptable and compatible with other uses of the beach." Several navigation channels are within the Surf City and North Topsail Beach project vicinity. They are the AIWW, New Topsail Inlet and Connecting Channels and New River Inlet. When practicable, beach compatible, maintenance dredged material from these navigation channels may be placed on the nourished beach. However, because of the distances from the navigation channels to the nourished beach that would rarely, if ever, be practicable. Any dredged material from navigation channels would be purely supplemental material that would help maintain the project profile.

10.12.8 Policies on Ocean Mining (15A NCAC 07M .1200) and 15A NCAC 07H. 0208(b)(12) Submerged Lands Mining

Mining activities affecting the federal jurisdiction ocean and its resources can, and probably would, also affect the state jurisdictional ocean and estuarine systems and vice-versa. Therefore, it is state policy that every avenue and opportunity to protect the physical ocean environment and its resources as an integrated and interrelated system would be used. Cultural resources and hard-bottom surveys of the offshore borrow areas have been completed. No single, isolated magnetic anomalies or acoustic targets were identified during the survey of the borrow areas and no further cultural resources studies are anticipated for the project. By letter of November 2, 2004, the North Carolina SHPO concurred with the reported findings. As identified through the myriad of investigative studies discussed in Section 8.01.8.2 to identify and avoid nearshore and offshore hard bottom resources, the Corps has demonstrated a commitment to avoidance and minimization of impacts to hard bottom communities. No dredging activities would occur in or near hard bottom communities. For the full discussion of impacts to hard bottoms, see Section 8.01.8.2.

Dredging impacts to the benthic populations of the marine ecosystem from turbidity would be local and temporary but not permanent. Similarly, recent studies show that benthic impacts may be limited to the immediate vicinity of dredging operations. Also, to minimize effects, work would be performed between December 1 and March 31 of the year, during times of low biological activity. For the full discussion of benthic impacts, see Sections 8.01.6 and 8.01.7. Because: (1) no cultural resources sites are present in the area, (2) no hardbottoms are in or near the proposed offshore disposal sites, and (3) the effects of turbidity and sedimentation plumes on offshore hard bottom would be insignificant, the project would not be expected to adversely affect the state jurisdictional ocean and estuarine systems. For more detailed information, see the following sections of the report: Section 2.01 Marine Environment, 2.05 Cultural Resources, 7.04.3 Borrow Area Use Plan, 8.01 Marine Environment, 8.06 Cultural Resources, Appendix I Biological Assessment, and Appendix J Cumulative Effects.

The proposed coastal storm damage reduction project at Surf City and North Topsail Beach conforms to the relevant enforceable policies of Subchapters 7H and 7M of Title 15A of North Carolina's Administrative Code.

10.12.9 Other State Policies

The proposed project has been determined to be consistent with other state policies found in the state's Coastal Management Program document that are applicable. Those include the following:

North Carolina Mining Act. The removal of material from the offshore borrow areas that are within 3 nautical miles of shore have been reviewed by the North Carolina Division of Land Resources and a determination has been made that removal of sand from the sea floor within the 3 miles territorial limits is not an activity that would be classified as mining under the North Carolina Mining Act (G. S. 74-7). *Mining* is defined as:

(a) The breaking of the surface soil to facilitate or accomplish the extraction or removal of mineral, ores, or other solid matter.

(b) Any activity or process constituting all or part of a process for the extraction or removal of minerals, ores, soils, and other solid matter from their original location.

(c) The preparation, washing, cleaning, or other treatment of minerals, ores, or other solid matter so as to make them suitable for commercial, industrial, or construction use.

North Carolina Dredge and Fill Law (G.S. 113-229). Pursuant to the North Carolina Dredge and Fill Law clean, beach quality material dredged from navigational channels within the active nearshore, beach or inlet shoal systems will not be removed permanently from the active nearshore, beach or inlet shoal system. This dredged material will be disposed of on the ocean beach or shallow active nearshore area where it is environmentally acceptable and compatible with other uses of the beach. As discussed in Section 10.12.7, when practicable, clean, beach quality material from maintenance dredging of navigation channels may be placed on the nourished beach at Surf City and North Topsail Beach. Any dredged material from navigation channels would be purely supplemental material that would help maintain the project profile.

Clean Water Act. A section 401 Water Quality Certificate under the Clean Water Act of 1977 (P.L. 95-217), as amended, is required for the proposed project and would be requested from the NCDWQ. Work would not proceed until the section 401 certification is received.

Pursuant to section 404 of the Clean Water Act, the impacts associated with the discharge of fill material into waters of the United States are discussed in the section 404(b)(1) (P.L. 95-217) Guidelines Analysis in Appendix G of the report. Discharges associated with dredging in the offshore borrow areas are considered incidental to the dredging operation, and therefore, are not being considered as being a discharge addressed under the Section 404 (b)(1) Guidelines Analysis.

Sedimentation and Erosion Control. Pursuant to the Sedimentation Pollution Control Act of 1973, a state-approved soil erosion and sedimentation control plan would be implemented during construction to minimize soil loss and erosion.

10.12.10 Local Land Use Plans

Compliance with all applicable CAMA Land Use Plans is discussed below.

On the basis of the information in the 1991 *Pender County Land Use Plan Update*, ocean beaches and shorelines are valuable for public and private recreation and are within natural hazard areas. Pender County's overall policy and management objective for the estuarine system is to, "give the highest priority to their protection to perpetuate their biological, social, economic, and aesthetic values to ensure that development

occurring within these AEC's is compatible with natural characteristics so as to minimize the likelihood of significant loss of private property and public resources." (15 NCAC 07H .0203). Also, the *Pender County Land Use Plan* states, "Beach nourishment projects are the responsibility of Surf City." With the exception of the Island Business District/Town Center, the shoreline at Surf City is zoned Residential. According to the *Surf City Land Use Plan*, dated 2005, the town is concerned about the long-term effects of continuing erosion and believes that beach nourishment, followed by regular renourishment, is the best method of dealing with the problem of erosion.

The Onslow County Land Use Plan, dated 1997, states, "Onslow County desires to minimize the hazards to life, health, public safety, and development within flood hazard areas." According to the Onslow County Land Use Plan and the 1996 Town of North Topsail Beach Land Use Plan, the shoreline at North Topsail Beach is classified as Urban Transition. Most development within this classification consists of single and multi-family residences and special uses allowed by the North Topsail Beach zoning ordinance. The town of North Topsail Beach also supports beach renourishment projects and as stated in the 1996 LUP, "...the [t]own is currently investigating potential funding sources for beach renourishment projects."

The proposed coastal storm damage reduction project is sponsored by the towns of Surf City and North Topsail Beach in conjunction with the Corps. The project would result in a wider, more stable beach, thus enhancing the recreational opportunities, biological habitat, and economic and aesthetic values of the beach. Therefore, the proposed project is consistent with all applicable CAMA Land Use Plans.

On the basis of the information presented in this Feasibility Report and EIS, the proposed project is consistent with the North Carolina Coastal Management Program. This determination is being provided to the state for its review and concurrence.

10.13 Coastal Barrier Resources Act

The Coastal Barrier Resources Act (CBRA) of 1982 (P.L. 97-348) prohibits expenditure of federal funds for activities within the designated limits of the Coastal Barrier Resources System unless specifically exempted by section 6 of the act. As stated in that section, federal expenditures are allowable in association with maintenance of existing channel improvements, including disposal of dredged material related to such improvements. Designated maps showing all sites included in the system in North Carolina show Topsail Unit (L06) to be within the Coastal Barrier Resource System and protected under the Coastal Barrier Improvement Act of 1990 (USFWS 1990). This site is *not* included in the project area (Appendix A, Figure A-1) and would not be affected by the selected plan (Appendix A, Figure A-7).

10.14 Estuary Protection Act

The Estuary (Estuarine) Protection Act provides a means to protect, conserve, and restore estuaries in a manner that maintains balance between the need for natural resource

protection and conservation and the need to develop estuarine areas to promote national growth. The act authorizes the Secretary of the Interior to work with the states and other federal agencies in undertaking studies and inventories of estuaries of the United States. The proposed project would be expected to have minimal effect on the estuarine environment, as discussed in Section 8 of this report; therefore the project would be in compliance with the Estuary Protection Act.

10.15 Sedimentation and Erosion Control

Pursuant to the Sedimentation Pollution Control Act of 1973, a state-approved soil erosion and sedimentation control plan would be implemented during construction to minimize soil loss and erosion.

10.16 Prime and Unique Agriculture Land

According to the Soil Surveys for Pender County and Onslow counties, North Carolina, the soils on the beach that could be affected by the proposed project are not designated by the Natural Resource Conservation Service as prime or unique agriculture lands. No impacts to prime and unique agriculture lands would be expected to occur.

Table 10.1. The relationship of the proposed action to federal laws and policies

Title of public law	U.S. Code	Compliance status
Abandoned Shipwreck Act of 1987	43 U.S.C. 2101	Full Compliance
American Indian Religious Freedom Act	42 U.S.C. 1996	Not Applicable
Agriculture and Food Act (Farmland Protection Policy Act) of 1981	7 U.S.C. 4201 et seq.	Not Applicable
American Folklife Preservation Act of 1976, As Amended	20 U.S.C. 2101	Not Applicable
Anadromous Fish Conservation Act of 1965, As Amended	16 U.S.C. 757 a et seq.	Full Compliance
Antiquities Act of 1906, As Amended	16 U.S.C. 431	Full Compliance
Archeological and Historic Preservation Act of 1974, As Amended	16 U.S.C. 469	Full Compliance
Archeological Resources Protection Act of 1979, As Amended	16 U.S.C. 470	Full Compliance
Bald Eagle Act of 1972	16 U.S.C. 668	Not Applicable
Buy American Act	41 U.S.C. 102	Full Compliance
Civil Rights Act of 1964 (P.L. 88-352)	6 U.S.C. 601	Full Compliance
Clean Air Act of 1972, As Amended	42 U.S.C. 7401 et seq.	Full Compliance
Clean Water Act of 1972, As Amended	33 U.S.C. 1251 et seq.	Full Compliance
Coastal Barrier Resources Act of 1982	16 U.S.C. 3501-3510	Full Compliance
Coastal Zone Management Act of 1972, As Amended	16 U.S.C. 1451 et seq.	Full Compliance
Comprehensive Environmental Response, Compensation and Liability Act of 1980	42 U.S.C. 9601	Not Applicable
Conservation of Forest Lands Act of 1960	16 U.S.C. 580 mn	Not Applicable
Contract Work Hours	40 U.S.C. 327	Full Compliance
Convict Labor	18 U.S.C. 4082	Full Compliance
Copeland Anti-Kickback	40 U.S.C. 276c	Full Compliance
Davis Bacon Act	40 U.S.C. 276	Full Compliance
Deepwater Port Act of 1974, As Amended	33 U.S.C. 1501	Not Applicable
Emergency Flood Control Funds Act of 1955, As Amended	33 U.S.C. 701m	Not Applicable
Emergency Wetlands Resources Act	16 U.S.C. 3901-3932	Full Compliance
Endangered Species Act of 1973	16 U.S.C. 1531	Full Compliance
Estuary Program Act of 1968	16 U.S.C. 1221 et seq.	Full Compliance
Equal Opportunity	42 U.S.C. 2000d	Full Compliance
Farmland Protection Policy Act	7 U.S.C. 4201 et seq.	Not Applicable
Federal Environmental Pesticide Act of 1972	7 U.S.C. 136 et seq.	Full Compliance
Federal Water Project Recreation Act of 1965, As Amended	16 U.S.C. 4601	Full Compliance
Fish and Wildlife Coordination Act of 1958, As Amended	16 U.S.C. 661	Full Compliance
Flood Control Act of 1944, As Amended, Section 4	16 U.S.C. 460b	Full Compliance
Food Security Act of 1985 (Swampbuster)	16 U.S.C. 3811 et seq.	Not Applicable
Hazardous Substance Response Revenue Act of 1980, As Amended	26 U.S.C. 4611	Not Applicable

Note: Items identified as being in *Full Compliance* assumes their compliance status after the NEPA process is complete.

Table 10.1. (*continued*)

Title of public law	U.S. Code	Compliance status
Historic and Archeological Data Preservation	16 U.S.C. 469	Full Compliance
Historic Sites Act of 1935	16 U.S.C. 461	Full Compliance
Jones Act	46 U.S.C. 292	Full Compliance
Land and Water Conservation Fund Act of 1965	46 U.S.C. 4601	Not Applicable
Magnuson Fishery Conservation and Management Act	16 U.S.C. 1801	Full Compliance
Marine Protection, Research and Sanctuaries Act of 1972	33 U.S.C. 1401	Full Compliance
Migratory Bird Conservation Act of 1928, As Amended	16 U.S.C. 715	Full Compliance
Migratory Bird Treaty Act of 1918, As Amended	16 U.S.C. 703	Full Compliance
National Environmental Policy Act of 1969, As Amended	42 U.S.C. 4321 et seq.	Full Compliance
National Historic Preservation Act of 1966, As Amended	16 U.S.C. 470	Full Compliance
National Historic Preservation Act Amendments of 1980	16 U.S.C. 469a	Full Compliance
Native American Religious Freedom Act of 1978	42 U.S.C. 1996	Not Applicable
Native American Graves Protection and Repatriation Act	25 U.S.C. 3001	Full Compliance
Native American Religious Freedom Act of 1978	16 U.S.C. 469a	Not Applicable
National Trails System Act	16 U.S.C. 1241	Not Applicable
Noise Control Act of 1972, As Amended	42 U.S.C. 4901 et seq.	Full Compliance
Outer Continental Shelf Lands Act 1953, as Amended	43 U.S.C. 1331-1356	Full Compliance
Rehabilitation Act (1973)	29 U.S.C. 794	Full Compliance
Reservoir Salvage Act of 1960, As Amended	16 U.S.C. 469	Not Applicable
Resource Conservation and Recovery Act of 1976	42 U.S.C. 6901-6987	Not Applicable
River and Harbor Act of 1888, Sect 11	33 U.S.C. 608	Not Applicable
River and Harbor Act of 1899, Sections 9, 10, 13	33 U.S.C. 401-413	Full Compliance
River and Harbor and Flood Control Act of 1962, Section 207	16 U.S.C. 460	Not Applicable
River and Harbor and Flood Control Act of 1970, Sections 122, 209 and 216	33 U.S.C. 426 et seq.	Full Compliance
Safe Drinking Water Act of 1974, As Amended	42 U.S.C. 300f	Full Compliance
Shipping Act	46 U.S.C. 883	Full Compliance
Submerged Lands Act of 1953	43 U.S.C. 1301 et seq.	Full Compliance
Superfund Amendments and Reauthorization Act of 1986	42 U.S.C. 9601	Not Applicable
Surface Mining Control and Reclamation Act of 1977	30 U.S.C. 1201-1328	Not Applicable
Toxic Substances Control Act of 1976	15 U.S.C. 2601	Not Applicable
Uniform Relocation and Assistance and Real Property Acquisition Policies Act of 1970, As Amended	43 U.S.C. 4601 et seq.	Full Compliance
Utilization of Small Business	15 U.S.C. 631, 644	Full Compliance
Vietnam Veterans	38 U.S.C. 2012	Not Applicable

Table 10.1. (*continued*)

Title of Executive Order	Executive Order number	Compliance status
Protection and Enhancement of Environmental Quality	11514/11991	Full Compliance
Protection and Enhancement of the Cultural Environment	11593	Full Compliance
Floodplain Management	11988	Full Compliance
Protection of Wetlands	11990	Full Compliance
Federal Compliance with Pollution Control Standards	12088	Full Compliance
Environmental Effects Abroad of Major Federal Actions	12114	Not Applicable
Offshore Oil Spill Pollution	12123	Full Compliance
Procurement Requirements and Policies for Federal Agencies for Ozone-Depleting Substances	12843	Full Compliance
Federal Compliance with Right-To-Know Laws and Pollution Prevention	12856	Full Compliance
Federal Actions to Address Environmental Justice and Minority and Low-Income Populations	12898	Full Compliance
Procurement Requirements and Policies for Federal Agencies for Ozone-Depleting Substances	12843	Full Compliance
Federal Compliance with Right-To-Know Laws and Pollution Prevention	12856	Full Compliance
Federal Actions to Address Environmental Justice and Minority and Low-Income Populations	12898	Full Compliance
Energy Efficiency and Water Conservation at Federal Facilities	12902	Full Compliance
Federal Acquisition and Community Right-To-Know	12969	Full Compliance
Protection Of Children from Environmental Health Risks and Safety Risks	13045	Full Compliance
Coral Reef Protection	13089	Full Compliance
Greening the Government through Waste Prevention, Recycling and Federal Acquisition	13101	Full Compliance
Invasive Species	13112	Full Compliance
Greening the Government Through Leadership in Environmental Management	13148	Full Compliance
Marine Protected Areas	13158	Full Compliance
Consultation and Coordination with Indian Tribal Governments	13175	Not Applicable
Responsibilities of Federal Agencies to Protect Migratory Birds	13186	Full Compliance
Executive Order Facilitation of Cooperative Conservation	13352	Full Compliance

11. SUMMARY OF AGENCY AND PUBLIC INVOLVEMENT

11.01 Scoping

On February 14, 2001, a scoping letter was sent to agencies, interest groups, and the public to request identification of significant resources and issues of concern. Eleven letters of comment were received. The scoping letter, a list of respondents and comment letters are in Appendix K. Comments received addressed various aspects of the project and generally (1) identified resource concerns or (2) other aspects of the project, such as alternatives analysis, dredging window, cumulative impact analysis, and such, needing to be thoroughly addressed. All comments received were considered during the continuation of project planning and design. Additional coordination has been conducted with representatives of the USFWS, NMFS, North Carolina Department of Archives and History, North Carolina Wildlife Resources Commission and the MMS.

11.02 Cooperating Agencies

The Minerals Management Service (MMS) was invited and has agreed to participate as a cooperating agency (pursuant to Section 1501.6 of the CEQ NEPA Regulations) during the preparation of the Integrated Feasibility Report and Environmental Impact Statement. MMS will assist in developing information and preparing environmental analyses in areas which the MMS has special expertise. This assistance enhances the interdisciplinary capability of the study team.

Beach nourishment measures, which include dredging of sediment from offshore borrow areas on the Outer Continental Shelf (OCS) may require authorization by the Minerals Management Service (MMS) for use during initial or maintenance construction or both (see Section 10.11). The MMS may undertake a connected action (i.e., authorize use of the OCS borrow area) that is related to, but unique from the proposed action. The MMS's proposed action is to issue a negotiated agreement pursuant to its authority under the Outer Continental Shelf Lands Act. The purpose of that action is to authorize the use of OCS sand (or other sediment) resources in beach nourishment and coastal restoration projects undertaken by federal, state or local government agencies, and/or in other federally authorized construction projects.

11.03 Fish and Wildlife Coordination

The Fish and Wildlife Coordination Act, as amended (16 U.S.C. 661, *et seq*), requires that the Corps coordinate and obtain comments from the USFWS, the NMFS, where applicable, and appropriate state fish and wildlife agencies, including the NCDMF and the North Carolina Wildlife Resources Commission. The USFWS provided a Planning Aid Report (PAR), dated September 9, 2003, which provided recommendations that have been considered during project development. Information regarding the components of the proposed action, potential alternatives, and related environmental issues has been coordinated with the USFWS, and its views are documented in a Fish & Wildlife Coordination Act (FWCA) Report, dated May 2010 (Appendix L). Specific fish and

wildlife recommendations and Corps responses to a draft version of the report, dated June 2008, are presented in the following paragraphs:

1. USFWS Recommendation: There should be a clear presentation of the federal interest in the project area. The discussion should distinguish between efforts to reduce damage during storms and efforts to replace land lost as rising sea level creates natural processes to move the island landward. There should be an acknowledgement that the ocean does not create permanent damage on the natural communities of barrier islands. What appears to be recession of the beach and dune results from the movement of some sand across the island to build up the natural communities on the sound side. Such movement is part of the natural, adaptive process of the island to sea level rise. The reduction in beach width is actually the result of the area being squeezed between the rising ocean and a fixed line of man-made structures. A clear presentation of the nature of the problem will provide the foundation for determining the federal interest and the development of alternatives.

Corps Response: Federal interest is demonstrated by the fact that this project has a favorable benefit to cost ratio and protects a public shoreline. The dune and berm project would reduce damages and prevent land losses due to both storm related, short term erosion and from long term erosion. In the without-project condition, erosion would continue to narrow the beach in front of existing structures, which would both reduce the suitability of the beach for recreation and for natural habitat. In addition, Topsail Beach is a fully developed barrier island, where sound-side deposition of sand by natural overwash processes is already severely restricted.

2. USFWS Recommendation: The efficacy of any program for replacing inundated beaches with imported fill material over 50 years will depend on global sea level rise during the period. Sea level rise along with more intense hurricanes will contribute to the destruction of a beach constructed, at least partially, in shallow ocean waters. Information from the Intergovernmental Panel on Climate Change (IPCC, 2007) and analysis such as Rahrnstorf (2007) should be used in project planning.

Corps Response: The SLR value used in the Surf City and North Topsail Beach (SCNTB) analysis of 9.6 inches (0.8 ft.) over the next 100 years is within the likely range of SLR reported for all but the most pessimistic scenario family presented in the IPCC 2007, Special Report on Emissions Scenarios (SRES), as shown below:

SRES scenario family	Likely range of SLR
Scenario B1 (most optimistic)	7 to 15 inches
Scenario A1T	8 to 18 inches
Scenario B2	8 to 17 inches
Scenario A1B	8 to 19 inches
Scenario A2	9 to 20 inches
Scenario A1FI (most pessimistic)	10 to 23 inches

Over the 50-yr project life, the difference between the SCNTB value and the average SLR values for each of the IPCC 2007 scenarios range from 0.7 to 3.45 inches, with all but the two most pessimistic scenarios being less than 2 inches difference. A tremendous amount of effort would be required to generate the revised storm responses for these relatively small differences in sea level. The computational precision, rounding, curve-fitting, built-in uncertainty, and so on, that composes the analysis could possibly mask much of the expected differences in outcome. Further, it is likely that the without-project condition (with its diminished dune and berm) is going to be more sensitive to SLR than the with-project condition would be, which would only increase the net benefits for the beachfill project.

3. USFWS Recommendation: The Corps is within the [E]xecutive [B]ranch and is therefore required to comply with Executive Order (EO) 11988. This EO was enacted to avoid, to the extent possible, the long and short term adverse impacts associated with the occupancy and modification of floodplains and to avoid direct or indirect support of floodplain development wherever there is a practicable alternative (USACE 2006a, p. 118). Most of Topsail Island is in the 100-year floodplain (Pilkey et al. 1998, p. 171) and most of the island would be largely underwater in a category one or two hurricane and nearly completely submerged in a category three hurricane (Pilkey et al. 1998, p. 173). Except for some dune areas, the entire Surf City-North Topsail Beach project area is subject to hurricane storm surge flooding (USACE 2006b, p. 9). These dangers are reflected in the fact that the northern portion of Topsail Island is included in the Coastal Barrier Resource System (CBRS). Areas included the CBRS were generally considered unsuitable for development because they are vulnerable to hurricanes and other storm damage and because natural shoreline recession and the movement of unstable sediments undermine manmade structures. The current project area was excluded from the CBRS because it was developed at the time of the legislation and not because the development was at less risk. The Corps should present a comprehensive discussion of the justification for any conclusion that the proposed beach construction is in compliance with the requirements of Executive Order 11988. Compliance with this EO should not be based on the high cost of removing the structures, but rather whether the presence of existing structures and the additional growth that would be supported by the federal action represents unwise development in a hazardous floodplain.

Corps Response: As discussed fully in Section 10.08, the project is in full compliance with Executive Order 11988.

4. USFWS Recommendation: The goal of reducing storm damage could be achieved with less environmental harm by using nonstructural measures. However, the Draft GRR/EIS for West Onslow Beach determined (USACE 2006a, p. 54) that the nonstructural plan was not economically feasible and was not fully evaluated for technical feasibility or acceptability. This decision was based on consideration of the costs of removing or relocating structures, but without any economic consideration of the economic benefits to be derived from the natural resources of the area. There was an assumption that a nonstructural approach would continue to result in land losses (USACE 2006a, p. 59). Information presented in this report indicates that the nonstructural

approach, if implemented at all levels of government, would allow the formation of a wide, natural beach as the project adjusts its location landward. The remote, undisturbed beach which was recognized by the Corps (USACE 2006a, p. 59) as resulting from a no action approach in the area immediately south of the current project area would support tourism and provide significant economic benefits for the region. The Service recommends that the economic benefits of the nonstructural alternative receive greater consideration in the selection of the preferred course for federal action.

Corps Response: Further analysis of changes in recreation value of the nonstructural plan would most likely result in a negative value of recreational benefits, because there would be less lodging available for visitors. The benefit to cost ratio of 0.92 was developed using the most optimistic assumptions.

5. USFWS Recommendation: If beach construction is ultimately undertaken, the fill material should have a high degree of compatibility with the native beach. The North Carolina Sediment Criteria Rule, contained in the Technical Standards for Beachfill Projects (15A NCAC 07H .0312), should be used in regard to grain size and percent weight of calcium carbonate. In addition, compatibility should be established for other important characteristics such as organic content, heavy mineral content, and color.

Corps Response: The proposed borrow area sediments for this project would comply with grain size and percent weight requirements specified in 15A NCAC 07H .0312, *Technical Standards for Beachfill Projects*. The technical standards require compatibility of the native beach with borrow sources in regards to the percentage of silt, granular sediment, gravel, and calcium carbonate (or shell content for projects initiated before implementation of the rules). However, no federal or state requirements exist for compatibility in regards to organic content, heavy mineral content, or color. Therefore, a compatibility analysis for those items would not be conducted. The standards require that percent silt, granular sediment, and gravel in borrow material not exceed the amount found in the native beach plus 5 percent and the percent carbonate in borrow material not exceed the amount found in the native beach plus 15 percent. The silt, granular sediment, gravel content, and visual shell content for the Surf City/North Topsail Beach project are 1.2, 1.1, 0.5, and 9 percent respectively. Incorporating the tolerance permitted by the beachfill standards results in the following criteria: silt (6.2 percent), granular sediment (6.1 percent), gravel (5.5 percent), and calcium carbonate (24 percent). On the basis of current vibracore data, borrow areas A, F, L, S, and P exceed the standards for various characteristics. However, during the PED phase of the project additional borings or geophysical surveys would be performed to better delineate the borrow area boundaries and material types, with respect to the state sediment criteria rule, to ensure compatibility of beachfill material before placement. Because that additional analysis was included during PED, the borrow areas have been retained for further characterization. Before initial construction and each nourishment event, all material dredged for placement on the beach would comply with the sediment criteria rule.

6. USFWS Recommendation: If beach construction is ultimately undertaken, there should be a plan to monitor the quality of the fill material as it placed on the beach. There

should be an effective procedure for stopping operations if inappropriate material is being pumped onto the beach. Since such real time protective measures may not be completely effective, there should also be a plan for inspecting the constructed beach for areas of incompatible material and removing such material before the start of the nest sea turtle nesting season.

Corps Response: The Corps intends to perform rigorous boring analyses of proposed borrow areas to minimize the risk of placing incompatible material on the beach. Throughout the duration of construction operations, the Corps employs full-time construction inspection personnel to perform on-site inspections of the project operations to ensure quality control and compliance with contract specifications. Furthermore, the Corps receives daily production reports from the contractor that provide detailed information pertaining to the contractor's daily operations. All incompliance issues pertaining to compatibility concerns identified in the on-site inspections or the daily reports are immediately forwarded to the Corps environmental staff. Federal and state environmental agencies would be notified if, and how much, potentially incompatible material is encountered during dredging operations. If necessary, the Wilmington District would make the decision on a suitable contingency measure which could include moving the dredge to another site within the borrow area or to another borrow area, depending on availability of sediment, and would notify the agencies of such a contingency measure. However, there is still a risk that some incompatible material is placed on the beach because real-time protective measures are not 100 percent effective. Therefore, the Corps construction inspection personnel would inspect the beach for any significant amount of incompatible material within the project limits throughout the contract duration and if any incompatible material is identified within the constructed berm, the Corps would coordinate with the appropriate agencies to identify the quantity of material and discuss the methods of removal and disposal before the sea turtle nesting season.

7. USFWS Recommendation: Offshore sediment extraction and sediment disposal should be scheduled during the least sensitive period of the year for the organisms dependent on the habitats to be affected. Every effort should be made to complete all beach work, both actual placement and shaping, by the end of March for the benefit of important beach invertebrates and migratory shorebirds.

Corps Response: The proposed dredging window of December 1 through March 31 for initial construction and each nourishment event avoids the identified peak recruitment periods for surf zone fish (March through September [Hackney et al., 1996]) and invertebrate species (May through September [Hackney et al., 1996; Diaz, 1980; Reilly and Bellis, 1978]) in North Carolina. Beach nourishment would therefore be completed before the onshore recruitment of most surf zone fishes and invertebrate species. Furthermore, to complete the full initial construction template, while adhering to the December 1 to March 31 dredging window, the construction effort would occur over a four year time period. Therefore, the duration of each initial construction effort and each subsequent renourishment effort would be limited so that it does not preclude recruitment for any species during its entire recruitment period. Additionally, in accordance with recommendations provided by Hackney et al. (1996), the four initial construction events

would occur in stages along the beach, with the full template being constructed for each stage, instead of the entire beach being impacted within each construction event. That approach would also increase the speed of recovery for impacted areas by allowing for recruitment from adjacent un-impacted areas of the beach.

8. USFWS Recommendation: The Corps should ensure that no offshore hardbottom habitats are affected by sedimentation produced by the project, either as a result of offshore dredging or sediment washing off the beach. This goal may be accomplished by actual surveys of the offshore sediment extraction sites. The use of video surveys of established transects which has been undertaken could be used to monitor the biological health of offshore borrow areas. A sufficient buffer should be required between the dredging operation and hardbottoms. At a minimum, sediment extraction should comply with the North Carolina law (15A NCAC 07H. 0208(b)(12)(A)(iv)) requiring that mining of submerged land should not be conducted on or within 500 meters (1,640 feet) of significant biological communities, such as high relief hardbottom areas. Offshore hardbottoms that clearly show less biological significance could have reduced buffers provided that an adequate monitoring program is implemented. If the monitoring program indicates that offshore hardbottoms are being adversely affected, the project should include specific measures to mitigate any adverse impacts.

Corps Response: As discussed in Section 8.01.8.2, myriad nearshore and offshore investigations have been performed to assess the presence or absence of hard bottom within the proposed project area. Specifically, side-scan sonar and multibeam surveys were performed within the nearshore environment (within the –30 ft. contour) and high-resolution side-scan sonar surveys were performed within all proposed borrow areas. Identified anomalies in the nearshore were ground truthed using divers and video documentation to confirm the presence/absence of hard bottom. On the basis of ground-truth results of in-situ dive efforts, no hard bottom was identified within the depth of closure limits for the project. Additional ground-truth efforts were performed within select locations among the offshore borrow sites. Selected transects captured low, moderate, and high relief hard bottom areas as defined by the high-resolution side-scan imagery. Though hard bottom was documented at all but one transect, no high relief hard bottom was confirmed. Video surveys and benthic characterization assessments confirmed that the lower relief systems were adapted to high sedimentation conditions and reduced buffers would offer adequate protection. On the basis of the data collected from all the investigative studies, the proposed project would adhere to the 500 m buffer requirement for moderate and high-relief sites and would adhere to a 400 ft. buffer for identified low relief sits. To (1) ensure that required buffer distances are adhered to, (2) avoid physical impacts to hard-bottom resources, and (3) monitor the potential for leakage of sediment, the Corps would require all dredges to implement the Silent Inspector automated dredge plant monitoring system. In the event that a physical impact by the hopper dredge dragheads to previously unexposed hard bottom occurs, the incident would be thoroughly documented and coordinated with the appropriate state and federal resource agencies. Based on the outcome of this coordination, appropriate action would be taken to investigate and mitigate potential impacts.

Project monitoring of sedimentation impacts from dredging activities within the proposed 122-m (400-ft.) buffer would be implemented when appropriate. Sediment monitoring at select offshore transects, including controls, would occur before, during, and, if necessary, after construction and would include the installation of sediment traps (collectors) and in-situ sediment depth measurements. If sediment accumulation at the compliance transects is more than 10 percent of the sediment accumulated on average per day at the three control sites, the Corps would direct the contractor to stop dredging operations within the 122-m (400-ft.) buffer and move to another area 500 m (1,640 ft.) from the identified hard bottom sites.

On the basis of the available information pertaining to the dredged sediments, hopper dredge overflow activities, and associated potential turbidity plumes, and implementing a 122-m (400-ft.) to 500-m. (1,640-ft.) buffer distance depending on relief, no significant effects would be expected from the sedimentation and turbidity associated with the proposed dredging activities. The potential impacts to the hard-bottom communities would not be expected to exceed the natural sedimentation and turbidity conditions of the project area. For a thorough hard bottom impact evaluation, see Section 8.01.8.2 of the report.

9. USFWS Recommendation: While the use of highly compatible fill material would minimize turbidity and sedimentation due to runoff from the constructed beach, small inclusion of mud and silt pose a risk to nearshore hardbottoms. Project planning should establish a program to monitor the location, areal extent, and major organisms of nearshore hardbottoms before initial construction. If nearshore hardbottoms are present, these areas should be surveyed after initial construction to determine any adverse sedimentation and change in the biological community. If it appears likely that nearshore hardbottoms could be covered by sediment moving off the constructed beach, there should be a monitoring program to detect any overall loss of exposed hardbottoms and to develop and implement appropriate mitigation measures. Mitigation measures could include a reduction in the amount of beachfill near vulnerable hardbottoms.

Corps Response: See the above response to USFWS recommendation #8. On the basis of data collected from nearshore side-scan sonar, multibeam, and in-situ ground-truth surveys, no hard bottom was identified within the –30-ft. contour

10. USFWS Recommendation: Project plans should include measures to avoid adverse impacts associated with placement of the sediment pipeline and measures to monitor and mitigate any spills from the pipeline. During both initial construction and reconstruction events, the delivery pipeline should avoid areas where early shorebird reproductive activities may occur. Pipeline placement should avoid all hardbottom areas. There should be a plan to monitor pipelines for leaks and an established plan of action in the case a joint in the dredge pipe should break. This plan should describe measures to contain and clean the spill.

Corps Response: Dredging associated with the project would be accomplished using a hopper dredge. For beach nourishment projects, depending on the specific hopper dredge

used, the average hopper load ranges between 6,000 and 12,000 cubic yards. When a full load is achieved, the hopper dredge would sail to a *pumpout* location just offshore of the beach. The hopper dredge would pump the material out of the hopper into a submerged pipeline, which would approach the beach at a given area and extend to the placement area. Therefore, for hopper dredge pumpout operations, both submerged (in water) and exposed (on the beach) pipeline would transport the sediment to the placement area. For pipeline that is on dry beach, the contractor would be required to monitor the pipeline for leaks no less frequently than once every 2 hours. If a leak is detected, the contractor would perform an assessment and implement the appropriate fix to correct the problem. All pipeline inspections are logged and submitted daily to the Corps to document their completion.

For submerged pipeline, the contractor would be required to traverse the pipeline via a boat to perform a visual assessment for indications of a pipe leak. In addition to visual surveys, contractors can track pipe breaks or leaks using density gauges and meters onboard the dredge. According to the standard contract specifications, any pipe leak in the water or on land would be considered displaced material and its removal would be required according to an assessment of the severity of the situation. After the contractor and the Corps complete an assessment of the leak and after coordinating the assessment with the appropriate agencies, a cleanup measure would be implemented.

Bathymetric surveys, including side-scan sonar and multibeam techniques, as well as diver ground truth surveys have been performed by the Corps throughout the nearshore (less than –30 ft. NGVD) and have confirmed that no hard-bottom communities are present within the –30-ft. contour offshore of the proposed project area. Furthermore, seismic profile coverage, vibracores, and diver surveys have provided information, between the active beach (–23 ft NGVD) and 3 miles offshore of Surf City and North Topsail Beaches. Because hopper dredge pumpout stations would be just offshore of the project area, existing bathymetric survey data collected by the Corps would be used to ensure that submerged pipeline routes avoid hard-bottom communities.

All staging areas, pipeline routes, and associated construction activities for the project would avoid high-value piping plover and shorebird habitat, in the vicinity of New River Inlet, to the maximum extent practicable.

11. USFWS Recommendation: The project should include an annual monitoring program on beach and subtidal invertebrates that form an important food resource for shorebirds and surf fishes. While other monitoring programs have been implemented in North Carolina, each project has unique features such as the sediment source and the responses of invertebrates at one location may not be application to each beach construction effort. The project should include a requirement for a pre-project assessment of beach invertebrate biomass and community composition, i.e., the number of species present. The program should have adequate control areas such as Hutaff Island, south of Topsail Island, or Bear Island, north o the project area. After construction, the Corps should monitor the recovery of intertidal and near shore invertebrate populations. If the assessments indicate a significant decline in either biomass or the number of species

present when compared to control areas, there should be procedures in place to develop mitigation for this community. Data from these studies will be especially important if the reconstruction interval is reduced as sea level continues to rise. While the Corps predicted (USACE 2006a, p. 130) that benthic populations on West Onslow Beach may recovery within one to four years after large-scale sediment placement, a gradual reduction of the reconstruction interval could preclude adequate recovery and threaten these organisms which form an important base to the coastal food chain. The overall project plan should include funding for developing procedures to better understand mole crab and coquina clam life history requirements and developing effective measures to mitigate adverse impacts to these important resources.

Corps Response: Section 8.01.6 Benthic Resources—Beach and Surf Zone, addresses beach nourishment impacts to the benthic invertebrate community and discusses a thorough literature review indicating short-term impacts to benthic invertebrate populations with recovery occurring between 1–4 years depending on sediment compatibility. For study sites where nourished sediments were compatible with the native beach, recovery occurred within one year. Several Corps contracts addressing beach nourishment impacts to benthic invertebrate populations have recently been completed or are ongoing throughout the North Carolina beaches including Bogue Banks, Brunswick Beaches, and Dare County. The data that that has come back from the studies continue to support the large historical database, which indicates an initial impact to the benthic invertebrate resource with recovery occurring immediately after nourishment when the sediment is compatible with the native beach. Furthermore, the Dare County Beaches coastal storm damage reduction project has a significant monitoring plan, which includes a pre- and post-construction benthic invertebrate assessment. Because of the large historical monitoring database, the consistency of the data from these studies, and the continuing monitoring studies that are underway on other beach projects in North Carolina, the Corps does not plan to collect additional monitoring data for Surf City and North Topsail Beaches. However, the Corps is encouraged by the USFWS' recommendation to develop procedures to better understand benthic invertebrate life history requirements and the relationship those requirements have to beach activities. The opportunity to better understand the life cycle requirements of the benthic invertebrate community and the relationship to beach nourishment projects would allow for better management decisions to be made on future projects. The Corps recently participated in funding a study performed by Philip S. Kemp Jr., of the Carteret Community College, to investigate the feasibility of harvesting, holding, and culturing *Donax* spp. for resource enhancement aquaculture. The Corps is interested in putting together a workgroup, consisting of technical experts and resource agency representatives, to continue identifying study objectives that answer questions regarding critical life cycle requirements of benthic invertebrates. Additionally, the Corps will contribute funds to carry out subsequent scientific investigation to develop management guidelines and effective measures to mitigate identified impacts on such resources. Such a funding action would be fully coordinated with all concerned agencies.

12. USFWS Recommendation: A program for beach construction should include surveys for seabeach amaranth both before and for three years after sediment placement

in order to avoid direct burial and to monitor recovery of the plant. If the seabeach amaranth surveys that have been conducted within the Town of Topsail Beach since 1992 (USACE 2006a, p. 1-16) do not extend into the current project area, this work should be extended to include the current sediment placement areas. With the proposed four-year reconstruction cycle, surveys for this endangered plant would be made every year. If data indicate a declining trend in the presence of this federally threatened species, the development of mitigation measures may be advisable. The project should also monitor beach vitex in the project as part of an effort to eradicate this harmful invasive foreign plant.

Corps Response: The Corps would perform monitoring for seabeach amaranth on Surf City and North Topsail Beaches to assess the pre- and post-nourishment presence of plants. The survey would broken down into survey reaches for each town in accordance with the designated Corps sea beach amaranth survey reaches from 1991 to 2008 to maintain consistent data and survey techniques over time and results would be provided to USFWS. Beach vitex surveys are ancillary to seabeach amaranth surveys. Surveyors note the presence of beach vitex during amaranthus surveys, and the data is provided to the USFWS, which in turn is shared with the Carolinas Beach Vitex Task Force.

13. USFWS Recommendation: Nesting by sea turtles will benefit from strict sediment compatibility standards and work schedules that avoid the nesting and hatching season (May 1 through November 15). Current plans for beach construction avoid sediment disposal during this period. However, artificial beaches pose a risk to sea turtle nesting due to: (1) sediment compaction; (2) escarpment formation; and, (3) altered sand temperature which may occur as a result of a change in sediment color. To mitigate sediment compaction, the Service recommends that compaction monitoring should occur after each construction event and for three subsequent years. Considering that reconstruction is scheduled for every four years, a sediment compaction survey should be made each year of the project. However, compaction monitoring would not be required if the sediment used to construct the beach is completely washed away. Beach tilling should only be performed as a result of an identified compaction problem and not performed routinely in place of compaction monitoring. Similarly, visual surveys for escarpments should be made along the constructed beach immediately after completion of the sediment placement and prior to May 1. Additional surveys should be made for three years following initial construction. As with compaction monitoring, escarpment survey should be made each year of the project. Survey results should be submitted to the Service prior to any action being taken. After discussion with the Service, escarpments that interfere with sea turtle nesting or exceed 18 inches in height for a distance of 100 feet should be leveled to the natural beach contour by May 1. The Service should be contacted immediately if new escarpments that interfere with sea turtle nesting or exceed 18 inches in height for a distance of 100 feet form during the nesting and hatching season to determine the appropriate action to be taken. If it is determined that escarpment leveling is required during the nesting or hatching season, the Service will provide a brief written authorization that describes methods to be used to reduce the likelihood of impacting existing nests. A program for detecting and securing appropriate care for stranded sea turtles should be part of the project.

Corps Response: The proposed dredging and beach nourishment schedule of December 1 through March 31 for both initial construction and each nourishment interval would avoid the sea turtle nesting season. Therefore, no direct impacts to nesting sea turtles or incubating hatchlings would be expected. As identified in Section 4.00, Commitments to reduce impacts to Listed Species, of the Biological Assessment, the Corps is committed to assessing post-nourishment beach compaction, escarpment formation, and sea turtle nest temperature relative to sediment color. Sediment compaction could occur from the project and could affect the nesting environment of sea turtles. Though sediment placed on the beach would be compatible with the native material, the risk of sediment compaction and subsequent impacts to the nesting environment of sea turtles still exists. The USFWS has traditionally provided guidelines for assessing beach compaction, which include the use of a cone penetrometer instrument to assess compaction across 500-ft. spaced transects at varying stations and depths across the beach profile. A threshold value of 500 pound per square inch was used as an indicator for tilling requirements. Recent studies indicate that because of the variability of compaction measurement values among users (Piatkowski et al., 2001), among compaction instrumentation (Ferrell et al., 2001), as well as variability of compaction throughout a beach (Davis et al., 1999), care should be taken when performing quantitative assessments of sediment compaction. On the basis of the results and recommendations of the studies, the Wilmington District has modified its approach toward assessing beach compaction for nourishment and disposal projects and has been working with the NCWRC and the USFWS toward a more qualitative evaluation of post construction compaction conditions relative to native beach conditions. The results of such new coordinated process in evaluating post project beach compaction have been successful. Therefore, for initial construction and during each nourishment event, the Corps would work with the towns of Surf City and North Topsail Beaches and the NCWRC to continue the new compaction assessment protocol, but would not adhere to the traditional USFWS compaction guidelines. Tilling would be performed only if deemed necessary by the technical staff of the NCWRC, USFWS, and Corps, according to compaction assessment results.

Additionally, the beach would be monitored for escarpment formation before each nesting season. If an escarpment exceeds 18 inches for a distance of 100 ft. during construction operations it would be leveled. Furthermore, if it is determined that escarpment leveling is required during the nesting or hatching season, the towns or the Corps would coordinate with the USFWS to receive authorization that describes methods to be used to reduce the likelihood of affecting existing nests. Escarpment surveying and leveling would be performed by the Corps during initial construction and each nourishment interval, and the towns of Surf City and North Topsail Beaches would be responsible for surveys and, if necessary, leveling before the nesting season in the years between nourishment intervals.

The Corps is interested in understanding the threshold of sediment color change and resultant heat conduction on affecting temperature-dependent sex determination of sea turtles. The Corps would contribute funds for the NCWRC to continue its temperature studies to gather nest temperatures on nourished beaches throughout the state, including

Topsail Island, in comparison to non-nourished native sediment temperatures. This data could be used to help develop management criteria for sediment color guidelines.

Throughout the duration of each nourishment event, both initial construction and periodic nourishment, the contractor would be required to monitor for the presence of stranded sea turtles, live or dead. If a stranded sea turtle is identified, the contractor would immediately notify the NCWRC of the stranding and implement the appropriate measures as directed. Topsail Beach is home to the Karen Beasley sea turtle hospital, which has the facilities to provide care for stranded and injured sea turtles.

14. USFWS Recommendation: Piping plovers and other shorebirds are especially susceptible to human disturbance during territory establishment and early nesting attempts and after the chicks have hatched. Construction plans should determine whether any sections of the project area beaches are suitable nesting habitat for shorebirds and schedule work in such areas between December 1 and March 31.

Corps Response: The December 1 to March 31 construction window identified for the project would avoid disturbances to piping plovers and other shorebirds during territory establishment and early nesting attempts and after the chicks have hatched. Additionally, all staging areas, pipeline routes, and associated construction activities would avoid high-value piping plover and shorebird habitat, in the vicinity of New River Inlet, to the maximum extent practicable.

15. USFWS Recommendation: While the West Indian manatee is not likely to be in the project area during the proposed construction period, protective measures should be in place to safeguard this endangered species. Corps plans for the West Onslow Beach Project call (USACE 2006a, p. 1-12) for the implementation of the Service's *Precautions for General Construction in Areas Which May Be Used by the West Indian Manatee in North Carolina*. Those guidelines should provide adequate protection for this species.

Corps Response: The Corps would implement precautionary measures for avoiding impacts to manatees during construction activities as detailed in the *Guidelines for Avoiding Impacts to the West Indian Manatee in North Carolina Waters* established by the USFWS.

11.04 Coordination of this Document

A draft version of this report was provided to a standard list of federal, state, and local agencies; elected officials; environmental groups; and interested individuals for a 45-day review and comment period. Comments received and Corps responses to the comments are provided in Appendix T.

The current version of this report is being provided to the same list of federal, state, and local agencies; elected officials; environmental groups; and interested individuals for a 30-day review and comment period.

The Corps invites your comments and suggestions regarding the proposed action. In accordance with Council on Environmental Quality regulations (40 CFR 1500–1508) for implementing the NEPA, your comments should be as specific as possible and should be made with recognition that NEPA documents must focus on the issues that are truly significant to the proposed action rather than amassing needless detail. The NEPA process is intended to help public officials make decisions on the basis of an understanding of environmental consequences. NEPA directs that federal activities be conducted so as to attain the widest range of beneficial uses of the environment without degradation, risk to health or safety, or other undesirable or unintended consequences. As individual resources and stakeholder interests increasingly compete for priority, public officials are challenged to make management decisions that reflect a balance of the overall public interest. Please respond with a focus on essential issues that would be useful in guiding our decisions and actions as this project proceeds.

11.05 Recipients of this Document

(or Notice of Availability)

Federal Agencies

Advisory Council on Historic Preservation
Center for Disease Control and Prevention
Federal Emergency Management Administration
National Marine Fisheries Service, Southeastern Regional Office
National Marine Fisheries Service, Habitat Conservation Division, Beaufort Marine Fisheries Center, Beaufort, NC
National Park Service, Southeast Archeological Center
U.S. Coast Guard, Fifth District, Portsmouth, VA
U.S. Coast Guard, Marine Safety Office, Wilmington, NC
U.S. Forest Service, Southern Region, Atlanta, GA
U.S. Department of Agriculture, State and Area Conservationists, Natural Resources Conservation Service
U.S. Department of Energy, Office of Environmental Compliance
U.S. Department of Interior, Energy and Resources Division
U.S. Department of Interior, Office of Environmental Policy and Compliance
U.S. Department of Interior, Minerals Management Service, Herndon, VA
U.S. Department of Housing and Urban Development, Greensboro, NC
U.S. Department of Transportation, Federal Highway Administration, Raleigh, NC
U.S. Environmental Protection Agency, Region 4, Atlanta, GA
U.S. Environmental Protection Agency, Office of Federal Activities, Washington, D. C.
U.S. Fish and Wildlife Service, Raleigh Field Office
U.S. Marine Corps Base, Camp Lejeune, NC

State Agencies

NC Commission of Indian Affairs

NC Department of Environment and Natural Resources (NC State Clearinghouse)
NC Department of Transportation
NC Division of Coastal Management
NC Division of Marine Fisheries, Wilmington, NC
NC Division of Marine Fisheries, Shellfish Sanitation, Beaufort, NC
NC Department of Cultural Resources, Division of Archives and History
NC National Estuarine Research Reserve
NC Wildlife Resources Commission

Local Agencies

CAMA Officer, Surf City, NC
CAMA Officer, North Topsail Beach, NC
Cape Fear Council of Governments
North Topsail Beach Town Manager
Onslow County Emergency Services
Onslow County Board of Commissioners
Onslow County Planning & Development
Onslow County Manager
Onslow County Health Department
Pender County Board of Commissioners
Pender County Emergency Management
Pender County Manager
Pender County Planning Coordinator
Pender County Health Department
Sea Turtle Hospital, Topsail Beach
Surf City Town Manager
Topsail Beach Town Manager
Town of North Topsail Beach, NC
Town of Surf City
Town of Topsail Beach, NC

Elected Officials

Honorable Kay Hagan, US Senate
Honorable Richard Burr, US Senate
Honorable Walter B. Jones, US House of Representatives
Honorable Mike McIntyre, U.S. House of Representatives
Honorable Harry Brown, NC House of Representatives
Honorable George G. Cleveland, NC House of Representatives
Honorable Carolyn H. Justice, NC House of Representatives
Honorable R. C. Soles, Jr., North Carolina Senate
Honorable Russell E. Tucker, NC House of Representatives
Honorable Sandra Spaulding Hughes, NC House of Representatives
Pender County Board of Commissioners

Onslow County Board of Commissioners
Topsail Beach, Board of Commissioners

Conservation Groups

National Audubon Society
North Carolina Coastal Federation
North Carolina Coastal Land Trust
North Carolina Environmental Defense Fund
North Carolina Nature Conservancy
Pender Watch
Tar River Land Conservancy

Libraries, Museums, and News Media

NC Collection, Joyner Library, East Carolina University, Greenville, NC
Pender Chronicle
Jacksonville Daily News

Interested Businesses, Groups, and Individuals

Cape Fear Community College (Jason Rogers)
Duke University, Department of Department of Earth and Ocean Sciences(Geology), Dr. Orrin Pilkey
Land Management Group, Inc.
Mr. Ed Flynn
Mr. Glenn Hargett, Communications and Community Affairs Director, Jacksonville, NC
Mr. W. D. Aman, Sr.
Sea Turtle Hospital
UNC-Wilmington, Center for Marine Science (Troy Alphin)

12. CONCLUSIONS

The coastal storm problems and needs of the study area have been reviewed and evaluated with regard to the overall public interest and with consideration of engineering, economic, environmental, social, and cultural concerns. The conclusions of this study are as follows:

a. The Surf City and North Topsail Beach shorelines are susceptible to major damage and erosion from coastal storms.

b. The selected plan consist of a sand dune constructed to an elevation of 15 ft. above the NGVD, fronted by a 50-ft-wide beach berm constructed to an elevation of 7 ft. above NGVD. The berm and dune project extends along a reach of 52,150 ft. On the north end, the project would adjoin an adjacent nonfederal beachfill project for North Topsail Beach. At the south end, the project would transition into the federal beachfill project for Topsail Beach. If no adjacent beachfill project is occurring, the plan would include a transition consisting of a tapered berm only, starting with a transition berm width of 200 ft. that uniformly tapers to zero. If an adjacent beachfill project is occurring, any transition would be shorter and designed to fit the adjacent project.

c. The selected plan is feasible on the basis of engineering and economic criteria and is acceptable by environmental, cultural, and social laws and standards.

d. The selected plan is supported by the nonfederal sponsor—the towns of Surf City and North Topsail Beach. The sponsors have the capability to provide the necessary nonfederal requirements identified and described in report Section 9.02, Division of Plan Responsibilities.

13. RECOMMENDATIONS

This study addresses the needs for coastal storm damage risk reduction for the portion of Topsail Island that includes the towns of Surf City and North Topsail Beach. Other portions of Topsail Island have been or will be addressed in separate reports. The following recommendations include items for implementation by federal, North Carolina, and local governments and agencies, including the structural coastal storm damage reduction project.

Hurricane Risk Education

Numerous people die each year as a result of hurricanes, primarily because of the failure to evacuate to an area of safety. Any loss of life is tragic, and any number of those deaths might have been prevented. Even one death prevented is sufficient reason to improve our methods of educating the public on hurricane and storm threats and to ensure that all is done to warn all those residents or visitors to the coastline of North Carolina as to the dual hazards of wind and surge/waves. It is particularly vital to inform the public as to the potential for hurricane occurrence, particularly in the dangerous hurricane season, so they pay continued attention to media reports on weather. Education needs to include articulation of effects related to the potential magnitude of the threat, the urgency to heed potential calls to evacuate, and providing the means by which to make wise choices on evacuation methods and route (see recommendations given below under Hurricane Evacuation Planning). The following are suggested guidelines for implementation by state and local government, in the interests of good education on hurricane storm threats:

- Provide good science and information to the residents and visitors to coastal North Carolina, so they can understand the nature of the threat, and its possibility of happening at any time within the hurricane season. This information should be provided in both written form and as an initial *page* on televisions provided in visitor's housing, and also in a variety of venues, including the following:
    - Posting and televised education in supermarkets, libraries, and public buildings
    - Teacher-provided, posted, and televised education in schools and at public meetings and gatherings, at intervals not to exceed 1 year
    - Publicly posted and visitor-housing-posted information on evacuation routes, and procedures, on publicly accessible Web sites, updated regularly (minimum 1 yr.)

It is not possible to maintain the lives and safety of coastal North Carolina residents and visitors if they do not have sufficient warning and if they then do not use that knowledge to evacuate in a timely manner.

Education of hurricane risks is an ongoing effort of multiple agencies and educational institutions and not a funded program under existing Corps authorities. Updating Web sites containing evacuation routes and procedures should be done under existing programs implemented by the state and local governments.

Hurricane and Storm Warning

Residents and visitors to the coast of North Carolina need to recognize that they live in, or visit, a high-hazard area. Although certain times of the year pose less risk than others, each year's hurricane season provides a strong possibility of hurricane impact somewhere along the coast of North Carolina. All residents and visitors need to be made aware of the current hurricane threat. But first, meteorological conditions must be evaluated, and any threat must be assessed and characterized by experts at NOAA's National Weather Service. That interpretation must then be passed to national and local media for dissemination. Continued support of NOAA's program, and the following supportive activities are critical to an adequate warning process:

- Ongoing efforts to upgrade the existing system of NOAA buoys, transmission capabilities, and advanced warning measures that provide data on the location and nature of weather conditions.
- Efforts directed at the interpretation of that data and its dissemination to the media and public, through the National Weather Service.
- Public appreciation for the need to be aware at all times of, and the need to listen to weather reports and advice given on various media. Television weather reports, radio, and the Internet all provide excellent, up-to-date information on weather conditions, and the development of threatening situations. Simply living in or visiting the barrier islands of North Carolina should be sufficient to create a consistent and ongoing process of being exceptionally aware of the weather and its potential consequences.
- The vital importance of heeding the advice of experts. One should know what needs to be done when a storm is approaching. Family members should conduct evacuation drills, keep needed phone numbers and travel supplies on hand, and be prepared to leave on short notice. One should be aware of evacuation routes, keep a full tank of gas during the hurricane season and have a plan for where one should go, how to maintain contact with other family members, and where one will relocate temporarily, particularly if the event turns out to be longer than expected.

Hurricane Evacuation Planning Upgrading

The critical need for adequate evacuation planning was borne out by Hurricanes Bertha, Fran, and Floyd, of the late 1990s, and brought even more to the forefront by the monumental impacts of Hurricane Katrina in 2005. An evacuation plan is an essential component of a comprehensive plan for ensuring the safety of residents of, and visitors, to the coast of North Carolina. The preservation of life is the single most important goal and objective of the recommendations. Joint Federal Emergency Management Agency (FEMA)/NOAA/Corps/North Carolina studies of evacuation routes and populations along the coastline has provided a tremendous amount of value to-date in aiding local government, individual, and family readiness in the face of approaching events. Support for that program is a critical element of the recommendations for the towns of Surf City and North Topsail Beach in support of its residents and visitors. The towns of Surf City and North Topsail Beach both have evacuation and emergency response plans already in place. Important facets of these plans include:

- Annual review of hurricane evacuation plans

- State evacuation route signage
- Reverse 911 phone systems
- Low frequency AM Station
- NIMMS (emergency response command and control) training for all emergency personnel
- WEBEOC.org – a website for coordinating communication during emergencies
- Mutual aid agreements with inland emergency agencies
- Coordination of evacuation and emergency shelters with Onslow/Pender County Emergency Management
- Active re-entry pass system, for safe re-entry after an event

The following are important additional recommendations in support of efforts to support Hurricane Evacuation Planning:

- Much can still be done to update this ongoing effort and to provide new and more widely disseminated data and tools for evacuation planning by the state and the towns of Surf City and North Topsail Beach, and also for use by individuals and families in their preparation for an impending event.
- Evacuation route signage is an important part of a successful evacuation campaign. Maintenance of hurricane evacuation route signage is viewed as a vital link in ensuring the safety of residents and visitors alike.
- The provision of additional signage illustrating surge height achieved during past events would be an added and continual link to ongoing education efforts. That could take the form of signs placed in locations in which there is significant traffic, such as major thoroughfares, where pedestrians walk, and particularly in those highest hazard zones according to elevation/depth data.

Evacuation Planning is an ongoing effort of multiple agencies, including the Corps, but its implementation is not a funded program under existing Corps authorities. Updating Web sites containing evacuation routes and procedures should be periodically updated under existing programs implemented by North Carolina.

Floodplain Management

Management of the floodplain is a nonfederal responsibility, yet it is considered a key component of all plans for hurricane and storm damage reduction. The towns of Surf City and North Topsail Beach participate in the National Flood Insurance Program, which requires the towns to engage in active and responsible floodplain management. In Surf City, property owners have 2,148 flood insurance policies composed of nearly $480 million insurance in force. North Topsail Beach property owners possess 1,384 flood insurance policies providing approximately $240 million insurance in force. Because so much of the Surf City and North Topsail Beach are within a recognized floodplain, the towns continue to engage in activities that reduce threats to existing and potential future development, including structure setbacks, building code and construction monitoring, and flood zone management. The Corps encourages the towns to continue to update building codes and encourage strong pursuit of activities such as first-floor elevation and

building code upgrading in the effort to reduce the potential for future structural and content damage.

Building Codes

The towns of Surf City and North Topsail Beach have adopted the IBC to guide the design and construction of residential and commercial structures in the study area. To ensure that the latest design and construction techniques are being used that apply to hurricane-resistant construction, all future construction is encouraged to follow the latest version of the IBC (2007) and ensure enforcement of the codes through diligent building permit processing and on-site inspections of construction. Annual training classes on the use and enforcement of the new IBC should be encouraged. In addition, Surf City and North Topsail Beach should consider adopting the document *FEMA 550 Guidelines for Elevating Residential Structures on the Gulf Coast* as a part of their updated building codes for construction, because of the possibility of surge inundation associated with hurricane events.

Long-Term Critical Infrastructure and Services Upgrading

Upgrading critical infrastructure and services, such as Fire and Police services, is considered a vital recommendation in the reduction of threats to lives and property. The need to bring those services up to immediate restoration in the wake of a hurricane is of vital importance to the community. The methodical upgrading of the towns' Fire and Police services facilities as part of their capital improvement programs will provide long-term savings in capital outlay, and potentially save lives and residential and commercial property damage. Such a program may be instituted under a modified capital improvement program, where structures reaching the end of their economic life are successively replaced by upgraded structures, locating vital communications and power supplies above the elevation of a maximum probable surge event, and capable of surviving the ravages of wind or surge, as funds become available.

Upgrading or replacing services is primarily a local charge, implemented through capital improvement plans, with funding from a variety of federal, state, and local resources, and will take many years to accomplish, because of the varying age and condition of each facility.

Structural Damage Reduction Features

On the basis of the conclusions of this study, I recommend the implementation of the selected plan, identified as Plan 1550, which consists of a 52,150-ft-long dune system to be constructed to an elevation of 15 ft NGVD fronted by a 7-ft NGVD elevation, 50-ft-wide beach berm, with such modifications thereof as in the discretion of the Commander, Corps, may be advisable, at an initial first construction cost estimated at $123,135,000 (October 2010 price levels). The baseline cost estimate for construction in FY 2015 is $138,493,000.

As a result of the Feasibility study and EIS, I recommend that the project be authorized and implemented in accordance with the findings of this report.

I further recommend that construction of the proposed project be contingent on the project sponsor giving written assurances satisfactory to the Secretary of the Army that it will do the following:

a. Provide 35 percent of initial project costs assigned to coastal storm damage reduction, plus 50 percent of initial project costs assigned to reducing damages to undeveloped public lands, plus 50 percent of initial project costs assigned to recreation, plus 100 percent of initial project costs assigned to reducing damages to undeveloped private lands and other private shores that do not provide public benefits and 50 percent of periodic nourishment costs assigned to hurricane and storm damage reduction, plus 100 percent of periodic nourishment costs assigned to reducing damages to undeveloped private lands and other private shores that do not provide public benefits and as further specified below:

(1). Enter into an agreement which provides, before executing the PPPA, 25 percent of design costs.

(2). Provide, during the first year of construction, any additional funds needed to cover the nonfederal share of design costs.

(3). Provide all lands, easements, and rights-of-way, and perform or ensure the performance of all relocations determined by the federal government to be necessary for the initial construction, periodic nourishment, operation, and maintenance of the project.

(4). Provide, during construction, any additional amounts as are necessary to make its total contribution equal to 35 percent of initial project costs assigned to hurricane and storm damage reduction plus 100 percent of initial project costs assigned to reducing damages to undeveloped private lands and other private shores that do not provide public benefits and 50 percent of periodic nourishment costs assigned to hurricane and storm damage reduction, plus 100 percent of periodic nourishment costs assigned to reducing damages to undeveloped private lands and other private shores that do not provide public benefits.

b. Operate, maintain, and repair the completed project, or functional portion of the project, at no cost to the federal government, in a manner compatible with the project's authorized purposes and in accordance with applicable federal and state laws and regulations and any specific directions prescribed by the federal government.

c. Give the federal government a right to enter, at reasonable times and in a reasonable manner, on property that the nonfederal sponsor, now or hereafter, owns or controls for access to the project for the purpose of inspecting, operating, maintaining, repairing, replacing, rehabilitating, or completing the project. Completion of OMRR&R by the federal government will not relieve the nonfederal sponsor of responsibility to meet the nonfederal sponsor's obligations, or to preclude the federal

government from pursuing any other remedy at law or equity to ensure faithful performance.

d. Hold and save the United States free from all damages arising from the initial construction, periodic nourishment, OMRR&R of the project and any project related betterments, except for damages due to the fault or negligence of the United States or its contractors.

e. Keep and maintain books, records, documents, and other evidence pertaining to costs and expenses incurred pursuant to the project, for a minimum of 3 years after completion of the accounting for which such books, records, documents, and other evidence is required, to the extent and in such detail as will properly reflect total costs of construction of the project, and in accordance with the standards for financial management systems set forth in the Uniform Administrative Requirements for Grants and Cooperative Agreements to State and Local Governments at 32 CFR 33.20.

f. Perform, or cause to be performed, any investigations for hazardous substances that are determined necessary to identify the existence and extent of any hazardous substances regulated under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), P.L. 96-510, as amended, 42 U.S.C. 9601–9675, that may exist in, on, or under lands, easements, or rights-of-way that the federal government determines to be required for the initial construction, periodic nourishment, operation, and maintenance of the project. However, for lands that the federal government determines to be subject to the navigation servitude, only the federal government will perform such investigations unless the federal government provides the nonfederal sponsor with prior specific written direction, in which case, the nonfederal sponsor will perform such investigations in accordance with such written direction.

g. Assume, as between the federal government and the nonfederal sponsor, complete financial responsibility for all necessary cleanup and response costs of any CERCLA-regulated materials in, on, or under lands, easements, or rights-of-way that the federal government determines to be necessary for the initial construction, periodic nourishment, operation, or maintenance of the project.

h. Agree that, as between the federal government and the nonfederal sponsor, the nonfederal sponsor will be considered the operator of the project for the purpose of CERCLA liability, and to the maximum extent practicable, operate, maintain, and repair the project in a manner that will not cause liability to arise under CERCLA.

i. Comply with the applicable provisions of the Uniform Relocation Assistance and Real Property Acquisition Policies Act of 1970, P.L. 91-646, as amended by (42 U.S.C. 4601–4655), and the Uniform Regulations contained in 49 CFR Part 24, in acquiring lands, easements, and rights-of-way, required for the initial construction, periodic nourishment, operation, and maintenance of the project, including those necessary for relocations, borrow materials, and dredged or excavated material

disposal, and inform all affected persons of applicable benefits, policies, and procedures in connection with that act.

j. Comply with all applicable federal and state laws and regulations, including section 601 of the Civil Rights Act of 1964, P.L. 88-352 (42 U.S.C. 2000d), Department of Defense Directive 5500.11 issued pursuant thereto, as well as Army Regulation 600-7, titled *Nondiscrimination on the Basis of Handicap in Programs and Activities Assisted or Conducted by the Department of the Army*, and all applicable federal labor standards and requirements, including, 40 U.S.C. 3141–3148 and 40 U.S.C. 3701–3708 (revising, codifying, and enacting without substantial change the provisions of the Davis-Bacon Act (formerly 40 U.S.C. 276a *et seq.*), the Contract Work Hours and Safety Standards Act (formerly 40 U.S.C. 327 *et seq.*) and the Copeland Anti-Kickback Act (formerly 40 U.S.C. 276c *et seq.*).

k. Comply with section 402 of the WRDA of 1986, as amended (33 U.S.C. 701b-12), which requires the nonfederal interest to participate in and comply with applicable federal floodplain management and flood insurance programs, prepare a floodplain management plan within one year after the date of signing a PPA, and implement the plan no later than one year after project construction is complete.

l. Provide the nonfederal share of that portion of the costs of mitigation and data recovery activities associated with historic preservation, that are in excess of 1 percent of the total amount authorized to be appropriated for the project, in accordance with the cost-sharing provisions of the agreement.

m. Participate in and comply with applicable federal floodplain management and flood insurance programs.

n. Do not use federal funds to meet the nonfederal sponsor's share of total project costs unless the federal granting agency verifies in writing that the expenditure of such funds is authorized.

o. Prevent obstructions of or encroachment on the project (including prescribing and enforcing regulations to prevent such obstructions or encroachments), which might reduce the level of damage reduction it affords, hinder operation and maintenance or future periodic nourishment, or interfere with its proper function, such as any new developments on project lands or the addition of facilities that would degrade the benefits of the project.

p. Not less than once each year, inform affected interests of the extent of damage reduction afforded by the project.

q. Publicize floodplain information in the area concerned and provide such information to zoning and other regulatory agencies for their use in preventing unwise future development in the floodplain and in adopting such regulations as might be

necessary to prevent unwise future development and to ensure compatibility with damage reduction levels provided by the project.

r. For so long as the project remains authorized, the nonfederal sponsor must ensure continued conditions of public ownership, access, and use of the shore on which the amount of federal participation is based.

s. Provide and maintain necessary access roads, parking areas, and other public use facilities, open and available to all on equal terms.

t. At least twice annually and after storm events, perform surveillance of the beach to determine losses of nourishment material from the project design section and provide the results of such surveillance to the federal government.

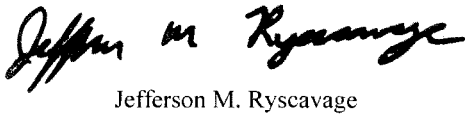
u. Comply with section 221 of P.L. 91-611, Flood Control Act of 1970, as amended (42 U.S.C. 1962d-5b), and section 103 of the WRDA of 1986, P.L. 99-662, as amended (33 U.S.C. 22130, which provides that the Secretary of the Army must not commence the construction of any water resources project or separable element thereof, until the nonfederal sponsor has entered into a written agreement to furnish its required cooperation for the project or separable element.

The nonfederal sponsor (both towns) have indicated that they have available the necessary funds to provide the nonfederal share of the project first costs and periodic renourishment costs. I am confident that the nonfederal sponsor will provide their share.

This recommendation is subject to the cost-sharing policies as outlined in this report and is endorsed, provided that, before construction, the nonfederal sponsor enters into a written PPA, as required by P.L. 91-611 section 221, as amended.

The total first cost of the project, at Oct 2010 price levels, is $123,135,000. The federal share of the total first project cost is estimated at $80,038,000. The nonfederal share of the total first project cost is estimated at $43,097,000. As previously indicated, the total project benefit-cost ratio is 3.7 to 1, which means that for every dollar spent for the project, 3 dollars and 70 cents are realized in NED benefits from the project.

The recommendations contained herein reflect the information available at this time and current departmental policies governing formulation of individual projects. They do not reflect program and budgeting priorities inherent in the formulation of a national Civil Works construction program nor the perspective of higher review levels within the Executive Branch. Consequently, the recommendations may be modified before they are transmitted to the Congress as proposals for implementation funding. However, prior to transmittal to the Congress, the sponsor, the states, interested federal agencies, and other parties will be advised of any modifications and will be afforded an opportunity to comment further.



Jefferson M. Ryscavage
Colonel, U.S. Army
District Commander

14. POINT OF CONTACT

Any comments or questions regarding this Feasibility Report and EIS should be addressed to Ms. Jan Brodmerkel, Project Manager, U.S. Army Corps of Engineers, 69 Darlington Avenue, Wilmington, NC 28403, telephone (910) 251-4673.

15. REFERENCES

Anderson, D.G. 1996 Approaches to Modeling Regional Settlement in the Archaic Period Southeast. In *Archaeology of the Mid-Holocene Southeast*, edited by Kenneth E. Sassaman and David G. Anderson. University Press of Florida, Gainesville, FL.

Anderson, D.G., L.D. O'Steen, K.E. Sassaman. 1996. Environmental and Chronological Considerations. In *The Paleoindian and Early Archaic Southeast*, ed. D.G. Anderson and K.E. Sassaman. The University of Alabama Press, Tuscaloosa, AL.

Anderson, D.G., and M.K. Faught. 2000. Paleoindian artefact distributions: evidence and implications. *American Antiquity* 74:507–13.

Angley, W. 1984. *An Historical Overview of Bogue Inlet.* North Carolina Division of Archives and History, Raleigh, NC.

Armstrong, D., B. Stevens, and J. Hoeman. 1982. *Distribution and abundance of Dungeness crab and Crangon shrimp, and dredged-related mortality of invertebrates and fish in Grays Harbor, Washington.* Technical Report. School of Fisheries, University of Washington, Washington Department of Fisheries, and U.S. Army Engineer District, Seattle, WA.

Bartol, S.M., J.A. Musick and M.L. Lenhardt. 1999. Auditory evoked potentials of the loggerhead sea turtle (*Caretta caretta*). *Copeia* 3(1999) 836–840.

Beasley, Jean. 2004. Director. Karen Beasley Sea Turtle Rescue and Rehabilitation Center. Personal Communication

Blanton, D.B. 1996. Accounting for Submerged Mid-Holocene Archaeological Sites. In *Archaeology of the Mid-Holocene Southeast*, ed. K.E. Sassaman and D.G. Anderson. University Press of Florida, Gainesville, FL.

Blair S. B. Flynn, T. McIntosh, L. Hefty. 1990. *Environmental Impacts of the 1990 Bal Harbor Beach Renourishment Project: Mechanical and Sedimentation Impact on Hard-Bottom Areas Adjacent to the Borrow Area.* Metro-Dade DERM Technical Report 90-15. Miami, FL.

Blanton, J.O., J. Amft, R.A. Luettich Jr., J.L. Hench and J.H. Churchill. 1999. Tidal and subtidal fluctuations in temperature, salinity, and pressure for the winter 1996 larval ingress experiment – Beaufort Inlet, NC. *Fisheries Oceanography*. (suppl. 2):134–152.

Boehlert, G.W., and B.C. Mundy. 1988. Roles of behavioral and physical factors in larval and juvenile fish recruitment to estuarine nursery areas. *American Fisheries Society Symposium* 3:51–67.

Boss, S.K., and C.W. Hoffman. 2001. *Geologic Framework Derived From High-Resolution Seismic Reflection, Side-Scan Sonar, and Vibracore Data Offshore Oregon Inlet to Duck, Dare County, North Carolina*. Prepared for U.S. Minerals Management Service, International Activities and Marine Minerals Division, Herndon, VA.

Bowen, P.R., and G.A. Marsh. 1988. *Benthic Faunal Colonization of an Offshore Borrow Pit in Southeastern Florida*. Misc. Rept. D-88-5. U.S. Army Corps of Engineers, Dredging Operations Technical Support program, Vicksburg, MS.

Buell, J. 1992. *Fish Entrainment Monitoring of the Western-Pacific Dredge R.W. Lofgren During Operations Outside the Preferred Work Period*. Prepared for the Western-Pacific Dredging Company, by Buell and Associates, Inc., Portland, OR.

Burgess, C.C., and A.J. Bianchi. 2004. *An Economic Profile Analysis of the Commercial Fishing Industry of North Carolina Including Profiles for State-Managed Species*. NOAA Award No. NA16FW1543. North Carolina Department of Environment and Natural Resources North Carolina Division of Marine Fisheries; License and Statistics Section, Morehead City, NC.

Burrel, I.V.G. Jr. 1986. Species Profiles: Life Histories and Environmental Requirements of Coastal Fishes and Invertebrates (South Atlantic)—American Oyster. U.S. Army Corps of Engineers TR EL-82-4. U.S. Fish and Wildlife Service. *Biological Report*. 82(11.57).

Burton, W., S. Weisberg, and P. Jacobson. 1992. *Entrainment effects of maintenance hydraulic dredging in the Delaware River Estuary on Striped Bass Ichthyoplankton. Report*. Prepared for Delaware Basin Fish and Wildlife Management Cooperative, Trenton, NJ, by Versar, Inc., Columbia, MD.

Byrnes, M.R., R.M. Hammer, B.A. Vittor, S.W. Kelley, D.B. Snyder, J.M. Côté, J.S. Ramsey, T.D. Thibaut, N.W. Phillips, and J.D. Wood. 2003. *Collection of Environmental Data Within Sand Resource Areas Offshore North Carolina and the Environmental Implications of Sand Removal for Coastal and Beach Restoration*. OCS Report MMS 2000-056. U.S. Department of the Interior, Minerals Management Service, Leasing Division, Sand and Gravel Unit, Herndon, VA.

Cacchione D.A., D.E. Drake, W.D. Grant, and G.B. Tate. 1984. Rippled Scour Depressions on the Inner Continental Shelf Off Central California. *Journal of Sedimentary Petrology* 54(4):1280–1291.

Cahoon, Larry. October 24, 2006. Biological Oceanographer and Professor. University of North Carolina at Wilmington. Personal Communication.

Cahoon, L.B., and J.E. Cooke. 1992. Benthic microalgal production in Onslow Bay, North Carolina, USA. *Marine Ecological Progress Series.* 84:185–196.

Cahoon, L.B., R.S. Redman, and C.R. Tronzo. 1990. Benthic microalgal biomass in sediments of Onslow Bay, North Carolina. *Estuarine, Coastal, and Shelf Science.* 31:805–816.

Cameron, Sue. 2004, September 8. North Carolina Wildlife Resources Commission, Waterbird Biologist. Personal communication,.

Carey, Penny. March 23, 2010. Environmental Protection Agency. Personal Communication.

Carriker, M., M. LaSalle, R. Mann, and D. Pritchard. 1986. Entrainment of oyster larvae by hydraulic cutterhead dredging operations: Workshop Conclusions and Recommendations. Entrainment of Larval Oysters, *American Malacological Bulletin,* Special Edition (3):71–4.

Churchill, J.H., J.O. Blanton, J.L. Hench, R.A. Luettich Jr., and F.E. Werner. 1999. Flood tide circulation near Beaufort Inlet, North Carolina: Implications for larval recruitment. *Estuaries* 22:1057–1070.

Clarke, D., C. Dickerson, and K. Reine. 2002. Characterization of Underwater Sounds Produced by Dredges. In *Proceedings of the Third Specialty Conference on Dredging and Dredged Material Disposal.* May 5–8 2002, Orlando, FL.

Cleary, W.J. March 2007. Professor of Geology. University of North Carolina at Wilmington. Personal communication.

Cleary, W.J. 2002. *An Assessment of the Availability of Beachfill Quality of Sand Offshore Topsail Beach, Pender County, NC.* HDR Engineering, Inc. of the Carolinas, Sunset Beach, NC.

Cleary, W.J. 2003. *An Assessment of the Availability of Beachfill Quality Sand Offshore North Topsail Beach and Surf City North Carolina.* HDR Engineering, Inc., of the Carolinas, Sunset Beach, NC.

Cleary, W.J. 2005, November 11. Professor, University of North Carolina, Wilmington Earth Sciences Department. Personal communication.

Cleary, W.J., and T.P. Marden. 1999. *Shifting Shorelines: A pictorial Atlas of North Carolina Inlets.* 2nd ed. North Carolina Sea Grant, Raleigh, NC.

CSA (Coastal Science Associates, Inc.). 2002. *Bogue Banks Beach Nourishment Second Post-Dredge Environmental Monitoring Study*. Prepared for Carteret County, NC, Town of Pine Knoll Shores, NC, Town of Indian Beach, NC, and Town of Emerald Isle, NC, by Coastal Science Associates, Inc., Columbia, SC.

Compton, R., L. Goodwin, R. Handy, and V. Abbott. 2008. A Critical Examination of Worldwide Guidelines for Minimising the Disturbance to Marine Mammals During Seismic Surveys. *Marine Policy* 32:255–262.

Coston-Clements, L., L.R. Settle, D.E. Hoss, and F.A. Cross. 1991. *Utilization of the Sargassum habitat by marine invertebrates and vertebrates—A review*. NOAA Technical Memorandum NMFS-SEFSC-296. National Oceanic and Atmospheric Administration, St. Petersburg, FL.

Cushing, D.H. 1988. The Study of Stock and Recruitment. In *Fish Population Dynamics* 2nd ed. ed. J.A. Gulland. John Wiley and Sons, Ltd.

Cutter G.R. Jr., and R.J. Diaz, 1998. Part 1: Benthic Habitats and Biological Resources Off the Virginia Coast 1996 and 1997. In *Final Report Environmental Studies Relative to Potential Sand Mining in the Vicinity of the City of Virginia Beach, Virginia*. Minerals Management Service, Herndon, VA.

Daniel, H. 2001. Replenishment versus retreat: the cost of maintaining Delaware's beaches *Ocean & Coastal Management* 44(1–2):87–104.

Day, J.H., J.G. Field, and M.P. Montgomery, 1971. The Use of numerical methods to determine the distribution of benthic fauna across the continental shelf of North Carolina. *Journal of Animal Ecology* 40:93–125.

Dechant, J. A., M. L. Sondreal, D. H. Johnson, L. D. Igl, C. M. Goldade, and B.D. Parkin, and B. R. Euliss. 2003. Effects of management practices on grassland birds: Willet. Northern Prairie Wildlife Research Center, Jamestown, ND. Northern Prairie Wildlife Research Center Online. <http://www.npwrc.usgs.gov/resource/literatr/grasbird/will/will.htm>. Updated December 12, 2003. Accessed January 11, 2010.

Delaney, A.D., C.J. Kruempel, M.J. Lybolt, and S.E. Prekel. 2006. *Town of Palm Beach Reach 7, Phipps Ocean Park Beach Restoration Project: Pre-Construction, Construction, and Post-Construction Biological Monitoring Report*. Prepared for the Town of Palm Beach, FL, by Coastal Planning and Engineering, Inc., Boca Raton, FL.

Dew, C.B., and J.H. Hecht. 1994. Recruitment, growth, mortality, and biomass production of larval and early juvenile Atlantic tomcod in the Hudson River estuary. *Transactions of the American Fisheries Society* 1235):681–702.

Diaz, H. 1980. The mole crab *Emerita talpoida* (say): A case study of changing life history pattern. *Ecological Monographs* 50(4):437–456.

Dolan, R., Fucella, J., and Donahue C. 1992. *Monitoring and Analysis of Beach Nourishment Placed on Pea Island, North Carolina, Alligator River National Wildlife Refuge 1991–1992*. Coastal Research Associates, Charlottesville, VA.

Faught, M.K. 2004. The Underwater Archaeology of Paleolandscapes, Apalachee Bay, Florida. *American Antiquity* 69:275–289.

FEMA (Federal Emergency Management Agency). 1994. *A Unified National Program for Floodplain Management*. Federal Interagency Floodplain Management Task Force. FEMA 248. Federal Emergency Management Agency, Washington, D.C.

FEMA. 2009. *Recommended Residential Construction for Coastal Areas – Building on Strong and Safe Foundations*. FEMA P-550, Second Edition. Federal Emergency Management Agency, Washington DC.

Fisher, Lou. July 24, 2008. Biologist. Broward County Environmental Protection, Department, Biological Resources Division. Personal communication.

Francesconi, Jim. August 11, 2004. Artificial Reef Coordinator. North Carolina Division of Marine Fisheries. Personal communication.

Fritz Rhode. August 9, 2008. Fisheries Biologist, North Carolina Division of Marine Fisheries. Personal communication.

Gajewski, L.S., and S. Uscinowicz. 1993. Hydrologic and sedimentologic aspects of mining marine aggregate from the Slupsk Bank (Baltic Sea). *Marine Georesources and Geotechnology* 11:229–244.

Geo-Marine. 2008. *Marine Resources Assessment Update for the Cherry Point Operating Area*. Contract #N62470-02-D-9997, CTO 0056. Prepared for Department of the Navy, U.S. Fleet Forces Command, Norfolk, VA. by Geo-Marine, Inc., Hampton, VA.

Geo-Marine. 2005. *Taking Marine Mammals Incidental to Specified Activities; Port of Miami Construction Project (Phase II)*. 70 FR 21174. April 25, 2005 and Department of the Navy. 2008. Marine Resource Assessment Update for the Cherry Point Operating Area. Contract #N62470-02-D-9997, CTO 0056. Prepared for the Department of the Navy, U.S. Fleet Force Command, Norfolk, VA, by Geo-Marine, Inc., Hampton VA.

Goodyear, A.C. 2006. Recognizing the Redstone Fluted Point in the South Carolina Paleoindian Point Database. *Current Research in the Pleistocene* 26:100–102.

Greenhorne & O'Mara, Inc. 2004. *Final Report Marine Geophysical Investigation for the Evaluation of Sand Resource Areas Offshore Topsail Island North Carolina*. Prepared for US Army Corps of Engineers, Wilmington, NC, by Greenhorne & O'Mara, Inc., Raleigh, NC.

Hackney, C.T., M.H. Posey, S.W. Ross, and A.R. Norris. 1996. *A Review and Synthesis of Data on Surf Zone Fishes and Invertebrates in the South Atlantic Bight and the Potential Impacts from Beach Nourishment.* Prepared for the U.S. Army Corps of Engineers, Wilmington, NC.

Hall, W. 2004. *Archaeological Remote Sensing Survey of Topsail and West Onslow Beaches Offshore Borrow Areas.* Prepared for the U.S. Army Corps of Engineers, Wilmington, NC.

Hargrove, T. 1983. *Archaeological Test Excavations at 31NH256, the L.H. Jordan Permit Site, Cedar Island, New Hanover County, North Carolina.* Prepared for the U.S. Army Corps of Engineers, Wilmington, NC.

Hayden, B., and R. Dolan. 1974. Impact of beach nourishment on distribution of *Emerita talpoida*, the common mole crab. *Journal of the American Waterways, Harbors, and Coastal Engineering Division*; ASCE 100:WW2. pp. 123–132.

Haynes, G. 2002. The catastrophic extinction of mammoths and mastodons. *World Archaeology* 33:391–416.

Hettler, W.F. Jr., and J.A. Hare. 1998. Abundance and size of larval fishes outside the entrance to Beaufort Inlet, North Carolina. *Estuaries* 21(3):476–499

Hettler, W.F., D.S. Peters, D.R. Colby, and E.H. Laban. 1997. Daily variability in abundance of larval fishes inside Beaufort Inlet. *Fisheries Bulletin.* 95:477–493.

Hettler, W.F. Jr. 1998. Abundance and size of dominant winter immigrating fish larvae at two inlets into Pamlico Sound, North Carolina. *Brimleyana* 25:144–155.

Hettler, W.F. Jr., and D.L. Barker. 1993. Distribution and abundance of larval fishes at two North Carolina inlets. *Estuarine, Coastal and Shelf Science* 37:161–179.

Hettler, W.F. Jr. and A.J. Chester. 1990. Temporal distribution of ichthyoplankton near Beaufort Inlet, North Carolina. *Marine Ecology Progress Series.* 68:157-168.

Hitchcock, D.R., and B.R. Drucker. 1996. Investigation of benthic and surface plumes associated with marine aggregates mining in the UK. In *Conference Proceedings Oceanology International '96. Volume 2.* ISBN: 0 90025412 2. pp. 220-234.

Holland Consulting Planners, Inc. 1996 (certified by Coastal Resources Commission March 26, 1999). *Town of North Topsail Beach North Carolina, 1996 Land Use Plan.* Prepared for North Topsail Beach, NC, by Holland Consulting Planners, Inc., City, NC.

Hutchinson, D.L. 2002. *Foraging, Farming, and Coastal Biocultural Adaption in Late Prehistoric North Carolina.* University Press of Florida, Gainesville, FL.

Jarrett, J.T. 1976. *Tidal Prism—Inlet Area Relationships.* General Investigation of Tidal Inlets, GITI Report 3. U.S. Army Corps of Engineers, Wilmington District, Wilmington, NC.

Johnson, S.C. 1994. *The feeding habits of the Florida Pompano (*Trachinotus carolinus*) along Masonboro Island, North Carolina National Estuarine Research Reserve.* Unpubl. Directed Independent Study. University of North Carolina–Wilmington.

Johnson, R.O., and W.G. Nelson. 1985. Biological effects of dredging in an offshore borrow area. *Biological Sciences* 48(3):166–188.

Jutte, P.C., R.F. Van Dolah, and P.T. Gayes. 2002. Recovery of benthic communities following offshore dredging, Myrtle Beach, SC. *Shore and Beach* 70(3):25–30

Jutte, P.C., R.F. Van Dolah, G.Y. Ojeda, and P.T. Gayes. 2001. *An Environmental Monitoring Study of the Myrtle Beach Renourishment Project: Physical and Biological Assessment of Offshore Sand Borrow Site, Phase II – Cane South Borrow Area, Final Report.* Prepared for the U.S. Army Engineer District Charleston, Charleston, SC, by the South Carolina Marine Resources Research Institute, South Carolina Marine Resources Division, Charleston, SC.

Jutte, P.C., R.F. Van Dolah, M.V. Levisen, P. Donovan-Ealy, P.T. Gayes, and W.E. Baldwin. 1999. An Environmental Monitoring Study of the Myrtle Beach Renourishment Project: Physical and biological Assessment of Offshore Sand Borrow Site, Phase I – Cherry Grove Borrow Area, Final Report. Prepared for the US Army Engineer District, Charleston, SC, by the South Carolina Marine Resources Research Institute, South Carolina Marine Resources Division, Charleston, SC.

Kriesel, W., C. Landry, and A. Keeler. 2005. Coastal erosion management from a Community Economics Perspective: The feasibility and efficiency of user fees. *Journal of Agricultural and Applied Economics* 37(2):451–61.

Landry, C.E., A.G. Keeler, and W. Kriesel. 2003. An economic evaluation of beach erosion management alternatives. *Marine Resource Economics* 18(2):105–127.

Lankford, Thomas. 2004, August 12. Professor, University of North Carolina–Wilmington. Personal communication.

Leber, K.M. 1982. Seasonality of macroinvertebrates on a temperate, high wave energy sandy beach. *Bulletin of Marine Science* 32(1):86–98.

LeGrand, H.E. 1983. Southern Atlantic Coast Region. *American Birds* 37:978–980.

Levisen, M., and R. Van Dolah. 1996. *Environmental Evaluation of the Kiawah Island Beach Scraping Project. Final Report.* South Carolina Department of Natural Resources, Marine Resources Division, Charleston, SC.

Lewis, R.B. 2000. Sea-level rise and subsidence effects on Gulf Coastal archaeological site distributions. *American Antiquity* 65:525–541.

Lindquist, N., and L. Manning. 2001. *Impacts of Beach Nourishment and Beach Scraping on Critical Habitat and Productivity of Surf Fishes, Final Report to the NC Fisheries Resource Grant Program,* Morehead City, NC.

Lindquist, D.G., L.B. Cahoon, I.E. Clavijo, M.H. Posey, S.K. Bolden, L.A. Pike, S.W. Burk, and P.A. Cardullo. 1994. Reef fish stomach contents and prey abundance on reef and sand substrata associated with adjacent artificial and natural reefs in Onslow Bay, North Carolina. *Bulletin of Marine Science* 55(2–3):308–318.

Lybolt, M., and S. Tate. 2003. *Twelve-Month Post-Construction Environmental Monitoring of the Town of Palm Beach Mid-Town Beach Nourishment Project.* Coastal Planning & Engineering, Inc., Boca Raton, FL.

McAvoy, J.M. 1997. *Archaeological investigations of site 44SX202, Cactus Hill, Sussex County, Virginia.* Research Report Series No. 8. Department of Historic Resources, Richmond, VA.

McQuarrie, M.E. 1998. Geologic framework and short-term, storm-induced changes in shoreface morphology: Topsail Beach, NC. Masters thesis, Duke University, Department of the Environment, Durham, NC.

Moser, M.L., and T.B. Taylor. 1995. *Hard Bottom Habitat in North Carolina State Waters: A Survey of Available Data.* Prepared for North Carolina Division of Coastal Management Ocean Resources Taskforce, Morehead City, NC.

Moser, M.L., S.W. Ross, S.W. Snyder, and R.C. Dentzman. 1995. Distribution of Bottom Habitats on the Continental Shelf of North Carolina. In *Southeast Area Monitoring and Assessment Program—South Atlantic* (SEAMAP-SA). SEAMAP-SA Bottom Mapping Workgroup, Atlantic States Marine Fisheries Commission, Washington, DC.

Murray A. B. and E. R. Thieler. 2004. A new hypothesis and exploratory model for the formation of large-scale inner-shelf sediment sorting and rippled scour depressions. *Continental Shelf Research* 24:295–315.

NCDMF (North Carolina Department of Marine Fisheries). 2004. *North Carolina Fishery Management Plan—Blue Crab.* North Carolina Department of Environment and Natural Resources Division of Marine Fisheries, Morehead City, NC.

NCDMF (North Carolina Department of Marine Fisheries). 2006. *North Carolina Fishery Management Plan—Shrimp.* North Carolina Department of Environment and Natural Resources Division of Marine Fisheries, Morehead City, NC.

NCDMF (North Carolina Department of Marine Fisheries). 2007. *North Carolina Fishery Management Plan—Bay Scallop.* North Carolina Department of Environment and Natural Resources Division of Marine Fisheries, Morehead City, NC.

NCDMF (North Carolina Department of Marine Fisheries). 2008a. *North Carolina Fishery Management Plan—Hard Clam (Amendment 1)*. North Carolina Department of Environment and Natural Resources Division of Marine Fisheries, Morehead City, NC.

NCDMF (North Carolina Department of Marine Fisheries). 2008b. *North Carolina Fishery Management Plan—Oyster (Amendment II)*. North Carolina Department of Environment and Natural Resources Division of Marine Fisheries, Morehead City, NC.

NCDMF (North Carolina Department of Marine Fisheries). 2009. *Stock status of important coastal fisheries in North Carolina.* <http://www.ncfisheries.net/stocks/index.html>. Accessed May 2010.

NMFS (National Marine Fisheries Service). 1998. *Final Recovery Plan for the Shortnose Sturgeon* Acipenser brevirostrum. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, St. Petersburg, FL.

Naqvi, S.M., and C.H. Pullen. 1982. *Effects of beach nourishment and borrowing on marine organisms.* U.S. Army Corps of Engineers, Coastal Engineering Research Center, Misc. Rept. 82-14. Vicksburg, MS.

Nash, D., and S. Rogers. 2003. *The Dune Book.* North Carolina State University, North Carolina Sea Grant, City, NC.

Neff, J.F. 1985. Biological effects of drilling fluids, drill cuttings, and produced waters. In: The long-term effects of offshore oil and gas development: An assessment and research strategy, ed. D.F. Boesch and N.N. Rabalais. Elsevier Applied Science.

Neff, J.F. 1981. Fate and biological effects of oil well drilling fluids in the marine environment. In: *Final Technical Report to the USEPA.*

Nelson, W.G. 1989. An Overview of the Effects of Beach Nourishment on the Sand Beach Fauna. In *Beach Preservation Technology '88: Problems and Advancements in Beach Nourishment*, ed. L.S. Tait. pp. 295-310. Florida Shore and Beach Preservation Association, Tallahassee, FL.

Nelson, W.G. 1985. *Guidelines for Beach Restoration Projects.* Part I. Biological Guidelines. Report 76, Florida Sea Grant, Gainesville, FL.

Newell, R.C. and L.J. Seiderer. 2003. Ecological Impacts of Marine Aggregate Dredging on Seabed Resources. In *Review of Existing and Emerging Environmentally Friendly Offshore Dredging Technologies.* Prepared for the U.S. Department of Interior, Leasing Division, Sand and Gravel Unit Minerals Management Service, Herndon, VA.

NCDENR (North Carolina Department of Environment and Natural Resources). 2005. *Coastal Habitat Protection Plan.* North Carolina Department of Environment and Natural Resources, Division of Marine Fisheries, Morehead City, NC.

North Carolina Division of Coastal Management. *CAMA Rules and Policies*. (NCAC 07H. 0208 (Use Standards) (b) (12)(A)(iv)). <http://dcm2.enr.state.nc.us/Rules/rules.htm>. Accessed May 2010.

NCDMF (North Carolina Division of Marine Fisheries). 2009. Annual Fisheries Bulletin—2009 Commercial and Recreational Statistics. License and Statistics Section, Morehead City, NC. <http://www.ncfisheries.net/download/2009AnnualNC_FisheriesBulletin.pdf>. Accessed April 2010.

Onslow County, North Carolina. 1997. *CAMA Land Use Plan Update*. Onslow County, Jacksonville, NC.

Pender County, North Carolina. 2006. *CAMA Land Use Plan Update*. Onslow County, Burgaw, NC.

Peterson, C.H., D.H.M. Hickerson, and G.G. Johnson. 2000. Short-term consequences of nourishment and bulldozing on the dominant large invertebrates of a sandy beach. *Journal of Coastal Research* 16(2):368–378.

Phelps, D.S. 1981. *The Archaeology of Colington Island*. Archaeological ResearchReport No. 3. East Carolina University, Department of Sociology and Anthropology, Archaeology Laboratory, Greenville, NC.

Phelps, D.S. 1983. Archaeology of the North Carolina Coast and Coastal Plain: Problems and Hypotheses. In *The Prehistory of North Carolina: An Archaeological Symposium*, ed. M.A. Mathis and J.J. Crow. North Carolina Division of Archives and History, Raleigh, NC.

Poopetch, T. 1982. Potential effects of offshore tin mining on marine ecology. *Proceedings of the Working Group Meeting on Environmental Management in Mineral Resource Development,* Series No. 49, p. 70-73.

Posey, M.H., and T.D. Alphin. 2002. Resilience and stability in an offshore benthic community: Responses to sediment borrow activities and hurricane disturbance. *Journal of Coastal Research* 18(4):685–697.

Posey, M.H., and T.D. Alphin. 2000. Monitoring of Benthic Faunal Responses to Sediment Removal Associated With the Carolina Beach and Vicinity—Area South Project. Final Report. CMS Report No. 01-01.

Posey, M.H., and W.G. Ambrose Jr. 1994. Effects of proximity to an offshore hard-bottom reef on infaunal abundances. *Marine Biology* 118:745–753.

Posey, M.H. 1991. *Long-Term Effects of Sediment Removal on Infaunal Community Composition at a Borrow Site in the Lower Cape Fear River*. Prepared for the U.S. Army Corps of Engineers, Wilmington, NC.

Potter, E.F., J.F. Parnell, and R.P. Teulings. 1980. *Birds of the Carolinas*. University of North Carolina Press, Chapel Hill, NC.

Pullen, E., and S. Naqvi. 1983. Biological impacts on beach replenishment and borrowing. *Shore and Beach* April 1983.

Reilly, F.J. Jr., and V.J. Bellis. 1978. *A Study of the Ecological Impact of Beach Nourishment with Dredged Materials on the Intertidal Zone*. Technical Report No. 4. Institute for Coastal and Marine Resources, Greenville, NC.

Reilly, F.J. and V.J. Bellis. 1983. *A Study of the Ecological Impact of Beach Nourishment with Dredged Materials on the Intertidal Zone at Bogue Banks, North Carolina*. Misc. Rept. No. 83-3. U.S. Army Corps of Engineers, Coastal Engineering Research Center, Vicksburg, MS.

Richardson, W.J., C.R. Greene Jr., C.I. Malme, and D.H. Thomson (with contributions by S.E. Moore and B. Wursig). 1995. Marine Mammals and Noise.

Ridgway S.H., E.G. Wever, J.G. McCormick, J. Palin and J.H. Anderson. 1969. Hearing in the giant sea turtle, *Chelonia mydas. Proceedings from the National Acadamy of Sciences.* 64(1969):884–890.

Ridgway, S.H., E.G. Wever, J.G. McCormick, J. Palin and J. Anderson. 1970. Sensitivity of the green sea turtle's ear as shown by its electrical potentials. *Journal of Acoustical Society of America,* 47(1970):67.

Riggs, S.R., W.G. Ambrose Jr., J.W. Cook, S.W. Snyder, and S. Snyder. 1998. Sediment production on sediment-starved continental margins: The inter-relationships between hardbottoms, sedimentologic and benthic community processes, and storm dynamics. *Journal of Sedimentary Research* 68(1):155–168.

Riggs, S.R., W.J. Cleary, and S.W. Snyder. 1996. *Morphology and Dynamics of Barrier and Headland Shorefaces in Onslow Bay, North Carolina*. In: Carolina Geological Society, Fieldtrip Guide- book, pp. 33-48.

Ross, S.W. 1996. Surf zone fishes of the south Atlantic Bight. Section III, pp. 42-107. In *A review and synthesis of data on surf zone fishes and invertebrates in the South Atlantic Bight and the potential impacts from beach nourishment*, ed C.T. Hackney,, M.H. Posey, S.W. Ross, and A.R. Norris. Prepared for the U.S. Army Corps of Engineers, Wilmington, NC.

Ross, S.W. and J.E. Lancaster. 2002. Movements and site fidelity of two juvenile fish species using surf zone nursery habitats along the southeastern North Carolina coast. *Environmental Biology of Fishes* 63:161–172.

Ross, S. W. and J. E. Lancaster. 1996. *Movements of Juvenile Fishes using Surf Zone Nursery Habitats and the Relationship of Movements to Beach Nourishment along a North Carolina Beach: Pilot Project*. Prepared for National Oceanic and Atmospheric Administration, Office of Coastal Resource Management Silver Spring, MD and the U.S. Army Corps of Engineers, Wilmington, NC.

Russo, M. 1996. Southeastern Mid-Holocene Coastal Settlements. In *Archaeology of the Mid-Holocene Southeast*, ed. K.E. Sassaman and D.G. Anderson. University Press of Florida, Gainesville, FL.

Saloman, C.H., and S.P. Naughton. 1984. *Beach restoration with offshore dredged sand: Effects on nearshore macrofauna*. NOAA Tech. Mem. NMFS-SEF-133. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, St. Petersburg, FL.

Saloman, C.H., S.P. Naughton, and J.L. Taylor. 1982. *Benthic Community Response to Dredging Borrow Pits, Panama City Beach, Florida*. Miscellaneous Report NO. 82-3. U.S. Army Corps of Engineers, Coastal Engineering Research Center, Vicksburg, MS.

Saloman, C.H. 1974. *Physical, Chemical, and Biological Characteristics of the Nearshore Zone of Sand Key, Florida, Prior to Beach Restoration*. Vols. 1 & 2. National Marine Fisheries Service, Gulf Coast Fisheries Center, Panama City, FL.

Sassaman, K.E. 1996. Early Archaic Settlement in the South Carolina Coastal Plain. In

The Paleoindian and Early Archaic Southeast, ed. D.G. Anderson and K.E. Sassaman. The University of Alabama Press, Tuscaloosa, AL.

Sauer, J.R., J.E. Hines, and J. Fallon. 2008. *The North American Breeding Bird Survey, Results and Analysis 1966-2007*. Version 5.15.2008. Patuxent Wildlife Research Center, Laurel, MD.

Schafale, M.P., and A.S. Weakley. 1990. *Classification of the natural communities of North Carolina, third approximation*. North Carolina, Department of Environment and Natural Resources, Natural Heritage Program, Raleigh, NC.

Science Applications, Inc. 1981. *A Cultural Resource Survey of the Continental Shelf from Cape Hatteras to Key West*. 2 vols. Prepared for the Bureau of Land Management, New Orleans, LA, by Science Applications, Inc.

Settle, Larry. 2002, June 27. Fishery Biologist, National Marine Fisheries Service. Personal communication..

Sholar, T.M. 1975. Anadromous fisheries survey of the New and White Oak River systems. Completion Report. Oct. 73-June 75, AFCS-9. North Carolina Division of Marine Fisheries.

Schneider, C.W., R.B. Searles, and J.S. Child. 1991. *Seaweeds of the southeastern United States: Cape Hatteras to Cape Canaveral*. Illustrated by Julia S. Child. Duke University Press, Durham, NC.

SAFMC (South Atlantic Fishery Management Council). 1998. *Final habitat plan for the South Atlantic Region: Essential fish Habitat Requirements for Fishery Management Plans of the South Atlantic Fishery Management Council*. South Atlantic Fishery Management Council, Charleston, SC.

SEAMAP-SA (Southeast Area Monitoring and Assessment Program-South Atlantic). 2001. *Distribution of Bottom Habitats on the Continental Shelf from North Carolina through the Florida Keys*. Southeast Area Monitoring and Assessment Program-South Atlantic, Bottom Mapping Workgroup, Atlantic States Marine Fisheries Commission, Washington, DC.

Sherman, Stan. Environmental Senior Technician. North Carolina Department of Environment and Natural Resources, Shellfish Sanitation. Personal communication.

Street, M.W., A.S. Deaton, W.S. Chappell, and P.D. Mooreside. 2005. *North Carolina Coastal Habitat Protection Plan (CHPP)*. North Carolina Department of Environment and Natural Resources, Division of Marine Fisheries, Morehead City, NC.

Thieler, E. Robert. March 1, 2007. Research Geologist. USGS, Woods Hole Science Center, Woods Hole, MA. Personal communication.

Thieler, E.R., O.H. Pilkey Jr., W.J. Cleary, and W.C. Schwab. 2001. Modern Sedimentation on the Shoreface and Inner Continental Shelf at Wrightsville Beach, North Carolina, USA. *Journal of Sedimentary Research* 71(6):958–970.

Theiler, E.R., P.T. Gayes, W.C. Schwab, and M.S. Harris. 1999. Tracing Sediment Dispersal on Nourished Beaches: Two Case Studies. *Coastal Sediments*. New York, ASCE, p. 2118–2136.

Thomsen, F. S. McCully, D. Wood, F. Pace, and P. White. 2009. *A generic investigation into noise profiles of marine dredging in relation to the acoustic sensitivity of the marine fauna in UK waters with particular emphasis on aggregate dredging. Marine Aggregate Levy Sustainability Fund (MALSF)*. MEPF Ref No. MEPF/08/P21.

Town of North Topsail Beach. 1998. Code of Town of North Topsail Beach, North Carolina. Codified through Ordinances July 2, 1998 (Supplement 2).

Town of Surf City. 2005. Town of Surf City Land Use Plan 2005. Surf City, NC.

Turbeville, D.B. and G.A. Marsh. 1982. Benthic Fauna of an offshore borrow area in Broward County, FL. Misc. Report. 82-1. U.S. Army Corps of Engineers, Coastal Engineering Research Center, Vicksburg, MS.

USACE (U.S. Army Corps of Engineers). 1961. *The Intracoastal Waterway, Atlantic Section*. U.S. Army Corps of Engineers, U.S. Government Printing Office, Washington, DC.

USACE (U.S. Army Corps of Engineers), Wilmington District. 2009. *Final Integrated General Reevaluation Report and Environmental Impact Statement, Shore Protection, West Onslow Beach and New River Inlet (Topsail Beach), North Carolina*. February 2009 (Revised April 2009). U.S. Army Corps of Engineers, Wilmington District, Wilmington, NC.

USACE (U.S. Army Corps of Engineers). 2008. *Regional Biological Assessment for Dredging Activities in the Coastal Waters, Navigation Channels (including designated Ocean Dredged Material Disposal Sites (ODMDS)), and Sand Mining Areas in the South Atlantic Ocean*. U.S. Army Corps of Engineers, Wilmington District, Wilmington, NC. Submitted to NMFS on September 12, 2008.

USACE (U.S. Army Corps of Engineers), Wilmington District. 2008b. *Surf City/North Topsail Beach, NC Shore Protection Project, Hard Bottom Resource Confirmation and Characterization Study*. Contract W912HN-08-C-0009. Prepared for the U.S. Army Corps of Engineers), Wilmington District, Wilmington, NC, by ANAMAR Environmental Consulting Inc., City, ST, and Coastal Planning and Engineering, Inc., City, ST

USACE (U.S. Army Corps of Engineers). 2007a. Technical Memorandum, Topsail Beach Benthic Community Characterization Survey, Pender County, North Carolina. Prepared for U.S. Army Corps of Engineers , Wilmington District, Wilmington, NC, by Dial Cordy and Associates Inc., Wilmington, NC.

USACE (U.S. Army Corps of Engineers), Wilmington District. 2007b. *Draft Environmental Impact Statement. North Topsail Beach Shoreline Protection Project.* . Prepared for the U.S. Army Corps of Engineers, Wilmington District by Coastal Planning and Engineering, Inc., City, ST.

USACE (U.S. Army Corps of Engineers), Wilmington District. 2007c. *High-Resolution 3D Bathymetric Assessment of Potential Hard Bottom Habitats: Topsail Island, Surf City and North Topsail Island, NC January/February 2007*. Contract DACW54-02-D-0006. Prepared for the U.S. Army Corps of Engineers, Wilmington District, Wilmington, NC, by Greenhorne and O'Mara Consulting Engineers with sub-consultant Geodynamics.

USACE (U.S. Army Corps of Engineers), Wilmington District. 2006. *High-Resolution Remote Sensing of Potential Hard Bottom Habitats: Topsail Island, NC. July 2006.* Contract DACW54-02-D-0006. Prepared for the U.S. Army Corps of Engineers, Wilmington District, Wilmington, NC, by Greenhorne and O'Mara Consulting Engineers, City, ST, with sub-consultant Geodynamics, City, ST.

USACE (U.S. Army Corps of Engineers), Wilmington District. 2005. An Archaeological Remote Sensing Survey of Surf City – North Topsail Beaches Offshore Borrow Areas. Contract Number DACW 54-03-D-0002, Delivery Order 0005. Prepared for the U.S. Army Corps of Engineers, Wilmington District, Wilmington, NC, by Mid-Atlantic Technology and Environmental Research, Principal Investigator Wess Hall.

USACE (U.S. Army Corps of Engineers), Wilmington District. 2004a. *Marine Geophysical Investigation for the Evaluation of Sand Resource Areas Offshore Topsail Island North Carolina*. Final Report. Contract DACW54-02-D-0006, Delivery Order 0002. Prepared for the U.S. Army Corps of Engineers, Wilmington District, Wilmington, NC, by Greenhorne and O'Mara, Inc., with consultant Ocean Surveys Inc. (OSI).

USACE (U.S. Army Corps of Engineers), Wilmington District. 2004b. Year 2 Recovery from impacts of beach nourishment on surf zone and nearshore fish and benthic resources on Bald Head Island, Caswell Beach, Oak Island, and Holden Beach, North Carolina: Final study findings. Prepared for the U.S. Army Corps of Engineers, Wilmington District, Wilmington, NC, by Versar, Inc., Columbia, MD.

USACE (U.S. Army Corps of Engineers), Wilmington District. 2003. An Assessment of the Availability of Beachfill Quality Sand Offshore North Topsail Beach and Surf City, North Carolina. Prepared for the U.S. Army Corps of Engineers, Wilmington District, Wilmington, NC, by HDR Engineering, Inc., of the Carolinas City, ST, in association with William J. Cleary, PhD, PG.

USACE (U.S. Army Corps of Engineers). 2002. *Coastal Engineering Manual.* Engineer Manual 1110-2-1100 (in 6 volumes). U.S. Army Corps of Engineers, Washington, DC.

USACE (U.S. Army Corps of Engineers), New York District. 2001. The New District's Biological Monitoring Program for the Atlantic Coast of New Jersey, Asbury Park to Manasquan Section Beach Erosion Control Project, Phases II-III, During Construction and 1st Year Post-Construction Studies. U.S. Army Corps of Engineers, New York District, New York, NY.

USACE (US. Army Corps of Engineers), Wilmington District. 2000. *Hurricane Fran Effects on Communities With and Without Shore Protection: A Case Study at Six North Carolina Beaches.* U.S. Army Corps of Engineers, Wilmington District, Wilmington, NC.

USACE (U.S. Army Corps of Engineers), Wilmington District. 1997. *Environmental Assessment, Use of Hopper Dredge with Overflow as an Additional Maintenance Dredging Method for Portions of Wilmington Harbor, North Carolina.* (and FONSI 1997). U.S. Army Corps of Engineers, Wilmington District, Wilmington, NC

USACE (USACE Permit #200000325 and NC CAMA Permit #124001. NCAC 07H. 0208 (Use Standards) (b) (12)(A)(iv)). North Carolina Division of Coastal Management. CAMA Rules and Policies. Effective October 1 2009. <http://dcm2.enr.state.nc.us/Rules/rules.htm>. Accessed May 2010.

U.S. Department of Interior, Minerals Management Service (MMS). 2004. Review of Existing and Emerging Environmentally Friendly Offshore Dredging Technologies. Prepared by W.F. Baird and Associates, Ltd. and research Planning, Inc. for the MMS Leasing Division, Sand and Gravel Unit.

U.S. Department of the Interior, Minerals Management Service (MMS). 1999. Environmental Report Use of Federal Offshore Sand Sources for Beach and Coastal Restoration in New Jersey, Maryland, Delaware, and Virginia. OCS Study MMS 99-0036. Office of International Activities and Marine Minerals. Prepared by The Louis Berger Group, Inc. Contract Number 1435-01-98-RC-30820.

USEPA (U.S. Environmental Protection Agency). 2006. *Current Methodologies and Best Practices in Preparing Port Emission Inventories*. Final Report. Prepared by ICF Consulting for the U.S. Environmental Protection Agency, Office of Policy, Economics and Innovation, Sector Strategies Program, Washington, DC.

USFWS (U.S. Fish and Wildlife Service). 1989. 1989 *Status Update: U.S. Atlantic coast piping plover*. Unpublished Report, Newton Corner, MA.

U.S. Water Resources Council. 1983. *Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies*. U.S. Water Resources Council.

Van Dolah, R.F., R.M. Martore, A.E. Lynch, P.H. Wendt, M.V. Levisen, D.J. Whitaker, and W.D. Anderson. 1994. *Environmental Evaluation of the Folly Beach Project*. Final report, U.S. Army Corps of Engineers, Charleston District, Charleston, SC, and the South Carolina Department of Natural Resources, Marine Resources Division, Columbia, SC.

Van Dolah, R.F., R.M. Martore, and M.V. Levisen. 1993. Physical and biological monitoring study of the Hilton Head beach nourishment project. Prepared for the Town of Hilton Head Island by the South Carolina Marine Resources Research Institute, South Carolina Marine Resources Division, Charleston, SC.

Van Dolah, R.F., P.H. Wendt, R.M. Martore, M.V. Levisen, and W.A. Roumillat. 1992. *A Physical and Biological Monitoring Study of the Hilton Head Beach Nourishment Project*. Marine Resources Division, South Carolina Wildlife and Marine Resources Department, Charleston, South Carolina.

Van Dolah, R.F., D.R. Calder, D.M. Knott. 1984. Effects of Dredging and Open-Water Disposal on Benthic Macroinvertebrates in South Carolina Estuary. *Estuaries* 7(1):28–97.

Vargas-Angel B., B. Riegl, R.E. Dodge, D.S Gilliam, H.A. Halter, and E.C. Hodel. 2004. An experimental histopathological rating scale for sedimentation stress in the Caribbean coral *Montastraea cavernosa*. In *Proceedings of the 10th Int. Coral Reef Symposium*, Okinawa, Japan, 2004. p 1168–1172.

Versar. 2006. *Year one pre-construction environmental monitoring for the Dare County beach shoreline protection project, Dare County, North Carolina*. 5 sections plus appendices Prepared for the U.S. Army Corps of Engineers, Wilmington District, Wilmington, NC, by Versar Inc., Columbia, MD,.

Versar. 2002. *Effects of dredged material beach disposal on surf zone and nearshore fish and benthic resources on Bald Head Island, Caswell Beach, Oak Island, and Holden Beach, North Carolina: Interim study findings*. 2 volumes. Prepared for the U.S. Army Corps of Engineers, Wilmington District, Wilmington, NC, by Versar, Inc., Columbia, MD.

Ward, H.T. and S. Davis Jr. 1999. *Time Before History: The Archaeology of North Carolina*. The University of North Carolina Press, Chapel Hill, NC.

Whiteside, P.G.D., K. Ooms, and G.M. Postma. 1995. Generation and decay of sediment plumes from sand dredging overflow. In *Proceedings of the 14th World Dredging Conference Amsterdam, The Netherlands*. pp. 877–892.

Wilber, P., and M. Stern. 1992. A Re-examination of Infaunal Studies That Accompany Beach Nourishment Projects. In *Proceedings of the 5th Annual National Conference on Beach Preservation Technology*. pp. 242–257.

Wolcott, T.G. 1978. Ecological role of ghost crabs, *Ocypode quadrata*, on an ocean beach: scavengers or predators? *Journal of Experimental Marine Biology and Ecology*. 31:67–82.

Zinski, S. C. 2006. Blue Crab Archives. <http://www.blue-crab.org/spawning.htm>. Updated June 2006. Accessed May 2010.

http://www.ncfisheries.net/rules.htm

http://www.chelonia.org

http://si.wes.army.mil/

16. LISTS OF PREPARERS

16.01 Preparers

The following people provided major support in developing and preparing this *Feasibility Report and Environmental Impact Statement.*

Name (Report role)	Expertise	Discipline
Doug Piatkowski EIS Preparation	Environmental Impact Statement	Marine Biology
Jenny Owens EIS Preparation	Environmental Compliance	Physical Scientist
Jan Brodmerkel Project Management	Project Management	Civil Engineering
Doug Wall Coastal Engineer	Coastal Engineering Modeler	Civil Engineering
Ray Livermore Geotechnical	Geotechnical Analysis	Environmental Engineering
John Caldwell Cost Engineering	Cost Engineering	Civil Engineering
Garry Pennington Nonstructural Plans	Structural Engineering	Civil Engineering
Frank Snipes Economic Analysis	Economic & Social Analysis	Economics & Water Resources
Doug Greene Lead Planner	Planning	Civil Engineering
Richard Kimmel Cultural Resources	Historical & Underwater Archaeology	Anthropology
Belinda Estabrook Real Estate	Real Estate	Real Estate

16.02 Reviewers

The following people provided major support in the Agency Technical Review (ATR) of this *Feasibility Report and Environmental Impact Statement.* The ATR was coordinated by Larry Cocchieri of the Coastal Storm Damage Reduction Center of Expertise in North Atlantic Division.

Name (District)	Expertise	Discipline
John Winkelman (New England)	Lead and Coastal/H&H	Coastal/H&H
Jeff Strahan (Norfolk)	Plan Formulation	Planning/Economics
Elisabeth Sears (Norfolk)	Environmental	Biology/Oceanography
Marcos Paiva (New England)	Cultural Resources	Cultural Resources
Ed O'Leary (New England)	Economics/Recreation	Economics/Recreation
Bruce Uibel (Philadelphia)	Geotechnical	Geotechnical
Joe Ellsworth (Mobile)	Cost Engineering	Cost Engineering
Adam Oestreich (Baltimore)	Real Estate	Real Estate

Final Integrated Feasibility Report and Environmental Impact Statement

on

Coastal Storm Damage Reduction

SURF CITY AND NORTH TOPSAIL BEACH, NORTH CAROLINA

Appendix A

Project Maps

Appendix A

Project Maps

Page A-2	Figure A-1	Environmental Planning Considerations 1 of 2
Page A-3	Figure A-1	Environmental Planning Considerations 2 of 2
Page A-4	Figure A-2	Wetlands
Page A-5	Figure A-3	Primary Nursery Areas
Page A-6	Figure A-4	Shellfishing Closures
Page A-7	Figure A-5	Water Quality Classification
Page A-8	Figure A-6	Borrow Areas 1 of 2
Page A-9	Figure A-6	Borrow Areas 2 of 2
Page A-10	Figure A-7	Selected Plan
Page A-11	Figure A-8, 1 of 14	Plan Details, 1 of 14, Reaches 26-29
Page A-12	Figure A-8, 2 of 14	Plan Details, 2 of 14, Reaches 29-33
Page A-13	Figure A-8, 3 of 14	Plan Details, 3 of 14, Reaches 33-37
Page A-14	Figure A-8, 4 of 14	Plan Details, 4 of 14, Reaches 37-41
Page A-15	Figure A-8, 5 of 14	Plan Details, 5 of 14, Reaches 41-44
Page A-16	Figure A-8, 6 of 14	Plan Details, 6 of 14, Reaches 45-48
Page A-17	Figure A-8, 7 of 14	Plan Details, 7 of 14, Reaches 49-52
Page A-18	Figure A-8, 8 of 14	Plan Details, 8 of 14, Reaches 53-56
Page A-19	Figure A-8, 9 of 14	Plan Details, 9 of 14, Reaches 57-60
Page A-20	Figure A-8, 10 of 14	Plan Details, 10 of 14, Reaches 60-64
Page A-21	Figure A-8, 11 of 14	Plan Details, 11 of 14, Reaches 64-68
Page A-22	Figure A-8, 12 of 14	Plan Details, 12 of 14, Reaches 68-72
Page A-23	Figure A-8, 13 of 14	Plan Details, 13 of 14, Reaches 72-75
Page A-24	Figure A-8, 14 of 14	Plan Details, 14 of 14, Reaches 76-78

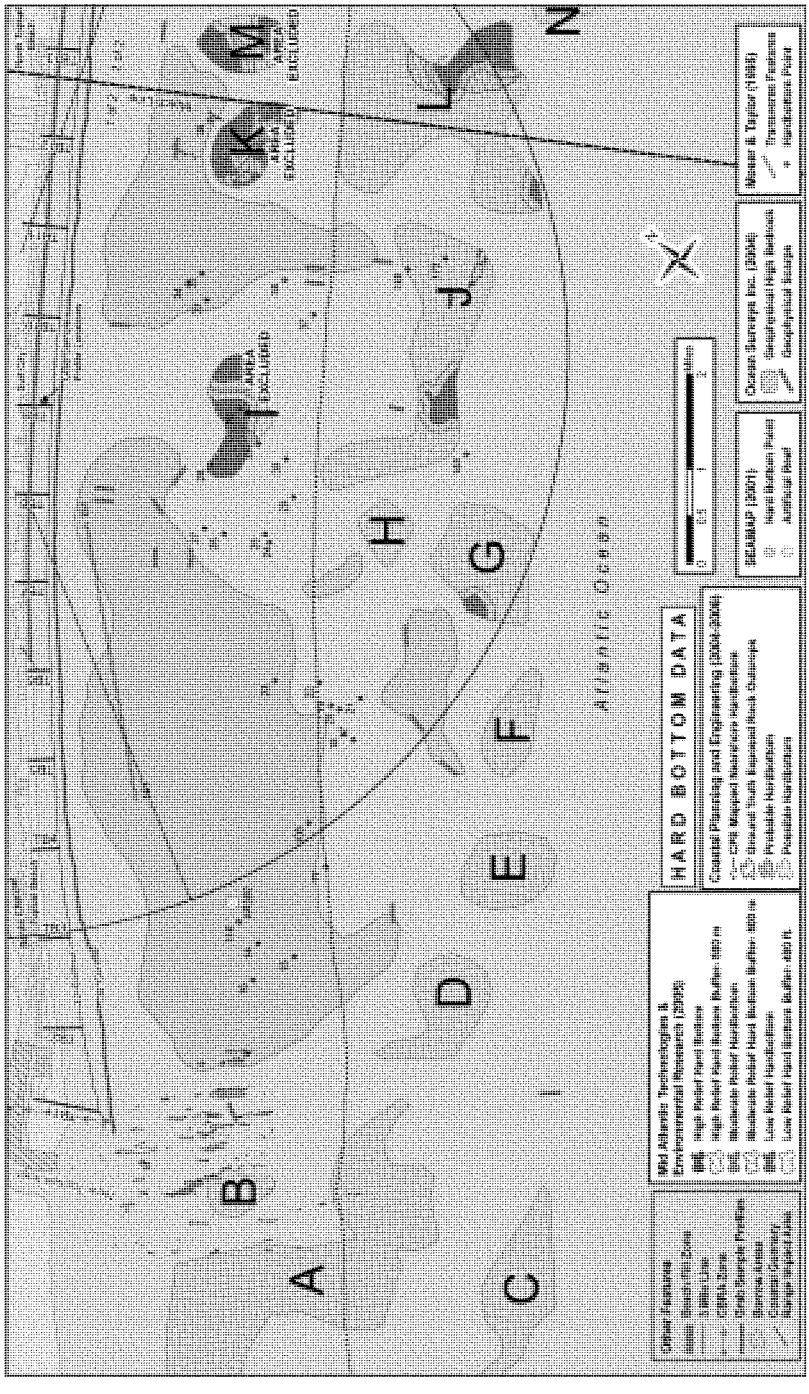


Figure A-1 Environmental Considerations 1 of 2

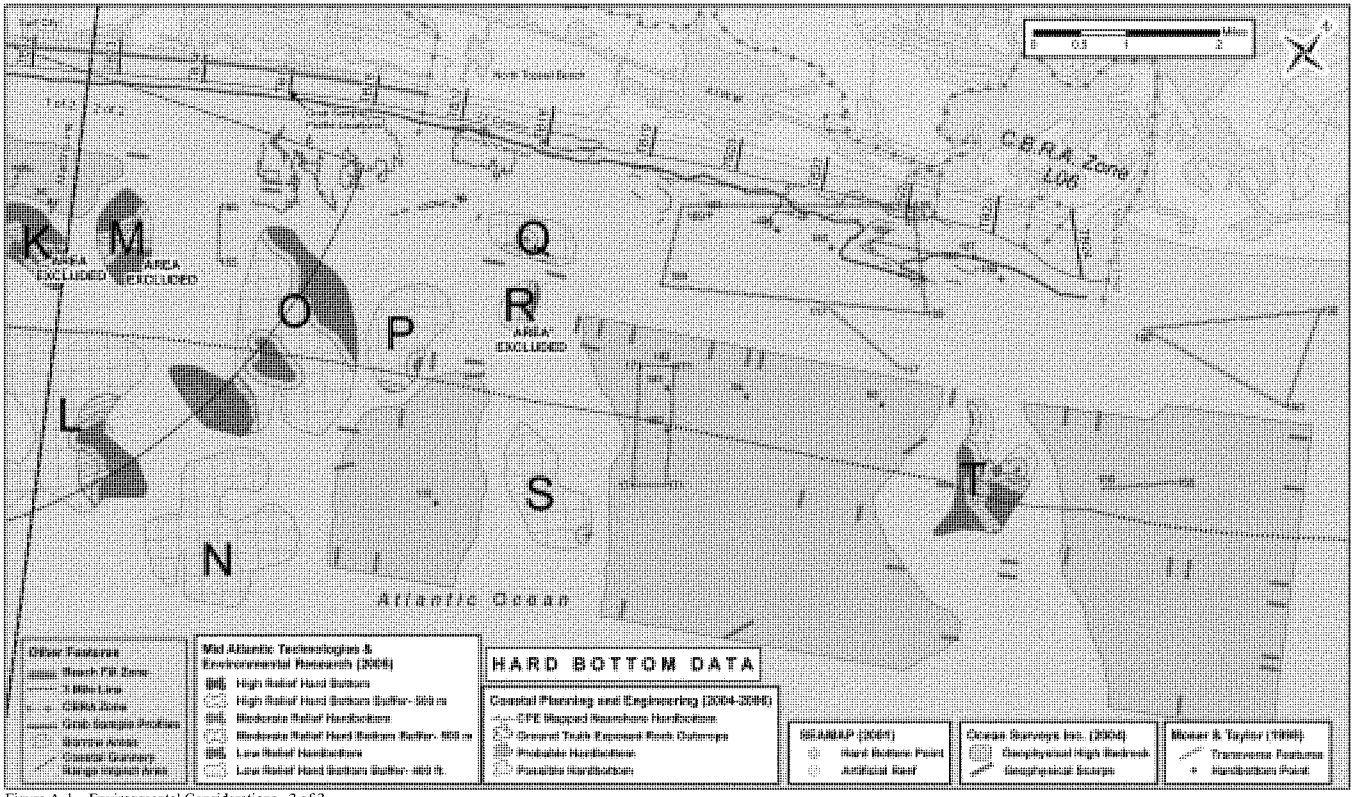


Figure A-1 Environmental Considerations 2 of 2

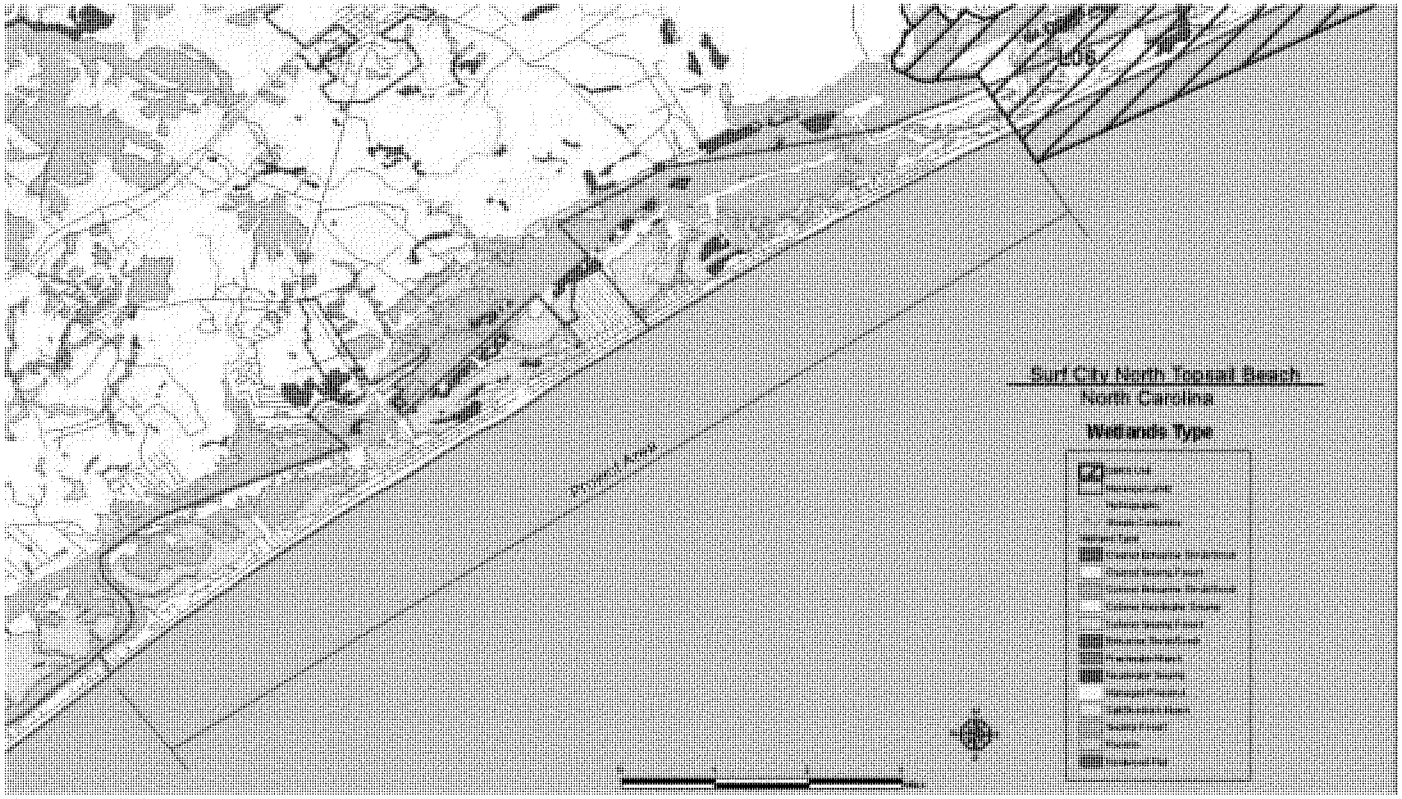


Figure A-2 Wetlands

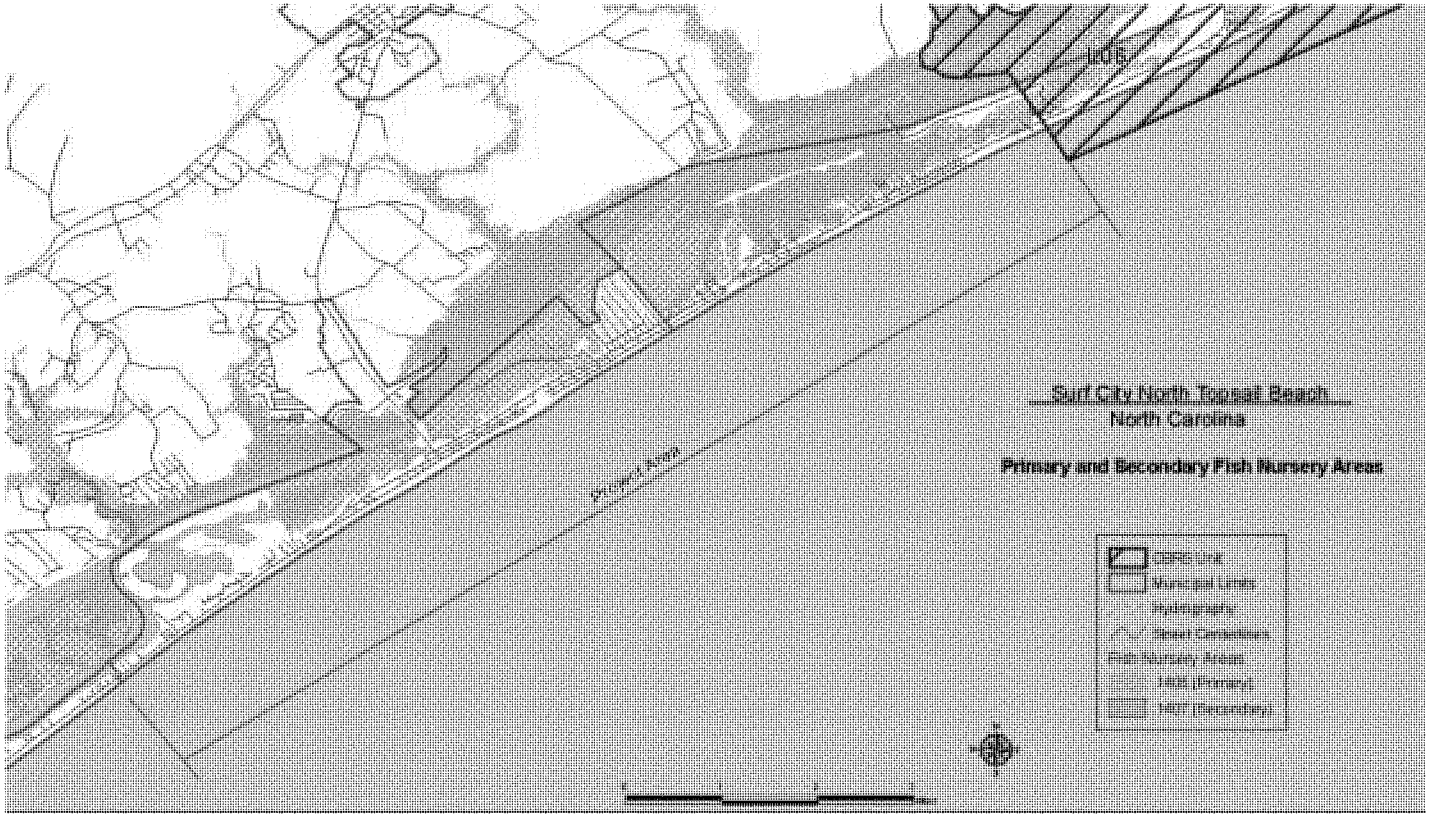


Figure A-3 Primary Nursery Areas

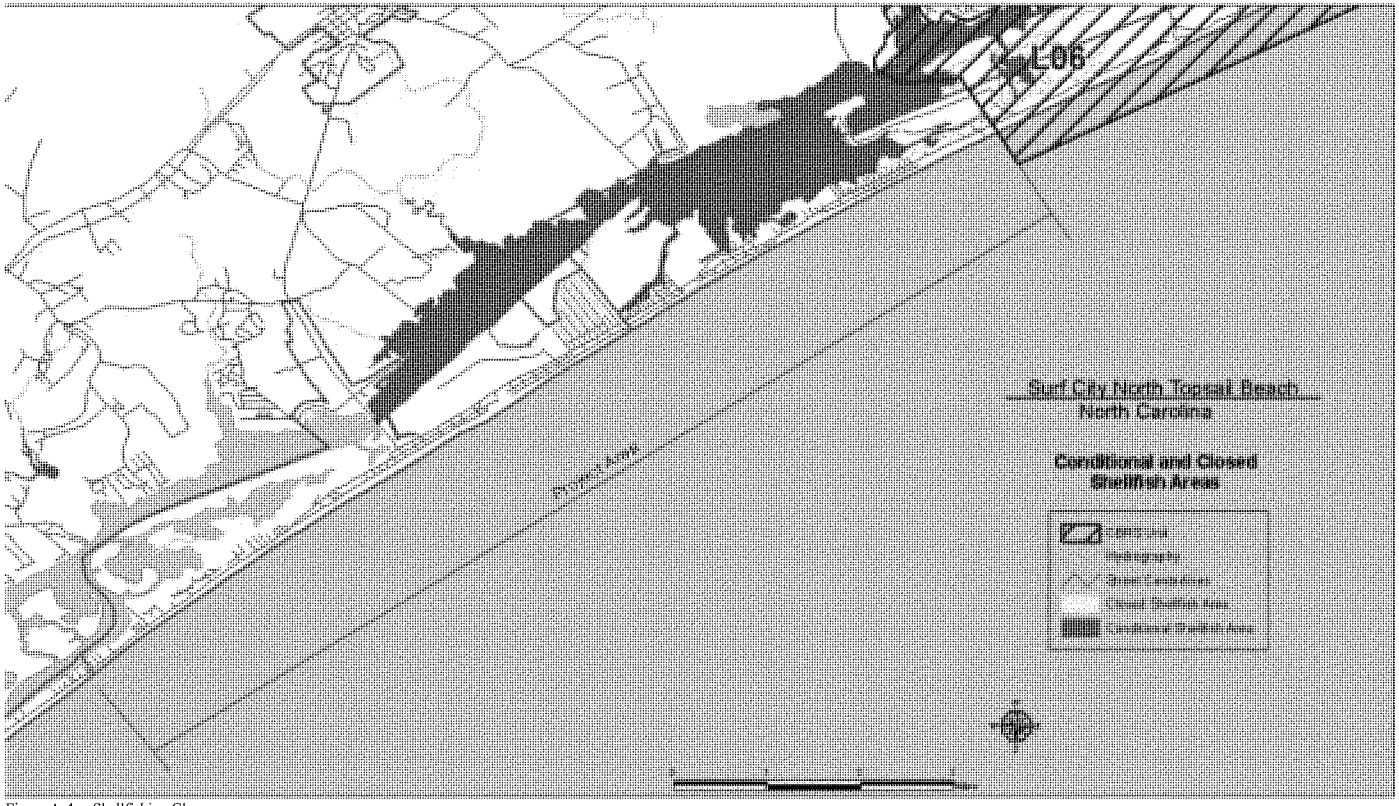


Figure A-4 Shellfishing Closures

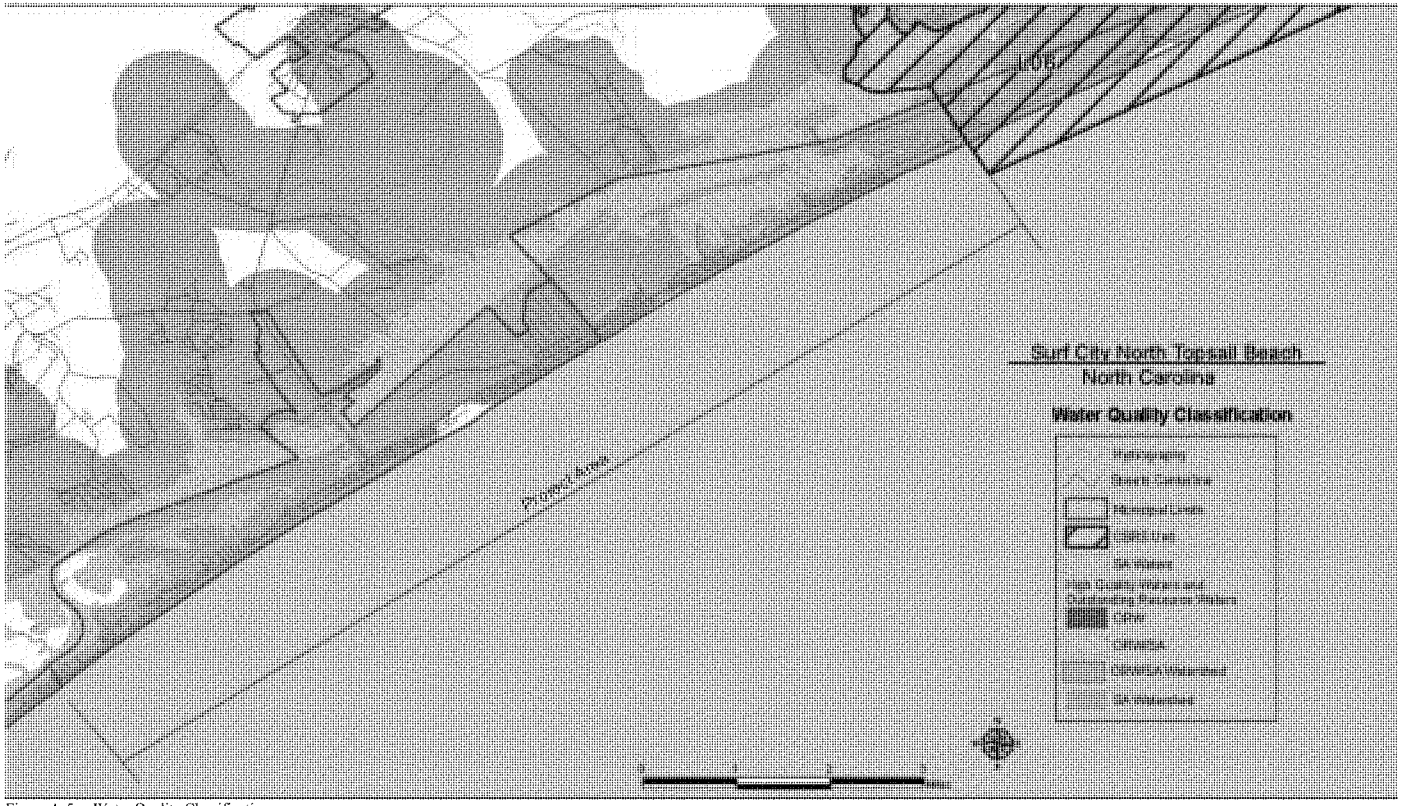


Figure A-5 Water Quality Classification

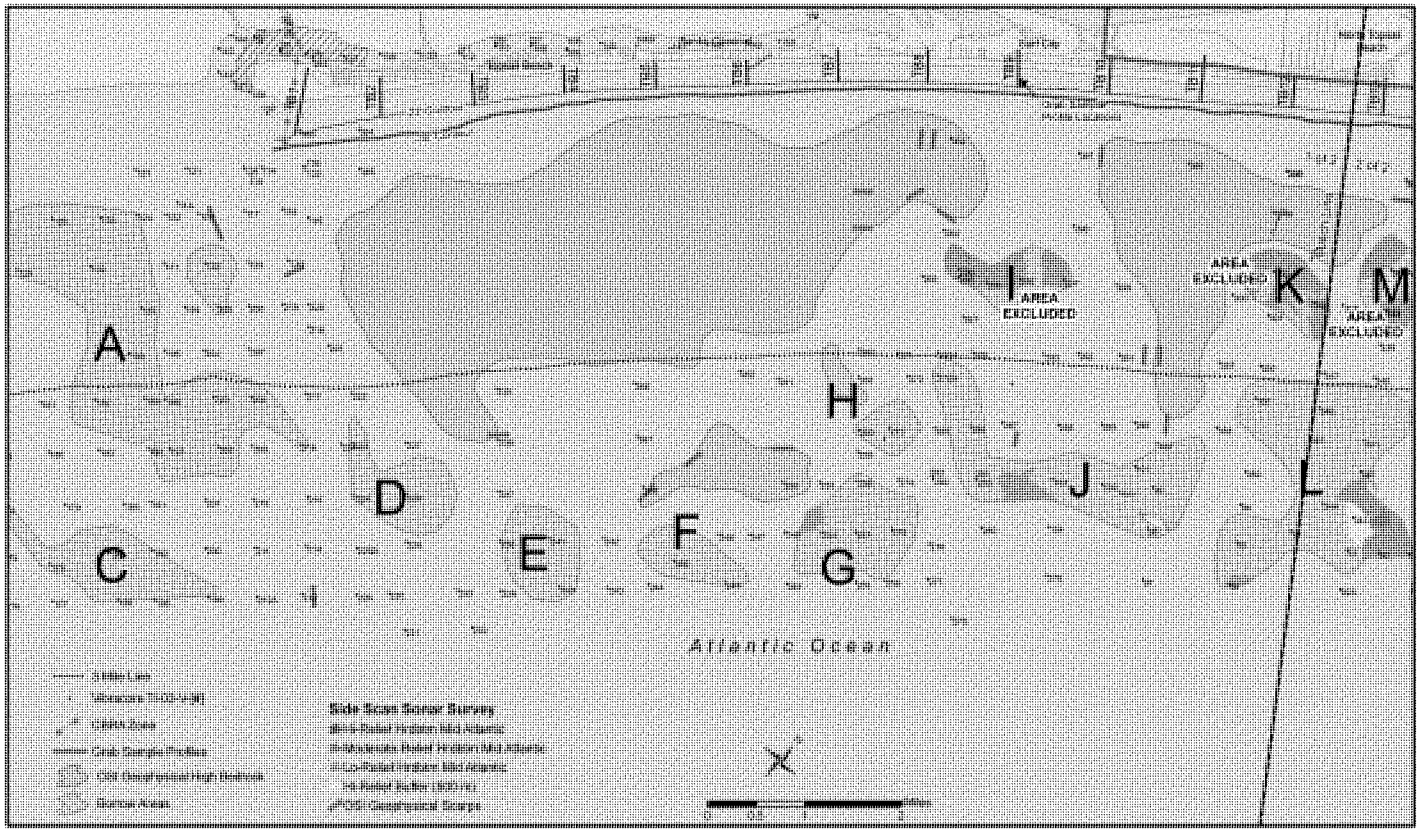


Figure A-6 Borrow Areas 1 of 2

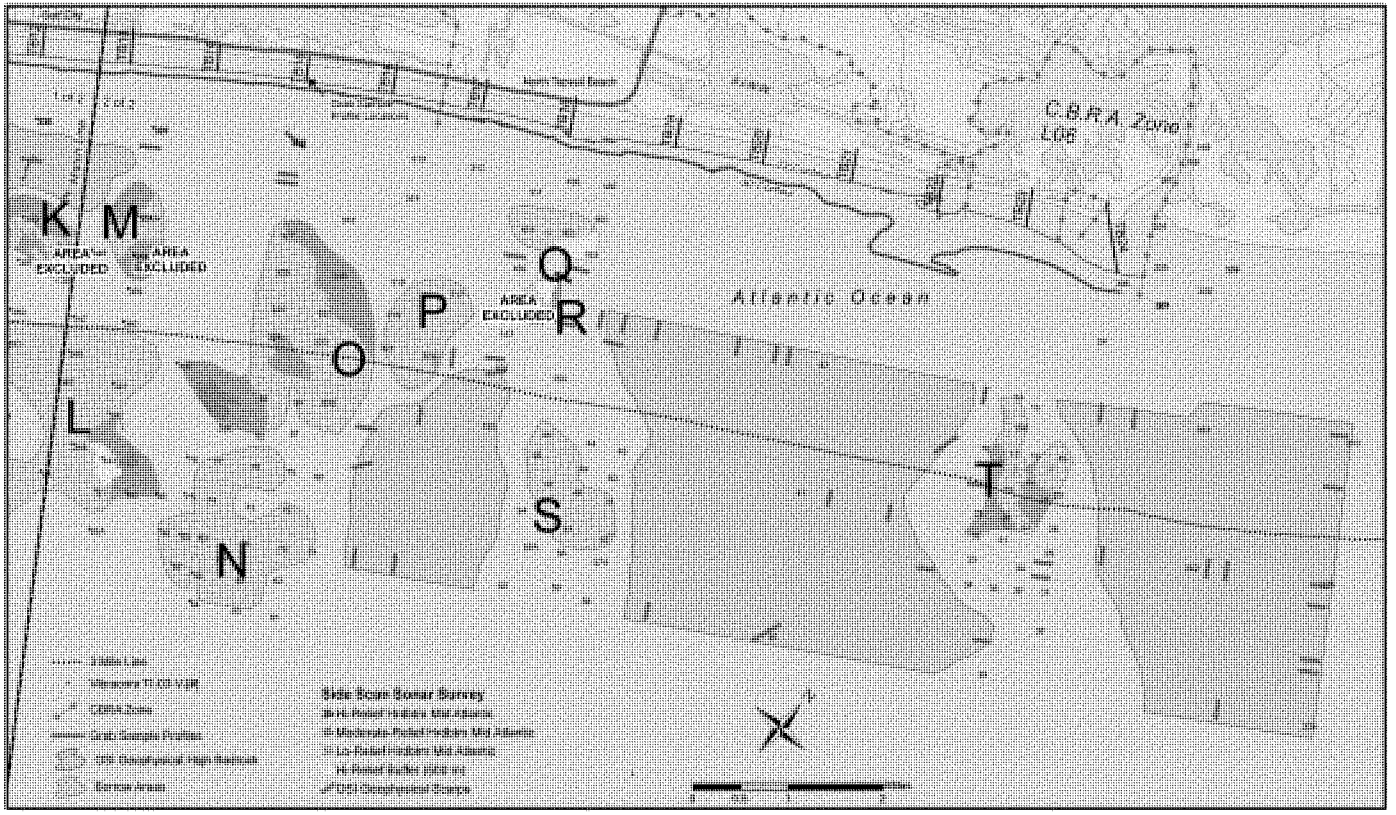


Figure A-6 Borrow Areas 2 of 2

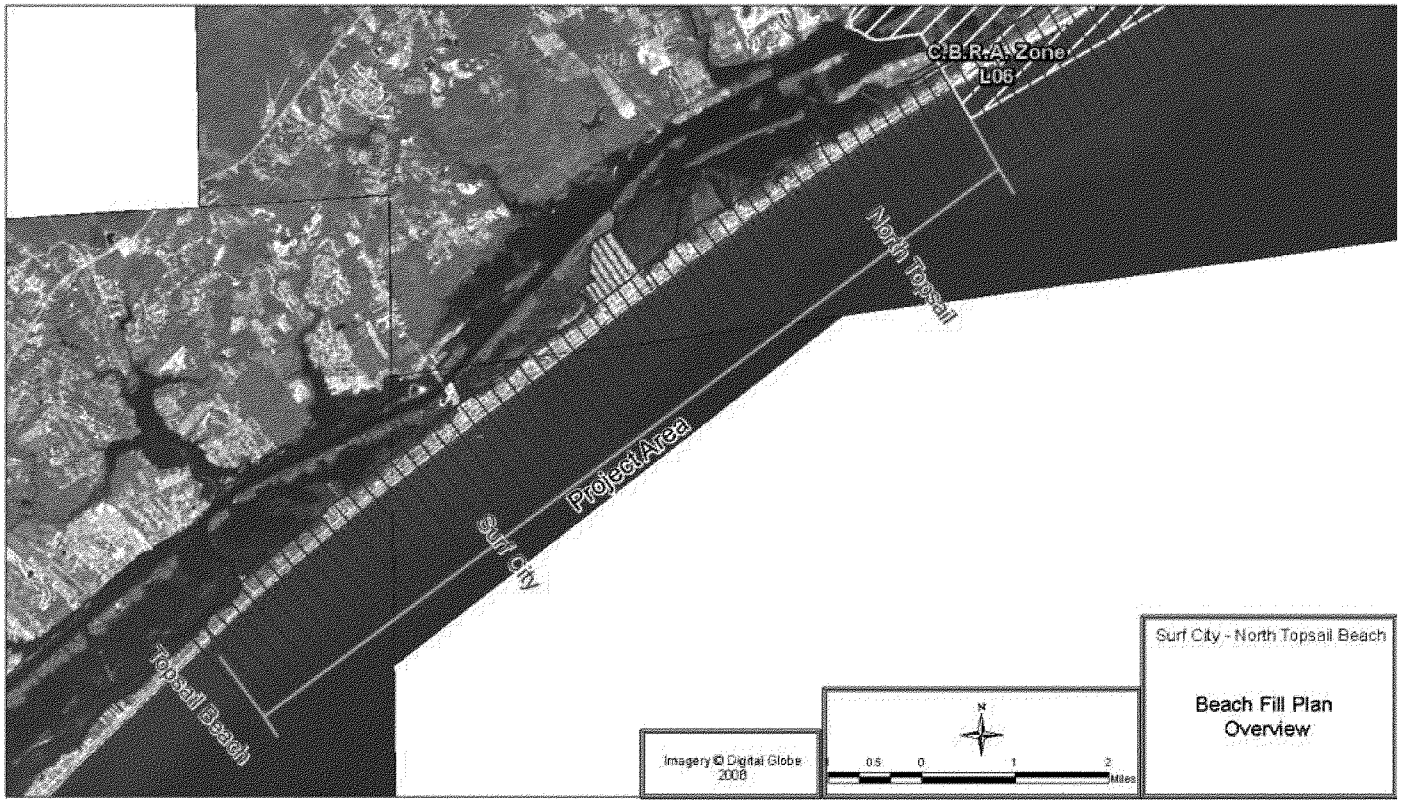


Figure A-7 Selected Plan, Plan 1550, NED Plan, Plan View

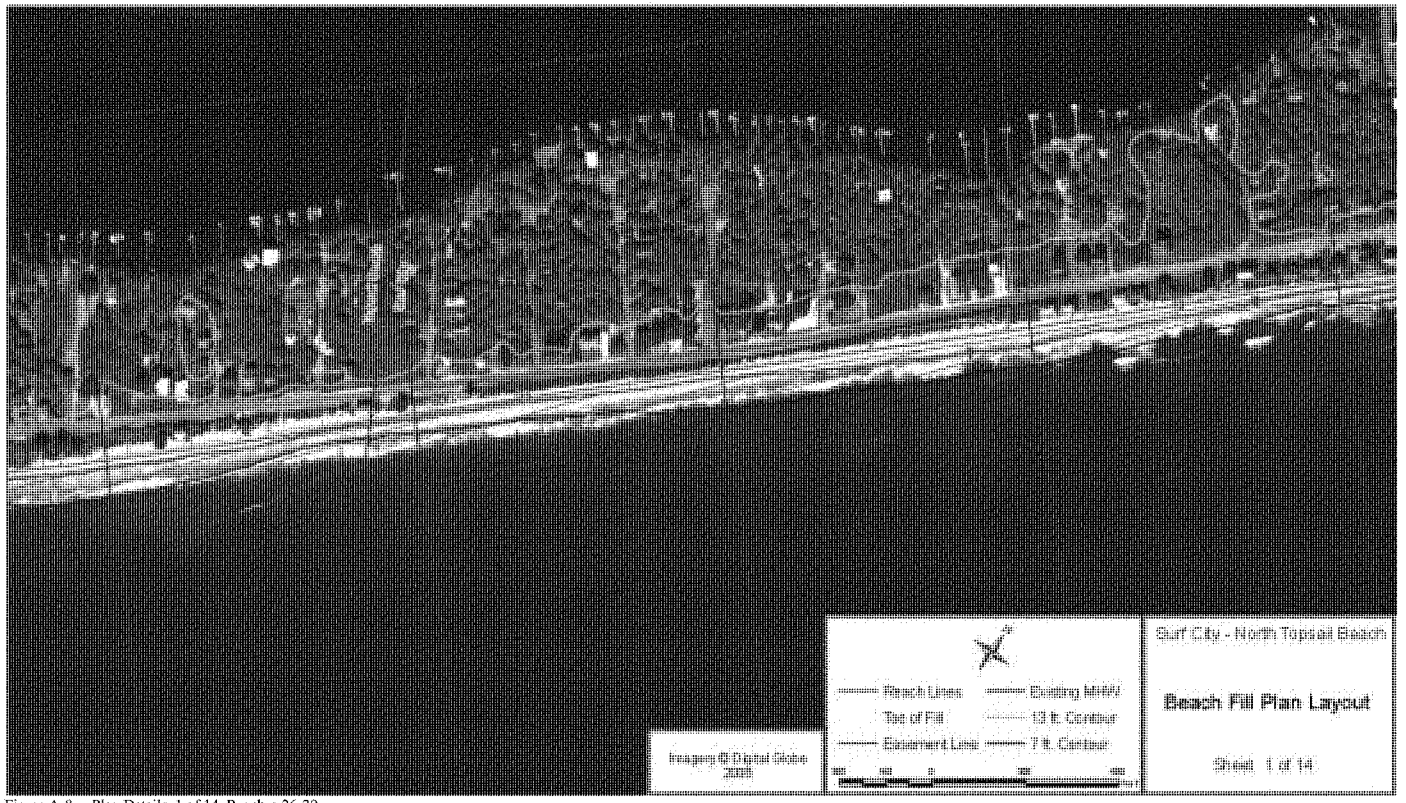


Figure A-8 Plan Details, 1 of 14, Reaches 26-29



Figure A-8 Plan Details, 2 of 14, Reaches 29-33



Figure A-8 Plan Details, 3 of 14, Reaches 33-37

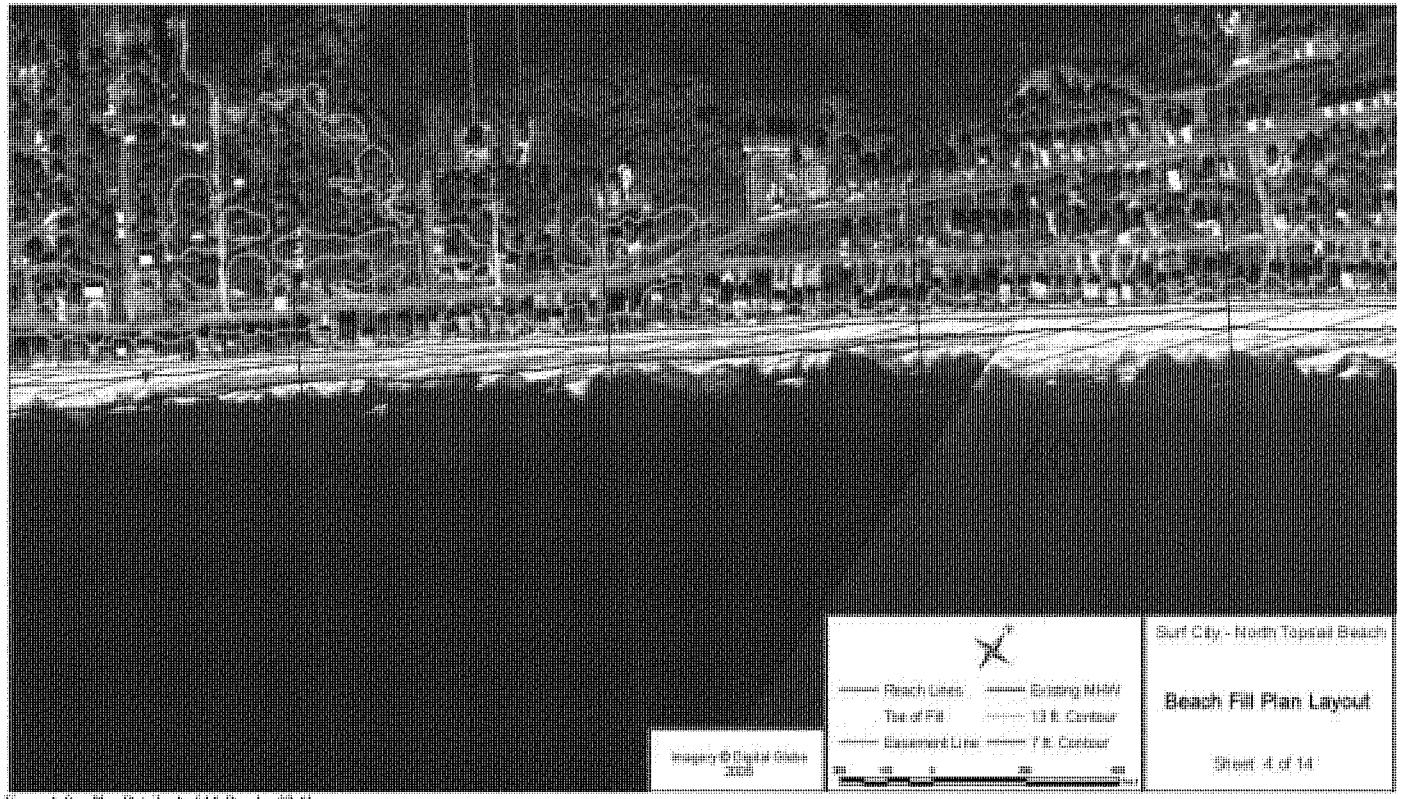


Figure A-8 Plan Details, 4 of 14, Reaches37-41

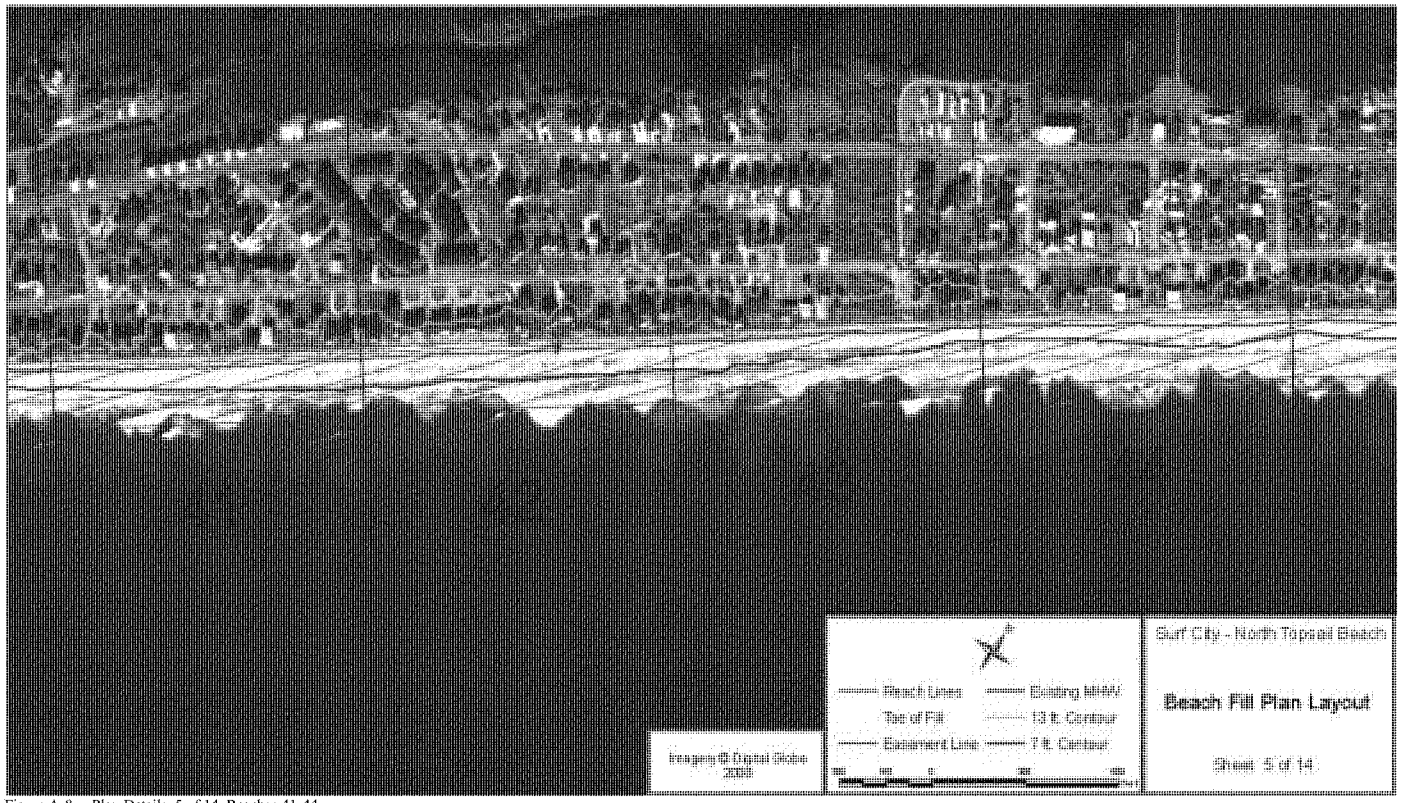


Figure A-8 Plan Details, 5 of 14, Reaches 41-44

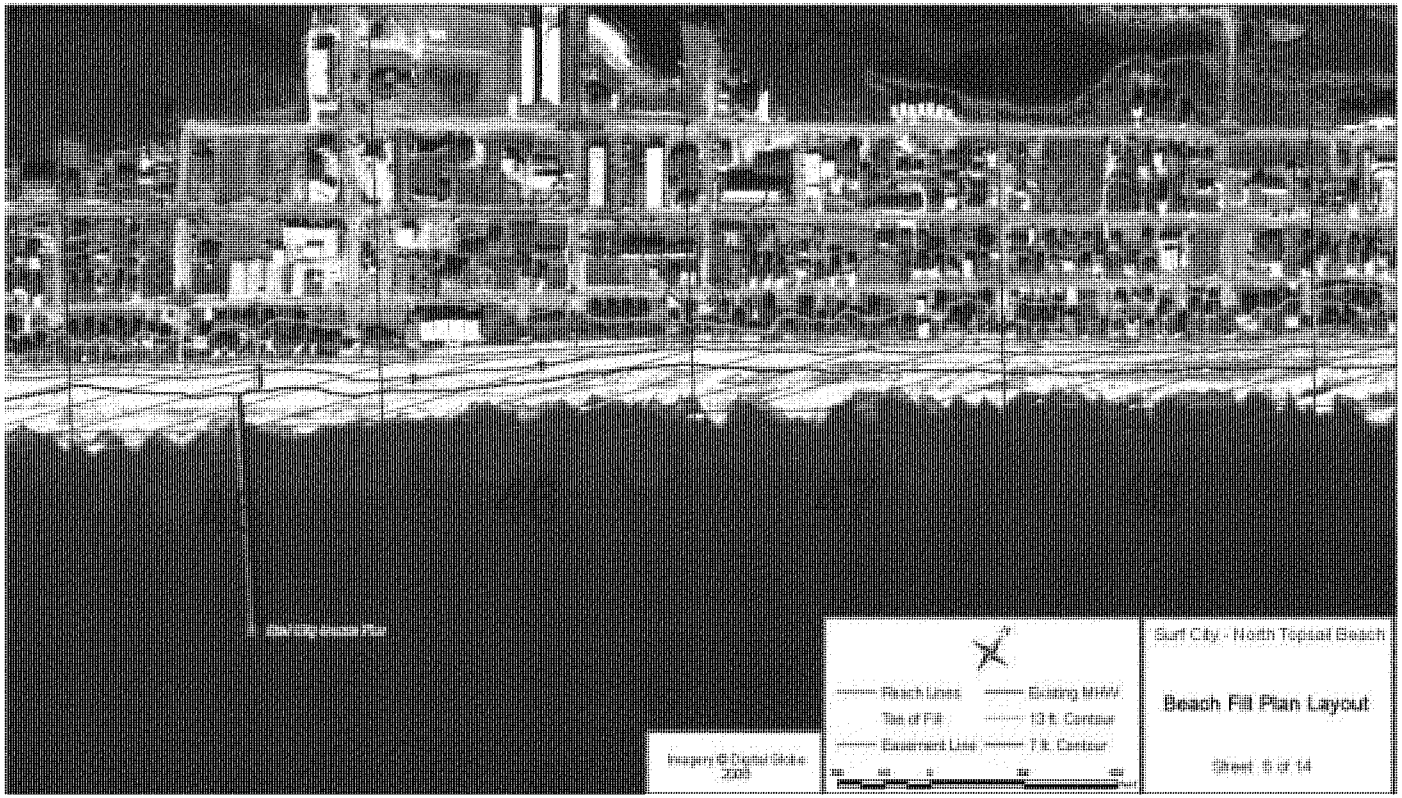


Figure A-8 Plan Details, 6 of 14, Reaches 45-48

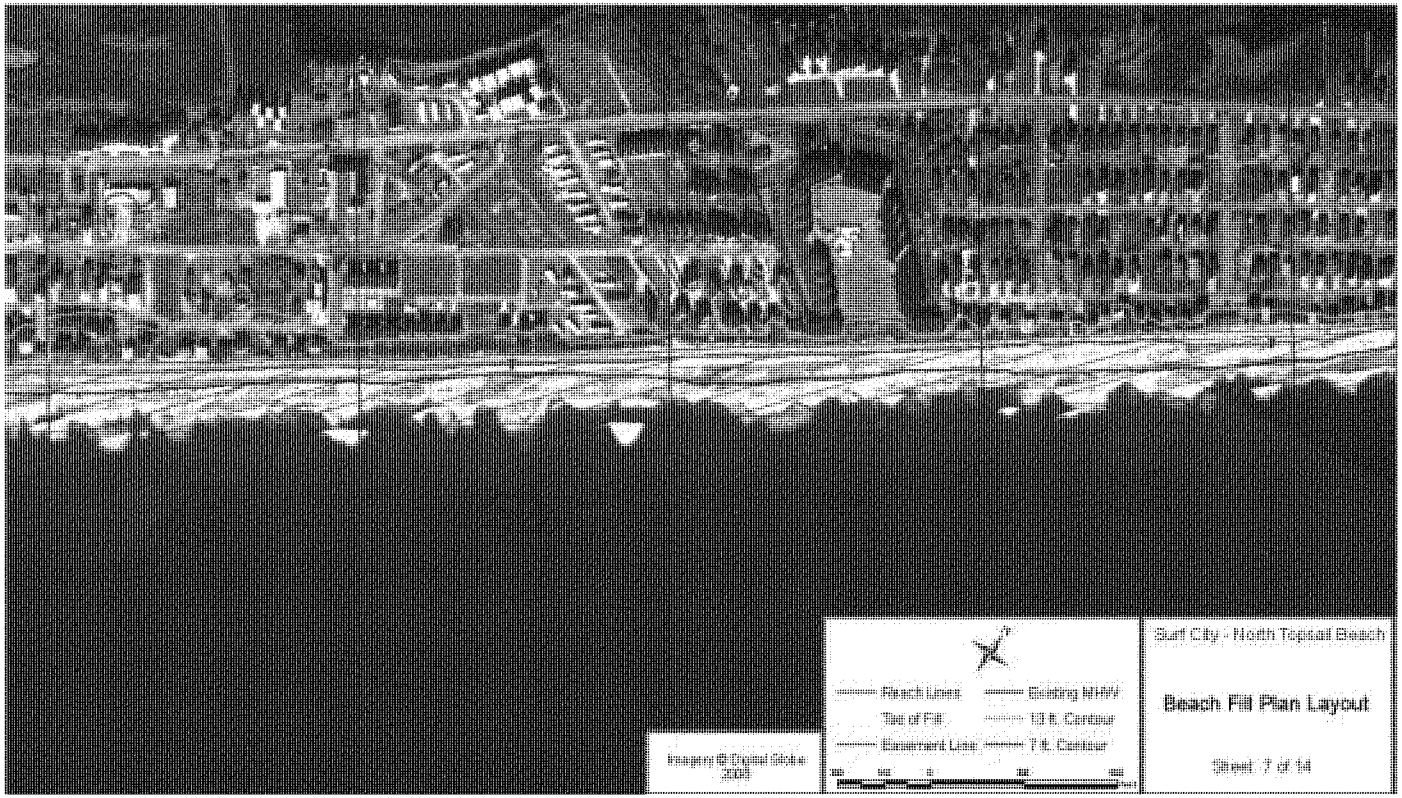


Figure A-8 Plan Details, 7 of 14, Reaches 49-52



Figure A-6 Plan Details, 6 of 14, Reaches 5A-5b

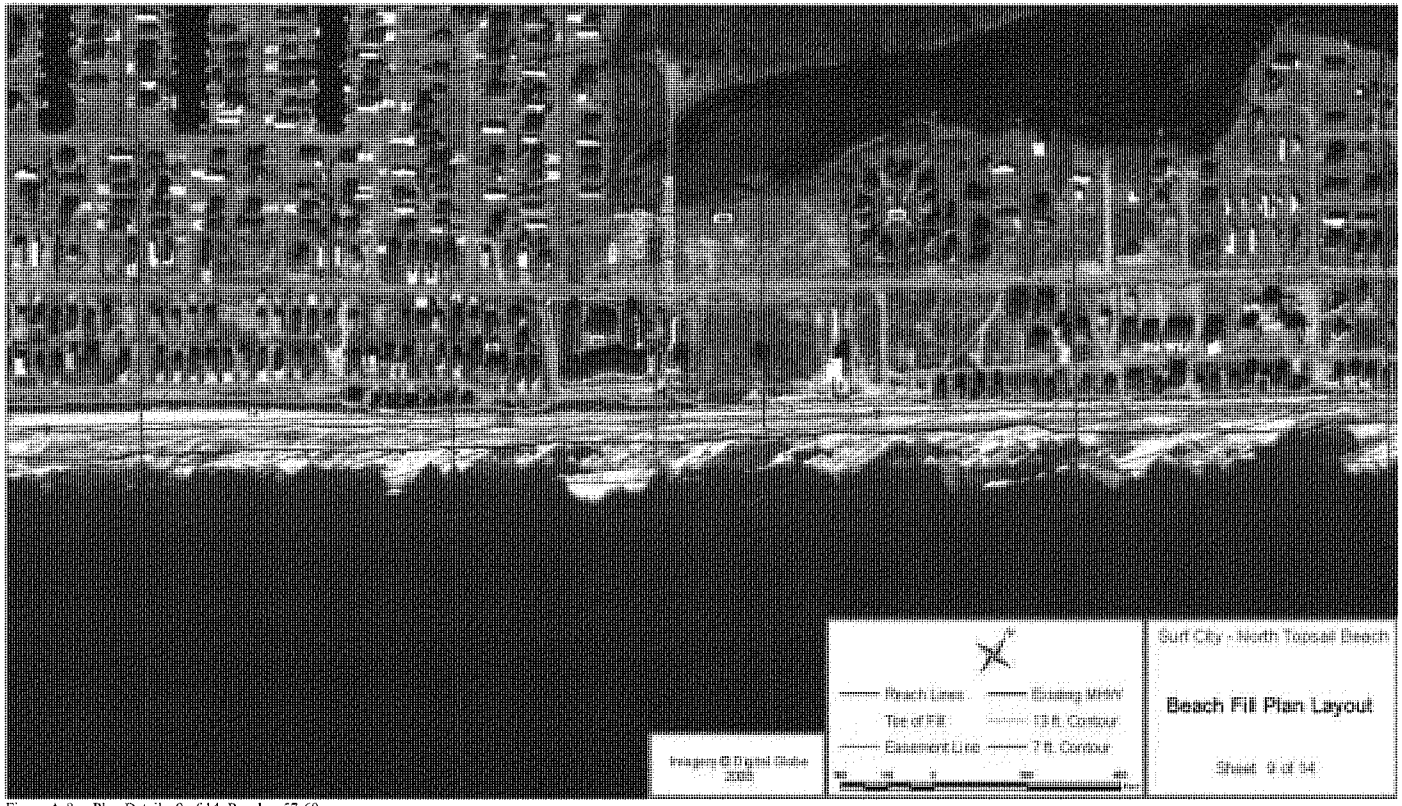


Figure A-8 Plan Details, 9 of 14, Reaches 57-60

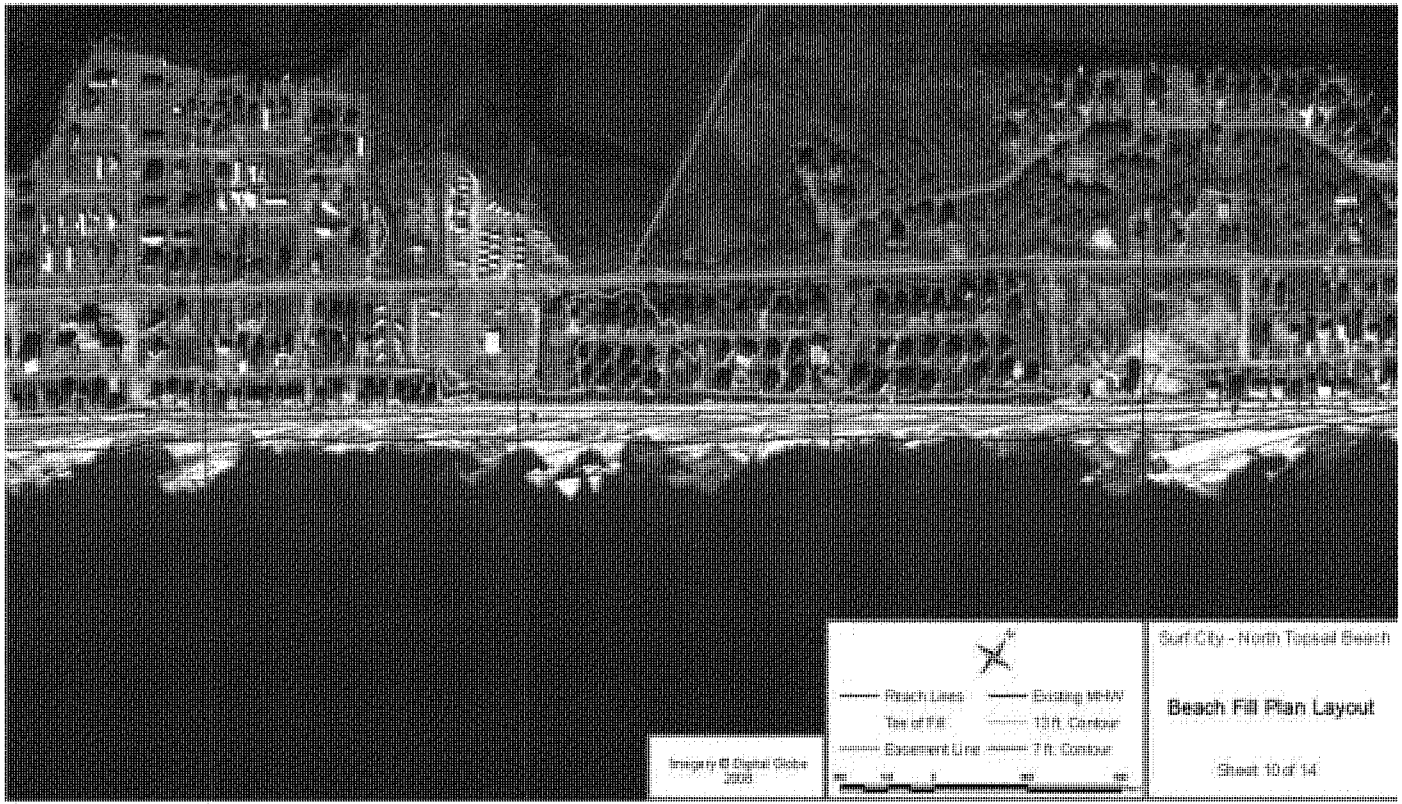


Figure A-8 Plan Details, 10 of 14, Reaches 68-84

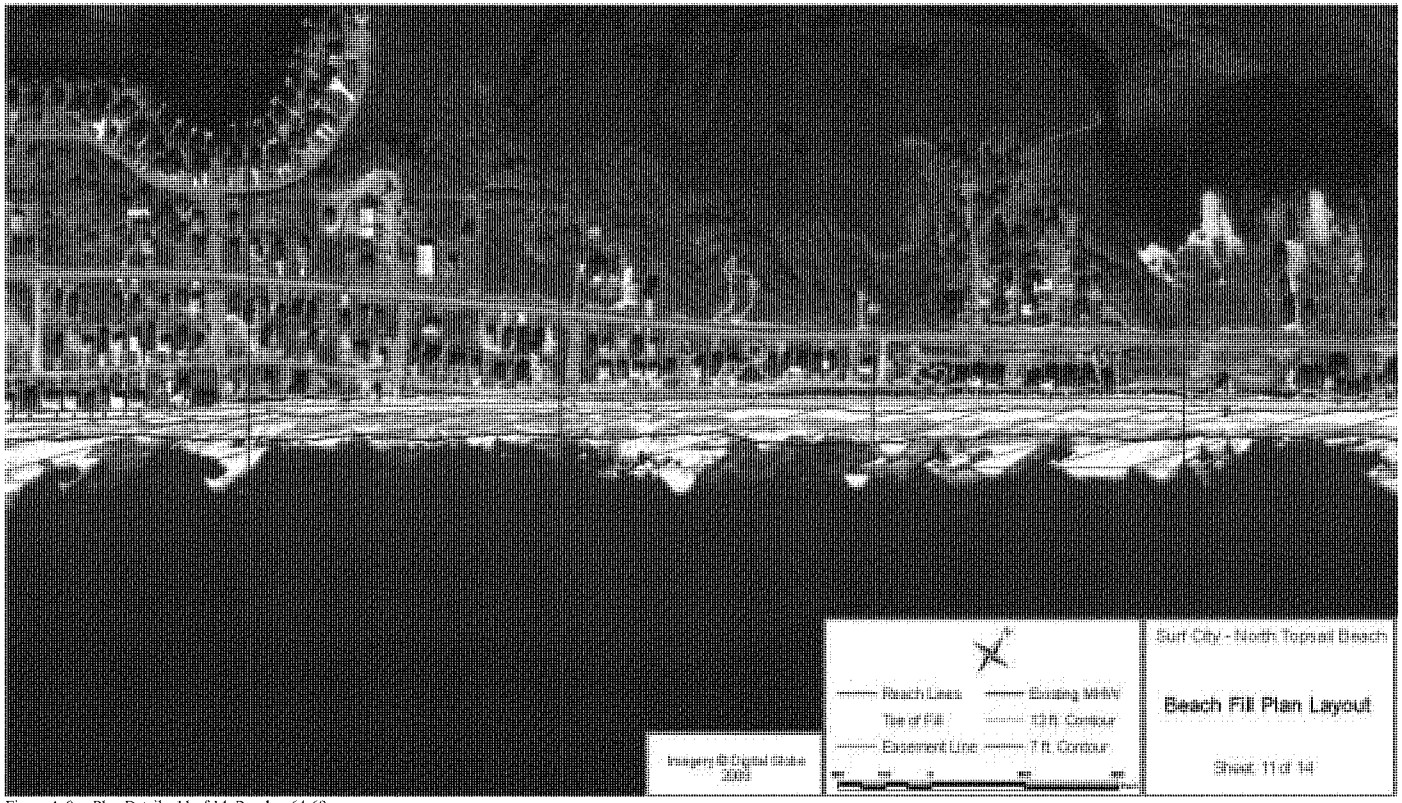


Figure A-8 Plan Details, 11 of 14, Reaches 64-68

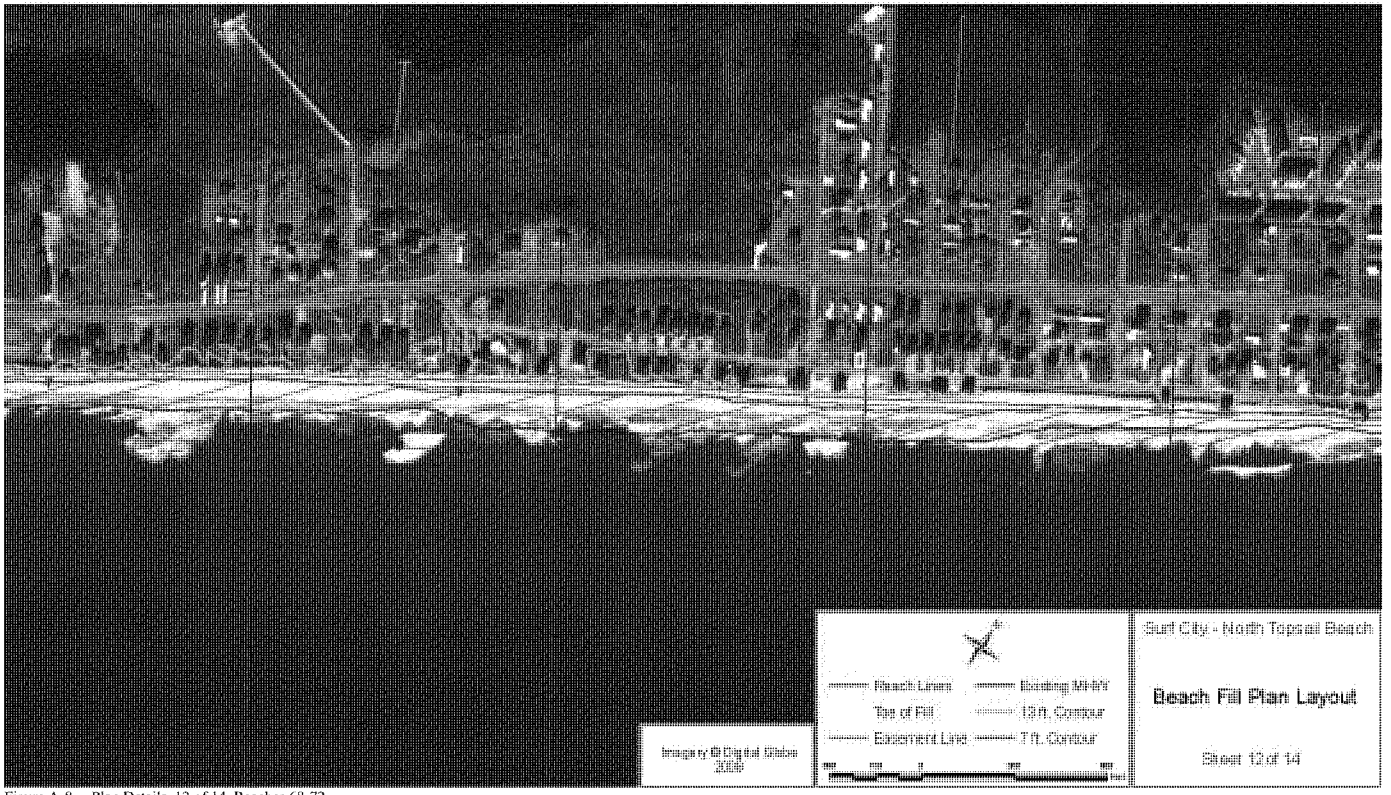


Figure A-8 Plan Details, 12 of 14, Reaches 68-72

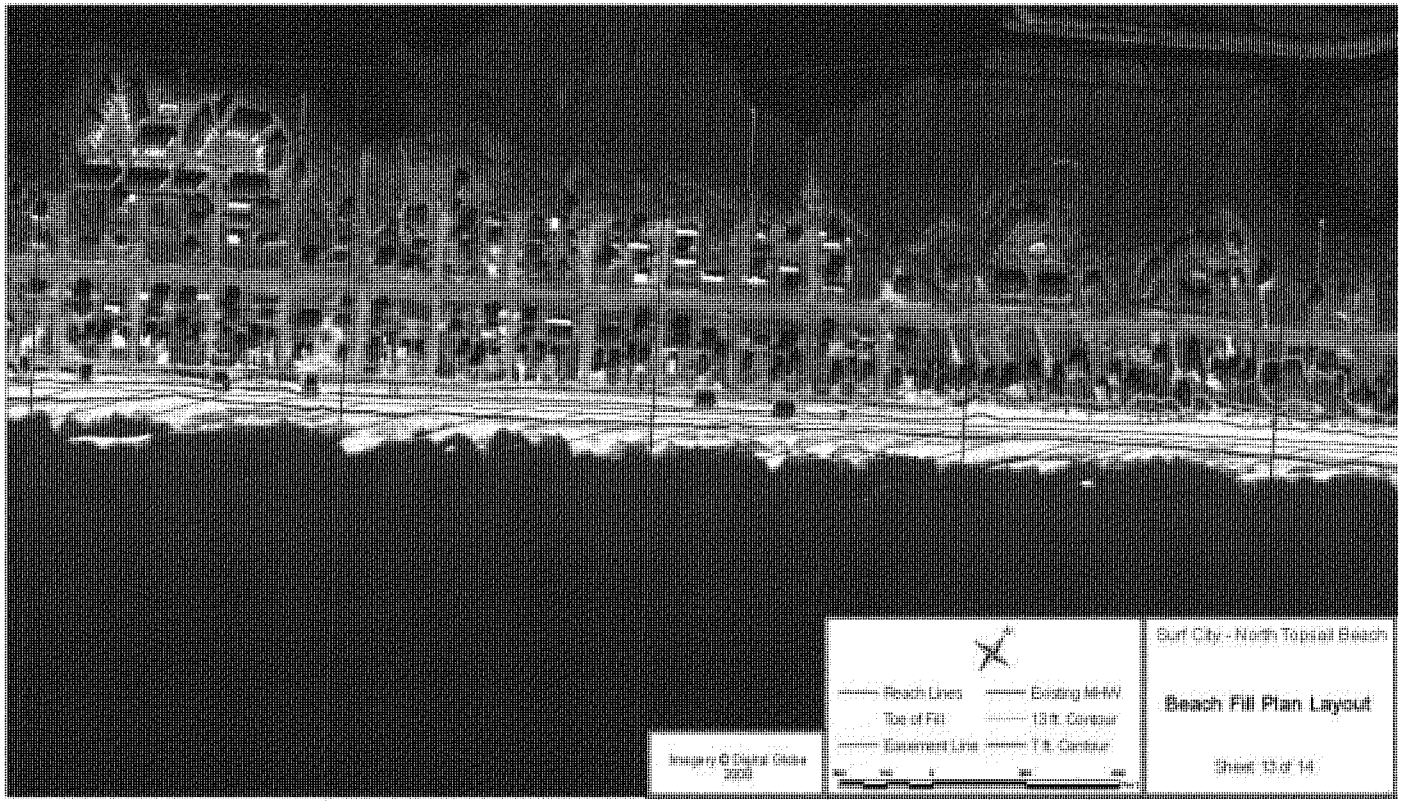


Figure A-8 Plan Details, 13 of 14, Reaches 72-75

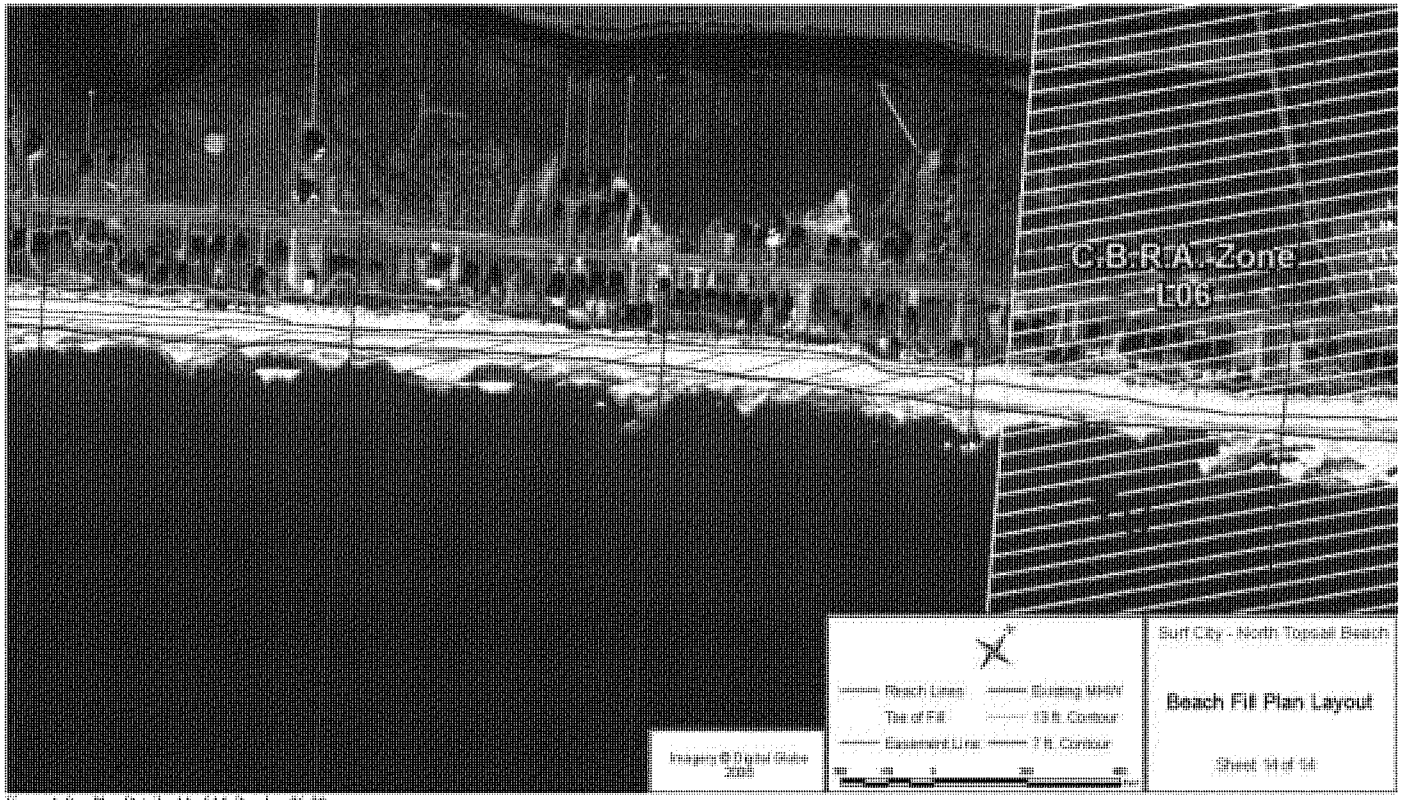


Figure A-8 Plan Details, 14 of 16, Reaches 7A-7B

FEASIBILITY REPORT
AND
ENVIRONMENTAL IMPACT STATEMENT

COASTAL STORM DAMAGE REDUCTION PROJECT
SURF CITY AND NORTH TOPSAIL BEACH
NORTH CAROLINA

Appendix B
Economic Analysis

Appendix B: Economic Analysis

1.0 Introduction. 6
1.01 Coastal Storm Damage Study Area. 6
1.02 Recreation Day User Study Area 7
1.03 Regional Economic Impact Area 8
2.0 Existing Economic Conditions: 8
2.01 Basic Economic Assumptions 8
2.02 Demographics 9
In Labor Force 9
Employment by Leading Industry 9
Per capita & Household Income 9
2.03 Shoreline Ownership 10
2.04 Commercial and Recreational Fishing 10
2.05 Development Added to Existing Condition 11
2.06 Storm Related Emergency Costs 11
2.06.1 Beach Scraping/Pushing 12
2.06.2 Sandbagging Structures 13
2.06.3 NCDOT Emergency Costs 14
2.06.4 Damage to Public Property 14
2.06.5 Damage to Other Private Property 14
2.06.6 Post Storm Recovery Costs 14
2.07 Determination of Structure Values 14
2.07.1 Cost of Residential Construction. 15
2.07.2 Commercial Structure Values. 15
2.07.3 Value of Structures by Reach 15
2.07.4 Value of Structures by Type 17
2.08 Land Values 19
2.08.1 Ocean front lots 19
2.08.2 Second row lots 20
2.08.3 Interior lots 20
3.0 Future Economic Conditions (Without Project) 21
3.01 Projected Population Growth 21
3.02 Assumed Conditions at beginning of Period of Analysis Without Project Condition 22
3.03 Assumed Replacement of Residential Structures During Period of Analysis 22
3.04 Assumed Replacement of Commercial Structures During Period of Analysis 23
3.05 Summary of Future Without Project Economic Conditions 23
4.0 Coastal Storm Damages without Project 23
4.01 Damage Categories Defined 24
4.01_Damage Categories Defined (continued) 25
4.01.1 Storm Erosion 25
4.01.2 Flood 26

4.01.3 Wave 26
4.01.4 Land lost or Long Term Erosion (LTE) 26
4.01.5 Summary of Damages 26
5.0. Economic Variables, Assumptions, and Methodology Applied in COASTAL Storm Damage Model (GRANDUC) 30
5.01 General Global Data 30
5.02 Base Year 30
5.03 Interior Lot Value per Square Foot 30
5.04 Initial Benefits 31
5.05 Other Annual Benefits 31
5.06 Flood Damage Curves 31
5.07 Erosion Damage Curves 31
5.08 Variables Specific to Structure File 32
5.08.1 Structure Type – flood damage curve 34
5.08.2 Structure Value 34
5.08.3 Content Value 34
5.08.4 Elevation at ground 35
5.08.5 Elevation at First Floor 36
5.08.6 Erosion Type 36
5.08.7 Erosion Indicator 38
6.0. Alternatives to Reduce COASTAL Storm Damages 39
6.01 Structural Plans 39
6.02 Non-structural Plans 41
7.0 Economics of NED Plan (Plan 1550) 41
7.01 Economic Damages – remaining with plan 41
7.02 Economic Benefits 43
7.02.1 Coastal Storm Damage Reduction Benefits 43
7.02.2 Reduced Emergency Costs Benefits 43
7.02.3 Benefits During Construction 44
7.02.4 Recreation Benefits 45
7.02.5 Commercial and Recreational Fishing Impacts: 46
7.02.6 Summary of Benefits to NED Plan 46
7.03 Project Costs for NED Plan 46
7.03.1 First Costs 47
7.03.2 Interest During Construction 48
7.03.3 Total Investment Cost 51
7.03.4 Present Value of Future Nourishment Costs 51
7.04 Average Annual Project Costs for NED Plan 52
7.04.1 I&A of Total Investment 52
7.04.2 Annual OMRR&R 52
7.04.3 Annual Monitoring 52
7.04.4 I&A of Future Nourishment 52
7.05 Benefit/Cost Comparison for NED Plan 53
8.0. Regional Economic Development (RED) Impacts 54
8.01 Preserve Tax Base and, Property Values 55
8.02 Employment Stability 55

8.03 Community and Regional Growth 55
8.04 Displacement of People, Businesses, and Farms 55
9.0 Uncertainty and Sensitivity of analysis to variation of Values and Assumptions 56
9.01 Coastal Storm Damage Reduction 56
9.01.1 Erosion indicators (Topsail Beach example) 56
9.01.2 Erosion Damage Curves 57
9.02 Exclude Recreation Benefits 57
9.03 Interest Rate 57
9.04 Land Values 58

List of Tables

Table B-1 - North Carolina Counties within Driving Distance of Surf City and North Topsail Beach

Table B-2 - Population, Income, Housing Summary for 2000

Table B-3A - Value of Structures by Reach, Surf City, NC

Table B-3B- Value of Structures by Reach, North Topsail Beach, NC

Table B-4 - Description of Four Significant Structure Types

Table B-5 - Value of Structures by Type

Table B-6 - Present Value of Coastal Storm Damages (Without Project)

Table B-7 - Average Annual Coastal Storm Damages (Without Project)

Table B- 8 - Sample Structure File

Table B-9 - Economic Comparisons, Average Annual Amounts

Table B-10 – Present Value of Remaining Damages with NED Plan

Table B-11 - Remaining Average Annual Coastal Storm Damages with NED Plan

Table B-12 - Average Annual Coastal Storm Damage Reduction Benefits with NED Plan

Table B-13 – Benefits During Construction, Plan 1550 (NED Plan)

Table B-14 - Summary of Averge Annual Benefits to NED Plan

Table B-15 – Summary of Expenditures During Construction

Table B-16 - Calculation of Interest during Construction for NED Plan

Table B-17 - Project Annual Costs, Plan 1550 (NED Plan)
Table B- 18 - Summary of Initial Construction & Annual Costs for NED Plan
Table B-19 – Project Annual Benefits, Plan 1550 (NED Plan)
Table B-20 - Annual Benefits, Costs, and Benefit-Cost Ratio – NED Plan
Table B-21 – Sensitivity Analysis - Erosion Indicators

List of Figures

Figure B-1 - Coastal Storm Damage Reduction Study Area
Figure B-2 - Recreation Demand Study Area
Figure B- 3 - Post storm Beach Scraping – Emergency Costs
Figure B-4 – Beach scraping following Hurricane Fran
Figure B-5 – Sandbags in place but threatened
Figure B- 6 - Four typical new structures on Topsail Island
Figure B- 7 - Interior Lot Sales in Dollars per Square Foot
Figure B- 8 - Population Growth Pender and Onslow Counties Actual 1920-2000 and Projected to 2029
Figure B- 9 - Hurricane Surge and Wave Impacts.
Figure B-10 – Coastal storm damage after Hurricane Fran 1996
Figure B- 11 – Present Value of Coastal Storm Damages by Damage Category – Without Project Condition
Figure B-12 - Erosion curve for Residential 1-story on Short Pilings (#21)
Figure B-13 - Erosion curve for Residential 2-story on Long Pilings (#24)
Figure B-14 - Erosion curve for Residential 1-story Full Enclosure on Short Pilings (# 2)
Figure B-15 - Erosion curve all commercial, residential on slab foundation, plus all 2nd and 3rd row structures (# 31)
Figure B-16 - Illustrations of Structure and Lot Distances entered into GRANDUC model
Figure B-17 - Illustration of Residential Structure Elevations

Figure B-18 - Illustration of Shoreline Types (High dune and Low dune)
Figure B-19 – Illustration of Erosion Indicator
Figure B-20 – Topsail Island home raised on piling foundation 2004
Figure B-21 – Distribution of Initial Construction Costs – Plan 1550 (NED) Plan
Figure B-22 – Compare Erosion Distance using Different Indicators

List of Attachments

Attachment B-1 Description of Structure Types

Attachment B-2 Erosion Damage Curves

Attachment B-3 Structure Files

Attachment B-4 Rogers, Spencer, 2002. "Erosion Damage Thresholds in North Carolina" North Carolina Sea Grant

1.0 INTRODUCTION.

The total economic impact area for Surf City and North Topsail Beach is far-reaching. All of Top sail I sland i s i mportant bec ause of the t ransportation system. R esidents a nd v isitors m ust c ross ov er on e of two b ridges o ver the Atlantic Intracoastal Waterway (AIWW) to gain access to the Town of Surf City and the Town of North Topsail Beach. The first is a swing bridge that provides access near the center of Surf City and NC Highways 210 and 50. The second is a high-rise bridge crossing the AIWW in the northern section of North Topsail Beach f or NC Hi ghway 210. The s tudy ar ea for coastal storm d amage reduction, beach r ecreation us e, and regional ec onomic de velopment (RED) are described in the sections below.

1.01 Coastal Storm Damage Study Area.

The towns of Surf City and North Topsail Beach, North Carolina are subject to damages f rom hu rricanes and storm r elated e rosion. The study ar ea was limited to the area approximately 500 feet from the shoreline. This area includes commercial and residential structures l ocated on oc ean f ront l ots, a s w ell as two or three rows beyond the shoreline. Streets, highways, and utilities are also included in the area threatened by flood, waves, storm erosion, and l ong-term erosion. The study area begins at the Topsail Beach-Surf City town limits and covers a di stance o f about 17 miles, goi ng t he f ull l ength of t he Surf Cit y shoreline (6 m iles) and the pr imary no n-CBRA p ortion (3.8 m iles) of No rth Topsail Beach. The coastal storm damage study area is divided into "reaches" of approximately 1,000 feet as shown in Figure B-1.

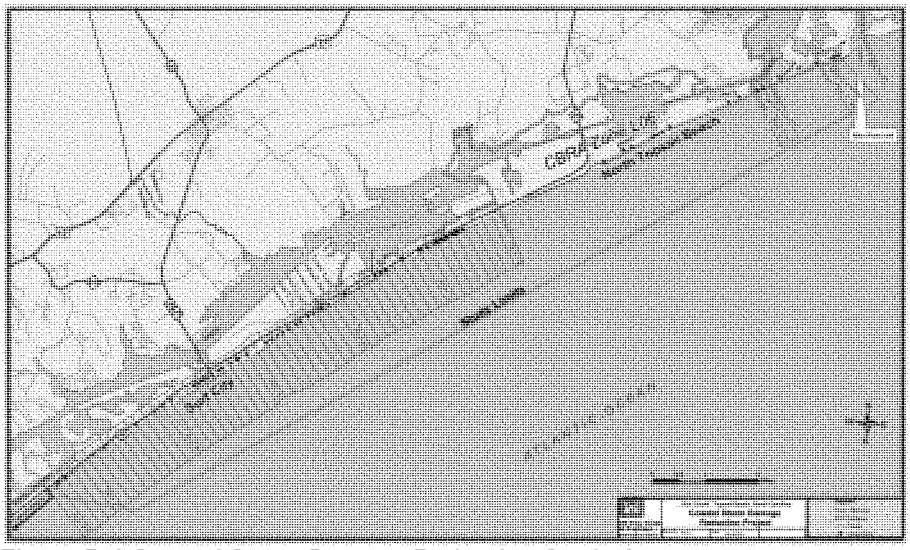


Figure B-1 Coastal Storm Damage Reduction Study Area

1.02 Recreation Day User Study Area

Overnight visitors come from as far away as 3,000 miles; however, the 46 counties listed in Table B-1 and shown in Figure B-2 were selected as being within a reasonable driving distance of Surf City and North Topsail Beach. The purpose of the survey of potential day users was to collect data that will show the frequency of visits and the total number of trips to Surf City and North Topsail Beach. It is expected that the analysis will show that persons from nearby counties will visit more frequently than persons from the more distant counties.

Table B-1 - North Carolina Counties within Driving Distance of Surf City and North Topsail Beach, NC

Anson	Edgecombe	Martin	Robeson
Beaufort	Franklin	Montgomery	Sampson
Bertie	Granville	Moore	Scotland
Bladen	Greene	Nash	Stanly
Brunswick	Halifax	New Hanover	Vance
Carteret	Harnett	Northampton	Wake
Chatham	Hertford	Onslow	Warren
Columbus	Hoke	Orange	Washington
Craven	Johnston	Pamlico	Wayne
Cumberland	Jones	Pender	Wilson
Duplin	Lee	Pitt	
Durham	Lenoir	Richmond	

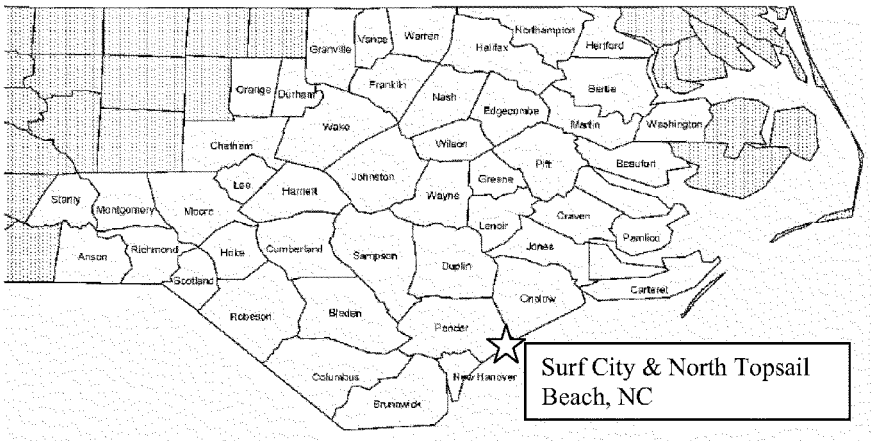


Figure B-2 – Recreation Demand Study Area

The recreation demand and methodology recommended for the beach user benefit analysis are presented in Appendix O –Recreation. According to the U. S. Census the population of the forty-five-county area grew from 3,036,000 in 1990 to 3,686,000 in 2000, an increase of more than 20 percent in the decade.

1.03 Regional Economic Impact Area

The local economic impact area includes all of Topsail Island and the nearby areas of both Pender County and Onslow County, North Carolina. Topsail Island includes not only Surf City and North Topsail Beach but also Topsail Beach on the south end of the island. Highways 50 and 210 connect the island to the mainland portion of the two counties. The boundaries of Pender and Onslow counties are shown in Figure B-2.

2.0 EXISTING ECONOMIC CONDITIONS:

2.01 Basic Economic Assumptions

This study is in compliance with the evaluation procedures outlined in the Water Resource Council's Economic and Environmental Principles and Guidelines (P&G) for Water and Related Land Resources Implementation Studies, dated 10 March 1983, and Corps of Engineers policy guidance on Coastal Storm Damage

Reduction, ER 1105-2-100, dated 22 April 2000. The following basic economic assumptions were used in the analysis of damages, benefits, and costs.

- **Interest rate.** The FY 2011 Federal interest rate is 4.125 percent.
- **Price level**. October 2010 price levels.
- **Period of Analysis.** The analysis is based on a 50-year period.

2.02 Demographics

Demographics for the existing economic conditions for the two-county study area include census data for population, housing, and personal income, which are shown in Table B-2. The full-time resident population was estimated to be nearly 2236 in 2000. Estimates of peak season population vary. According to the towns of Surf City and North Topsail Beach officials, the estimated peak summer time population of the two towns is greater than 30,000.

Table B-2 - Population, Income, Housing Summary

	Pender County	Onslow County	Surf City	North Topsail
Population year-round(2007 estimate)	50,430	169,302	1,766	898
Population year-round (2000 census)	41,082	150,355	1,393	843
Population peak season (Estimated)			15,438	15,000-20,000
Ave. Household size	2.49	2.72	2.02	1.87
Housing Units	20,798	55,726	2,578	2,085
Occupied year-round	16,054	48,122	689	451
Seasonal or vacant	4,744	7,604	1,889	1,634
In Labor Force	19,087	85,054	754	545
Civilian	18,972	52,670		
Unemployed	1,076	3,650		
Armed Forces	115	32,384		
Employment by Leading Industry				
Construction	2,468	5,022		
Manufacturing	2,632	2,682		
Retail trade	2,367	7,496		
Education, health & social services	2,704	10,865		
Per capita & Household Income				
Per capita money income	$17,882	$14,853	$25,242	$33,972
Median Household Income 1999	$35,902	$33,756	$40,521	$45,982

Source: U.S. Census Bureau (http://factfinder.census.gov) and U.S. Dept. of Commerce – Bureau of Economic Analysis (http://bea.doc.gov/bea)
Office of State Budget and Management (2007 population estimates)

2.03 Shoreline Ownership

Public ownership of the shore in the town of Surf City and North Topsail Beach includes dedicated roads and lands below mean high water (MHW) owned by the State of North Carolina. Other parcels are owned by the towns of Surf City and North Topsail Beach, including the Coastal Area Management Act (CAMA) public access points. The primary ownership of the 828 oceanfront parcels is private. Privately owned properties included in the Project are considered to be in fee simple ownership. Included within the project limits are single family residential units, multi family and condominium units, and commercial properties, including the fishing piers. Other information related to ownership of the shoreline is contained in the Real Estate Report.

2.04 Commercial and Recreational Fishing

The North Carolina Division of Marine Fisheries (NCDMF) reported nearly 600,000 pounds of commercial finfish and shellfish landings in the vicinity of New Topsail Inlet in both 2003 and 2004. Significant shellfish landings included over 200,000 pounds reported from Hampstead and over 100,000 pounds reported from Surf City in 2003. Finfish landings reported from Hampstead exceeded 100,000 pounds in both 2003 and 2004. The commercial value of all finfish and shellfish landings reported in the vicinity of New Topsail Inlet was nearly $800,000 in both 2003 and 2004.

Recreational fishing includes fishing from head boats, charter boats, private boats, piers, and the surf. Fishing from head boats is best in the winter months for snapper and grouper. Fishing from charter boats is excellent for King mackerel and bottomfish during the winter. Offshore, gulfstream species, like yellowfin tuna and Wahoo are available. Inside fishing has been successful for inshore species such as red drum, speckled trout, and flounder.

Private boat anglers can find bluefin tuna in the nearshore area, king mackerel and other bottomfish species in the offshore, and other species such as speckled trout, red drum, and flounder can be found in the inside areas of the creeks and Atlantic Intracoastal Waterway. NCDMF reports that shore fishing activity will be limited in this area.

2.05 Development Added to Existing Condition

The without project structure inventory assumes typical residential structures will be built on the 112 suitable vacant first row lots and an additional other 340 lots. Currently, there are vacant lots existing, but based on the established building patterns and the coastal North Carolina real estate market trends, it is expected that these structures will be built by the end of construction in 2018.

The typical residential structure presently constructed on Topsail Island has the following characteristics: two-story, approximately 2,100 square feet of heated space, built on a piling foundation, and includes no more than a small enclosure on the ground level to provide a staircase or elevator for access.

The value of these additional 450 structures is about $273,000 each, totaling approximately $160 million. This value is based on a typical residential structure of 2,100 square feet and a construction cost of $130.00 per square foot. It is also assumed that all these structures will meet building codes for piling depth and first-floor elevation.

2.06 Storm Related Emergency Costs

Information was collected from the officials of the towns, Pender County, Onslow County, state, and federal sources following recent hurricanes and storms. Benefits from prevention of emergency costs are estimated to have an equivalent annual value of $99,000 for Surf City and $235,000 for North Topsail Beach, for a total of $334,000 over the entire project length. This category of benefits is not very precise and is relatively minor compared to CSDR benefits (1 to 2%) and so, is dropped from the total.

Emergency costs prevented refer to expected annual expenditures that residents and governments are experiencing under the without project condition that a project would preclude. Other damages prevented include storm damages that are not covered under the National Flood Insurance Program, but represent financial drains on public and private storm victims that could be prevented. The items in this benefit category called emergency costs and other damages prevented include (1) beach scraping/pushing; (2) sandbagging: (3) emergency costs incurred by the North Carolina Department of Transportation; (4) damages to public property like water and electric utility distribution systems and public access walkways; (5) damages to private property other than structures and contents such as walkways, driveways, and cleanup costs; and, (6) post-storm recovery expenses and storm related expenses from increased police patrolling, inspections, and permits. These categories are described in detail below:

2.06.1 Beach Scraping/Pushing

Beach scraping/pushing refers to the practice of bull dozing a short dune or small berm in front of a residence or business so that it might offer some measure of protection from erosion. These costs are based on a bulldozer and operator pushing sand during two or three low tides. The practice requires a permit, and these records were used to help quantify these expenditures as project benefits. A large Coastal Storm Damage Reduction project would prevent the owners of the residence or business from incurring this expense. Figures B-3 and B-4 show scraping and pushing after hurricane Fran on Topsail Island in 1996.

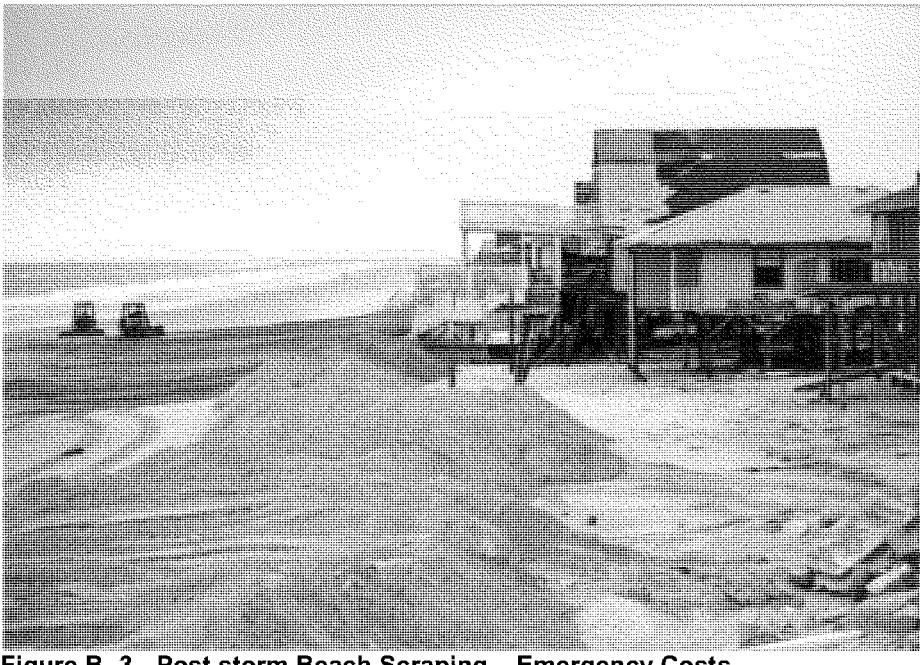


Figure B- 3 - Post storm Beach Scraping – Emergency Costs



Figure B-4 - Beach scraping following Hurricane Fran

2.06.2 Sandbagging Structures

Sandbagging structures is another emergency measure that has been fairly commonplace over recent years in this area. An example of sandbagging is shown in Figure B-5. This requires a permit that is only granted if the property is in imminent danger of being lost to erosion.



Figure B-5 - Sandbags in place but threatened February 2005.

2.06.3 NCDOT Emergency Costs

Emergency costs incurred by the North Carolina Department of Transportation (NCDOT) represent the average costs to NCDOT for removing sand from the ocean front roads in the study area following the storms. Bulldozers push the sand overwashed from the storms off the roads and deposit it between the ocean front structures. From there, private home and business owners must pay to have the sand redistributed in front of their properties.

2.06.4 Damage to Public Property

Damages to public property include things like damages to the water and electric utility distribution systems, and public access walkways, bath houses, and parking lots. Since traditional structural and content damage curves do not apply to these types of damages, this damage prevented category is based on interviews with public works officials concerning storm related damages that could have been prevented by a large Coastal Storm Damage Reduction project.

2.06.5 Damage to Other Private Property

Damages to private property other than structures and contents include storm damages that are not covered under the National Flood Insurance Program. These include things like water damage to private walkways, driveways, steps, landscaping, automobiles, and private cleanup costs.

2.06.6 Post Storm Recovery Costs

Preventable post-storm recovery expenses are based on data from interviews with public officials regarding preventable debris removal costs incurred over the last five years of storms, and storm related expenses from increased police patrolling, inspections, and permits.

2.07 Determination of Structure Values

The value of residential structures is limited to replacement cost less depreciation. Replacement value is the maximum cost to the owner if a structure is destroyed. If a significantly depreciated structure is destroyed and replaced, the difference between the old and new value is a betterment where the additional cost is offset by the additional utility and comfort of the new construction. Other measures of property value include fair market value and the income producing value. These measures are not considered appropriate for

National Economic Development benefits to protection of beach property. Fair market value is influenced by proximity to the ocean or sound, corresponding views of the beach and ocean, and short-term fluctuations in the local real estate market. Basing value on income can also produce significantly higher estimates. It is assumed that rental income lost to the owner will be transferred to some other owner in an alternate location. Therefore, the loss of income is considered a regional economic loss and not a loss to the National Economic Development account.

2.07.1 Cost of Residential Construction.

The average cost of residential construction on Topsail Island was determined according to the quality of initial construction. Three quality levels were discussed with local homebuilders. The economy level of quality was estimated to cost $90.00 per heated square foot. Average quality costs approximately $130.00 per square foot. Custom quality costs approximately $140.00 per square foot. No structure was assigned a greater value regardless of the quality. The square footage areas for most structures were available at the Pender County and Onslow County tax offices.

2.07.2 Commercial Structure Values.

Values for commercial structures were based on visual surveys and talking to some business managers and owners. Pender County and Onslow County tax data was also used for comparison.

2.07.3 Value of Structures by Reach

The value of structures within the coastal storm damage study area is estimated to be $360,815,000 with a total value, including contents, estimated at $477,542,000. The value of structures by reach is shown in Table B-3A and B-3B. The estimated value of residential and commercial contents is discussed in paragraph 5.08.3 under the topic Variables Specific to Structure File.

Table B-3A – Value of Structures by Reach, Surf City

Values October 2010			
Reach	**Structures**	**Contents**	**Combined**
27	$ 6,081,800	$ 1,918,200	$ 8,000,000
28	$ 4,959,100	$ 1,605,500	$ 6,564,600
29	$ 5,136,500	$ 1,751,100	$ 6,887,600
30	$ 7,759,100	$ 2,689,200	$ 10,448,300
31	$ 7,856,500	$ 2,716,900	$ 10,573,400
32	$ 9,083,700	$ 2,919,900	$ 12,003,600
33	$ 8,077,900	$ 2,702,600	$ 10,780,500
34	$ 8,160,000	$ 2,781,500	$ 10,941,500
35	$ 7,292,600	$ 2,545,700	$ 9,838,300
36	$ 8,305,600	$ 2,862,500	$ 11,168,100
37	$ 6,393,500	$ 2,189,900	$ 8,583,400
38	$ 7,837,000	$ 2,682,100	$ 10,519,100
39	$ 7,344,900	$ 2,486,200	$ 9,831,100
40	$ 8,567,000	$ 2,945,500	$ 11,512,500
41	$ 8,876,600	$ 3,085,000	$ 11,961,600
42	$ 8,785,400	$ 3,005,000	$ 11,790,400
43	$ 10,840,000	$ 3,744,200	$ 14,584,200
44	$ 6,887,600	$ 2,410,400	$ 9,298,000
45	$ 8,894,000	$ 3,106,500	$ 12,000,500
46	$ 13,795,800	$ 4,801,200	$ 18,597,000
47	$ 8,968,900	$ 3,104,500	$ 12,073,400
48	$ 7,555,100	$ 2,649,200	$ 10,204,300
49	$ 9,364,600	$ 3,238,800	$ 12,603,400
50	$ 8,168,200	$ 2,815,300	$ 10,983,500
51	$ 4,081,500	$ 1,436,400	$ 5,517,900
52	$ 11,103,500	$ 3,817,000	$ 14,920,500
53	$ 7,758,100	$ 2,679,000	$ 10,437,100
54	$ 6,839,400	$ 2,333,500	$ 9,172,900
55	$ 6,790,200	$ 2,430,900	$ 9,221,100
56	$ 5,523,000	$ 1,913,100	$ 7,436,100
57	$ 5,670,700	$ 1,966,400	$ 7,637,100
58-SC	$ 3,915,400	$ 1,281,600	$ 5,197,000
Surf City Total	$ 246,673,200	$ 84,614,800	$ 331,288,000

Table B-3B– Value of Structures by Reach, North Topsail Beach

Values October 2010			
Reach	**Structures**	**Contents**	**Combined**
58-NTB	$ 1,705,000	$ 484,900	$ 2,189,900
59	$ 5,502,500	$ 1,603,500	$ 7,106,000
60	$ 5,530,200	$ 1,504,000	$ 7,034,200
61	$ 5,048,300	$ 1,395,400	$ 6,443,700
62	$ 9,130,900	$ 2,533,400	$ 11,664,300
63	$ 9,172,900	$ 2,599,000	$ 11,771,900
64	$ 7,222,900	$ 2,072,000	$ 9,294,900
65	$ 6,445,700	$ 1,832,100	$ 8,277,900
66	$ 4,917,100	$ 1,372,800	$ 6,289,900
67	$ 3,917,500	$ 1,086,800	$ 5,004,200
68	$ 4,549,000	$ 1,413,800	$ 5,962,900
69	$ 4,646,400	$ 1,300,000	$ 5,946,500
70	$ 7,157,300	$ 2,012,600	$ 9,169,800
71	$ 3,915,400	$ 1,071,400	$ 4,986,800
72	$ 4,922,200	$ 1,370,800	$ 6,293,000
73	$ 4,965,300	$ 1,404,600	$ 6,369,900
74	$ 5,025,800	$ 1,392,300	$ 6,418,100
75	$ 5,261,600	$ 1,432,300	$ 6,693,900
76	$ 4,257,900	$ 1,163,700	$ 5,421,500
77	$ 6,379,100	$ 1,835,200	$ 8,214,300
78	$ 4,470,100	$ 1,230,300	$ 5,700,400
North Topsail Beach Total	$ 114,143,100	$ 32,110,900	$ 146,254,000

2.07.4 Value of Structures by Type

When the 81 road segments (Type 64) are excluded, there are a total of 1,817 structures in the structure damage database. There are 19 structure types, including roads, in the study area; however, only three structure types (Types 56, 59, and 60) equal or exceed 10 percent of the total value. In addition, single story residences on pilings with small or no enclosure (Type 55), account for 119 structures and 6.27 percent of the total inventory value. Two-story residences on pilings with small or no enclosure (Type 56), account for 540 structures and 28.45 percent, including the 450 structures assumed to be added by 2018. Figure B-6 shows four newly constructed type 56 structures. Types 59 (1-story) and 60 (2-story), on pilings with partial to full enclosures, account for 432 (22.76 %) and 471 structures (24.82 %) respectively.

Descriptions of the four predominant structure types follow in Table B-4. For the complete set of structure type definitions see attachment B-1. The value of

structures in the study area is presented in Table B-5 by structure type. Table B-5 shows both the value and number of structures in each type

Table B-4 – Description of Four Significant Structure Types

Structure Type	Description of Significant Structure Types	Percent of Total Value and number of structures –Surf City & North Topsail Beach
55	Residential – 1-story, raised on pilings, small or no enclosure	6.3% 114
56	Residential – 2-story, raised on pilings, small or no enclosure	28.8% 520
59	Residential - 1-story, raised on pilings – partial to full enclosure	22.7% 410
60	Residential – 2-story, raised on pilings, partial to full enclosure	24.8% 448



Figure B- 6 - Four typical new structures (all Type 56) built in 2004 on Topsail Island, NC

Table B-5 – Value of Structures by Type In thousand dollars

Flood_Curve	Count		Structures	Contents	Combined
1	101		$ 8,492,100	$ 2,947,600	$ 11,439,700
2	76		$ 12,038,500	$ 3,981,000	$ 16,019,500
5	9		$ 1,042,700	$ 372,200	$ 1,414,800
11	1		$ 46,100	$ 16,400	$ 62,500
17	1		$ 172,200	$ 61,500	$ 233,800
24	2		$ 310,700	$ 110,700	$ 421,400
25	3		$ 159,900	$ 46,100	$ 206,100
33	1		$ 287,100	$ 102,500	$ 389,600
35	3		$ 470,600	$ 168,100	$ 638,700
38	6		$ 1,124,700	$ 532,100	$ 1,656,800
45	1		$ 35,900	$ 18,500	$ 54,300
49	1		$ 183,500	$ 65,600	$ 249,100
53	3		$ 345,500	$ 254,300	$ 599,800
55	114		$ 13,203,200	$ 4,499,800	$ 17,703,000
56	520		$ 160,540,800	$ 51,256,300	$ 211,797,200
59	410		$ 58,715,000	$ 20,073,400	$ 78,788,400
60	448		$ 96,734,400	$ 32,082,100	$ 128,816,500
62	31		$ 452,100	$ 136,400	$ 588,500
64	75		$ 6,458,000	$ -	$ 6,458,000
Totals	1,806		$ 360,815,000	$ 116,727,000	$ 477,542,000

2.08 Land Values

Land values in all North Carolina coastal counties are escalating in general due to increased population growth in the U.S. coastal regions. Lot sales in the Topsail Island portions of Pender and Onslow counties are designated as ocean front, second row, and interior lots. To prevent the influence of water view or proximity to the ocean overriding the value, only the interior lot values are used in the analysis. Following hurricane Ophelia in 2005, the town requested approval from FEMA to haul in approximately 22,000 cubic yards (29,000 tons) of sand to distribute over 7,000 linear feet of beach. This is not considered a long term solution or effective measure against long term erosion or coastal storm damage. Therefore, it is not practical to equate the cost of fill to the land value lost due to long term erosion. A summary of values for ocean front lots, second row lots, and interior lots is presented below.

2.08.1 Ocean front lots

Ocean front lots are higher in risk for storm damage and erosion but continue to be highly desirable. These values were not used in the land loss estimates.

2.08.2 Second row lots

These values were not used in the land loss estimates.

2.08.3 Interior lots

The value and desirability of interior lots vary greatly; however, values based on sold prices, continue to increase. Higher interior lot values may be due to the limited number of all vacant lots in Surf City and North Topsail Beach and the fact that interior lots are less susceptible to storm and erosion damages. This data supports the estimated value of $25.00 per square foot. Interior lot values are used to estimate the losses to land caused by long-term erosion. Sales data for interior lots is shown in Figure B-7.

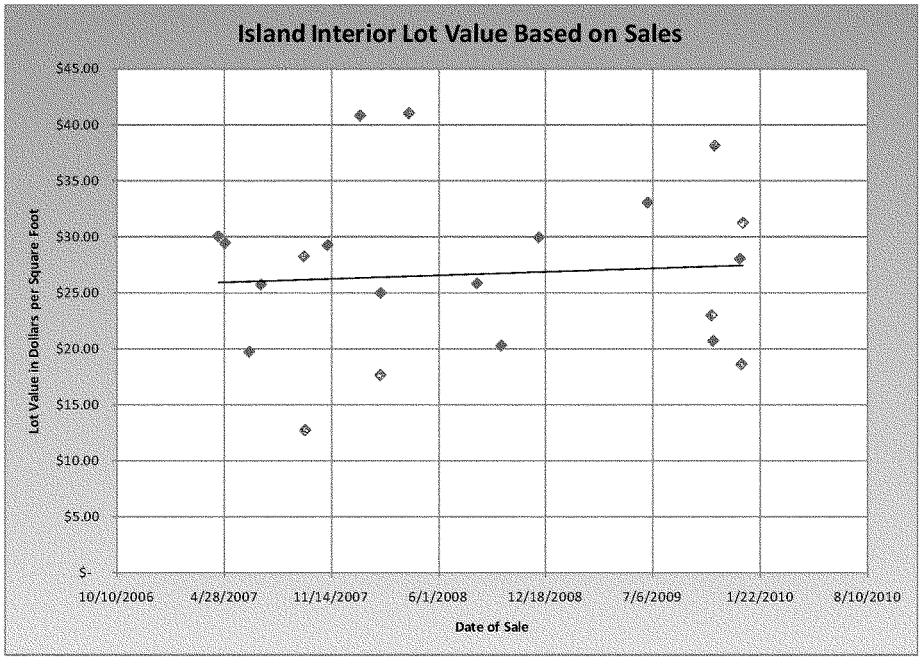


Figure B- 7- Interior Lot Sales in Dollars per Square Foot

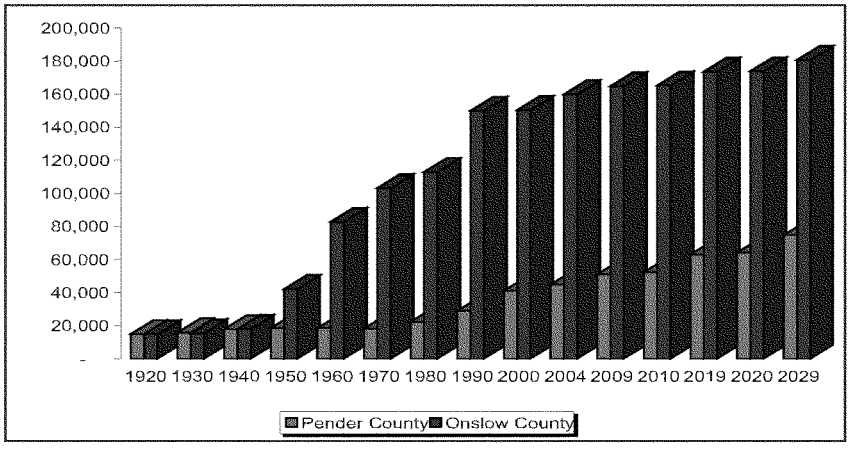
3.0 FUTURE ECONOMIC CONDITIONS (WITHOUT PROJECT)

3.01 Projected Population Growth

Projected population growth for Pender and Onslow counties are found at the North Carolina State Demographer's website. Figure B-8 shows both historical population from 1920 to 2000 and population projections for Pender and Onslow counties through 2029. Since all suitable lots are expected to be developed by the base year 2018, no additional growth in the number of residential or commercial structures is projected for the analysis. The assumptions used for structure replacement could result in fewer structures if storms destroyed a structure following its earlier replacement.

According to the North Carolina demographics office, the population of this 45-county recreation day user demand area is expected to reach 4.3 million in 2010, 5.0 million in 2020, and over 5.6 million in 2029. Therefore it is reasonable to expect recreation visitation at Surf City and North Topsail Beach to increase over the next 25 to 50 years.

Figure B- 8– Population Growth - Pender and Onslow Counties Actual 1920-2000 and Projected to-2029



3.02 Assumed Conditions at beginning of Period of Analysis Without Project Condition

The period of analysis begins when the project improvement is in place and the benefits to the public begin to accrue. It is assumed that this condition could occur by FY2018. All suitable vacant lots are expected to be developed by the base year in 2018; however, no additional growth in the number of residential or commercial structures is projected during the period of analysis. For the buildable lots to be developed by the base year 2018, an average of about 60 structures in the study area would be required per year. North Carolina CAMA regulations preclude replacement of a structure only after the lot is deemed unbuildable when set back restrictions dictate that structures cannot be put back on the lot. 15A NCAC 07H .2501 allows for a great deal of latitude for meeting rebuilding criteria following damages due to hurricanes or tropical storms. Issuing emergency permits for rebuilding on lots meeting a minimal setback restriction is generally the rule, not the exception in North Carolina. Common practice and historical evidence allow for rebuilding structures lost in storms provided setback restrictions are met. However, the analysis presented in this report limits the number of replacements to one. After long-term erosion has claimed more distance on the oceanfront lot than the building requires to be put back, our storm damage model ceases to reinstate the same property. This assumption will prevent the overestimation of the without project coastal storm damages.

3.03 Assumed Replacement of Residential Structures During Period of Analysis

It is assumed that all structures replaced in the study area as a result of coastal storm erosion damages will be similar to the existing distribution of residential and commercial use.

It is assumed that residential structures removed by long-term erosion will not be replaced during the 50-year period of analysis. Likewise, it is assumed that residential structures destroyed by wave, flood, or storm erosion will be replaced in the economic damage model (GRANDUC) by a residential structure that meets the following building codes and standards in place by flood plain regulations. This includes a setback requirement of at least sixty feet from the established line of vegetation. A minimum lot depth of 100 feet is required to replace a structure. Because of uncertainty, a structure can be replaced only once in GRANDUC during the period of analysis. Replacement residential structures are assumed to have only parking, storage, and normal provision for access on the ground level. The first living floor will be elevated on pilings, well above the Base Flood Elevation or high enough to accommodate under-house parking, whichever is greater. Pilings for all first row replacement structures will be 16 feet below grade or 5 feet below mean sea level. These replacement

structures are assumed to have the same characteristics as the typical house now being built on vacant lots (Figure B-6).

3.04 Assumed Replacement of Commercial Structures During Period of Analysis

Commercial structures that are replaced in the economic damage model during the period of analysis will be identical to the structure destroyed except for the first floor elevation. The first floor elevation of commercial structures will be set at ten feet above "ground" (on-grade) elevation. This assumption incorporates the enforcement of the damage reduction regulations including flood plain management and building codes now in force. When taken out, structure types 5-54 (flood damage curve numbers) are assumed to be replaced by the same type with the same value. These types include apartments (type 5), hotels (type 27), and motels (type 33), Condominiums are assigned to one of these three types. It is assumed that commercial or multi-family zoning will remain the same for the replacement structures.

3.05 Summary of Future Without Project Economic Conditions

In summary, the future economic conditions are assumed to have the same distribution of residential use and commercial development as the existing condition. Structures that are significantly damaged or destroyed are assumed to be replaced by more damage-resistant structures of the same type but replaced no more than one time. All structures not damaged or destroyed are assumed to remain without any modification. No "teardowns" are built into the analysis where older structures are assumed to be torn down/demolished and replaced by more expensive units based on investment speculation related to the high demand for coastal real estate.

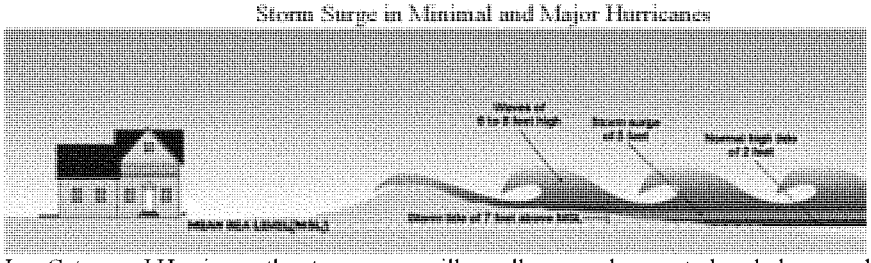
4.0 COASTAL STORM DAMAGES WITHOUT PROJECT

The accumulated present value of coastal storm damages over the 50-year period of analysis without a damage reduction project totals $400,850,000 in October 2010 price levels. These damages are shown by damage category and reach segment in Table B-6. Average annual damages (average annual equivalent amounts, 50-yrs, 4.125%) are calculated by using the 50-year interest and amortization factor as shown in Table B-7.

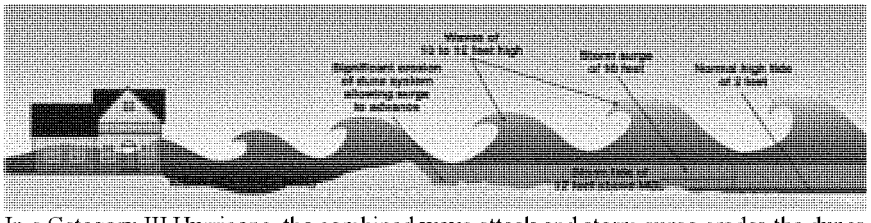
4.01 Damage Categories Defined

Figure B- 9 graphically shows the impact of tides, storm surge, and wave action that may occur during minimal and major hurricanes. (USACE, Mobile District, 1999). It should be noted that hurricane wind speed, the deciding factor in storm category by FEMA, does not determine the level of damages in the storm damage model. The impact of wind is not shown in the figure and wind damage is not estimated in the storm damage model. The present value of damages in each of the four damage categories is presented in Table B-6 and in Figure B-12. Coastal storm damages are calculated under with and without project conditions for damages to structures and contents, roadways, and land lost due to long-term erosion.

In many cases damages are calculated for more than one category since storms frequently generate flood inundation, waves, and storm erosion simultaneously. The damage model, GRANDUC, calculates damages in all the appropriate categories and selects the category with the greatest damage and ignores the other damages. This technique prevents the overestimation or double counting of damages.



In a Category I Hurricane, the storm surge will usually cause damage to beach dunes and structures placed on the seaward side of the dune line.



In a Category III Hurricane, the combined wave attack and storm surge erodes the dunes, exposing coastal structures to the most damaging effects of the surge. Although his wind speeds only placed Georges in Category II, the storm surge estimates were in line with Category III.

Courtesy of Escambia County Department of Public Safety.

Figure B- 9 Hurricane Surge and Wave Impacts

4.01 Damage Categories Defined (continued)

4.01.1 Storm Erosion

Storm erosion damages result from the undermining of structure pilings and foundations due to hurricane and tropical storms. Damages due to storm induced erosion are the major damages that are generally computed by the economic damage model. The first element in determining the potential impact of storm induced erosion on the amount of damage to a coastal structure is how much of the protective beach (either existing or projected) remains in front of and under the structure during the storm. If the storm induced erosion only reaches the front of the building, damage due to storm erosion is assumed to be zero and any damage to the structure would be that caused by either wave impact or inundation.

Earlier analyses for previous coastal storm damage studies along the coast of North Carolina, predicted that once the 0.5 foot point of erosion reaches the mid-point of the buildings supported on piles, all protective measures fronting the building have been removed exposing the building to the full brunt of the storm including direct wave impact and inundation. Due to the nature of the results obtained from the numerical storm erosion model (SBEACH), the landward extent of the impact of the storm erosion has been interpreted as the landwardmost point where the storm profile is 0.5 foot below the pre-storm profile. This particular standard for storm induced erosion or zone of influence was established by the developers of the SBEACH (Coastal & Hydraulics Laboratory formerly the Coastal Engineering Research Center) when the model was applied to the formulation of the storm damage reduction project for Panama City Beach, Florida.

The analysis of Surf City and North Topsail Beach is founded on using an erosion indicator of 2.0 feet for both the with and without project beach profiles. The 0.5 foot erosion indicator is used rarely and only for structures with slab foundations or roadbeds.

While the vertical scour around the ocean front piles may not cause the building to collapse, the open exposure caused by the storm induced erosion and lowering of the beach fronting the building is judged to be sufficient to result in complete loss of the economic value of the building even though the building may be left standing. The loss of the economic value of the building may come from the inability of the owner to reestablish a useable sewer system or obtain potable water. In these cases, the building will eventually have to be torn down. The damage associated with this condition has been broadly termed erosion damage, however, as demonstrated by the explanation provided above, the cause of the damage is not limited to erosion, rather it is due to the conditions created by the erosion that exposes the building to the maximum forces of the storm. A typical

new structure on the ocean front is required to be built with piling depths 16 feet below the surface of the ground or 5 feet below mean sea level whichever is a greater depth. Oceanfront structures built prior to 1986 are assumed to have piling depths of 8 feet below the ground. The storm damage structure inventory includes 160 homes on short pilings (8-foot depth), 141 homes on long pilings (16-foot depth or –5 feet m.s.l.), and 186 homes on concrete slab foundations. The remainder of the structures are built on pilings with varying sizes of enclosures.

4.01.2 Flood

Flood damages are caused by inundation related to rises in tide and storm surge. Damages begin when flooding and overwash reaches the structure or enclosure.

4.01.3 Wave

Wave damages result from waves over and above the storm surge making contact with the structures. Waves impacting the structure three feet or more above the first living area elevation are expected to result in total loss of the structure. Figure B-10 illustrates the effect of both flood from storm surge and waves.

4.01.4 Land lost or Long Term Erosion (LTE)

Land losses result from long-term erosion based on the analysis of historical erosion including rises in sea level. Land lost to long-term erosion is computed by multiplying the expected annual loss of land in acres by the value of nearshore interior lots. Fill material was also considered to reduce land losses due to long-term erosion. However, in the formulation of alternative plans, no suitable upland borrow sites were identified. Therefore, the cost of fill is not considered a practical limiting factor or substitute for the value of interior lots in the calculation of land lost or long term erosion.

4.01.5 Summary of Damages

Examples of coastal storm erosion damage at Surf City and North Topsail Beach are shown in Figure B-10 The present value of coastal storm damages by damage category and reach is shown in table B-6 and figure B-11for the without project condition.



Figure B-10- Coastal storm damage after Hurricane Fran 1996

Table B-6 – Present Value of Coastal Storm Damages (Without Project)

	Damages					
	Present Value					
Reach	Erosion	Flood	Wave	Land	Total Damage	Annual Total
27	$ 5,952,000	$ 2,000	$ -	$ 220,000	$ 6,174,000	$ 294,000
28	$ 282,000	$ -	$ -	$ 110,000	$ 392,000	$ 19,000
29	$ 6,688,000	$ 2,000	$ -	$ 134,000	$ 6,823,000	$ 324,000
30	$ 4,531,000	$ 6,000	$ -	$ 223,000	$ 4,760,000	$ 226,000
31	$ 2,627,000	$ 1,000	$ -	$ 410,000	$ 3,038,000	$ 144,000
32	$ 1,827,000	$ 28,000	$ -	$ 671,000	$ 2,526,000	$ 120,000
33	$ 3,539,000	$ 25,000	$ -	$ 315,000	$ 3,880,000	$ 184,000
34	$ 1,473,000	$ 32,000	$ -	$ 118,000	$ 1,624,000	$ 77,000
35	$ 4,431,000	$ 58,000	$ -	$ 118,000	$ 4,607,000	$ 219,000
36	$ 2,784,000	$ 28,000	$ 1,000	$ 118,000	$ 2,931,000	$ 139,000
37	$ 5,341,000	$ 22,000	$ -	$ 126,000	$ 5,489,000	$ 261,000
38	$ 8,291,000	$ 27,000	$ 83,000	$ 137,000	$ 8,539,000	$ 406,000
39	$ 7,195,000	$ 74,000	$ 32,000	$ 402,000	$ 7,703,000	$ 366,000
40	$ 9,579,000	$ 64,000	$ 196,000	$ 581,000	$ 10,419,000	$ 495,000
41	$ 8,679,000	$ 18,000	$ 10,000	$ 402,000	$ 9,109,000	$ 433,000
42	$ 6,479,000	$ 7,000	$ 4,000	$ 406,000	$ 6,896,000	$ 328,000
43	$ 11,281,000	$ 16,000	$ 39,000	$ 477,000	$ 11,814,000	$ 562,000
44	$ 10,592,000	$ 112,000	$ 225,000	$ 1,181,000	$ 12,110,000	$ 576,000
45	$ 9,217,000	$ 171,000	$ 1,000	$ 1,065,000	$ 10,454,000	$ 497,000
46	$ 6,893,000	$ 154,000	$ 5,000	$ 1,071,000	$ 8,124,000	$ 386,000
47	$ 12,860,000	$ 179,000	$ 129,000	$ 1,411,000	$ 14,578,000	$ 693,000
48	$ 14,691,000	$ 170,000	$ 78,000	$ 1,785,000	$ 16,724,000	$ 795,000
49	$ 17,408,000	$ 51,000	$ 18,000	$ 1,995,000	$ 19,472,000	$ 926,000
50	$ 11,500,000	$ 41,000	$ -	$ 1,142,000	$ 12,683,000	$ 603,000
51	$ 2,563,000	$ 144,000	$ 260,000	$ 848,000	$ 3,815,000	$ 181,000
52	$ 13,934,000	$ 73,000	$ 1,632,000	$ 1,007,000	$ 16,646,000	$ 792,000
53	$ 12,409,000	$ 38,000	$ 1,250,000	$ 1,461,000	$ 15,157,000	$ 721,000
54	$ 7,088,000	$ 11,000	$ 858,000	$ 1,421,000	$ 9,377,000	$ 446,000
55	$ 3,554,000	$ 65,000	$ 170,000	$ 913,000	$ 4,702,000	$ 224,000
56	$ 669,000	$ 50,000	$ 216,000	$ 626,000	$ 1,561,000	$ 74,000
57	$ 4,216,000	$ 46,000	$ 266,000	$ 1,556,000	$ 6,083,000	$ 289,000
58	$ 6,044,000	$ 54,000	$ 282,000	$ 1,750,000	$ 8,131,000	$ 387,000
59	$ 5,261,000	$ 41,000	$ 542,000	$ 1,511,000	$ 7,355,000	$ 350,000
60	$ 7,129,000	$ 28,000	$ 723,000	$ 1,327,000	$ 9,207,000	$ 438,000
61	$ 3,374,000	$ 70,000	$ 710,000	$ 673,000	$ 4,827,000	$ 230,000
62	$ 7,823,000	$ 13,000	$ 34,000	$ 1,254,000	$ 9,123,000	$ 434,000
63	$ 6,000,000	$ 72,000	$ 131,000	$ 939,000	$ 7,141,000	$ 340,000
64	$ 5,880,000	$ 108,000	$ 1,115,000	$ 1,425,000	$ 8,528,000	$ 406,000
65	$ 5,728,000	$ 97,000	$ 596,000	$ 1,080,000	$ 7,501,000	$ 357,000
66	$ 5,092,000	$ 46,000	$ 241,000	$ 884,000	$ 6,262,000	$ 298,000
67	$ 7,372,000	$ 9,000	$ 218,000	$ 1,482,000	$ 9,082,000	$ 432,000
68	$ 4,133,000	$ 138,000	$ 685,000	$ 854,000	$ 5,811,000	$ 276,000
69	$ 4,181,000	$ 343,000	$ 544,000	$ 645,000	$ 5,714,000	$ 272,000
70	$ 3,384,000	$ 136,000	$ 893,000	$ 565,000	$ 4,978,000	$ 237,000
71	$ 3,826,000	$ 15,000	$ 816,000	$ 914,000	$ 5,570,000	$ 265,000
72	$ 11,061,000	$ 1,000	$ 769,000	$ 1,640,000	$ 13,470,000	$ 641,000
73	$ 10,119,000	$ 1,000	$ 757,000	$ 1,522,000	$ 12,398,000	$ 590,000
74	$ 8,862,000	$ 4,000	$ 705,000	$ 1,141,000	$ 10,712,000	$ 509,000
75	$ 3,145,000	$ 76,000	$ 307,000	$ 987,000	$ 4,514,000	$ 215,000
76	$ 2,626,000	$ 36,000	$ 144,000	$ 962,000	$ 3,767,000	$ 179,000
77	$ 3,418,000	$ 119,000	$ 223,000	$ 922,000	$ 4,682,000	$ 223,000
78	$ 3,031,000	$ 38,000	$ 267,000	$ 531,000	$ 3,867,000	$ 184,000
Subtotal	$ 336,062,000	$ 3,160,000	$ 16,175,000	$ 45,458,000	$ 400,850,000	$ 19,061,000
107	$ 3,743,000	$ 15,000	$ 802,000	$ 900,000	$ 5,460,000	$ 260,000
108	$ 10,867,000	$ 1,000	$ 748,000	$ 1,614,000	$ 13,230,000	$ 629,000
114	$ 9,920,000	$ 1,000	$ 738,000	$ 1,495,000	$ 12,154,000	$ 578,000
115	$ 8,704,000	$ 3,000	$ 686,000	$ 1,125,000	$ 10,518,000	$ 500,000
Total	$ 369,296,000	$ 3,180,000	$ 19,149,000	$ 50,592,000	$ 442,212,000	$ 21,028,000

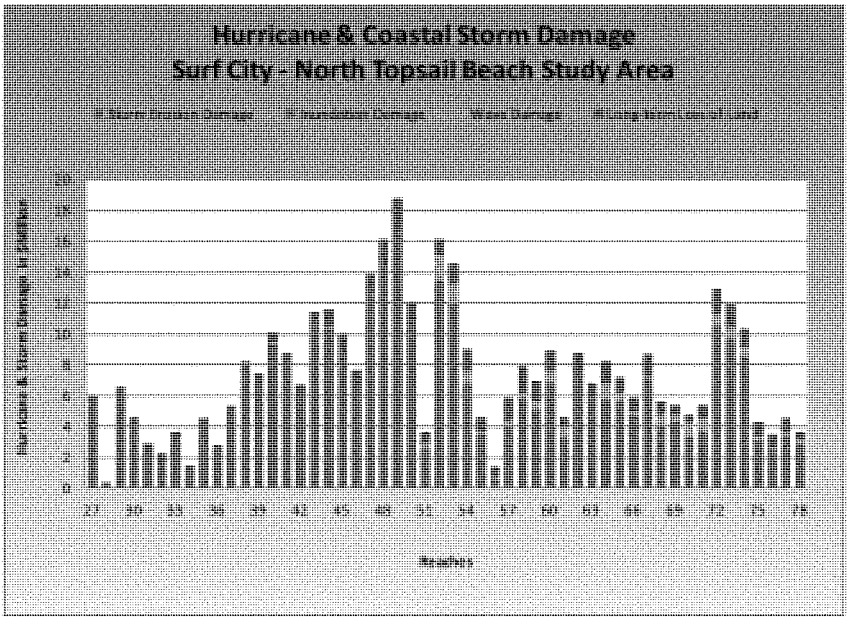


Figure B- 11 - Present Value of Coastal Storm Damages by Damage Category – Without Project Condition

Table B-7 – Average Annual Coastal Storm Damages (Without Project)

Base Condition Coastal Storm Damages - Average Annual Equivalent Amount					
Reach	**Total Damage**	**Storm Erosion**	**Flood**	**Wave**	**Land Lost**
27-78	$19,061,000	$ 15,980,000	$150,000	$769,000	$2,262,000

5.0. ECONOMIC VARIABLES, ASSUMPTIONS, AND METHODOLOGY APPLIED IN COASTAL STORM DAMAGE MODEL (GRANDUC)

In the Wilmington District Coastal Storm Damage Model the economic input includes a set of general global data that applies to the entire analysis, the estimated base year when damage reduction measures could be in place, flood damage curves, erosion damage curves, miscellaneous benefits to be included, and the variable inputs for each structure in the structure inventory data base or structure file. More information on the General Risk and Uncertainty – Coastal model (GRANDUC) is presented in Appendix D Coastal Engineering.

5.01 General Global Data

Based on the general economic assumptions, the global values are as follows:

- Interest Rate –4- 1/8 percent.
- Price Level –October 2010 price level.
- Economic Period of Analysis – 50 years beyond the base year.
- Wave damage assumption – waves three feet above the first floor elevation will result in the total loss of the structure.

5.02 Base Year

The Base Year is defined as the first year coastal storm damage reduction measures could be in effect. It is expected that damage reduction measures could be implemented by 2018.

5.03 Interior Lot Value per Square Foot

Long term erosion damages or land losses are based on the estimated value of interior lots. The data on lots actually sold support a value of $25.00 per square foot at the October 2010 price level.

5.04 Initial Benefits

The economic damage model (GRANDUC) allows the entry of initial benefits – such as "Benefits during Construction." At the time of the scoping runs, the detailed construction schedule had not been developed. Therefore, no initial benefits were included in the analysis.

5.05 Other Annual Benefits

GRANDUC also allows for the addition of other type of NED benefits – such as "Recreation." The final determination of recreation benefits was not completed in time to include in the model runs. The recreation benefits were added external to the GRANDUC model calculation. The estimated recreation benefits are presented in Appendix O – Recreation. No other "Annual Benefits" for recreation were added to the GRANDUC model. This also supports the formulation of the NED Plan using coastal storm damage reduction benefits alone.

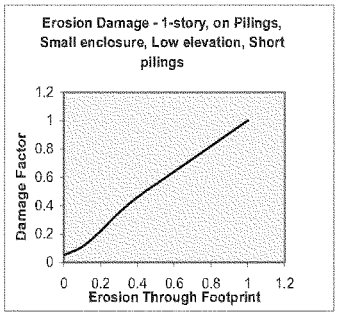
5.06 Flood Damage Curves

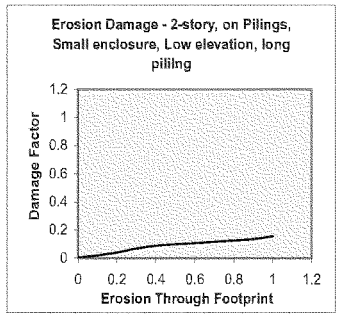
Flood damages due to inundation are determined by the combined height of the storm still water level and a superimposed wave height. Based on the elevation of this combined height and the elevation of the structures first floor, the amount of inundation damage is determined from a standard set of inundation damage curves. Unless the predicted amount of storm induced erosion is sufficient to completely erode the ocean front dune, the residual height of the seaward edge of the beach is generally sufficient to limit the height of the wave that could be transmitted across the beach face without breaking. Accordingly, since the conditions necessary to cause a prediction of significant inundation related damages is rather severe, damages due to the inundation (combined storm still water level and wave height) rarely controls.

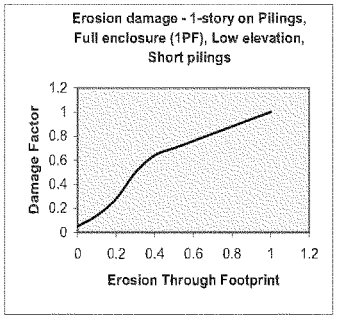
5.07 Erosion Damage Curves

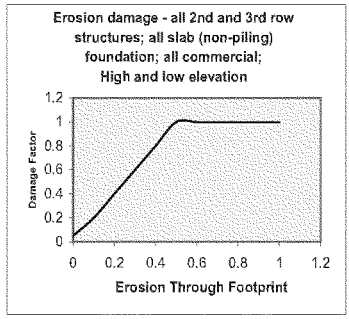
Based on the significant number of first row structures, sample erosion curves are shown by structure type in Figures 12, 13, 14, and 15. A complete set of erosion types and associated erosion curves are found in attachment B-2 to this appendix. The erosion-damage curves used for this analysis are compilations of curves assigned for each part of the structure. The enclosure is given a value of 40 percent of the entire structure and the rest of the structure is given a value of 60 percent of the entire structure value. These percentages were then used to weight the damage curves for the home and the enclosure and derive a composite damage curve.

Figures -12, 13, 14, and 15 Composite Erosion Damage Curves









5.08 Variables Specific to Structure File

Table B- 8 - Sample Structure File

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Reach	ID_USACE	REF-FRNT of LOT	LOT_LENGTH	LOT_WIDTH	REF_FRNT of STRUC	STRUC_LENGTH	Attack Angle Ratio	STRUC_TYPE	STRUC_VALUE	CONTENT_VALUE	GRELEV_SUR	FFLOOR_ELEV	ACTIVE	EROSION TYPE	ARMOR	FLANKING
3	003OCEA2103A	0	150	83	247	35		56	$225,000	$90,000	7.4	17.6	1	24	-1	2.0
3	003OCEA2104A	504	150	111	431	35		56	$225,000	$90,000	5.9	18.5	1	31	-1	2.0

The structure file shown in Table B-8 describes the value of each structure, the horizontal and vertical location of the structure within the coastal damage

model, and specifies which flood damage curve and erosion damage curve is appropriate for the structure. As illustrated in Figure B-16, the lot distance (Col. 3) and structure distance (Col. 6) are measured from a "Reference Line" established in the coastal storm generation models and incorporated into the GRANDUC model. The structure length (Col. 7) defines the structure footprint used in the storm erosion estimates.

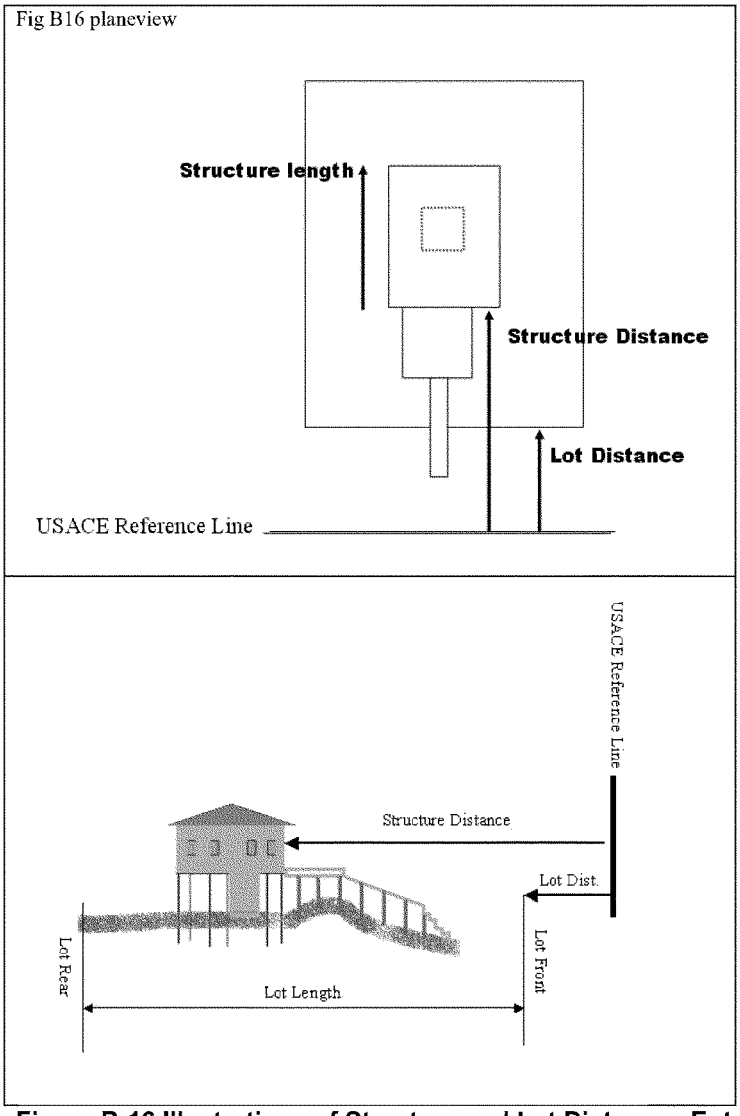


Figure B-16 Illustrations of Structure and Lot Distances Entered into GRANDUC model (plane view and side view).

5.08.1 Structure Type – flood damage curve

Structure type denotes the flood damage curve that is to be used with each sturucture. A description of all structure types, both residential and commercial are attached to this appendix, Attachment B-1. Residential structure types for all residential structures in the study area were based on visual observation by district personnel including documentation with digital photographs. Descriptions included the number of levels (1,1.5, or 2 story), type of foundation (P=on pilings, N=not on pilings), if piling foundation what is the size of enclosure (S=small <300SF; P=partial >300SF; F=full; or N=none). Commercial business types include hotels, motels, garages, etc. A complete list of the commercial and residential business types used is found in Attachment B-1 to this appendix.

5.08.2 Structure Value

Structure values are entered in dollars based on the replacement cost less depreciation. Determinations of commercial structure values and description of the business type were made by district personnel with additional checking against tax records. Structure values represent the replacement value less depreciation at the current price levels. The district personnel consulted with local real estate agents, appraisers, business owners, and building contractors as needed. While some information on structures was obtained from the Pender County and Onslow County tax offices; replacement costs are based on site-specific building cost for Topsail Island.

5.08.3 Content Value

Contents to residential structures include personal possessions, including furniture, clothing, dishes, cooking utensils, linens, jewelry, stereo equipment, etc. For homeowners' insurance coverage, the standard coverage for contents is 50 percent of the dwelling coverage. For beach communities like Topsail Beach, Surf City, and North Topsail Beach, the estimated value of contents of an average residential structure would be less than 50 percent of the value of the structure. The main factor in this conclusion is that nearly 75 percent of the structures are not owner-occupied year round. Many of the seasonal 75 percent are rented to vacationers during the spring and summer beach season. Contents include beds, furniture, reclining chairs, color cable televisions, VCR's and DVD players, microwave ovens, clothes washers and dryers, and telephones. Built-in appliances are included in the value of the structure. Contents for residential structures are estimated to be 40 percent of the structure value. This percentage is consistent with a detailed Residential Flood Damage survey taken in the Northern Gulf Coast (USACE, Mobile District, 1999). This area is similar to Topsail Island and is primarily single-family residential structures. Based on the 1999 survey, content damage was

reported in 81 of 192 cases, with a mean content-to-structure damage of about 35 percent.

Estimates of values of contents of commercial structures in the primary study area are based on interviews with businessmen and insurance agents familiar with the Topsail Island oceanfront, as well as empirical data collected for past studies. Businesses are entered into the damage model with a code for type of commercial activity. Each type of business has a unique content factor applied to its structural values. After weighing responses from motel managers and insurance agents in the study area, this is considered appropriate. It is also consistent with the commercial content data that originally came from a Galveston District study but were updated by the Wilmington District to reflect North Carolina beach data.

5.08.4 Elevation at ground

Ground elevations for the vast majority of North Topsail Beach were taken from FEMA elevation certificates. Elevations for Surf City were established by surveys and in some cases were estimated from 2-foot contour maps. The Wilmington District contracted with the engineering and surveying firm of Greenhorne & O'Mara, Inc. to perform survey work on Topsail Island. The field surveys were completed during the week of May 19-23, 2003.

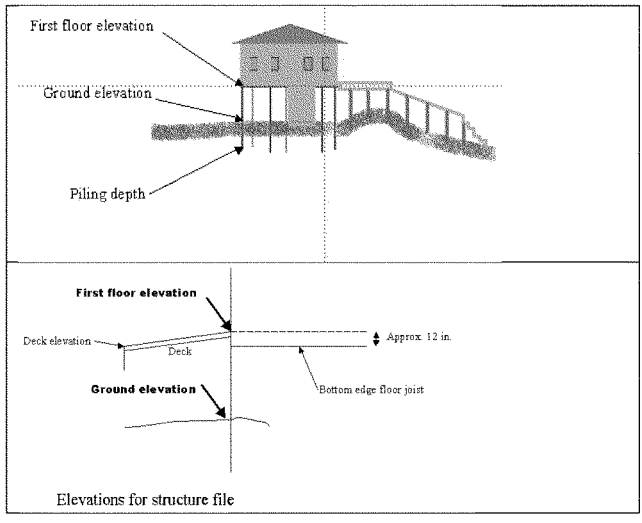


Figure B- 17 - Illustration of Residential Structure Elevations

5.08.5 Elevation at First Floor

The first-floor elevations were taken from FEMA elevation certificates or surveyed by the location of the front entry threshold as shown in Figure B-18. First floor elevations were surveyed under contract with the engineering and surveying firm Greenhorne & O'Mara, Inc.for the Surf City and North Topsail Beach study area. Data collected by North Carolina State University students for FEMA following hurricane Fran in 1996 were also compared and used for missing structures. In these cases the first floor elevation was adjusted by one foot to get the top of the floor joist versus the bottom of floor joist measured by NCSU. In a few cases first floor elevations were estimated by adding 10 or 12 feet to the ground elevations. Likewise, this assumption was used to indicate the first floor elevation of all structures replaced during the period of analysis.

5.08.6 Erosion Type

The erosion type in the structure file directs which erosion curve is used to calculate storm erosion damages. Variables include type of foundation, depth of piling penetration, type of shoreline (see Figure B-18), and the size of any enclosures around the piling foundation. The type of foundation on Topsail Island is mostly residential built on pilings. Most commercial and some residential structures are built on a slab foundation.

The historical effects of long-term and storm related erosion on oceanfront structures along the beaches of North Carolina are not well documented. Very little data exists on how these structures react to storm forces of varying degrees of intensity. This lack of data has lead to the designing of erosion-damage curves comprised largely through professional judgment. The state of the art of modeling these relationships is improving, however, following the hurricanes of 1996-1999 along the North Carolina coast. Researchers like Spencer Rogers of North Carolina Sea Grant have begun collecting and analyzing data and publishing papers on this subject. In his report, "Erosion Damage Thresholds in North Carolina," Mr. Rogers derived storm induced damage curves based on observed changes over time in coastal construction in North Carolina (Attachment B-4).

The curves used in this analysis are derived from these erosion-damage curves and are based on field data including the following structure characteristics:

❶Oceanfront or not
❷Number of stories
❸On piles or not, long or short piles
❹ Type of enclosure (none, finished, unfinished)
❺Size of the under house enclosure (none, small, partial, fully enclosed)

❻High or low existing dune (potential to undermine 1st row structures) see illustration in Figure B-18.
❼Structure type (commercial or residential)

For this analysis, these data were collected for every structure along the oceanfront and first row of development back from the oceanfront, along with their elevation and depreciated replacement value. The following further describes the four-character coding scheme of structure types used for this study, which was originally developed by a North Carolina State University team of researchers including Mr. Rogers. Descriptions included the number of levels (1,1.5, or 2 story), type of foundation (P=on pilings, N=not on pilings), if piling foundation what is the size of enclosure (S=small <300SF; P=partial >300SF; F=full; or N=none) and the quality of the enclosure (F=finished, N-unfinished, "blank"=unknown). These codes are assigned upon field inspection of each structure and matched with both an appropriate erosion-damage curve and an inundation-damage curve. The decision matrix used in the field is included in Attachment B-2.

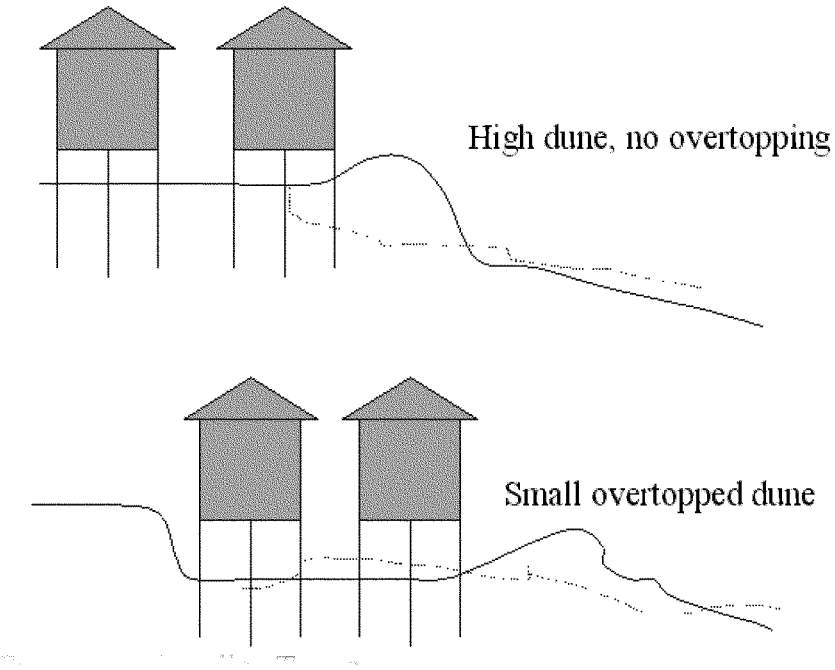


Figure B-18 - Shoreline Types with High and Low Elevation

5.08.7 Erosion Indicator

An indicator of erosion is measured as the vertical distance between the pre-storm and post-storm beach profile as shown in Figure B-19. The erosion damage curves are read based on how far the "erosion indicator" has proceeded through the structure footprint. In this analysis two erosion indicators were used. The most frequently used indicator is the 2-foot indicator. This indicator was chosen after consideration and interpretation of work by Spencer Rogers, North Carolina Sea Grant (Attachment B-4). For a limited number of structures built on concrete slab foundations and all street and roads, an erosion indicator of 0.5 feet was used. The work by Spencer Rogers, North Carolina Sea Grant, also introduces the possible use of a 4-foot erosion indicator. While use of the 4-foot indicator is not considered appropriate for the beach profiles of Surf City and North Topsail Beach, alternative analyses were run for the Topsail Beach General Re-evaluation Report and did not seriously impact the economic feasibility of the NED plan.

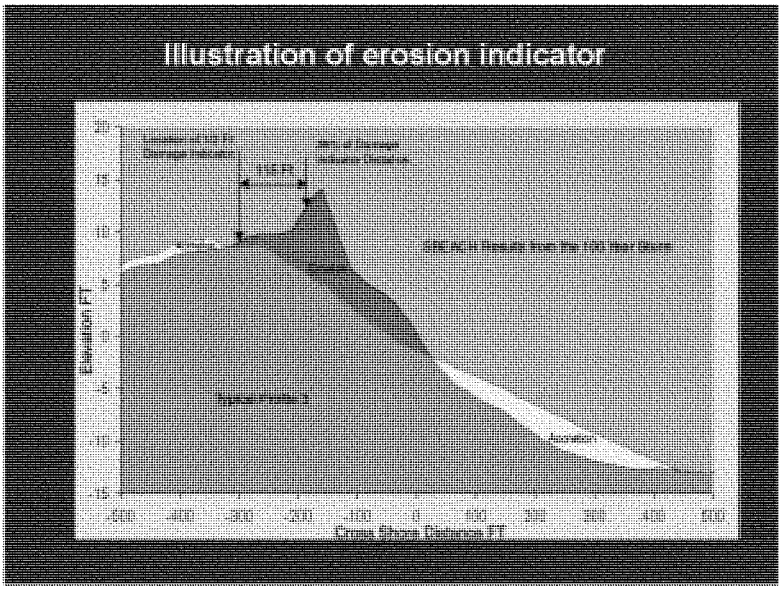


Figure B-19 - Illustration of erosion Indicator

The report "Erosion Damage Thresholds in North Carolina" by Spencer Rogers of the North Carolina Sea Grant is attached to this appendix as Attachment B-4.

6.0. ALTERNATIVES TO REDUCE COASTAL STORM DAMAGES

Expected storm and erosion related damages are first computed for the without project condition, then again for the various plans of improvement over approximately 10 miles of the primary study area. Structural, non-structural, and no action alternatives were considered. Structural plans include beach fill plans which have potential to prevent the progressive erosion of the shoreline, reduce damages caused by erosion, flooding, and wave impact during coastal storms, decrease storm related emergency expenditures, and increase the quality of recreational opportunities in the area. No action is also an alternative. However, the no action plan does not preclude emergency measures of dealing with erosion, such as beach scraping and sandbagging, but, in the long run, these emergency measures are assumed to be ineffective.

6.01 Structural Plans

Structural alternatives evaluated included various combinations of berm and dune heights. For example, Plan 1150 includes a dune height of 11 feet and a berm width of 50 feet. The initial array and the final array of plans are shown in Table B-9 below.

The continuous section between reach 58 and reach 78 were found to be feasible for several beach and dune alternatives. The two separate groups, reaches 103 to 105 and reaches 113-115 were not incrementally feasible for beachfill and excluded from further study.

Table B-9 - Economic Comparisons, Accumulated Present Value Amounts

Initial Array of Plans compared @ Dec 04 & 5-3/8%	Initial PV Net Benefits @ Dec 04 & 5-3/8%	Final Array of Plans compared @ Jan 05 & 5-3/8%	Final PV Benefits @ Jan 05 & 5-3/8%	Final PV Costs @ Jan 05 & 5-3/8%	Final PV Net Benefits @ Jan 05 & 5-3/8
50	$127,918,906				
100	$145,153,980				
150	$150,997,603				
1125	$139,831,147				
1150	$143,834,869	1150	$ 232,736,623	$ 98,214,372	$134,522,251
1175	$148,539,323				
1325	$171,819,955				
1350	$170,998,193	1350	$ 263,768,009	$105,229,962	$158,538,047
1375	$167,426,693				
		1450	$ 271,728,277	$111,442,663	$160,285,614
1525*	$178,870,873				
1550	$174,056,978	**1550**	$ 280,191,291	$114,804,658	$165,386,633
1575	$168,701,068	1575	$ 284,257,490	$125,623,007	$158,634,483
		1650	$ 280,577,629	$121,578,509	$158,999,120
		1750	$ 285,877,003	$125,762,429	$160,114,574

*Net benefits in this table were based on using identical unit costs for borrow material. However, it is estimated that costs for building a 25 ft dune and berm plan are at least 8% higher than for building plans with berm widths of greater than 25 ft. One of the primary reasons for the greater unit cost under a 25 ft plan is the additional equipment that is needed to move pipe along the beach as the dredge is pumping, since the narrow berm width does not allow pumping at one location for as long. Using the higher unit cost, the net benefit of the 1525 plan is about $167 million dollars.

All beach nourishment plans shown have positive net NED benefits; however, the plan with the greatest net NED benefits is Plan 1550 (see footer for table B-9). The NED Plan is defined as the alternative that maximizes net NED benefits. Therefore, Plan 1550 is designated as the NED Plan.

6.02 Non-structural Plans

The non-structural plans consist of retreats, relocations, and demolitions applied to threatened structures on an individual case-by-case basis. However, none of the non-structural plans were found to be feasible. Figure B-20 shows one of the rare non-structural projects involving the raising of a structure. A general description of the non-structural analysis is presented in the main report.



Figure B- 20 Topsail Island home raised on piling foundation 2004.

7.0 ECONOMICS OF NED PLAN (PLAN 1550)

7.01 Economic Damages – remaining with plan

A major consideration in evaluating any plan is the estimated damages remaining with the project plan. The accumulated present value of remaining damages for Plan 1550 is presented in Table B-10. A summary of average annual equivalent remaining damages is shown in Table B-11.

Table B-10 – Present Value of Remaining Damages with NED Plan

Reach	Erosion	Flood	Wave	Land	Total Damages
27	$ 278,000	$ 24,000	$ -	$ -	$ 302,000
28	$ 37,000	$ -	$ -	$ -	$ 38,000
29	$ 534,000	$ 2,000	$ -	$ -	$ 536,000
30	$ 1,546,000	$ 7,000	$ -	$ -	$ 1,552,000
31	$ 1,732,000	$ 2,000	$ -	$ -	$ 1,734,000
32	$ 540,000	$ 34,000	$ -	$ -	$ 574,000
33	$ 998,000	$ 27,000	$ -	$ -	$ 1,025,000
34	$ 963,000	$ 36,000	$ -	$ -	$ 998,000
35	$ 379,000	$ 77,000	$ -	$ -	$ 456,000
36	$ 311,000	$ 37,000	$ -	$ -	$ 348,000
37	$ 501,000	$ 25,000	$ -	$ -	$ 527,000
38	$ 620,000	$ 50,000	$ 14,000	$ -	$ 685,000
39	$ 558,000	$ 104,000	$ 9,000	$ -	$ 670,000
40	$ 454,000	$ 108,000	$ 54,000	$ -	$ 616,000
41	$ 947,000	$ 26,000	$ 5,000	$ -	$ 979,000
42	$ 1,329,000	$ 11,000	$ 4,000	$ -	$ 1,345,000
43	$ 1,328,000	$ 24,000	$ 18,000	$ -	$ 1,370,000
44	$ 956,000	$ 195,000	$ 6,000	$ -	$ 1,158,000
45	$ 240,000	$ 183,000	$ -	$ -	$ 423,000
46	$ 166,000	$ 204,000	$ -	$ -	$ 370,000
47	$ 701,000	$ 235,000	$ 4,000	$ -	$ 939,000
48	$ 974,000	$ 214,000	$ 15,000	$ -	$ 1,202,000
49	$ 846,000	$ 112,000	$ 2,000	$ -	$ 960,000
50	$ 195,000	$ 64,000	$ -	$ -	$ 259,000
51	$ 366,000	$ 211,000	$ 84,000	$ -	$ 662,000
52	$ 2,108,000	$ 122,000	$ 824,000	$ -	$ 3,054,000
53	$ 811,000	$ 122,000	$ 936,000	$ -	$ 1,869,000
54	$ 490,000	$ 95,000	$ 577,000	$ -	$ 1,161,000
55	$ 318,000	$ 126,000	$ 27,000	$ -	$ 470,000
56	$ 175,000	$ 77,000	$ 43,000	$ -	$ 294,000
57	$ 605,000	$ 77,000	$ 75,000	$ -	$ 758,000
58	$ 575,000	$ 142,000	$ 83,000	$ -	$ 800,000
59	$ 432,000	$ 106,000	$ 207,000	$ -	$ 745,000
60	$ 786,000	$ 48,000	$ 322,000	$ -	$ 1,155,000
61	$ 365,000	$ 75,000	$ 225,000	$ -	$ 665,000
62	$ 1,107,000	$ 30,000	$ 5,000	$ -	$ 1,141,000
63	$ 325,000	$ 126,000	$ 33,000	$ -	$ 484,000
64	$ 464,000	$ 190,000	$ 338,000	$ -	$ 992,000
65	$ 490,000	$ 190,000	$ 335,000	$ -	$ 1,015,000
66	$ 572,000	$ 55,000	$ 165,000	$ -	$ 792,000
67	$ 1,743,000	$ 19,000	$ 104,000	$ -	$ 1,867,000
68	$ 396,000	$ 235,000	$ 259,000	$ -	$ 889,000
69	$ 588,000	$ 499,000	$ 392,000	$ -	$ 1,479,000
70	$ 493,000	$ 185,000	$ 392,000	$ -	$ 1,069,000
71	$ 502,000	$ 62,000	$ 461,000	$ -	$ 1,024,000
72	$ 743,000	$ 62,000	$ 536,000	$ -	$ 1,341,000
73	$ 725,000	$ 51,000	$ 422,000	$ -	$ 1,198,000
74	$ 539,000	$ 47,000	$ 400,000	$ -	$ 986,000
75	$ 188,000	$ 138,000	$ 38,000	$ -	$ 364,000
76	$ 199,000	$ 55,000	$ 111,000	$ -	$ 364,000
77	$ 378,000	$ 180,000	$ 52,000	$ -	$ 611,000
78	$ 627,000	$ 91,000	$ 95,000	$ -	$ 813,000
	$34,243,000	$5,217,000	$7,672,000	$ -	$ 47,128,000

Table B-11 – Remaining Average Annual Coastal Storm Damages with Plan 1550 (NED Plan)

Remaining Coastal Storm Damages - Average Annual Equivalent Amount					
Reach	**Storm Erosion**	**Flood**	**Wave**	**Land**	**Total Damage**
27-78	$1,628,000	$ 248,000	$365,000	$0	$2,241,000

7.02 Economic Benefits

The primary benefits to the NED plan are the coastal storm damage reduction benefits. The total damage reduction benefits are computed by subtracting the remaining damages from the total without project damages. Coastal storm damage reduction benefits total $16,820,000 and are shown by type in Table B-12.

7.02.1 Coastal Storm Damage Reduction Benefits

Table B-12 – Average Annual Coastal Storm Damage Reduction Benefits with Plan 1550 (NED Plan)

Category of Damages Reduced				Total Benefits
Storm Erosion	**Flood-Inundation**	**Wave**	**Long-Term-Erosion**	
$14,352,000	($98,000)	$404,000	$2,162,000	$16,820,000

7.02.2 Reduced Emergency Costs Benefits

Benefits from reduction of emergency costs are estimated to have an equivalent annual value of $99,000 for Surf City and $235,000 for North Topsail Beach, for a total of $334,000 over the entire project length based on records from hurricanes Bertha, Fran, Bonnie, and Floyd. *This category of benefits is not very precise and is relatively minor compared to CSDR benefits (1 to 2%) and so, is dropped from the total.*

Emergency cost reductions refer to expected annual expenditures that residents and governments are experiencing under the without project condition that a project would preclude. Other damage reductions include storm damages that are not covered under the National Flood Insurance Program, but represent financial drains on public and private storm victims that a large beach nourishment project could reduce. The categories lumped into this benefit called emergency costs and other damages reduced include (1) beach scraping/pushing; (2) sandbagging: (3) emergency costs incurred by the North

Carolina Department of Transportation; (4) damages to public property; (5) damages to private property other than structures and contents; and, (6) post-storm recovery expenses.

7.02.3 Benefits During Construction

Construction of NED Plan could begin following contract award 30 September 2014. Allowing for environmental constraints, construction could begin in December 2014 and continue for approximately six months for each consecutive environmental dredging window. Construction is assumed to continue through 30 April of each year of initial construction. This construction schedule would provide significant benefits from the project in 2018 (the base year). The project would be expected to be completed in 2018 prior to hurricane season and the peak recreation season.

Table B-13 Benefits During Construction for Plan 1550

PERIODS	MONTH	Activity	HSDR Benefits	HSDR Benefits	REC Benefits	REC Benefits	Interest Factors	HSDR Benefits with Interest	REC Benefits with Interest
1	NOV	MOB					1.165146	$0	$0
2	DEC	Dredge					1.160914	$0	$0
3	JAN						1.156697	$0	$0
4	FEB						1.152495	$0	$0
5	MAR						1.148308	$0	$0
6	APR	DE-MOB					1.144137	$0	$0
7	MAY	Till, DP, WO				$1,250,000	1.139981	$0	$1,424,976
8	JUN			$841,000		$1,250,000	1.135840	$955,241	$1,419,800
9	JUL			$841,000	25% REC	$1,250,000	1.131714	$951,771	$1,414,642
10	AUG		25% HSDR	$841,000	Benefits	$1,250,000	1.127603	$948,314	$1,409,503
11	SEP		Benefits	$841,000			1.123506	$944,869	$0
12	OCT			$841,000			1.119425	$941,437	$0
13	NOV	MOB					1.115359	$0	$0
14	DEC	Dredge					1.111307	$0	$0
15	JAN						1.107270	$0	$0
16	FEB						1.103248	$0	$0
17	MAR						1.099240	$0	$0
18	APR	DE-MOB					1.095247	$0	$0
19	MAY	Till, DP, WO				$2,500,000	1.091269	$0	$2,728,172
20	JUN			$1,682,000		$2,500,000	1.087304	$1,828,846	$2,718,261
21	JUL			$1,682,000	50% REC	$2,500,000	1.083355	$1,822,203	$2,708,387
22	AUG		50% HSDR	$1,682,000	Benefits	$2,500,000	1.079419	$1,815,583	$2,698,548
23	SEP		Benefits	$1,682,000			1.075498	$1,808,988	$0
24	OCT			$1,682,000			1.071591	$1,802,417	$0
25	NOV	MOB					1.067699	$0	$0
26	DEC	Dredge					1.063820	$0	$0
27	JAN						1.059956	$0	$0
28	FEB						1.056105	$0	$0
29	MAR						1.052269	$0	$0
30	APR	DE-MOB					1.048447	$0	$0
31	MAY	Till, DP, WO				$3,750,000	1.044638	$0	$3,917,393
32	JUN			$2,523,000		$3,750,000	1.040843	$2,626,048	$3,903,162
33	JUL			$2,523,000	75% REC	$3,750,000	1.037062	$2,616,508	$3,888,984
34	AUG		75% HSDR	$2,523,000	Benefits	$3,750,000	1.033295	$2,607,004	$3,874,857
35	SEP		Benefits	$2,523,000			1.029542	$2,597,533	$0
36	OCT			$2,523,000			1.025802	$2,588,098	$0
37	NOV	MOB					1.022075	$0	$0
38	DEC	Dredge					1.018363	$0	$0
39	JAN						1.014663	$0	$0
40	FEB						1.010977	$0	$0
41	MAR						1.007305	$0	$0
42	APR	DE-MOB					1.003646	$0	$0
43	MAY	Till, DP, WO	BASE YEAR BENEFITS 100 percent HSDR Benefits	$0	BASE Year 100 percent Recreation Benefits		1.000000	$0	$0
						Accumulated	PV	$26,854,859	$32,106,684
						4-1/8%	I&A - 50yrs	0.047551	0.047551
						Ave Ann Benefits		**$1,276,975**	**$1,526,705**
						During Construction		**$1,277,000**	**$1,527,000**

7.02.4 Recreation Benefits

Recreation benefits are based on the incremental change in demand with varying project conditions. Positive benefits derived from increased recreation visitation or improved recreation experience. The average annual equivalent recreation benefits for the NED plan were computed to be $12.7 million for Surf City and $7.9 million for North Topsail Beach for a total of $20.5 million. The recreation benefit analysis is presented in Appendix – O.

7.02.5 Commercial and Recreational Fishing Impacts:

The economic impacts of the NED plan or other nourishment plans on commercial and recreational fishing during construction are not expected to be significant. Impacts on shore fishing would be limited to the area where material is being placed on the beach. This localized and temporary impact can easily be avoided by anglers in the area. Nearshore fishing boats can operate around the dredging equipment operating in the area. The beach nourishment plan is not expected to impact inside fishing or the operation of commercial fishing boats operating inside or going through New Topsail Inlet. Unless there is extreme weather, the ocean going dredge will operate continuously. Therefore, the economic impact of commercial and recreational fishing is not expected to change with the project construction.

7.02.6 Summary of Benefits to NED Plan

A summary of the coastal storm damage reduction benefits, and recreation benefits is shown in Table B-14. Benefits during construction were computed primarily because the plan is expected to be constructed during three and one-half dredging windows and each increment would be completed prior to hurricane and peak recreation season.

Table B-14 - Summary of Benefits to NED Plan

Benefit Category	Average Annual Amount in Dollars
Hurricane & Storm Damage Reduction	$16.820,000
Reduced Emergency Costs	None claimed
Benefits during Construction	$2,804,000
Recreation (Appendix O)	$20,505,000
Total Average Annual NED Benefits	$40,129,000

7.03 Project Costs for NED Plan

Project first costs include the cost of construction, mobilization and demobilization, real estate, planning and engineering studies, supervision and administration, and interest during the four environmental dredging windows and construction period.

Determination of the economic costs of the plan consists of four basic steps. First, project First Costs are computed. First Costs include expenditures for project design and initial construction and related costs of supervision and administration. First Costs also include the lands, easements, and rights of way for initial project construction and periodic nourishment.

7.03.1 First Costs

Total First Costs are estimated to be $123,135,000 as presented in Appendix N Cost Engineering.

Table B-15 – Summary of Expenditures During Construction

PERIODS	MONTH	Activity	MOB	DE-MOB	Dredge	Real Estate	T, DP, WO	PED	Const Mgt	Total
1	NOV	MOB	$1,149,500					$109,571	$68,179	$1,327,250
2	DEC	Dredge			$6,208,938	$326,750		$109,571	$68,179	$6,713,438
3	JAN				$6,208,938	$326,750		$109,571	$68,179	$6,713,438
4	FEB				$6,208,938	$326,750		$109,571	$68,179	$6,713,438
5	MAR				$6,208,938	$326,750		$109,571	$68,179	$6,713,438
6	APR	DE-MOB		$1,149,500			$548,875	$109,571	$68,179	$1,876,125
7	MAY	Till, DP, WO					$548,875	$109,571	$68,179	$726,625
8	JUN									$0
9	JUL									$0
10	AUG									$0
11	SEP									$0
12	OCT									$0
13	NOV	MOB	$1,149,500					$109,571	$68,179	$1,327,250
14	DEC	Dredge			$6,208,938	$326,750		$109,571	$68,179	$6,713,438
15	JAN				$6,208,938	$326,750		$109,571	$68,179	$6,713,438
16	FEB				$6,208,938	$326,750		$109,571	$68,179	$6,713,438
17	MAR				$6,208,938	$326,750		$109,571	$68,179	$6,713,438
18	APR	DE-MOB		$1,149,500			$548,875	$109,571	$68,179	$1,876,125
19	MAY	Till, DP, WO					$548,875	$109,571	$68,179	$726,625
20	JUN									$0
21	JUL									$0
22	AUG									$0
23	SEP									$0
24	OCT									$0
25	NOV	MOB	$1,149,500					$109,571	$68,179	$1,327,250
26	DEC	Dredge			$6,208,938	$326,750		$109,571	$68,179	$6,713,438
27	JAN				$6,208,938	$326,750		$109,571	$68,179	$6,713,438
28	FEB				$6,208,938	$326,750		$109,571	$68,179	$6,713,438
29	MAR				$6,208,938	$326,750		$109,571	$68,179	$6,713,438
30	APR	DE-MOB		$1,149,500			$548,875	$109,571	$68,179	$1,876,125
31	MAY	Till, DP, WO					$548,875	$109,571	$68,179	$726,625
32	JUN									$0
33	JUL									$0
34	AUG									$0
35	SEP									$0
36	OCT									$0
37	NOV	MOB	$1,149,500					$109,571	$68,179	$1,327,250
38	DEC	Dredge			$6,208,938	$326,750		$109,571	$68,179	$6,713,438
39	JAN				$6,208,938	$326,750		$109,571	$68,179	$6,713,438
40	FEB				$6,208,938	$326,750		$109,571	$68,179	$6,713,438
41	MAR				$6,208,938	$326,750		$109,571	$68,179	$6,713,438
42	APR	DE-MOB		$1,149,500			$548,875	$109,571	$68,179	$1,876,125
43	MAY	Till, DP, WO					$548,875	$109,571	$68,179	$726,625
										$0
										$0
										$0
										$0
			$4,598,000	$4,598,000	$99,343,000	$5,228,000	$4,391,000	$3,068,000	$1,909,000	$123,135,000

7.03.2 Interest During Construction

Interest during construction accounts for the opportunity cost of capital incurred during the construction period. The cost of the project to be amortized is the investment incurred up to the time that the project begins to produce benefits, or the time when it is placed in operation. The investment cost at that time is the sum of construction and other initial costs plus interest during construction. Costs incurred during the construction period should be increased by adding compound interest at the applicable project discount rate from the date the expenditures are made to the beginning of the period of analysis (base year). The addition of interest during construction insures that costs and benefits are evaluated on an equivalent time basis (ER 1105-2-100, Appendix D).

Construction could begin in December 2014 and be completed on or before 30 April 2018. The interest on expenditures prior to the completion of the plan will be calculated at 4—1/8 percent interest. The expenditures by month, the cost of construction plus interest, and the net interest during construction (IDC) is shown in Table B-14 and Figure B-21.

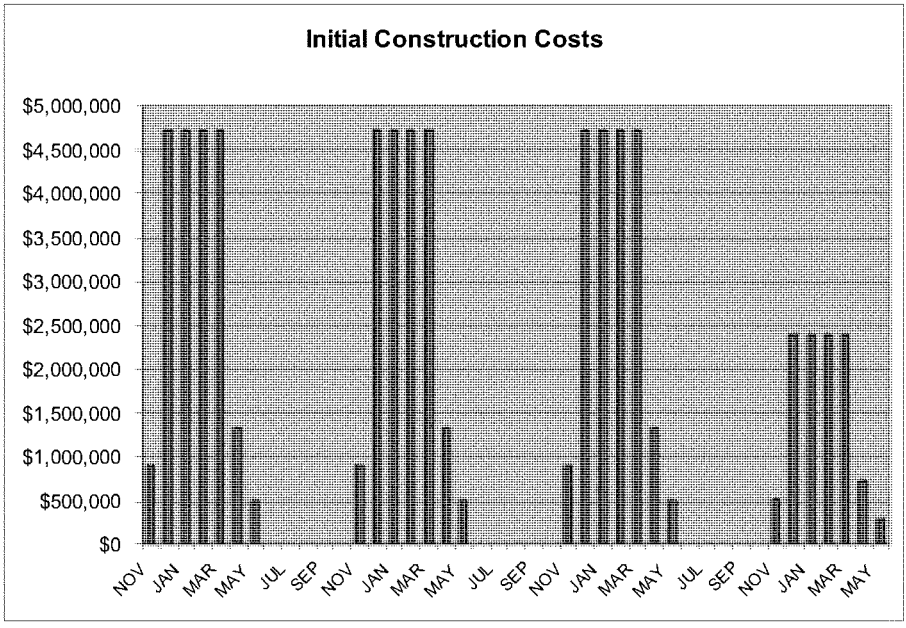


Figure B-21 - Distribution of Initial Construction Costs

Table B-16 Calculation of Interest during Construction for NED Plan

	IDC=		$9,512,574
PERIODS	MONTHS	Expenditures	PW AMT.
1	1.155031276	$1,327,250	$1,533,015
2	1.151074458	$6,713,438	$7,727,666
3	1.147131194	$6,713,438	$7,701,194
4	1.143201439	$6,713,438	$7,674,811
5	1.139285147	$6,713,438	$7,648,520
6	1.13538227	$1,876,125	$2,130,119
7	1.131492764	$726,625	$822,171
8	1.127616582	$0	$0
9	1.123753679	$0	$0
10	1.119904009	$0	$0
11	1.116067526	$0	$0
12	1.112244187	$0	$0
13	1.108433945	$1,327,250	$1,471,169
14	1.104636756	$6,713,438	$7,415,910
15	1.100852576	$6,713,438	$7,390,505
16	1.097081359	$6,713,438	$7,365,187
17	1.093323061	$6,713,438	$7,339,956
18	1.089577637	$1,876,125	$2,044,184
19	1.085845045	$726,625	$789,002
20	1.08212524	$0	$0
21	1.078418177	$0	$0
22	1.074723814	$0	$0
23	1.071042107	$0	$0
24	1.067373012	$0	$0
25	1.063716487	$1,327,250	$1,411,818
26	1.060072487	$6,713,438	$7,116,730
27	1.056440972	$6,713,438	$7,092,350
28	1.052821896	$6,713,438	$7,068,054
29	1.049215219	$6,713,438	$7,043,841
30	1.045620897	$1,876,125	$1,961,716
31	1.042038888	$726,625	$757,172
32	1.038469151	$0	$0
33	1.034911642	$0	$0
34	1.03136632	$0	$0
35	1.027833144	$0	$0
36	1.024312071	$0	$0
37	1.020803061	$1,327,250	$1,354,861
38	1.017306071	$6,713,438	$6,829,621
39	1.013821061	$6,713,438	$6,806,224
40	1.01034799	$6,713,438	$6,782,908
41	1.006886816	$6,713,438	$6,759,672
42	1.0034375	$1,876,125	$1,882,574
43	1	$726,625	$726,625
	Totals	$123,135,000	$132,647,574
		IDC	$9,512,574
		rounded	$9,513,000

7.03.3 Total Investment Cost

The total investment cost of the NED plan is equal to the initial construction plus interest during construction. Therefore, total investment cost is equal to $132,648,000 as shown in Table B-16. The cost of future nourishment is shown separately.

7.03.4 Present Value of Future Nourishment Costs

The accumulated present value of all nourishment cost is calculated by discounting all cash flows in future years back to the base year 2018 at the appropriate interest rate. The accumulated present worth of all future nourishment is $80,696,000 as shown in Table B-18.

Table B-17 Project Annual Costs – Plan 1550 NED (October 2010 price levels)

interest rate =	4.125%	years of analysis =	50
ITEM	**YEAR**	**AMOUNT**	**PRESENT VALUE, 2014**
Total Investment Cost	2014	$132,648,000	$132,648,000
Renourishment	2020	$20,866,000	$16,372,000
Renourishment	2026	$27,724,000	$17,069,000
Renourishment	2032	$27,724,000	$13,393,000
Renourishment	2038	$27,724,000	$10,508,000
Renourishment	2044	$27,724,000	$8,245,000
Renourishment	2050	$27,724,000	$6,470,000
Renourishment	2056	$46,053,000	$8,639,000
Total Investment Cost, Present Value			$213,344,000
Annual Costs			
Interest & Amortization @ 4-1/8%			$10,145,000
Monitoring			$505,000
OMRR&R			$52,000
Total Annual Cost			$10,702,000
Cost level	Oct-10		

7.04 Average Annual Project Costs for NED Plan

Average annual project costs are comprised of the interest and amortization of both the total investment (including interest during construction) and total accumulated present worth of the future nourishment. In addition to interest and amortization (I&A), annual costs include the operation and maintenance and the required annual monitoring cost.

7.04.1 I&A of Total Investment

Total investment is converted to an average annual equivalent value by amortizing the investment over the 50-year period of analysis. The 50-year interest and amortization (I&A) factor at 4 – 1/8 percent is 0.047551. The annual interest and amortization of the total investment is $6,308,000 as shown in Table B-18.

7.04.2 Annual OMRR&R

The non-Federal average annual repair cost refers to the sponsor's expense of repairing the berm, replacing any destroyed beach access walkways following storms, and replanting and fertilizing dune vegetation as necessary. The annual cost of operation and maintenance is estimated to be $52,000.

7.04.3 Annual Monitoring

Monitoring is an additional annual cost that is estimated to be $505,000.

7.04.4 I&A of Future Nourishment

The accumulated present value of future nourishment is converted to an average annual equivalent value by amortizing the present value over the 50-year period of analysis. The 50-year interest and amortization (I&A) factor at 4 – 1/8 percent is 0.047551. The annual interest and amortization of the future nourishment is $3,837,000 as shown in Table B-18.

Table B- 18 - Summary of Initial Construction & Annual Costs - NED Plan

Cost Elements	Cost in Dollars – October 2010 price level
Initial Construction	$123,135,000 (reference Appendix N)
Interest during Construction	$ 9,513,000 (Table B-14)
Total Investment Cost	$132,648,000
Interest & Amortization 50yr, 4-1/8%	$6,308,000
Present Value Future Nourishment	$80,696,000
Interest & Amortization 50yr, 4-1/8%	$3,837,000
Annual Monitoring Costs	$505,000
Annual OMRR&R	$52,000
PV Initial and Future Construction	$213,344,000 (Table B-17)
Total Average Annual Cost	**$10,702,000**

7.05 Benefit/Cost Comparison for NED Plan

The Plan 1550 beachfill is expected to decrease the estimated annual expected coastal storm damages from $19,061,000 to $2,241,000. The difference of $16,820,000 is the Plan 1550 storm damage reduction benefits. The annual recreation benefits are estimated to be $20,505,000. Benefits during construction are $59,000,000 with an annual equivalent of $2,804,000. Total annual benefits summarized in Table B-19 are $40,129,000. The damage totals in Table B-19 are based on the selection of the highest of the three damage estimates added to the coastal storm damage total and the remaining two estimates are ignored to ensure no double counting of damages or benefits. The negative amount computed for flood in Table B-19 results from flood inundation damages to structures that were assumed to be destroyed by waves in the without-project condition This multi-step process ensures that damage and benefits are not overstated in the estimates and in no way should be interpreted that the with-project condition is inducing damages in one damage category.

Table B-19 Project Annual Benefits – Plan 1550 NED (October 2010 price levels)

Benefit Category	Expected Annual Benefit
Coastal Storm Damage Reduction	
Storm Erosion	$14,352,000
Flood*	($98,000)
Wave	$404,000
Land and Long Term Erosion	$2,162,000
Subtotal, rounded	$16,820,000
Recreation	$20,505,000
Sub Total Annualized Benefits	$37,325,000
Benefits During Construction, Annual Equivalent	$2,804,000
Total Annual Benefits	**$40,129,000**

* Note: Benefit reported as negative due to change in damage category.

Total average annual equivalent benefits to the NED plan equal $40,129,000 including recreation benefits. When compared to the average annual cost of $10,702,000, the net benefits over cost equals $29,427,000. The benefit-to-cost ratio is 3.7 to 1.0 as shown in Table B-20.

Table B-20 Annual Benefits, Costs, and Benefit-Cost Ratio – NED Plan

NED Plan	Benefits[1]	Costs	Net Benefits	Benefit/Cost Ratio
1550	$40,129,000	$10,702,000	$29,427,000	3.7

8.0. REGIONAL ECONOMIC DEVELOPMENT (RED) IMPACTS

The following regional economic impacts will be addressed based on the interest of the local sponsor and the surrounding Pender and Onslow counties. Local governments seek to preserve the tax base and encourage the growth in overall property values, to create stability in the labor force and the employment of the labor force. The steady growth of the local community and surrounding region is considered a worthy goal by the state and local governments. Displacement of people, businesses and farms in the study area is not a desirable outcome that sometimes may result from either continued storm damages or even some types of construction.

[1] Coastal storm damage reduction benefits plus recreation benefits.

8.01 Preserve Tax Base and Property Values

Real property, including land and structures, in the town of Surf City and North Topsail Beach is subject to property tax by Pender County or Onslow County and the town. The tax base and property values will be preserved with implementation of a coastal storm damage reduction plan. Land loss and long-term erosion eventually renders lots unbuildable with a significantly lower economic value. Typically, the tax valuation of the ocean front lots is severely reduced to reflect the diminished utility of the land. Lower tax valuations may result in lower county and town tax revenues unless there is offsetting development in other areas.

8.02 Employment Stability

Tourism is highly valued as a source of employment and income. Employment related to recreation can be less than ideal because of the seasonal nature of recreation and tourism. Increased recreation visitation may improve the income of service industries in the two-county study area. It is unlikely that employment will be significantly impacted with or without storm damage reduction measures. Gains or losses in income or employment are considered regional impacts.

8.03 Community and Regional Growth

Implementation of effective damage reduction measures will ensure that the current growth trends in population and recreation visitation will continue. Protection of the streets and highways in the study area preserve community cohesion and encourage the tourism industry on the island, including the towns of Surf City and North Topsail Beach.

8.04 Displacement of People, Businesses, and Farms

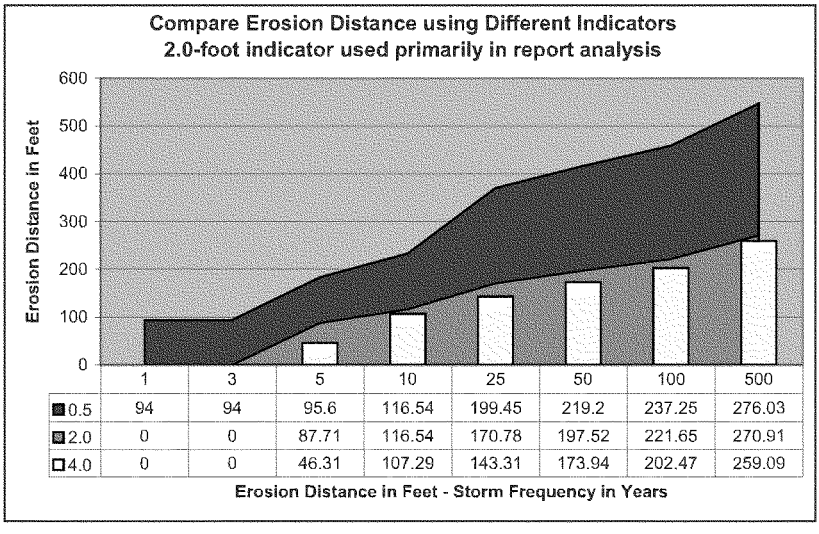
Implementation of damage reduction measures under consideration is not expected to displace people, businesses, or farms.

9.0 UNCERTAINTY AND SENSITIVITY OF ANALYSIS TO VARIATION OF VALUES AND ASSUMPTIONS

9.01 Coastal Storm Damage Reduction

9.01.1 Erosion indicators (Topsail Beach example)

In order to illustrate the effect of using different erosion indicators, the results of the Topsail Beach NED plan is shown in Figure B-22 and Table B-21 for the Topsail Beach NED plan. Analyses prior to Topsail Beach used the 0.5-foot indicator exclusively. The storm erosion damages presented in this report are based on using the 2.0-foot erosion indicator for 98.5 percent of the structures. The 0.5-foot indicator was used to estimate storm erosion damages to streets, highway, and structures built on concrete slab foundations. The 2.0-foot erosion indicator was used for 597 structures including the 34 commercial structures. Support for this assumption was found in "Erosion Damage Thresholds in North Carolina" (Attachment B-4, pages 12-13) by Spencer Rogers, dated 21 April 2002. An erosion threshold of 2 feet or less may generate more realistic damage estimates than using an erosion threshold of 4 feet when using the SBEACH model. The 0.5-foot erosion indicator was used for 6 single-story homes built on slab foundations, 3 two-story homes built on slabs, and the 27 street segments. Likewise, Surf City and North Topsail Beach used the 2.0 foot indicator in virtually all cases except for structures built on concrete slabs.



	1	3	5	10	25	50	100	500
0.5	94	94	95.6	116.54	199.45	219.2	237.25	276.03
2.0	0	0	87.71	116.54	170.78	197.52	221.65	270.91
4.0	0	0	46.31	107.29	143.31	173.94	202.47	259.09

Figure B-22 – Compare Erosion Distance using Different Indicators

Table B- 21 – Sensitivity Analysis - Erosion Indicators

	HSDR benefits	Erosion	Flood	Wave	Land	Costs	B/C Ratio
Base Totals	$ 135,347,131	$ 113,186,049	$ 2,282,826	$ 5,214,450	$ 14,663,809	$ -	N/A
Base_4ft_sel	$ 130,866,658	$ 110,113,473	$ 2,129,122	$ 5,203,235	$ 13,420,826	$ -	N/A
Percentage change	3.31%	2.71%	6.73%	0.22%	8.48%	#DIV/0!	
Base_4ft_all	$ 116,875,279	$ 95,403,732	$ 2,240,801	$ 5,910,281	$ 13,320,463	$ -	N/A
Percentage change	13.65%	15.71%	1.84%	-13.34%	9.16%	#DIV/0!	
RemD1550 Totals	$ 13,226,516	$ 7,351,470	$ 3,555,428	$ 2,316,568	$ 3,045	$ 55,892,000	N/A
RemD1550_4ft_sel	$ 12,832,179	$ 7,130,600	$ 3,367,687	$ 2,330,848	$ 3,045	$ 55,892,000	N/A
Percentage change	2.98%	3.00%	5.28%	-0.62%	0.00%	0.00%	
RemD1550_4ft_all	$ 10,798,196	$ 4,810,061	$ 3,450,991	$ 2,534,156	$ 2,990	$ 55,892,000	N/A
Percentage change	18.36%	34.57%	2.94%	-9.39%	1.81%	0.00%	
Benefits1550 Totals	$ 122,120,615	$ 105,834,579	$ (1,272,602)	$ 2,897,882	$ 14,660,764	$ (55,892,000)	2.18
Benefits1550_4ft_sel	$ 118,034,479	$ 102,982,873	$ (1,238,566)	$ 2,872,387	$ 13,417,781	$ (55,892,000)	2.11
Percentage change	3.35%	2.69%	2.67%	0.88%	8.48%	0.00%	
Benefits1550_4ft_all	$ 106,077,083	$ 90,593,671	$ (1,210,190)	$ 3,376,125	$ 13,317,473	$ (55,892,000)	1.90
Percentage change	13.14%	14.40%	4.90%	-16.50%	9.16%	0.00%	

Estimates presented in GRR (2.0 ft indicator with a few 0.5-ft indicators for slab const. and roads)
Assume 4ft erosion indicator for selected structures (1st row post-1986 construction)
Assume 4ft erosion indicator for ALL structures

9.01.2 Erosion Damage Curves

Erosion Damage curves, erosion distance, structure distance, and the erosion damage indicator combine to produce estimates of storm damage erosion. The risk and uncertainty of several parameters is addressed in the GRANDUC modeling procedures and included in Appendix D.

9.02 Exclude Recreation Benefits

When the $22,032,000 average annual recreation benefits are excluded, the benefit to cost ratio is reduced. In this case, the benefits to coastal storm damage reduction are $18,097,000 annually. Based on the average annual costs of $10,702,000, the remaining benefits would be $7,395,000 resulting in a BCR of 1.7 to 1.

9.03 Interest Rate

In compliance with Executive Order 12893, all benefits and costs were computed using a 7.0 percent interest rate for comparison in the final report. When the average annual benefits to the NED plan at 7 percent are compared to the 4.125 percent total average annual benefits increased very slightly to $41,669,000 or less than 2 percent. Average annual costs increased to $14,227,000, resulting in net benefits of $27,442,000 and a benefit-to-cost ratio of 2.9 counting all NED benefits. The BCR at 4.125 percent was 3.7 to 1.

9.04 Land Values

Interior land values were based on actual sales data over a three-year period; however, recent market fluctuations raise the question of how sensitive the economic justification of the NED plan is to rising or falling land values. If the interior land values at Wrightsville Beach, a beach 30 miles south of the study area, were used the BCR for the plan would rise to 3.0 to 1 for CSDR benefits alone and up to 5.0 to 1 with all benefits including recreation. On the other hand, if land values dropped to $20.00 per square foot the result would be to lower the BCR to 1.2 to 1 for CSDR benefits alone and 3.4 to 1 including recreation benefits. The probability of values rising is greater than falling beyond the present market conditions.

Structure Type	Building inventory codes	Old Code	Flood Curve Type	Content value factor
COMMERCIAL				
Apartments		001	5	1.4
Appliances		002	6	1.75
Auto Dealership		003	7	1.18
Auto Junk Yard		004	8	6
Auto Parts		005	9	3.33
Bait Stand		006	10	1.67
Bank		007	11	1.39
Barber Shop		008	12	1.118
Beauty Shop		009	46	1.375
Boat Stalls		010	13	2
Book Store		011	14	2.68
Bowling Alley		012	15	1.515
Business, Pole Shed (farm), Garage, Frame Tobacco Barn		013,071, 011A,076	16	2.664,1.5,1.4,1.9
Church		014	17	1.47
Cleaners		015	18	2.385
Cleaners-sub		016	47	3.176
Clinic-medical		017	19	2.5
Clothing		018	50	3.575
Dentist Office		019	51	2.647
Depart.Store		020	20	2.765
Doctor's Office		021	21	1.845
Drug, Super		022	48	2.533
Funeral Home		023	22	1.176
Furniture		024	23	1.946
Garage, Stable, Animal Barn		025,077	24	1.606,1.4
Hall, Organiz, Pool House		026	25	1.176
Hardware		027	26	3.5
Hotel		028	27	2.724
Jewelry, Greenhouse		029,012A	28	8.5, 1.2
Laundry		030	29	2
Liquor		031	30	1.52
Lumber		032	31	2.198
Market, Super, Poultry Houses		033,078	32	2.7,2.8
Market, Drive		034	49	1.923
Motel		035	33	1.5
Newspaper		036	34	3.125
Office Bldg.		037	35	1.588

Structure Type	Building inventory codes	Old Code	Flood Curve Type	Content value factor
Post Office, Fertilizer Tank, Swimming Pool, Tennis Courts		038,075, 013A,014A	36	1.176,1.4,1.15,0
Private Club		039	37	1.32
Restaurant		040	38	2.66
Rest Home		041	39	2
School		042	40	1.294
Service Station		043	41	1.524
Theater		044	42	1.796
Theater, Drive In		045	52	1.376
TV Station		046	43	1.699
Tavern		047	44	1.416
Variety Store, Pierhouse		048	53	2.67
Wash-a-teria (bathhouse)		049	54	2.235
Warehouse, Storage Building (farm&res), Bulk Tobacco Barn (farm)		050,072, 010A,074	45	3.47,1.5,1.5,1.5
Grain Bin		073	65	3.5
RESIDENTIAL				
Res type 1A	1NNN		1	*
Res type 2A	1NF, 2NNN, 2NF, 3PF, 3NN		2	*
Res type 3A			3	*
Res type 4A			4	*
Res type 1H	1PN		55	*
Res type 2H	2PN, 3PN		56	*
Res type 4H&3H			57	*
Res type 1B			58	*
Res type 1HL	1PF, 1PP, 1PS		59	*
Res type 2HL	2PF, 2PP, 2PS, 3PP, 3PS		60	*
Res type 4HL			61	*
5A Mobile Homes			62	*
Upper floors			63	*
Highways			64	

Key to GRANDUC Residential
and
Highway Structure Types
plus Condos upper floors & Highways

Structure Types - Coastal Residential

Enter Type in Col. 9 of Structure File

Enter GRANDUC Flood Types for Flood Curve Types		Description	Acceptable Floor Elevations
1	⇨	**One story**	0-6 feet
58	⇨	**One story with Basement**	0-9 feet
55	⇨	**One story High-raised**	4-15 feet
59	⇨	**One story High-raised with 1/2 living area below**	0-6 feet
2	⇨	**Two story (essentially 2 full stories)**	0-6 feet
n/a		Two story with Basement	0-9 feet
56	⇨	**Two story High-raised**	4-15 feet
60	⇨	**Two story High-raised with 1/2 living area below**	0-6 feet
3	⇨	**Split level - All space in living area**	0
n/a		Split level - Garage on lowest level	0
n/a		Split level - 1/2 garage 1/2 living area on lowest level	0-4 feet
4	⇨	**1 1/2 story**	0-6 feet
n/a		1 1/2 story with Basement	0-9 feet
57	⇨	**1 1/2 story High-raised**	4-15 feet
61	⇨	**1 1/2 story High-raised with 1/2 living area below**	0-6 feet
62	⇨	**Mobile Home**	0-6 feet
63	⇨	**Residential Condos - upper floors**	
64	⇨	**Highways**	

All residential structures have a set content percentage of 30 %, 40 %, or 50 %.

FLOOD DAMAGE CURVES BY TYPE OF STRUCTURE

Flood Type 1

Inundation in feet	Structure Damage	Inundation in feet	Content Damage
-24	0	-24	0
-7	0	-1	0
-6	0.005	0	0.112
-1	0.01	1	0.24
0	0.093	2	0.364
1	0.136	3	0.429
2	0.233	4	0.46
5	0.361	5	0.52
10	0.523	10	0.865
15	0.725	15	0.955
16	0.8	16	1
20	0.85	17	1
24	0.85	24	1

Flood Type 2

Inundation in feet	Structure Damage	Inundation in feet	Content Damage
-24	0	-24	0
-7	0	-7	0
-6	0.003	-1	0
-1	0.006	0	0.073
0	0.07	1	0.178
1	0.091	2	0.259
2	0.145	3	0.303
5	0.25	4	0.4
10	0.36	5	0.5
15	0.54	10	0.58
16	0.57	15	0.82
20	0.675	16	0.86
24	0.765	17	1
		24	1

Flood Type 3

Inundation in feet	Structure Damage	Inundation in feet	Content Damage
-24	0	-24	0
-7	0	-1	0
-6	0	0	0.034
-1	0	1	0.153
0	0.028	2	0.213
1	0.048	3	0.253
2	0.07	4	0.32
5	0.202	5	0.44
10	0.43	10	0.716
15	0.618	15	0.907
16	0.666	16	0.936
20	0.776	17	0.943
24	0.84	24	1

Flood Type 4

Inundation in feet	Structure Damage	Inundation in feet	Content Damage
-24	0	-24	0
-7	0	-1	0
-6	0.004	0	0.093
-1	0.007	1	0.21
0	0.079	2	0.312
1	0.109	3	0.366
2	0.18	4	0.43
5	0.29	5	0.51
10	0.42	10	0.8
15	0.5	15	0.87
16	0.505	16	0.88
20	0.595	17	1
24	0.75	24	1

Flood Type 5

Inundation in feet	Structure Damage
-24	0
-1	0
0	0.15
1	0.195
2	0.212
3	0.23
4	0.254
5	0.289
6	0.318
7	0.346
9	0.42
11	0.505
13	0.58
14	0.61
24	1

Inundation in feet	Content Damage
-24	0
0	0
24	0.0001

Flood Type 6

Inundation in feet	Structure Damage
-24	0
-1	0
0	0.05
1	0.14
2	0.23
3	0.315
4	0.38
5	0.44
6	0.505
7	0.56
9	0.63
10	0.655
12	0.71
14	0.75
24	1

Inundation in feet	Content Damage
-24	0
0	0
24	0.0001

Flood Type 7

Inundation in feet	Structure Damage
-24	0
-1	0
0	0.035
1	0.064
2	0.091
3	0.135
4	0.195
5	0.292
6	0.428
7	0.575
8	0.675
10	0.777
12	0.866
14	0.94
24	1

Inundation in feet	Content Damage
-24	0
0	0
24	0.0001

Flood Type 8

Inundation in feet	Structure Damage
-24	0
-1	0
0	0.07
1	0.14
2	0.21
3	0.26
4	0.279
5	0.28
6	0.289
8	0.309
9	0.32
10	0.33
12	0.349
14	0.38
24	1

Inundation in feet	Content Damage
-24	0
0	0
24	0.0001

Flood Type 9

Inundation in feet	Structure Damage
-24	0
-1	0
0	0.04
1	0.105
2	0.19
3	0.268
4	0.324
5	0.369
6	0.41
8	0.49
10	0.55
12	0.61
13	0.64
14	0.667
24	1

Inundation in feet	Content Damage
-24	0
0	0
24	0.0001

Flood Type 10

Inundation in feet	Structure Damage
-24	0
-1	0
0	0.06
1	0.1
2	0.124
3	0.16
4	0.232
5	0.37
6	0.54
7	0.74
8	0.832
10	0.9
12	0.93
14	0.936
24	1

Inundation in feet	Content Damage
-24	0
0	0
24	0.0001

Flood Type 11

Inundation in feet	Structure Damage
-24	0
-1	0
0	0.01
1	0.05
2	0.132
3	0.21
4	0.23
5	0.242
6	0.26
7	0.278
8	0.3
10	0.35
12	0.394
14	0.45
24	1

Inundation in feet	Content Damage
-24	0
0	0
24	0.0001

Flood Type 12

Inundation in feet	Structure Damage
-24	0
-1	0
0	0.04
1	0.07
2	0.146
3	0.245
4	0.311
5	0.385
6	0.45
7	0.52
8	0.571
10	0.667
12	0.748
14	0.819
24	1

Inundation in feet	Content Damage
-24	0
0	0
24	0.0001

Flood Type 13

Inundation in feet	Structure Damage
-24	0
-1	0
0	0.05
1	0.09
2	0.13
3	0.17
4	0.21
5	0.26
6	0.32
7	0.37
8	0.425
10	0.521
12	0.6
14	0.655
24	1

Inundation in feet	Content Damage
-24	0
0	0
24	0.0001

Flood Type 14

Inundation in feet	Structure Damage
-24	0
-1	0
0	0.09
1	0.17
2	0.235
3	0.294
4	0.36
5	0.483
6	0.61
7	0.752
8	0.837
10	0.871
12	0.91
14	0.92
24	1

Inundation in feet	Content Damage
-24	0
0	0
24	0.0001

Flood Type 15

Inundation in feet	Structure Damage
-24	0
-1	0
0	0.24
1	0.3
2	0.327
3	0.35
4	0.393
5	0.461
6	0.549
7	0.62
8	0.681
10	0.752
12	0.809
14	0.851
24	1

Inundation in feet	Content Damage
-24	0
0	0
24	0.0001

Flood Type 16

Inundation in feet	Structure Damage
-24	0
-1	0
0	0.037
1	0.085
2	0.152
3	0.216
4	0.269
5	0.345
6	0.444
7	0.548
8	0.641
10	0.768
12	0.87
14	0.945
24	1

Inundation in feet	Content Damage
-24	0
0	0
24	0.0001

Flood Type 17

Inundation in feet	Structure Damage
-24	0
-1	0
0	0.12
1	0.165
2	0.19
3	0.218
4	0.248
5	0.28
6	0.32
7	0.37
8	0.425
10	0.529
12	0.63
14	0.73
24	1

Inundation in feet	Content Damage
-24	0
0	0
24	0.0001

Flood Type 18

Inundation in feet	Structure Damage
-24	0
-1	0
0	0.05
1	0.11
2	0.19
3	0.27
4	0.39
5	0.52
6	0.68
7	0.841
8	0.954
10	0.98
12	0.982
14	0.985
24	1

Inundation in feet	Content Damage
-24	0
0	0
24	0.0001

Flood Type 19

Inundation in feet	Structure Damage
-24	0
-1	0
0	0.07
1	0.161
2	0.272
3	0.37
4	0.415
5	0.466
6	0.49
7	0.52
8	0.549
10	0.592
12	0.635
14	0.68
24	1

Inundation in feet	Content Damage
-24	0
0	0
24	0.0001

Flood Type 20

Inundation in feet	Structure Damage
-24	0
-1	0
0	0.15
1	0.201
2	0.286
3	0.366
4	0.435
5	0.495
6	0.552
7	0.615
8	0.666
10	0.751
12	0.84
14	0.973
24	1

Inundation in feet	Content Damage
-24	0
0	0
24	0.0001

Flood Type 21

Inundation in feet	Structure Damage
-24	0
-1	0
0	0.02
1	0.07
2	0.168
3	0.26
4	0.34
5	0.43
6	0.51
7	0.58
8	0.645
10	0.77
12	0.859
14	0.95
24	1

Inundation in feet	Content Damage
-24	0
0	0
24	0.0001

Flood Type 22

Inundation in feet	Structure Damage
-24	0
-1	0
0	0.17
1	0.245
2	0.31
3	0.38
4	0.465
5	0.545
6	0.625
7	0.705
8	0.775
10	0.841
12	0.876
14	0.915
24	1

Inundation in feet	Content Damage
-24	0
0	0
24	0.0001

Flood Type 23

Inundation in feet	Structure Damage
-24	0
-1	0
0	0.147
1	0.251
2	0.341
3	0.4
4	0.442
5	0.472
6	0.497
7	0.524
8	0.554
10	0.622
12	0.679
14	0.739
24	1

Inundation in feet	Content Damage
-24	0
0	0
24	0.0001

Flood Type 24

Inundation in feet	Structure Damage
-24	0
-1	0
0	0.03
1	0.072
2	0.121
3	0.168
4	0.202
5	0.241
6	0.28
7	0.32
8	0.365
10	0.458
12	0.545
14	0.636
24	1

Inundation in feet	Content Damage
-24	0
0	0
24	0.0001

Flood Type 25

Inundation in feet	Structure Damage
-24	0
-1	0
0	0.015
1	0.033
2	0.06
3	0.105
4	0.178
5	0.233
6	0.3
7	0.36
8	0.43
10	0.568
12	0.695
14	0.821
24	1

Inundation in feet	Content Damage
-24	0
0	0
24	0.0001

Flood Type 26

Inundation in feet	Structure Damage
-24	0
-1	0
0	0.04
1	0.103
2	0.185
3	0.248
4	0.288
5	0.327
6	0.37
7	0.415
8	0.465
10	0.548
12	0.638
14	0.724
24	1

Inundation in feet	Content Damage
-24	0
0	0
24	0.0001

Flood Type 27

Inundation in feet	Structure Damage
-24	0
-1	0
0	0.11
1	0.21
2	0.3
3	0.37
4	0.42
5	0.465
6	0.51
7	0.56
8	0.61
10	0.7
12	0.79
14	0.88
24	1

Inundation in feet	Content Damage
-24	0
0	0
24	0.0001

Flood Type 28

Inundation in feet	Structure Damage
-24	0
-1	0
0	0.07
1	0.16
2	0.27
3	0.37
4	0.44
5	0.51
6	0.57
7	0.63
8	0.7
10	0.8
12	0.876
14	0.92
24	1

Inundation in feet	Content Damage
-24	0
0	0
24	0.0001

Flood Type 29

Inundation in feet	Structure Damage
-24	0
-1	0
0	0.05
1	0.12
2	0.204
3	0.29
4	0.37
5	0.45
6	0.52
7	0.598
8	0.65
10	0.732
12	0.816
14	0.899
24	1

Inundation in feet	Content Damage
-24	0
0	0
24	0.0001

Flood Type 30

Inundation in feet	Structure Damage
-24	0
-1	0
0	0.08
1	0.13
2	0.17
3	0.21
4	0.249
5	0.29
6	0.349
7	0.4
8	0.455
10	0.56
12	0.65
14	0.74
24	1

Inundation in feet	Content Damage
-24	0
0	0
24	0.0001

Flood Type 31

Inundation in feet	Structure Damage
-24	0
-1	0
0	0.03
1	0.058
2	0.081
3	0.13
4	0.2
5	0.28
6	0.35
7	0.42
8	0.498
10	0.637
12	0.78
14	0.92
24	1

Inundation in feet	Content Damage
-24	0
0	0
24	0.0001

Flood Type 32

Inundation in feet	Structure Damage
-24	0
-1	0
0	0.06
1	0.192
2	0.349
3	0.482
4	0.561
5	0.641
6	0.72
7	0.8
8	0.857
10	0.901
12	0.922
14	0.94
24	1

Inundation in feet	Content Damage
-24	0
0	0
24	0.0001

Flood Type 33

Inundation in feet	Structure Damage
-24	0
-1	0
0	0.1
1	0.164
2	0.21
3	0.28
4	0.363
5	0.455
6	0.54
7	0.63
8	0.7
10	0.749
12	0.79
14	0.829
24	1

Inundation in feet	Content Damage
-24	0
0	0
24	0.0001

Flood Type 34

Inundation in feet	Structure Damage
-24	0
-1	0
0	0.02
1	0.069
2	0.122
3	0.187
4	0.245
5	0.302
6	0.36
7	0.41
8	0.46
10	0.56
12	0.66
14	0.76
24	1

Inundation in feet	Content Damage
-24	0
0	0
24	0.0001

Flood Type 35

Inundation in feet	Structure Damage
-24	0
-1	0
0	0.26
1	0.349
2	0.41
3	0.48
4	0.545
5	0.604
6	0.66
7	0.714
8	0.763
10	0.825
12	0.879
14	0.932
24	1

Inundation in feet	Content Damage
-24	0
0	0
24	0.0001

Flood Type 36

Inundation in feet	Structure Damage
-24	0
-1	0
0	0.05
1	0.08
2	0.095
3	0.103
4	0.113
5	0.125
6	0.135
7	0.145
8	0.158
10	0.181
12	0.21
14	0.239
24	1

Inundation in feet	Content Damage
-24	0
0	0
24	0.0001

Flood Type 37

Inundation in feet	Structure Damage
-24	0
-1	0
0	0.06
1	0.185
2	0.334
3	0.44
4	0.485
5	0.53
6	0.57
7	0.61
8	0.66
10	0.741
12	0.825
14	0.905
24	1

Inundation in feet	Content Damage
-24	0
0	0
24	0.0001

Flood Type 38

Inundation in feet	Structure Damage
-24	0
-1	0
0	0.08
1	0.199
2	0.318
3	0.43
4	0.52
5	0.59
6	0.66
7	0.73
8	0.787
10	0.86
12	0.93
14	0.968
24	1

Inundation in feet	Content Damage
-24	0
0	0
24	0.0001

Flood Type 39

Inundation in feet	Structure Damage
-24	0
-1	0
0	0.12
1	0.205
2	0.27
3	0.34
4	0.413
5	0.49
6	0.55
7	0.62
8	0.68
10	0.78
12	0.88
14	0.975
24	1

Inundation in feet	Content Damage
-24	0
0	0
24	0.0001

Flood Type 40

Inundation in feet	Structure Damage
-24	0
-1	0
0	0.04
1	0.22
2	0.29
3	0.34
4	0.39
5	0.44
6	0.48
7	0.529
8	0.573
10	0.66
12	0.745
14	0.83
24	1

Inundation in feet	Content Damage
-24	0
0	0
24	0.0001

Flood Type 41

Inundation in feet	Structure Damage
-24	0
-1	0
0	0.065
1	0.128
2	0.205
3	0.278
4	0.327
5	0.374
6	0.42
7	0.47
8	0.517
10	0.614
12	0.705
14	0.802
24	1

Inundation in feet	Content Damage
-24	0
0	0
24	0.0001

Flood Type 42

Inundation in feet	Structure Damage
-24	0
-1	0
0	0.02
1	0.075
2	0.163
3	0.21
4	0.221
5	0.231
6	0.242
7	0.25
8	0.251
10	0.252
12	0.261
14	0.27
24	1

Inundation in feet	Content Damage
-24	0
0	0
24	0.0001

Flood Type 43

Inundation in feet	Structure Damage
-24	0
-1	0
0	0.03
1	0.06
2	0.085
3	0.11
4	0.14
5	0.17
6	0.2
7	0.231
8	0.27
10	0.338
12	0.405
14	0.47
24	1

Inundation in feet	Content Damage
-24	0
0	0
24	0.0001

Flood Type 44

Inundation in feet	Structure Damage
-24	0
-1	0
0	0.03
1	0.13
2	0.455
3	0.631
4	0.665
5	0.679
6	0.691
7	0.701
8	0.715
10	0.74
12	0.76
14	0.781
24	1

Inundation in feet	Content Damage
-24	0
0	0
24	0.0001

Flood Type 45

Inundation in feet	Structure Damage
-24	0
-1	0
0	0.04
1	0.12
2	0.23
3	0.336
4	0.43
5	0.51
6	0.59
7	0.68
8	0.741
10	0.801
12	0.86
14	0.905
24	1

Inundation in feet	Content Damage
-24	0
0	0
24	0.0001

Flood Type 46

Inundation in feet	Structure Damage
-24	0
-1	0
0	0.01
1	0.06
2	0.114
3	0.232
4	0.33
5	0.418
6	0.5
7	0.6
8	0.67
10	0.74
12	0.81
14	0.875
24	1

Inundation in feet	Content Damage
-24	0
0	0
24	0.0001

Flood Type 47

Inundation in feet	Structure Damage
-24	0
-1	0
0	0.04
1	0.059
2	0.07
3	0.101
4	0.22
5	0.39
6	0.56
7	0.75
8	0.88
10	0.925
12	0.941
14	0.961
24	1

Inundation in feet	Content Damage
-24	0
0	0
24	0.0001

Flood Type 48

Inundation in feet	Structure Damage
-24	0
-1	0
0	0.05
1	0.18
2	0.36
3	0.495
4	0.569
5	0.635
6	0.7
7	0.775
8	0.826
10	0.855
12	0.876
14	0.901
24	1

Inundation in feet	Content Damage
-24	0
0	0
24	0.0001

Flood Type 49

Inundation in feet	Structure Damage
-24	0
-1	0
0	0.02
1	0.14
2	0.255
3	0.375
4	0.495
5	0.6
6	0.708
7	0.828
8	0.911
10	0.97
12	0.98
14	0.995
24	1

Inundation in feet	Content Damage
-24	0
0	0
24	0.0001

Flood Type 50

Inundation in feet	Structure Damage
-24	0
-1	0
0	0.05
1	0.187
2	0.431
3	0.595
4	0.66
5	0.72
6	0.773
7	0.83
8	0.87
10	0.911
12	0.94
14	0.964
24	1

Inundation in feet	Content Damage
-24	0
0	0
24	0.0001

Flood Type 51

Inundation in feet	Structure Damage
-24	0
-1	0
0	0.02
1	0.05
2	0.091
3	0.155
4	0.245
5	0.358
6	0.5
7	0.662
8	0.781
10	0.84
12	0.865
14	0.891
24	1

Inundation in feet	Content Damage
-24	0
0	0
24	0.0001

Flood Type 52

Inundation in feet	Structure Damage
-24	0
-1	0
0	0.01
1	0.012
2	0.019
3	0.029
4	0.06
5	0.091
6	0.13
7	0.169
8	0.21
10	0.28
12	0.351
14	0.421
24	1

Inundation in feet	Content Damage
-24	0
0	0
24	0.0001

Flood Type 53

Inundation in feet	Structure Damage
-24	0
-1	0
0	0.045
1	0.106
2	0.179
3	0.244
4	0.295
5	0.345
6	0.392
7	0.433
8	0.48
10	0.572
12	0.66
14	0.745
24	1

Inundation in feet	Content Damage
-24	0
0	0
24	0.0001

Flood Type 54

Inundation in feet	Structure Damage
-24	0
-1	0
0	0.06
1	0.2
2	0.395
3	0.524
4	0.58
5	0.625
6	0.67
7	0.716
8	0.76
10	0.835
12	0.905
14	0.971
24	1

Inundation in feet	Content Damage
-24	0
0	0
24	0.0001

Flood Type 55

Inundation in feet	Structure Damage	Inundation in feet	Content Damage
-24	0	-24	0
-14	0.01	-14	0.007
-5	0.035	-13	0.008
-1	0.055	-6	0.06
0	0.093	-2	0.125
1	0.136	-1	0.13
2	0.233	0	0.14
3	0.36	1	0.26
4	0.39	2	0.38
5	0.455	3	0.52
10	0.536	4	0.635
15	0.735	5	0.78
16	0.8	10	0.945
20	0.85	14	1
24	1	24	1

Flood Type 56

Inundation in feet	Structure Damage	Inundation in feet	Content Damage
-24	0	-24	0
-14	0.006	-14	0.011
-6	0.025	-13	0.012
-2	0.033	-6	0.045
-1	0.035	-1	0.094
0	0.07	0	0.101
1	0.091	1	0.187
2	0.145	2	0.286
3	0.229	3	0.38
4	0.253	4	0.45
5	0.29	5	0.534
10	0.369	10	0.633
15	0.548	16	0.86
20	0.675	17	1
24	1	24	1

Flood Type 57

Inundation in feet	Structure Damage	Inundation in feet	Content Damage
-24	0	-24	0
-14	0.007	-14	0.001
-6	0.03	-6	0.04
-1	0.04	-2	0.082
0	0.079	0	0.093
1	0.109	1	0.21
2	0.186	2	0.312
3	0.28	3	0.43
4	0.302	4	0.54
5	0.336	5	0.673
10	0.431	10	0.81
15	0.503	14	0.86
16	0.505	16	0.88
20	0.595	17	1
24	1	24	1

Flood Type 58

Inundation in feet	Structure Damage	Inundation in feet	Content Damage
-24	0	-24	0
-7	0.01	-8	0.005
-2	0.05	-3	0.115
0	0.1	-2	0.125
1	0.14	-1	0.13
2	0.223	0	0.2
3	0.258	1	0.34
4	0.278	2	0.48
5	0.327	3	0.52
10	0.536	4	0.635
13	0.632	5	0.78
16	0.8	10	0.945
17	0.835	13	0.992
20	0.85	14	1
24	1	24	1

Flood Type 59

Inundation in feet	Structure Damage	Inundation in feet	Content Damage
-24	0	-24	0
-6	0.002	-1	0
0	0.007	0	0.021
1	0.035	1	0.112
2	0.055	2	0.157
7	0.165	3	0.198
8	0.2	4	0.243
9	0.208	5	0.282
10	0.317	7	0.322
11	0.421	8	0.377
12	0.452	10	0.542
16	0.61	12	0.717
17	0.625	13	0.82
20	0.677	17	0.952
24	1	24	1

Flood Type 60

Inundation in feet	Structure Damage	Inundation in feet	Content Damage
-24	0	-24	0
-6	0.001	-1	0
0	0.004	0	0.014
1	0.022	1	0.068
6	0.099	2	0.098
7	0.102	3	0.126
8	0.126	4	0.154
9	0.158	5	0.179
10	0.208	7	0.205
12	0.317	8	0.251
13	0.355	10	0.402
16	0.433	12	0.536
17	0.447	17	0.674
20	0.548	22	0.866
24	1	24	1

Flood Type 61

Inundation in feet	Structure Damage	Inundation in feet	Content Damage
-24	0	-24	0
-7	0	-1	0
-6	0.002	0	0.016
0	0.005	3	0.148
1	0.027	5	0.211
7	0.125	7	0.241
8	0.152	8	0.282
10	0.27	9	0.343
11	0.346	10	0.444
12	0.37	11	0.54
13	0.406	12	0.625
16	0.49	13	0.73
17	0.513	17	0.85
20	0.567	22	0.895
24	1	24	1

Flood Type 62

Inundation in feet	Structure Damage	Inundation in feet	Content Damage
-24	0	-24	0
-7	0	-1	0
-6	0.005	0	0.06
-3	0.01	1	0.215
-1	0.03	2	0.316
0	0.08	3	0.365
1	0.272	4	0.5
2	0.417	5	0.63
3	0.6	6	0.74
4	0.93	7	0.82
5	0.96	8	1
10	0.978	24	1
11	0.98		
24	1		

Flood Type 63

Inundation in feet	Structure Damage
-24	0
-14	0
-13	0
-2	0
-1	0
1	0
2	0
3	0
14	0
16	0
19	0
21	0
22	0
24	0

Inundation in feet	Content Damage
-24	0
-10	0
-7	0
-3	0
0	0
5	0
7	0
8	0
9	0
12	0
13	0
16	0
24	0

Flood Type 64

Inundation in feet	Structure Damage
-24	0
-1	0
0	0.0065
1	0.013
2	0.023
3	0.033
4	0.038
5	0.042
7	0.052
10	0.066
12	0.077
15	0.095
18	0.113
20	0.125
24	0.15

Inundation in feet	Content Damage
-24	0
0	0
24	0

Flood Type 65

Inundation in feet	Structure Damage
-24	0
-1	0
0	0.028
1	0.085
2	0.152
3	0.216
5	0.345
7	0.548
8	0.641
9	0.708
10	0.768
11	0.826
15	1
20	1
24	1

Inundation in feet	Content Damage
-24	0
0	0
24	0

Attachment B-2 – Erosion Damage Curves

Decision tree for assigning Erosion Curves to Structures

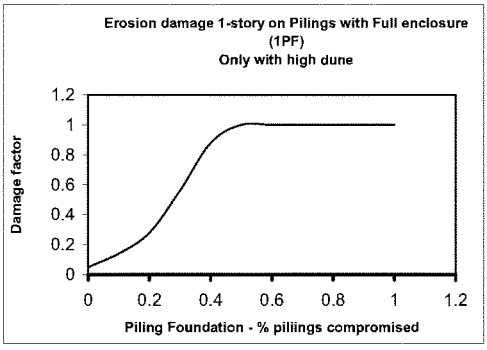
Ocean-front	Building Code	Ground Elevation	Piling Length	Erosion Curve #
		for short pilings high if ≥12 feet NGVD	assume short if building date is prior 1986	
		for long pilings high if ≥16 feet NGVD		
Yes, or 1	1PF	high	both	1
Yes, or 1	1PF	low	short	2
Yes, or 1	1PF	low	long	3
Yes, or 1	2PF	high	both	4
Yes, or 1	2PF	low	short	5
Yes, or 1	2PF	low	long	6
Yes, or 1	3PF	high	both	7
Yes, or 1	3PF	low	long	8
Yes, or 1	3PF	low	short	9
Yes, or 1	1PP	high	both	10
Yes, or 1	1PP	low	long	11
Yes, or 1	1PP	low	short	12
Yes, or 1	2PP	high	both	13
Yes, or 1	2PP	low	long	14
Yes, or 1	2PP	low	short	15
Yes, or 1	3PP	high	both	16
Yes, or 1	3PP	low	short	17
Yes, or 1	3PP	low	long	18
Yes, or 1	1PS	high	both	19
Yes, or 1	1PS	low	long	20
Yes, or 1	1PS	low	short	21
Yes, or 1	2PS	high	both	22
Yes, or 1	2PS	low	short	23
Yes, or 1	2PS	low	long	24
Yes, or 1	3PS	high	both	25
Yes, or 1	3PS	low	long	26
Yes, or 1	3PS	low	short	27
Yes, or 1	1PN,2PN,3PN	high	both	28
Yes, or 1	1PN,2PN,3PN	low	long	29
Yes, or 1	1PN,2PN,3PN	low	short	30
No, or 0	Any	Any	Any	31
Yes, or 1	1NN, 2NN, 3NN, 1NF, 2NF, & all commercial structures	Any	Any	31
Yes, or 1	Upper Floors	any	both	32
Yes, or 1	mobile, utility, pools	any	both	33
Yes, or 1	highways	any	N/A	34

* if dune elevation ≥16 feet do not need to assign long or short pilings because they have the same erosion curve.

1PF high dune Curve #1

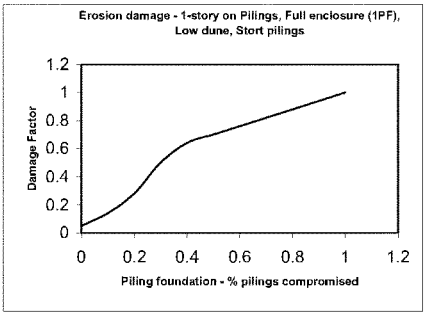
Erosion factor	Value to enclosure	damage to enclosure	value to house	damage to house	composite damage
0	0.4	0.05	0.6	0.05	0.05
0.1	0.4	0.2	0.6	0.1	0.14
0.2	0.4	0.4	0.6	0.2	0.28
0.3	0.4	0.8	0.6	0.4	0.56
0.4	0.4	1	0.6	0.8	0.88
0.5	0.4	1	0.6	1	1
0.6	0.4	1	0.6	1	1
0.7	0.4	1	0.6	1	1
0.8	0.4	1	0.6	1	1
0.9	0.4	1	0.6	1	1
1	0.4	1	0.6	1	1

**Assume high dune Elevation equal or exceed 12 feet above NGVD.



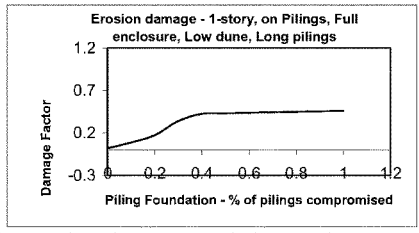
1PF low elevation, short pilings Curve #2

Erosion factor	Value to enclosure	damage to enclosure	value to house	damage to house	composite damage
0	0.4	0.05	0.6	0.05	0.05
0.1	0.4	0.2	0.6	0.1	0.14
0.2	0.4	0.4	0.6	0.2	0.28
0.3	0.4	0.8	0.6	0.3	0.5
0.4	0.4	1	0.6	0.4	0.64
0.5	0.4	1	0.6	0.5	0.7
0.6	0.4	1	0.6	0.6	0.76
0.7	0.4	1	0.6	0.7	0.82
0.8	0.4	1	0.6	0.8	0.88
0.9	0.4	1	0.6	0.9	0.94
1	0.4	1	0.6	1	1

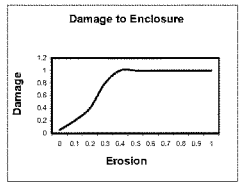


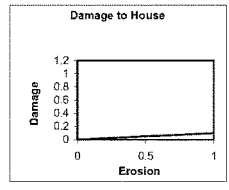
1PF low elevation, long piling Curve #3

Erosion factor	Value to enclosure	damage to enclosure	value to house	damage to house	composite damage
0	0.4	0.05	0.6	0	0.02
0.1	0.4	0.2	0.6	0.01	0.086
0.2	0.4	0.4	0.6	0.02	0.172
0.3	0.4	0.8	0.6	0.03	0.338
0.4	0.4	1	0.6	0.04	0.424
0.5	0.4	1	0.6	0.05	0.43
0.6	0.4	1	0.6	0.06	0.436
0.7	0.4	1	0.6	0.07	0.442
0.8	0.4	1	0.6	0.08	0.448
0.9	0.4	1	0.6	0.09	0.454
1	0.4	1	0.6	0.1	0.46



*these graphs are for the appendices for the Bogue 933 project.

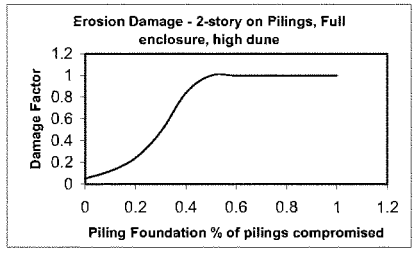




2PF high dune Curve #4

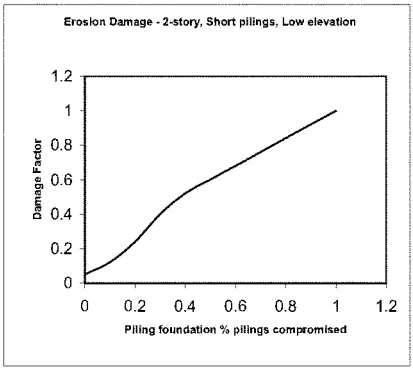
Erosion factor	Value to enclosure	damage to enclosure	value to house	damage to house	composite damage
0	0.2	0.05	0.8	0.05	0.05
0.1	0.2	0.2	0.8	0.1	0.12
0.2	0.2	0.4	0.8	0.2	0.24
0.3	0.2	0.8	0.8	0.4	0.48
0.4	0.2	1	0.8	0.8	0.84
0.5	0.2	1	0.8	1	1
0.6	0.2	1	0.8	1	1
0.7	0.2	1	0.8	1	1
0.8	0.2	1	0.8	1	1
0.9	0.2	1	0.8	1	1
1	0.2	1	0.8	1	1

**Assume high dune



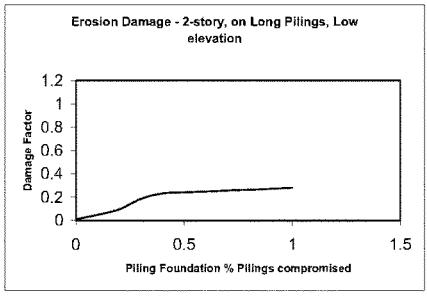
2PF low elevation (<12) and short pilings (<= Curve #5

Erosion factor	Value to enclosure	damage to enclosure	value to house	damage to house	composite damage
0	0.2	0.05	0.8	0.05	0.05
0.1	0.2	0.2	0.8	0.1	0.12
0.2	0.2	0.4	0.8	0.2	0.24
0.3	0.2	0.8	0.8	0.3	0.4
0.4	0.2	1	0.8	0.4	0.52
0.5	0.2	1	0.8	0.5	0.6
0.6	0.2	1	0.8	0.6	0.68
0.7	0.2	1	0.8	0.7	0.76
0.8	0.2	1	0.8	0.8	0.84
0.9	0.2	1	0.8	0.9	0.92
1	0.2	1	0.8	1	1



2PF Low elevation (<16) and long pilings (>= Curve #6

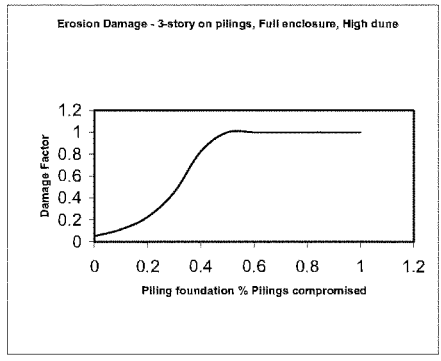
Erosion factor	Value to enclosure	damage to enclosure	value to house	damage to house	composite damage
0	0.2	0.05	0.8	0	0.01
0.1	0.2	0.2	0.8	0.01	0.048
0.2	0.2	0.4	0.8	0.02	0.096
0.3	0.2	0.8	0.8	0.03	0.184
0.4	0.2	1	0.8	0.04	0.232
0.5	0.2	1	0.8	0.05	0.24
0.6	0.2	1	0.8	0.06	0.248
0.7	0.2	1	0.8	0.07	0.256
0.8	0.2	1	0.8	0.08	0.264
0.9	0.2	1	0.8	0.09	0.272
1	0.2	1	0.8	0.1	0.28



3PF high dune Curve #7

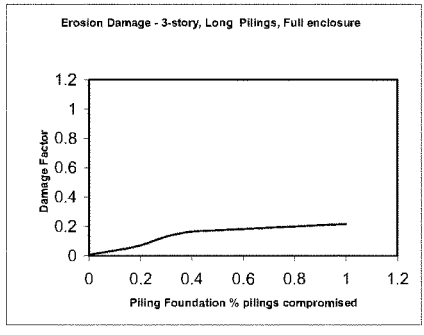
Erosion factor	Value to enclosura	damage to enclosure	value to house	damage to house	composite damage
0	0.13	0.05	0.87	0.05	0.05
0.1	0.13	0.2	0.87	0.1	0.113
0.2	0.13	0.4	0.87	0.2	0.226
0.3	0.13	0.8	0.87	0.4	0.452
0.4	0.13	1	0.87	0.8	0.826
0.5	0.13	1	0.87	1	1
0.6	0.13	1	0.87	1	1
0.7	0.13	1	0.87	1	1
0.8	0.13	1	0.87	1	1
0.9	0.13	1	0.87	1	1
1	0.13	1	0.87	1	1

**Assume high dune



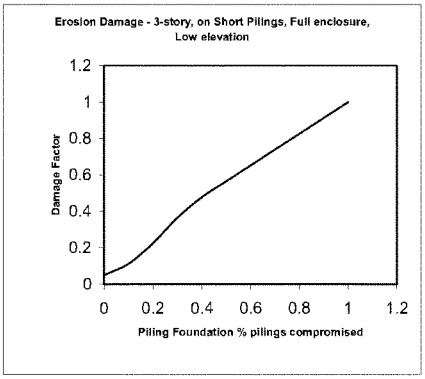
3PF low dune, long pilings Curve #8

Erosion factor	Value to enclosure	damage to enclosure	value to house	damage to house	composite damage
0	0.13	0.05	0.87	0	0.0065
0.1	0.13	0.2	0.87	0.01	0.0347
0.2	0.13	0.4	0.87	0.02	0.0694
0.3	0.13	0.8	0.87	0.03	0.1301
0.4	0.13	1	0.87	0.04	0.1648
0.5	0.13	1	0.87	0.05	0.1735
0.6	0.13	1	0.87	0.06	0.1822
0.7	0.13	1	0.87	0.07	0.1909
0.8	0.13	1	0.87	0.08	0.1996
0.9	0.13	1	0.87	0.09	0.2083
1	0.13	1	0.87	0.1	0.217



3PF low dune, short pilings Curve #9

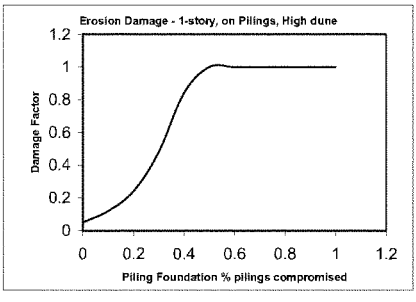
Erosion factor	Value to enclosure	damage to enclosure	value to house	damage to house	composite damage
0	0.13	0.05	0.87	0.05	0.05
0.1	0.13	0.2	0.87	0.1	0.113
0.2	0.13	0.4	0.87	0.2	0.226
0.3	0.13	0.8	0.87	0.3	0.365
0.4	0.13	1	0.87	0.4	0.478
0.5	0.13	1	0.87	0.5	0.565
0.6	0.13	1	0.87	0.6	0.652
0.7	0.13	1	0.87	0.7	0.739
0.8	0.13	1	0.87	0.8	0.826
0.9	0.13	1	0.87	0.9	0.913
1	0.13	1	0.87	1	1



1PP High dune, long or short pilings Curve #10

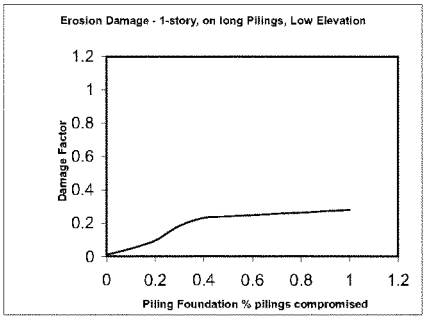
Erosion factor	Value to enclosure	damage to enclosure	value to house	damage to house	composite damage
0	0.2	0.05	0.8	0.05	0.05
0.1	0.2	0.2	0.8	0.1	0.12
0.2	0.2	0.4	0.8	0.2	0.24
0.3	0.2	0.8	0.8	0.4	0.48
0.4	0.2	1	0.8	0.8	0.84
0.5	0.2	1	0.8	1	1
0.6	0.2	1	0.8	1	1
0.7	0.2	1	0.8	1	1
0.8	0.2	1	0.8	1	1
0.9	0.2	1	0.8	1	1
1	0.2	1	0.8	1	1

**Assume high dune



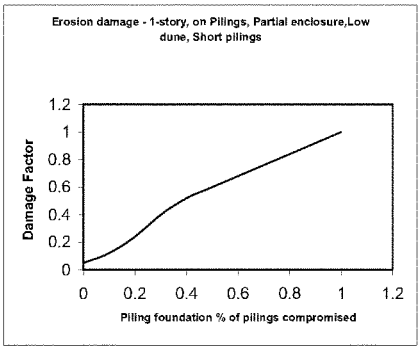
1PP Low elevation and long pilings Curve #11

Erosion factor	Value to enclosure	damage to enclosure	value to house	damage to house	composite damage
0	0.2	0.05	0.8	0	0.01
0.1	0.2	0.2	0.8	0.01	0.048
0.2	0.2	0.4	0.8	0.02	0.096
0.3	0.2	0.8	0.8	0.03	0.184
0.4	0.2	1	0.8	0.04	0.232
0.5	0.2	1	0.8	0.05	0.24
0.6	0.2	1	0.8	0.06	0.248
0.7	0.2	1	0.8	0.07	0.256
0.8	0.2	1	0.8	0.08	0.264
0.9	0.2	1	0.8	0.09	0.272
1	0.2	1	0.8	0.1	0.28



1PP low elevation, short pilings Curve #12

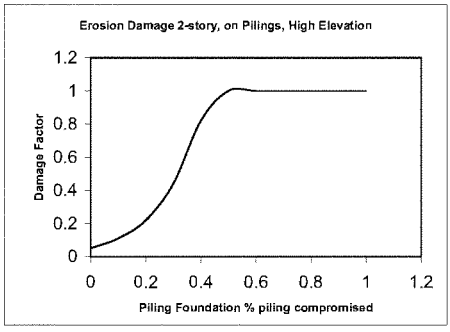
Erosion factor	Value to enclosure	damage to enclosure	value to house	damage to house	composite damage
0	0.2	0.05	0.8	0.05	0.05
0.1	0.2	0.2	0.8	0.1	0.12
0.2	0.2	0.4	0.8	0.2	0.24
0.3	0.2	0.8	0.8	0.3	0.4
0.4	0.2	1	0.8	0.4	0.52
0.5	0.2	1	0.8	0.5	0.6
0.6	0.2	1	0.8	0.6	0.68
0.7	0.2	1	0.8	0.7	0.76
0.8	0.2	1	0.8	0.8	0.84
0.9	0.2	1	0.8	0.9	0.92
1	0.2	1	0.8	1	1



2PP high elevation, short or long piling Curve #13

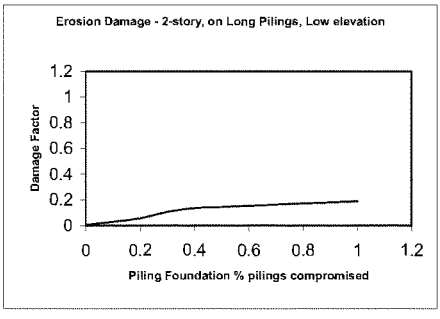
Erosion factor	Value to enclosure	damage to enclosure	value to house	damage to house	composite damage
0	0.1	0.05	0.9	0.05	0.05
0.1	0.1	0.2	0.9	0.1	0.11
0.2	0.1	0.4	0.9	0.2	0.22
0.3	0.1	0.8	0.9	0.4	0.44
0.4	0.1	1	0.9	0.8	0.82
0.5	0.1	1	0.9	1	1
0.6	0.1	1	0.9	1	1
0.7	0.1	1	0.9	1	1
0.8	0.1	1	0.9	1	1
0.9	0.1	1	0.9	1	1
1	0.1	1	0.9	1	1

**Assume high dune



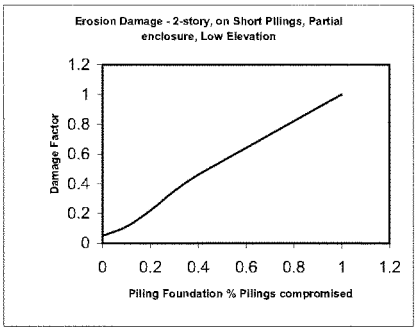
2PP low elevation and long pilings Curve #14

Erosion factor	Value to enclosure	damage to enclosure	value to house	damage to house	composite damage
0	0.1	0.05	0.9	0	0.005
0.1	0.1	0.2	0.9	0.01	0.029
0.2	0.1	0.4	0.9	0.02	0.058
0.3	0.1	0.8	0.9	0.03	0.107
0.4	0.1	1	0.9	0.04	0.136
0.5	0.1	1	0.9	0.05	0.145
0.6	0.1	1	0.9	0.06	0.154
0.7	0.1	1	0.9	0.07	0.163
0.8	0.1	1	0.9	0.08	0.172
0.9	0.1	1	0.9	0.09	0.181
1	0.1	1	0.9	0.1	0.19



2PP low elevation and short pilings Curve #15

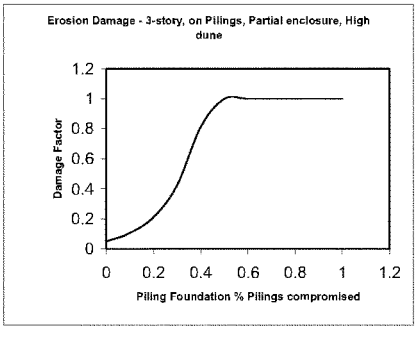
Erosion factor	Value to enclosure	damage to enclosure	value to house	damage to house	composite damage
0	0.1	0.05	0.9	0.05	0.05
0.1	0.1	0.2	0.9	0.1	0.11
0.2	0.1	0.4	0.9	0.2	0.22
0.3	0.1	0.8	0.9	0.3	0.35
0.4	0.1	1	0.9	0.4	0.46
0.5	0.1	1	0.9	0.5	0.55
0.6	0.1	1	0.9	0.6	0.64
0.7	0.1	1	0.9	0.7	0.73
0.8	0.1	1	0.9	0.8	0.82
0.9	0.1	1	0.9	0.9	0.91
1	0.1	1	0.9	1	1



3PP high dune, short or long pilings Curve #16

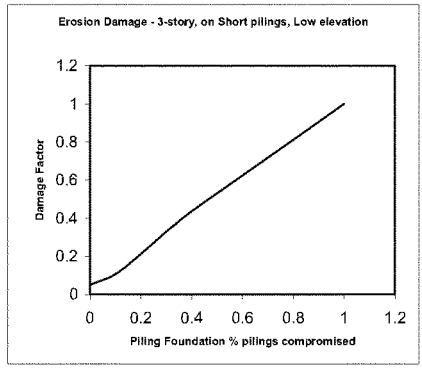
Erosion factor	Value to enclosure	damage to enclosure	value to house	damage to house	composite damage
0	0.06	0.05	0.94	0.05	0.05
0.1	0.06	0.2	0.94	0.1	0.106
0.2	0.06	0.4	0.94	0.2	0.212
0.3	0.06	0.8	0.94	0.4	0.424
0.4	0.06	1	0.94	0.8	0.812
0.5	0.06	1	0.94	1	1
0.6	0.06	1	0.94	1	1
0.7	0.06	1	0.94	1	1
0.8	0.06	1	0.94	1	1
0.9	0.06	1	0.94	1	1
1	0.06	1	0.94	1	1

**Assume high dune



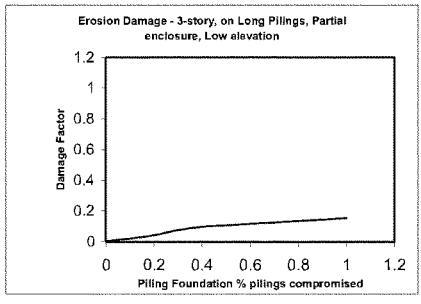
3PP low elevation, short pilings Curve #17

Erosion factor	Value to enclosure	damage to enclosure	value to house	damage to house	composite damage
0	0.06	0.05	0.94	0.05	0.05
0.1	0.06	0.2	0.94	0.1	0.106
0.2	0.06	0.4	0.94	0.2	0.212
0.3	0.06	0.8	0.94	0.3	0.33
0.4	0.06	1	0.94	0.4	0.436
0.5	0.06	1	0.94	0.5	0.53
0.6	0.06	1	0.94	0.6	0.624
0.7	0.06	1	0.94	0.7	0.718
0.8	0.06	1	0.94	0.8	0.812
0.9	0.06	1	0.94	0.9	0.906
1	0.06	1	0.94	1	1



3PP low elevation, long pilings Curve #18

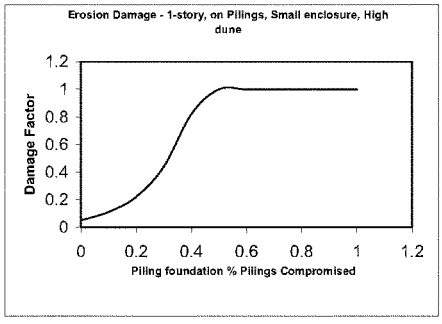
Erosion factor	Value to enclosure	damage to enclosure	value to house	damage to house	composite damage
0	0.06	0.05	0.94	0	0.003
0.1	0.06	0.2	0.94	0.01	0.0214
0.2	0.06	0.4	0.94	0.02	0.0428
0.3	0.06	0.8	0.94	0.03	0.0762
0.4	0.06	1	0.94	0.04	0.0976
0.5	0.06	1	0.94	0.05	0.107
0.6	0.06	1	0.94	0.06	0.1164
0.7	0.06	1	0.94	0.07	0.1258
0.8	0.06	1	0.94	0.08	0.1352
0.9	0.06	1	0.94	0.09	0.1446
1	0.06	1	0.94	0.1	0.154



1PS high dune Curve #19

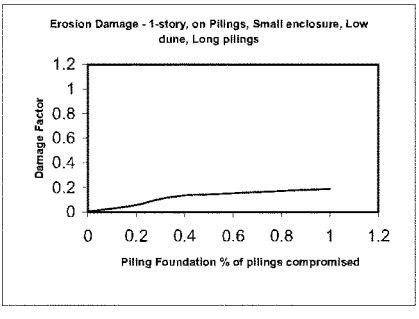
Erosion factor	Value to enclosure	damage to enclosure	value to house	damage to house	composite damage
0	0.1	0.05	0.9	0.05	0.05
0.1	0.1	0.2	0.9	0.1	0.11
0.2	0.1	0.4	0.9	0.2	0.22
0.3	0.1	0.8	0.9	0.4	0.44
0.4	0.1	1	0.9	0.8	0.82
0.5	0.1	1	0.9	1	1
0.6	0.1	1	0.9	1	1
0.7	0.1	1	0.9	1	1
0.8	0.1	1	0.9	1	1
0.9	0.1	1	0.9	1	1
1	0.1	1	0.9	1	1

**Assume high dune



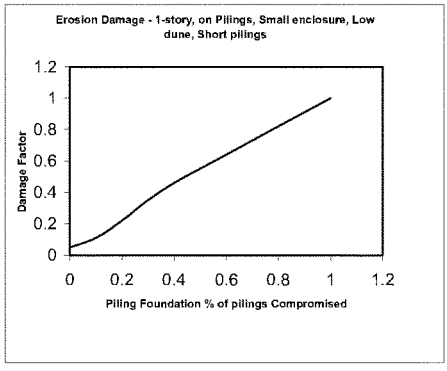
1PS low dune, long pilings Curve #20

Erosion factor	Value to enclosure	damage to enclosure	value to house	damage to house	composite damage
0	0.1	0.05	0.9	0	0.005
0.1	0.1	0.2	0.9	0.01	0.029
0.2	0.1	0.4	0.9	0.02	0.058
0.3	0.1	0.8	0.9	0.03	0.107
0.4	0.1	1	0.9	0.04	0.136
0.5	0.1	1	0.9	0.05	0.145
0.6	0.1	1	0.9	0.06	0.154
0.7	0.1	1	0.9	0.07	0.163
0.8	0.1	1	0.9	0.08	0.172
0.9	0.1	1	0.9	0.09	0.181
1	0.1	1	0.9	0.1	0.19



1PS low dune, short pilings Curve #21

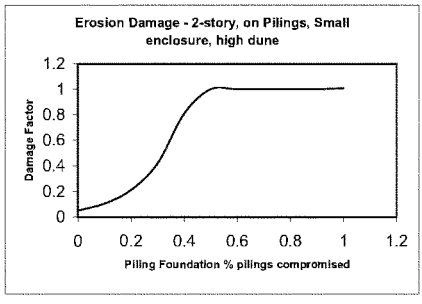
Erosion factor	Value to enclosure	damage to enclosure	value to house	damage to house	composite damage
0	0.1	0.05	0.9	0.05	0.05
0.1	0.1	0.2	0.9	0.1	0.11
0.2	0.1	0.4	0.9	0.2	0.22
0.3	0.1	0.8	0.9	0.3	0.35
0.4	0.1	1	0.9	0.4	0.46
0.5	0.1	1	0.9	0.5	0.55
0.6	0.1	1	0.9	0.6	0.64
0.7	0.1	1	0.9	0.7	0.73
0.8	0.1	1	0.9	0.8	0.82
0.9	0.1	1	0.9	0.9	0.91
1	0.1	1	0.9	1	1



2PS high dune, short or long pilings Curve #22

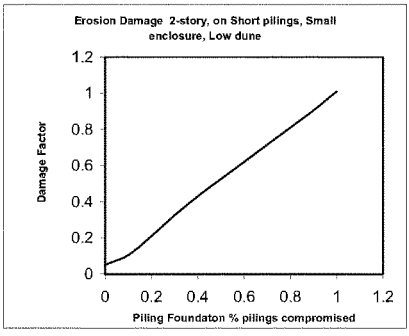
Erosion factor	Value to enclosure	damage to enclosure	value to house	damage to house	composite damage
0	0.05	0.05	0.95	0.05	0.05
0.1	0.05	0.2	0.95	0.1	0.105
0.2	0.05	0.4	0.95	0.2	0.21
0.3	0.05	0.8	0.95	0.4	0.42
0.4	0.05	1	0.95	0.8	0.81
0.5	0.05	1	0.95	1	1
0.6	0.05	1	0.95	1	1
0.7	0.05	1	0.95	1	1
0.8	0.05	1	0.95	1	1
0.9	0.05	1	0.95	1	1
1	0.06	1	0.95	1	1.0

**Assume high dune



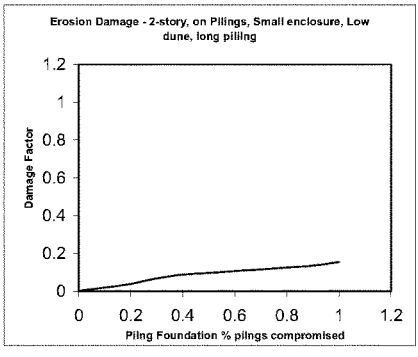
2PS low dune, short pilings Curve #23

Erosion factor	Value to enclosure	damage to enclosure	value to house	damage to house	composite damage
0	0.05	0.05	0.95	0.05	0.05
0.1	0.05	0.2	0.95	0.1	0.105
0.2	0.05	0.4	0.95	0.2	0.21
0.3	0.05	0.8	0.95	0.3	0.325
0.4	0.05	1	0.95	0.4	0.43
0.5	0.05	1	0.95	0.5	0.525
0.6	0.05	1	0.95	0.6	0.62
0.7	0.05	1	0.95	0.7	0.715
0.8	0.05	1	0.95	0.8	0.81
0.9	0.05	1	0.95	0.9	0.905
1	0.06	1	0.95	1	1.0



2PS Low elevation, long pilings Curve #24

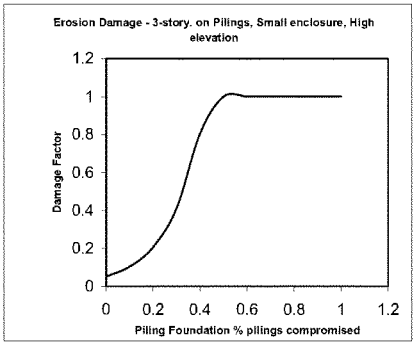
Erosion factor	Value to enclosure	damage to enclosure	value to house	damage to house	composite damage
0	0.05	0.05	0.95	0	0.0025
0.1	0.05	0.2	0.95	0.01	0.0195
0.2	0.05	0.4	0.95	0.02	0.039
0.3	0.05	0.8	0.95	0.03	0.0685
0.4	0.05	1	0.95	0.04	0.088
0.5	0.05	1	0.95	0.05	0.0975
0.6	0.05	1	0.95	0.06	0.107
0.7	0.05	1	0.95	0.07	0.1165
0.8	0.05	1	0.95	0.08	0.126
0.9	0.05	1	0.95	0.09	0.1355
1	0.06	1	0.95	0.1	0.2



3PS high elevation, long or short pilings Curve #25

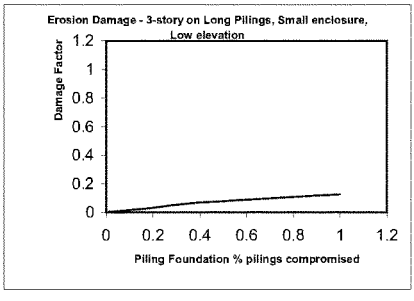
Erosion factor	Value to enclosure	damage to enclosure	value to house	damage to house	composite damage
0	0.03	0.05	0.97	0.05	0.05
0.1	0.03	0.2	0.97	0.1	0.103
0.2	0.03	0.4	0.97	0.2	0.206
0.3	0.03	0.8	0.97	0.4	0.412
0.4	0.03	1	0.97	0.8	0.806
0.5	0.03	1	0.97	1	1
0.6	0.03	1	0.97	1	1
0.7	0.03	1	0.97	1	1
0.8	0.03	1	0.97	1	1
0.9	0.03	1	0.97	1	1
1	0.03	1	0.97	1	1

**Assume high dune



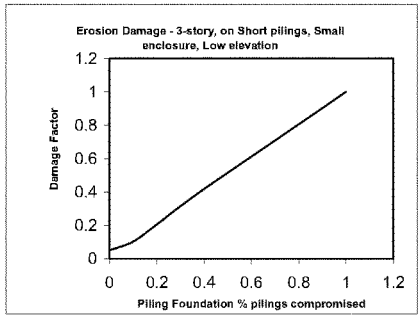
3PS low elevation, long pilings Curve #26

Erosion factor	Value to enclosure	damage to enclosure	value to house	damage to house	composite damage
0	0.03	0.05	0.97	0	0.0015
0.1	0.03	0.2	0.97	0.01	0.0157
0.2	0.03	0.4	0.97	0.02	0.0314
0.3	0.03	0.8	0.97	0.03	0.0531
0.4	0.03	1	0.97	0.04	0.0688
0.5	0.03	1	0.97	0.05	0.0785
0.6	0.03	1	0.97	0.06	0.0882
0.7	0.03	1	0.97	0.07	0.0979
0.8	0.03	1	0.97	0.08	0.1076
0.9	0.03	1	0.97	0.09	0.1173
1	0.03	1	0.97	0.1	0.127



3PS low elevation, short pilings Curve #27

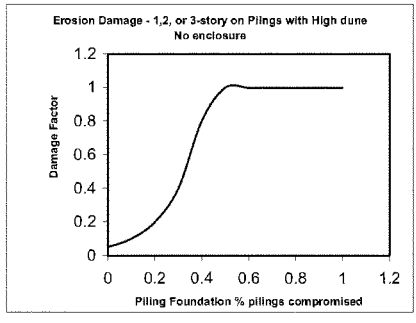
Erosion factor	Value to enclosure	damage to enclosure	value to house	damage to house	composite damage
0	0.03	0.05	0.97	0.05	0.05
0.1	0.03	0.2	0.97	0.1	0.103
0.2	0.03	0.4	0.97	0.2	0.206
0.3	0.03	0.8	0.97	0.3	0.315
0.4	0.03	1	0.97	0.4	0.418
0.5	0.03	1	0.97	0.5	0.515
0.6	0.03	1	0.97	0.6	0.612
0.7	0.03	1	0.97	0.7	0.709
0.8	0.03	1	0.97	0.8	0.806
0.9	0.03	1	0.97	0.9	0.903
1	0.03	1	0.97	1	1



1PN, 2PN, 3PN on high dune Curve #28

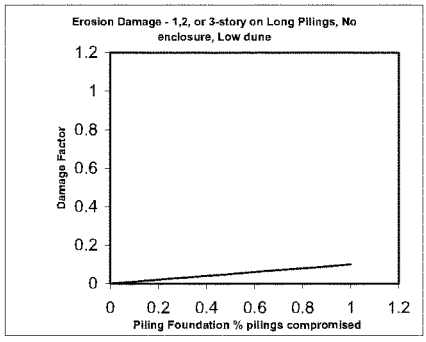
Erosion factor	Value to enclosure	damage to enclosure	value to house	damage to house	composite damage
0	0	0.05	1	0.05	0.05
0.1	0	0.2	1	0.1	0.1
0.2	0	0.4	1	0.2	0.2
0.3	0	0.8	1	0.4	0.4
0.4	0	1	1	0.8	0.8
0.5	0	1	1	1	1
0.6	0	1	1	1	1
0.7	0	1	1	1	1
0.8	0	1	1	1	1
0.9	0	1	1	1	1
1	0	1	1	1	1

**Assume high dune



1PN, 2PN, 3PN on low dune with long pilings — Curve #29

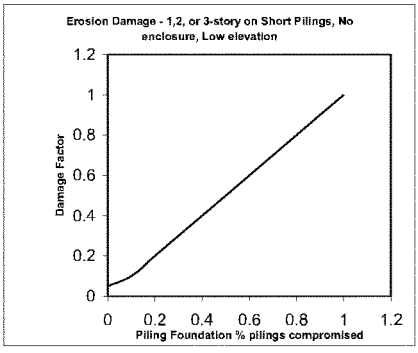
Erosion factor	Value to enclosure	damage to enclosure	value to house	damage to house	composite damage
0	0	0.05	1	0	0
0.1	0	0.2	1	0.01	0.01
0.2	0	0.4	1	0.02	0.02
0.3	0	0.8	1	0.03	0.03
0.4	0	1	1	0.04	0.04
0.5	0	1	1	0.05	0.05
0.6	0	1	1	0.06	0.06
0.7	0	1	1	0.07	0.07
0.8	0	1	1	0.08	0.08
0.9	0	1	1	0.09	0.09
1	0	1	1	0.1	0.1



Curve #30

1PN, 2PN, 3PN low elevation and short pilings

Erosion factor	Value to enclosure	damage to enclosure	value to house	damage to house	composite damage
0	0	0.05	1	0.05	0.05
0.1	0	0.2	1	0.1	0.1
0.2	0	0.4	1	0.2	0.2
0.3	0	0.8	1	0.3	0.3
0.4	0	1	1	0.4	0.4
0.5	0	1	1	0.5	0.5
0.6	0	1	1	0.6	0.6
0.7	0	1	1	0.7	0.7
0.8	0	1	1	0.8	0.8
0.9	0	1	1	0.9	0.9
1	0	1	1	1	1

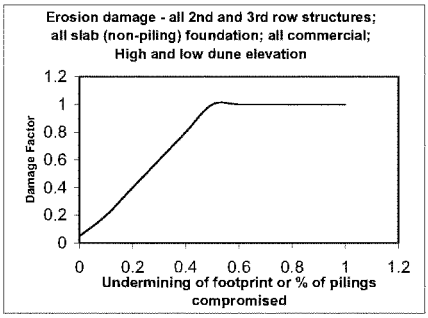


Curve #31

1NN, 2NN, 3NN, 1NF, 2NF, and all 2nd and 3rd row houses and commercial properties

Erosion factor	Value to enclosure	damage to enclosure	value to house	damage to house	composite damage
0	0	0.05	1	0.05	0.05
0.1	0	0.2	1	0.2	0.2
0.2	0	0.4	1	0.4	0.4
0.3	0	0.8	1	0.6	0.6
0.4	0	1	1	0.8	0.8
0.5	0	1	1	1	1
0.6	0	1	1	1	1
0.7	0	1	1	1	1
0.8	0	1	1	1	1
0.9	0	1	1	1	1
1	0	1	1	1	1

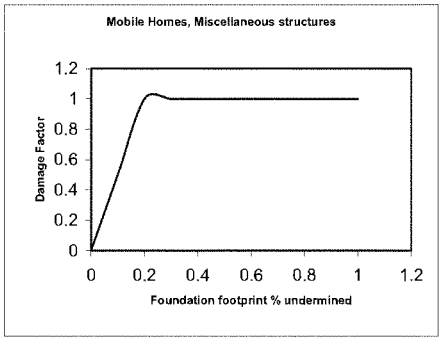
This curve is applied at any elevation



Curve #33

Mobile homes, utility buildings, oceanfront residential decks
detached decks, gazebos, pools, detached garages, buried public utilities

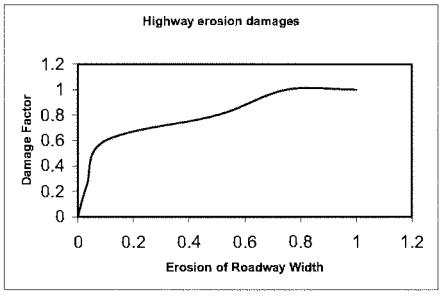
Erosion factor	Value to enclosure	damage to enclosure	value to house	damage to house	composite damage
0	0	0	1	0	0
0.1	0	0	1	0.5	0.5
0.2	0	0	1	1	1
0.3	0	0	1	1	1
0.4	0	0	1	1	1
0.5	0	0	1	1	1
0.6	0	0	1	1	1
0.7	0	0	1	1	1
0.8	0	0	1	1	1
0.9	0	0	1	1	1
1	0	0	1	1	1



Highway erosion damages

Curve #34

erosion	damage
0	0
0.033	0.25
0.1	0.6
0.5	0.8
0.75	1
1	1



Reach ID	USACE_ID	REF lot front	Lot length	Lot width	REF struc front	Struc length	AA Ratio	Flood Curve	Replacement Value of Structure in Dollars	Value of Contents in Dollars	G_elev	FF_elev	Active	Erosion Curve	Armor	Erosion Indicator
27	027S_SH3016A	0	107	140	57	35	1	59	$ 113,001	$ 40,355	20.3	31.6	1	1	-1	0.5
27	027S_SHHWY	110	64	1000	130	24	1	64	$ 42,450	$ -	16.22	16.2	1	34	-1	0.5
27	027BEEC0105A	280	80	90	269	30	1	1	$ 84,005	$ 30,000	10	13.6	1	31	-1	0.5
27	027BEEC0106A	280	80	90	284	40	1	59	$ 224,013	$ 80,000	9	17.5	1	31	-1	2
27	027HISP0105A	280	80	90	274	30	1	60	$ 190,411	$ 68,000	8	16.6	1	31	-1	2
27	027HISP0106A	280	80	90	281	35	1	59	$ 235,213	$ 84,000	8	16.4	1	31	-1	2
27	027OLEA0099A	186	174	77	213	45	1	59	$ 600,000	$ 180,000	22.2	28.3	1	31	-1	0.5
27	027OLEA0098A	190	174	77	210	40	1	56	$ 809,000	$ 242,700	20	32	1	31	-1	2
27	027OLEA0100A	190	174	77	210	40	1	56	$ 740,000	$ 222,000	20	32	1	31	-1	2
27	027S_SH2817A	186	174	77	223	55	1	59	$ 252,014	$ 90,000	19.5	29.3	1	31	-1	0.5
27	027S_SH2821A	186	174	77	196	55	1	59	$ 246,414	$ 88,000	19.4	28.8	1	31	-1	0.5
27	027S_SH2903A	186	174	77	196	25	1	59	$ 87,365	$ 31,200	19.1	24.9	1	31	-1	0.5
27	027S_SH2903G	276	74	77	249	30	1	24	$ 23,396	$ 8,355	14	14	1	31	-1	0.5
27	027S_SH2905A	186	174	77	216	35	1	59	$ 302,417	$ 108,000	20.3	29.5	1	31	-1	0.5
27	027S_SH2911A	186	94	90	200	40	1	56	$ 400,000	$ 120,000	24.6	26.2	1	31	-1	0.5
27	027S_SH3003A	186	94	90	178	40	1	59	$ 120,967	$ 43,200	20.5	25.6	1	31	-1	0.5
27	027S_SH3005A	186	94	90	174	35	1	59	$ 84,005	$ 30,000	20	25.2	1	31	-1	0.5
27	027S_SH3008A	0	125	90	83	20	1	60	$ 50,000	$ 10,000	19.4	24.7	1	28	-1	0.5
27	027S_SH3011A	186	94	90	191	25	1	1	$ 1,000	$ -	18.6	18.6	1	31	-1	0.5
27	027S_SH2819A	186	174	77	140	40	1	56	$ 590,000	$ 177,000	8	20	1	31	-1	2
27	027S_SHFF02A	186	94	90	120	40	1	56	$ 315,125	$ 109,150	8	20	1	31	-1	2
27	027S_SHFF03A	186	94	90	140	40	1	56	$ 315,125	$ 109,150	8	20	1	31	-1	2
27	027S_SHHWY	0	64	1000	115	34	1	64	$ 105,868	$ -	18.6	18.6	1	34	-1	0.5
-999																
28	028BLAN0109A	360	90	91	358	40	1	59	$ 156,809	$ 56,000	8	20.7	1	31	-1	2
28	028S_SH2719A	236	214	91	317	30	1	2	$ 488,348	$ 174,400	13.2	17.1	1	31	-1	0.5
28	028S_SH2719B	236	214	91	175	20	1	45	$ 35,000	$ 17,500	13.2	13.2	1	31	-1	2
28	028S_SH2721A	236	214	91	265	55	1	55	$ 207,212	$ 74,000	15	24	1	31	-1	2
28	028S_SH2723A	236	214	91	251	55	1	55	$ 206,092	$ 73,600	16.1	23.9	1	31	-1	2
28	028S_SH2725A	236	214	91	247	30	1	55	$ 95,205	$ 34,000	16.2	25.4	1	31	-1	2
28	028S_SH2735A	236	214	91	260	40	1	59	$ 352,820	$ 126,000	16.8	26.6	1	31	-1	2
28	028S_SH2805A	236	214	91	234	30	1	59	$ 67,204	$ 24,000	22.5	24.3	1	31	-1	2
28	028S_SH2807A	236	214	91	228	30	1	2	$ 112,006	$ 40,000	22.3	22.3	1	31	-1	0.5
28	028S_SHFF01A	210	450	91	265	40	1	56	$ 315,125	$ 109,150	16	28	1	24	-1	2
28	028S_SHFF02A	210	450	91	265	40	1	56	$ 315,125	$ 109,150	16	28	1	24	-1	2
28	028_S_SH0107	236	214	91	250	40	1	56	$ 595,000	$ 178,500	15	27	1	31	-1	2
28	028OLEA0098A	210	360	91	265	40	1	56	$ 730,000	$ 219,000	16	28	1	24	-1	2

Reach ID	USACE_ID	REF lot front	Lot length	Lot width	REF struc front	Struc length	AA Ratio	Flood Curve	Replacement Value of Structure in Dollars	Value of Contents in Dollars	G_elev	FF_elev	Active	Erosion Curve	Armor	Erosion Indicator
28	028OLEA0100A	210	450	91	265	40	1	56	$ 740,000	$ 222,000	16	28	1	24	-1	2
28	028S_SHFF05A	210	450	91	265	40	1	56	$ 315,125	$ 109,150	16	28	1	31	-1	2
28	028S_SHHWY	0	64	1000	165	34	1	64	$ 105,868	$ -	16.6	16.6	1	34	-1	0.5
-999																
29	029CHAN0128A	240	160	100	279	30	1	56	$ 113,001	$ 40,355	11	14.5	1	31	-1	2
29	029S_SH2610A	0	180	83	103	30	1	59	$ 201,611	$ 72,000	17.8	26.3	1	10	-1	0.5
29	029S_SH2612A	0	180	83	112	20	1	59	$ 235,213	$ 84,000	17.4	26.1	1	10	-1	0.5
29	029S_SH2614A	0	180	83	118	25	1	59	$ 162,409	$ 58,000	17	25.5	1	10	-1	0.5
29	029S_SH2615A	240	160	100	301	35	1	60	$ 113,001	$ 40,355	13.2	24.7	1	31	-1	0.5
29	029S_SH2618A	0	180	83	136	20	1	60	$ 332,659	$ 118,800	16.3	25.4	1	4	-1	0.5
29	029S_SH2620A	0	180	83	138	25	1	60	$ 113,001	$ 40,355	15.6	25.6	1	4	-1	0.5
29	029S_SH2622A	0	180	83	129	25	1	60	$ 254,254	$ 90,800	13.7	22.2	1	4	-1	0.5
29	029S_SH2625A	240	160	100	256	35	1	60	$ 220,653	$ 78,800	16	24.7	1	31	-1	0.5
29	029S_SH2626A	0	180	83	137	30	1	59	$ 224,013	$ 80,000	14.3	23.8	1	19	-1	0.5
29	029S_SH2701A	240	160	100	266	30	1	55	$ 49,283	$ 17,600	15.2	22.8	1	31	-1	0.5
29	029S_SH2702A	0	180	83	136	25	1	59	$ 189,291	$ 67,600	16	25.6	1	10	-1	0.5
29	029S_SH2704A	0	180	83	133	30	1	59	$ 123,207	$ 44,000	16.1	25	1	10	-1	0.5
29	029S_SH2705A	240	160	100	280	25	1	60	$ 280,016	$ 100,000	14.7	25.1	1	31	-1	0.5
29	029S_SH2707A	240	160	100	285	25	1	60	$ 268,815	$ 96,000	14.6	25.6	1	31	-1	0.5
29	029S_SH2708A	0	180	83	125	40	1	59	$ 145,608	$ 52,000	15.9	25.3	1	10	-1	0.5
29	029S_SH2711A	240	160	100	271	40	1	56	$ 580,000	$ 174,000	17	25.4	1	31	-1	2
29	029S_SH2712A	0	180	83	144	20	1	60	$ 201,611	$ 72,000	16.7	26	1	22	-1	0.5
29	029S_SH2714A	0	180	83	151	25	1	59	$ 151,209	$ 54,000	16.1	26.3	1	19	-1	0.5
29	029S_SHFF01A	240	160	100	300	40	1	56	$ 315,125	$ 109,150	14	26	1	31	-1	0.5
29	029S_SHFF02A	240	160	100	300	40	1	56	$ 315,125	$ 109,150	14	26	1	31	-1	0.5
29	029S_SHFF03A	240	160	100	280	40	1	56	$ 315,125	$ 109,150	14	26	1	31	-1	0.5
29	029S_SHHWY	170	64	1000	185	34	1	64	$ 105,868	$ -	13.3	13.3	1	34	-1	0.5
-999																
30	030CHAN0102A	240	150	67	284	20	1	59	$ 179,210	$ 64,000	13	16	1	31	-1	0.5
30	030CHAN0104A	240	150	67	297	30	1	60	$ 336,019	$ 120,000	14	18.3	1	31	-1	0.5
30	030CHAN0130A	240	150	67	293	14	1	60	$ 302,417	$ 108,000	10	11.4	1	31	-1	2
30	030S_SH2419A	240	150	67	277	30	1	60	$ 244,174	$ 87,200	17.7	28.5	1	31	-1	0.5
30	030S_SH2421A	240	150	67	274	45	1	60	$ 156,809	$ 56,000	14.5	25.2	1	31	-1	0.5
30	030S_SH2420A	0	180	59	136	30	1	56	$ 168,010	$ 60,000	15.1	24.8	1	28	-1	0.5
30	030S_SH2423A	240	150	67	281	35	1	56	$ 358,420	$ 128,000	15.1	24.6	1	31	-1	0.5
30	030S_SH2422A	0	180	59	136	30	1	56	$ 179,210	$ 64,000	14.2	24.4	1	28	-1	0.5
30	030S_SH2424A	0	180	59	135	25	1	56	$ 168,010	$ 60,000	14.3	24.4	1	28	-1	0.5

Reach ID	USACE_ID	REF lot front	Lot length	Lot width	REF struc front	Struc length	AA Ratio	Flood Curve	Replacement Value of Structure in Dollars	Value of Contents in Dollars	G_elev	FF_elev	Active	Erosion Curve	Armor	Erosion Indicator
30	030S_SH2425A	240	150	67	271	30	1	56	$ 257,615	$ 92,000	13	23.8	1	31	-1	0.5
30	030S_SH2426A	0	180	59	134	30	1	56	$ 179,210	$ 64,000	15.2	24.4	1	28	-1	0.5
30	030S_SH2427A	240	150	67	271	40	1	59	$ 100,806	$ 36,000	12.8	22.2	1	31	-1	0.5
30	030S_SH2428A	0	180	59	134	30	1	56	$ 168,010	$ 60,000	15.4	24.4	1	28	-1	0.5
30	030S_SH2430A	0	180	59	131	30	1	56	$ 179,210	$ 64,000	15.2	24.2	1	28	-1	0.5
30	030S_SH2501A	240	150	67	275	40	1	60	$ 227,373	$ 81,200	15.7	24.9	1	31	-1	0.5
30	030S_SH2502A	0	180	59	127	30	1	60	$ 280,016	$ 100,000	17.8	28	1	4	-1	0.5
30	030S_SH2503A	240	150	67	272	30	1	60	$ 244,174	$ 87,200	16.3	26	1	31	-1	0.5
30	030S_SH2504A	0	180	59	141	25	1	60	$ 336,019	$ 120,000	17.8	27.7	1	4	-1	0.5
30	030S_SH2505A	240	150	67	271	30	1	60	$ 244,174	$ 87,200	15.5	26.8	1	31	-1	0.5
30	030S_SH2506A	0	180	59	141	25	1	60	$ 241,934	$ 86,400	16.9	26.6	1	4	-1	0.5
30	030S_SH2507A	240	150	67	271	30	1	60	$ 224,013	$ 80,000	15.9	26.3	1	31	-1	0.5
30	030S_SH2508A	0	180	59	137	25	1	60	$ 255,375	$ 91,200	15.6	25.3	1	4	-1	0.5
30	030S_SH2510A	0	180	59	141	20	1	59	$ 100,806	$ 36,000	13.4	23.1	1	4	-1	0.5
30	030S_SH2512A	0	180	59	102	55	1	59	$ 313,618	$ 112,000	12.3	21.6	1	19	-1	0.5
30	030S_SH2514A	0	180	59	106	40	1	59	$ 112,006	$ 40,000	12.3	20.7	1	1	-1	0.5
30	030S_SH2602A	0	180	59	112	30	1	59	$ 224,013	$ 80,000	14.9	23.5	1	1	-1	0.5
30	030S_SH2604A	0	180	59	110	25	1	60	$ 229,613	$ 82,000	16.9	27.1	1	4	-1	0.5
30	030S_SH2608A	0	180	59	105	25	1	60	$ 211,692	$ 75,600	17.6	26.3	1	13	-1	0.5
30	030S_SHFF01A	240	150	67	280	40	1	56	$ 315,125	$ 109,150	12	24	1	31	-1	2
30	030KATE0102A	240	150	67	270	40	1	56	$ 310,000	$ 93,000	12	24	1	31	-1	2
30	030KATE0104A	240	150	67	275	40	1	56	$ 300,000	$ 90,000	12	24	1	31	-1	2
30	030S_SHFF04A	0	180	59	130	40	1	56	$ 315,125	$ 109,150	12	24	1	22	-1	2
30	030S_SHHWY	180	64	1000	195	34	1	64	$ 105,868	$ -	14.2	14.2	1	34	-1	0.5
-999																
31	031S_SH2309A	270	130	56	291	60	1	2	$ 362,901	$ 129,600	13.6	22	1	31	-1	0.5
31	031S_SH2310A	0	210	56	156	30	1	55	$ 62,724	$ 22,400	11.7	20.5	1	30	-1	2
31	031S_SH2311A	270	130	56	299	30	1	59	$ 100,806	$ 36,000	14	23.7	1	31	-1	0.5
31	031S_SH2312A	0	210	56	153	25	1	56	$ 209,452	$ 74,800	12.4	21.4	1	28	-1	0.5
31	031S_SH2313A	270	130	56	302	25	1	60	$ 224,013	$ 80,000	15.6	25.5	1	31	-1	0.5
31	031S_SH2314A	0	210	56	149	25	1	56	$ 196,011	$ 70,000	12.8	21.5	1	28	-1	0.5
31	031S_SH2316A	0	210	56	144	45	1	59	$ 168,010	$ 60,000	13.3	23.1	1	19	-1	0.5
31	031S_SH2317A	270	130	56	295	60	1	59	$ 162,409	$ 58,000	13.4	23.2	1	31	-1	0.5
31	031S_SH2318A	0	210	56	154	25	1	60	$ 155,689	$ 55,600	15.5	25.7	1	22	-1	0.5
31	031S_SH2319A	270	130	56	308	30	1	59	$ 103,046	$ 36,800	14	23.6	1	31	-1	0.5
31	031S_SH2320A	0	210	56	159	35	1	59	$ 98,566	$ 35,200	12.9	22	1	19	-1	0.5
31	031S_SH2321A	270	130	56	298	50	1	59	$ 137,768	$ 49,200	13.1	22.8	1	31	-1	0.5

Reach ID	USACE_ID	REF lot front	Lot length	Lot width	REF struc front	Struc length	AA Ratio	Flood Curve	Replacement Value of Structure in Dollars	Value of Contents in Dollars	G_elev	FF_elev	Active	Erosion Curve	Armor	Erosion Indicator
31	031S_SH2322	0	210	56	160	40	1	56	$ 560,000	$ 168,000	14	26	1	28	-1	0.5
31	031S_SH2323A	270	130	56	304	30	1	59	$ 136,648	$ 48,800	15.6	27.7	1	31	-1	0.5
31	031S_SH2324A	0	210	56	163	35	1	55	$ 86,245	$ 30,800	13.7	21.4	1	28	-1	0.5
31	031S_SH2325A	270	130	56	296	45	1	59	$ 94,085	$ 33,600	15	24.5	1	31	-1	0.5
31	031S_SH2326A	0	210	56	153	35	1	59	$ 100,806	$ 36,000	14.5	22.8	1	10	-1	0.5
31	031S_SH2403A	270	130	56	320	35	1	59	$ 145,608	$ 52,000	14.6	25.3	1	31	-1	0.5
31	031S_SH2404A	0	210	56	157	25	1	60	$ 392,022	$ 140,000	14.4	24.3	1	4	-1	0.5
31	031S_SH2405A	270	130	56	298	35	1	59	$ 112,006	$ 40,000	15	25.1	1	31	-1	0.5
31	031S_SH2406A	0	210	56	148	40	1	59	$ 156,809	$ 56,000	19	23.5	1	19	-1	0.5
31	031S_SH2407A	270	130	56	302	30	1	60	$ 190,411	$ 68,000	13.9	25	1	31	-1	0.5
31	031S_SH2408A	0	210	56	159	40	1	59	$ 179,210	$ 64,000	14.2	23.4	1	19	-1	0.5
31	031S_SH2410A	0	210	56	156	35	1	55	$ 112,006	$ 40,000	15.1	24.1	1	28	-1	0.5
31	031S_SH2411A	270	130	56	297	35	1	59	$ 190,411	$ 68,000	14.1	23	1	31	-1	0.5
31	031S_SH2412A	0	210	56	159	15	1	60	$ 201,611	$ 72,000	15.1	24.3	1	4	-1	0.5
31	031S_SH2413A	270	130	56	300	35	1	60	$ 280,016	$ 100,000	12	24.6	1	31	-1	0.5
31	031S_SH2414A	0	210	56	160	25	1	56	$ 134,408	$ 48,000	16.2	25.8	1	28	-1	0.5
31	031S_SH2417A	270	130	56	288	30	1	60	$ 244,174	$ 87,200	15.9	26	1	31	-1	0.5
31	031S_SH2415A	270	130	56	291	30	1	60	$ 358,420	$ 128,000	17	25.8	1	31	-1	0.5
31	031S_SH2416A	0	210	56	156	25	1	60	$ 168,010	$ 60,000	15.6	25.8	1	4	-1	0.5
31	031S_SH2418A	0	210	56	141	35	1	55	$ 156,809	$ 56,000	16.2	25.3	1	28	-1	0.5
31	031S_SHFF05A	270	200	56	300	40	1	56	$ 315,125	$ 109,150	13	25	1	31	-1	2
31	031S_SHFF04A	270	200	56	320	40	1	56	$ 315,125	$ 109,150	13	25	1	31	-1	2
31	031S_SHFF01A	270	200	56	300	40	1	56	$ 315,125	$ 109,150	13	25	1	31	-1	2
31	031S_SHFF02A	0	200	56	175	40	1	56	$ 315,125	$ 109,150	13	25	1	22	-1	2
31	031S_SHFF03A	0	200	56	175	40	1	56	$ 315,125	$ 109,150	13	25	1	22	-1	2
31	031S_SHHWY	200	64	1000	215	34	1	64	$ 105,868	$ -	13.7	13.7	1	34	-1	0.5
-999																
32	032S_OA0025A	340	110	207	371	40	1	55	$ 257,615	$ 92,000	13	23.6	1	31	-1	0.5
32	032S_SH2109A	230	110	62	259	45	1	55	$ 178,090	$ 63,600	11.8	20.9	1	31	-1	2
32	032S_SH2110A	0	170	333	97	25	1	55	$ 72,804	$ 26,000	10	18.4	1	32	-1	2
32	032S_SH2119A	230	110	62	238	45	1	55	$ 112,006	$ 40,000	9.7	17.8	1	31	-1	2
32	032S_SH2203A	230	110	62	246	45	1	59	$ 75,044	$ 26,800	11.3	19.7	1	31	-1	2
32	032S_SH2205A	230	110	62	242	45	1	55	$ 89,605	$ 32,000	10.5	18.3	1	31	-1	2
32	032S_SH2207A	230	110	62	254	35	1	60	$ 113,001	$ 40,355	12	26.3	1	31	-1	0.5
32	032S_SH2209A	230	110	62	247	40	1	59	$ 188,171	$ 67,200	12.3	22.8	1	31	-1	0.5
32	032S_SH2209S	0	0	0	312	15	1	1	$ 12,195	$ 4,355	14	15.7	1	31	-1	0.5
32	032S_SH2211A	230	110	62	245	30	1	59	$ 78,404	$ 28,000	11.6	20.5	1	31	-1	2

Reach ID	USACE_ID	REF lot front	Lot length	Lot width	REF struc front	Struc length	AA Ratio	Flood Curve	Replacement Value of Structure in Dollars	Value of Contents in Dollars	G_elev	FF_elev	Active	Erosion Curve	Armor	Erosion Indicator
32	032S_SH2216A	0	170	333	117	25	1	59	$ 168,010	$ 60,000	13.3	24.1	1	10	-1	0.5
32	032S_SH2301A	230	220	76	260	40	1	56	$ 175,000	$ 52,500	12.7	24.3	1	31	-1	2
32	032S_SH2308A	0	170	333	124	30	1	55	$ 58,243	$ 20,800	11.7	20.4	1	30	-1	2
32	032SAND0016A	340	110	207	349	40	1	56	$ 308,018	$ 110,000	13	20.4	1	31	-1	0.5
32	032SHEL0009A	340	110	207	359	40	1	56	$ 313,618	$ 112,000	11	20	1	31	-1	0.5
32	032S_SHFF01A	230	110	62	265	40	1	56	$ 315,125	$ 109,150	10	22	1	31	-1	2
32	032S_SHFF02A	230	110	62	265	40	1	56	$ 315,125	$ 109,150	10	22	1	31	-1	2
32	032S_SHFF03A	230	110	62	265	40	1	56	$ 315,125	$ 109,150	10	22	1	31	-1	2
32	032S_SHFF04A	230	220	76	275	40	1	56	$ 315,125	$ 109,150	10	22	1	31	-1	2
32	032S_SHFF05A	230	220	76	275	40	1	56	$ 315,125	$ 109,150	10	22	1	31	-1	2
32	032S_SH2305A	230	220	76	275	40	1	56	$ 350,000	$ 109,150	10	22	1	31	-1	2
32	032S_SHFF07A	230	220	76	285	40	1	56	$ 315,125	$ 109,150	10	22	1	31	-1	2
32	032S_SHFF08A	230	110	76	120	40	1	56	$ 315,125	$ 109,150	10	22	1	31	-1	2
32	032S_SH2306A	0	110	76	120	40	1	56	$ 240,000	$ 72,000	10	22	1	29	-1	2
32	032S_SH2304A	0	110	76	120	40	1	56	$ 260,000	$ 78,000	10	22	1	29	-1	2
32	032S_SH2302A	0	110	76	120	40	1	56	$ 250,000	$ 75,000	10	22	1	29	-1	2
32	032S_SH2216A	0	110	76	120	40	1	56	$ 275,000	$ 82,500	10	22	1	29	-1	2
32	032S_SH2214A	0	110	76	120	40	1	56	$ 220,000	$ 66,000	10	22	1	29	-1	2
32	032S_SH2212A	0	110	76	120	40	1	56	$ 398,000	$ 119,400	10	22	1	29	-1	2
32	032S_SH2210A	0	110	76	120	40	1	56	$ 375,000	$ 112,500	10	22	1	29	-1	2
32	032S_SH2208A	0	125	50	130	40	1	56	$ 290,000	$ 87,000	10	22	1	29	-1	2
32	032S_SH2206A	0	110	76	120	40	1	56	$ 220,000	$ 66,000	10	22	1	29	-1	2
32	032S_SH2204A	0	110	76	120	40	1	56	$ 280,000	$ 84,000	10	22	1	29	-1	2
32	032S_SH2202A	0	110	76	120	40	1	56	$ 280,000	$ 84,000	10	22	1	29	-1	2
32	032S_SH2116A	0	110	75	120	40	1	56	$ 295,000	$ 88,500	10	22	1	29	-1	2
32	032S_SH2114A	0	110	75	120	40	1	56	$ 320,000	$ 96,000	10	22	1	29	-1	2
32	032S_SH2112A	0	110	75	120	40	1	56	$ 295,000	$ 88,500	10	22	1	29	-1	2
32	032S_SHHWY	150	64	1000	165	34	1	64	$ 105,868	$ -	11.5	11.5	1	34	-1	0.5
-999																
33	033ELIZ0001A	345	50	100	348	25	1	60	$ 212,812	$ 76,000	12	20.8	1	31	-1	0.5
33	033S_SH1917A	240	200	57	310	30	1	60	$ 257,615	$ 92,000	9.1	20.3	1	31	-1	2
33	033S_SH1919A	240	120	57	304	30	1	60	$ 336,019	$ 120,000	9.1	20.1	1	31	-1	2
33	033S_SH1920A	0	80	71	141	40	1	59	$ 224,013	$ 80,000	9	18.9	1	2	-1	2
33	033S_SH1921A	240	200	57	302	30	1	60	$ 336,019	$ 120,000	8.9	20.1	1	31	-1	2
33	033S_SH1923A	240	200	57	315	35	1	59	$ 125,447	$ 44,800	8.7	20.7	1	31	-1	2
33	033S_SH1924A	0	80	71	131	35	1	59	$ 380,822	$ 136,000	10.3	19.9	1	11	-1	2
33	033S_SH1925A	240	200	57	310	20	1	59	$ 144,488	$ 51,600	11.8	21.3	1	31	-1	2

Reach ID	USACE_ID	REF lot front	Lot length	Lot width	REF struc front	Struc length	AA Ratio	Flood Curve	Replacement Value of Structure in Dollars	Value of Contents in Dollars	G_elev	FF_elev	Active	Erosion Curve	Armor	Erosion Indicator
33	033S_SH1926A	0	80	71	138	40	1	56	$ 290,000	$ 87,000	10.3	19.6	1	29	-1	2
33	033S_SH1928A	0	80	71	125	40	1	56	$ 475,000	$ 142,500	10	22	1	29	-1	2
33	033S_SH2001A	240	200	57	304	45	1	59	$ 168,010	$ 60,000	12.5	22.1	1	31	-1	0.5
33	033S_SH2002A	0	80	71	134	35	1	59	$ 134,408	$ 48,000	9.9	18.9	1	12	-1	2
33	033S_SH2003A	240	200	57	317	25	1	60	$ 190,411	$ 68,000	13.3	22.8	1	31	-1	0.5
33	033S_SH2004A	0	80	71	126	30	1	55	$ 140,008	$ 50,000	13.9	20.2	1	28	-1	0.5
33	033S_SH2007A	240	200	57	290	25	1	59	$ 210,572	$ 75,200	11.6	21.3	1	31	-1	2
33	033S_SH2008A	0	80	71	121	20	1	60	$ 224,013	$ 80,000	17.8	23.4	1	13	-1	0.5
33	033S_SH2010A	0	80	71	125	35	1	59	$ 112,006	$ 40,000	10.1	19.6	1	21	-1	2
33	033S_SH2011A	240	200	57	274	35	1	59	$ 112,006	$ 40,000	9.7	20.6	1	31	-1	2
33	033S_SH2012A	0	80	71	124	35	1	59	$ 134,408	$ 48,000	9.9	19.5	1	2	-1	2
33	033S_SH2013A	240	200	57	276	40	1	59	$ 114,247	$ 40,800	9.1	17.1	1	31	-1	2
33	033S_SH2014A	0	80	71	118	40	1	59	$ 100,806	$ 36,000	10.4	21.2	1	21	-1	2
33	033S_SH2015A	240	200	57	251	40	1	56	$ 300,000	$ 90,000	8.7	17.2	1	31	-1	2
33	033S_SH2016A	0	80	71	115	40	1	59	$ 156,809	$ 56,000	10.5	19.8	1	12	-1	2
33	033S_SH2018A	0	80	71	110	40	1	59	$ 168,010	$ 60,000	10.3	19.8	1	2	-1	2
33	033S_SH2101A	240	200	50	271	30	1	60	$ 235,213	$ 84,000	12	21.9	1	31	-1	0.5
33	033S_SH2102A	0	200	71	108	40	1	56	$ 100,000	$ 30,000	11.6	20.7	1	29	-1	2
33	033S_SH2103A	240	200	50	267	30	1	60	$ 227,373	$ 81,200	11.4	21.6	1	31	-1	2
33	033S_SH2104A	0	80	71	104	25	1	60	$ 179,210	$ 64,000	11.5	21.4	1	5	-1	2
33	033S_SH2106A	0	80	71	102	20	1	55	$ 72,804	$ 26,000	12.4	15.5	1	28	-1	0.5
33	033S_SH2107A	240	200	50	266	35	1	59	$ 190,411	$ 68,000	16	25.9	1	31	-1	0.5
33	033S_SH2105A	240	200	50	271	25	1	59	$ 239,694	$ 85,600	12.8	23.3	1	31	-1	0.5
33	033SHEL0007A	345	200	100	359	30	1	56	$ 190,411	$ 68,000	9	21.7	1	31	-1	2
33	033S_SH1925A	240	200	57	310	40	1	56	$ 560,000	$ 168,000	9	21	1	31	-1	2
33	033S_SH2009A	240	200	57	280	40	1	56	$ 250,000	$ 75,000	9	21	1	31	-1	2
33	033S_SH2005A	240	200	57	300	40	1	56	$ 240,000	$ 72,000	9	21	1	31	-1	2
33	033S_SH2006A	0	80	71	110	40	1	56	$ 240,000	$ 72,000	13	25	1	28	-1	2
33	033S_SHHWY	160	64	1000	175	34	1	64	$ 105,868	$ -	10.5	10.5	1	34	-1	0.5
-999																
34	034PELI0108A	75	75	80	400	30	1	60	$ 113,001	$ 40,355	13	19.9	1	31	-1	0.5
34	034S_SH1811A	125	130	56	306	35	1	59	$ 123,207	$ 44,000	8.3	17.3	1	31	-1	2
34	034S_SH1813A	125	130	56	311	45	1	2	$ 183,690	$ 65,600	11	10.6	1	31	-1	2
34	034S_SH1814A	0	80	83	138	35	1	59	$ 168,010	$ 60,000	10.3	20.7	1	12	-1	2
34	034S_SH1815A	125	130	56	322	45	1	59	$ 134,408	$ 48,000	11	18.7	1	31	-1	2
34	034S_SH1816A	0	80	83	143	35	1	59	$ 299,057	$ 106,800	13	23.8	1	1	-1	0.5
34	034S_SH1820A	230	130	83	178	35	1	60	$ 113,001	$ 40,355	19	26.4	1	31	-1	0.5

Reach ID	USACE_ID	REF lot front	Lot length	Lot width	REF struc front	Struc length	AA Ratio	Flood Curve	Replacement Value of Structure in Dollars	Value of Contents in Dollars	G_elev	FF_elev	Active	Erosion Curve	Armor	Erosion Indicator
34	034S_SH1821A	125	130	56	328	30	1	60	$ 268,815	$ 96,000	12	25.1	1	31	-1	0.5
34	034S_SH1822A	0	80	83	178	35	1	60	$ 113,001	$ 40,355	19	26.5	1	22	-1	0.5
34	034S_SH1824A	0	80	83	149	30	1	59	$ 128,807	$ 46,000	11.8	21.4	1	21	-1	2
34	034S_SH1825A	310	130	56	325	40	1	56	$ 315,125	$ 109,150	9.9	22	1	31	-1	2
34	034S_SH1826A	0	80	83	146	35	1	60	$ 441,305	$ 157,600	12.9	22.1	1	1	-1	0.5
34	034S_SH1827A	125	130	56	323	45	1	59	$ 159,049	$ 56,800	9.7	19.3	1	31	-1	2
34	034S_SH1829A	125	130	56	309	40	1	59	$ 80,645	$ 28,800	9.1	17.6	1	31	-1	2
34	034S_SH1830A	0	80	83	148	25	1	59	$ 474,907	$ 169,600	11.4	20	1	11	-1	2
34	034S_SH1831A	125	130	56	308	45	1	59	$ 145,608	$ 52,000	9.9	18.9	1	31	-1	2
34	034S_SH1834A	0	80	83	130	40	1	56	$ 265,000	$ 79,500	11	23	1	29	-1	2
34	034S_SH1901A	125	130	56	317	40	1	59	$ 134,408	$ 48,000	8.5	18.8	1	31	-1	2
34	034S_SH1902A	0	80	83	145	30	1	59	$ 144,488	$ 51,600	9	20.7	1	21	-1	2
34	034S_SH1905A	125	130	56	311	30	1	60	$ 244,174	$ 87,200	12	23.2	1	31	-1	0.5
34	034S_SH1906A	0	80	83	135	40	1	56	$ 600,000	$ 180,000	11	23	1	29	-1	2
34	034S_SH1908A	0	80	83	167	25	1	60	$ 302,417	$ 108,000	10.4	20.9	1	5	-1	2
34	034S_SH1909A	125	130	56	324	40	1	59	$ 134,408	$ 48,000	9.1	20.8	1	31	-1	2
34	034S_SH1912A	0	80	83	149	30	1	59	$ 132,168	$ 47,200	8.7	18.7	1	21	-1	2
34	034S_SH1914A	0	80	83	147	35	1	59	$ 190,411	$ 68,000	9.4	18.8	1	12	-1	2
34	034S_SH1916A	0	80	83	158	25	1	56	$ 224,013	$ 80,000	8.8	18.2	1	29	-1	2
34	034S_SHFF07A	125	130	56	320	40	1	56	$ 315,125	$ 109,150	10	22	1	31	-1	2
34	034S_SH1913A	125	130	56	320	40	1	56	$ 329,000	$ 98,700	10	22	1	31	-1	2
34	034S_SHFF05A	125	130	56	320	40	1	56	$ 315,125	$ 109,150	10	22	1	31	-1	2
34	034S_SHFF04A	125	130	56	320	40	1	56	$ 315,125	$ 109,150	10	22	1	31	-1	2
34	034S_SHFF03A	125	130	56	305	40	1	56	$ 315,125	$ 109,150	10	22	1	31	-1	2
34	034S_SHFF02A	125	130	56	320	40	1	56	$ 315,125	$ 109,150	10	22	1	31	-1	2
34	034S_SHFF01A	125	130	56	315	40	1	56	$ 315,125	$ 109,150	10	22	1	31	-1	2
34	034S_SHHWY	220	64	1000	235	34	1	64	$ 105,868	$ -	9.9	9.9	1	34	-1	0.5
-999																
35	035S_SH1618A	0	130	67	117	30	1	59	$ 118,727	$ 42,400	7.3	18.7	1	2	-1	2
35	035S_SH1619A	290	120	56	322	30	1	59	$ 112,006	$ 40,000	14	22.6	1	31	-1	0.5
35	035S_SH1622A	0	130	67	155	35	1	60	$ 113,001	$ 40,355	13	23.3	1	22	-1	0.5
35	035S_SH1622X	0	130	67	155	35	1	60	$ 113,001	$ 40,355	13	23.3	1	22	-1	0.5
35	035S_SH1623A	290	120	56	355	30	1	60	$ 319,218	$ 114,000	15	23.4	1	31	-1	0.5
35	035S_SH1625A	290	120	56	356	40	1	55	$ 90,725	$ 32,400	15	22.1	1	31	-1	0.5
35	035S_SH1701A	290	120	56	310	40	1	59	$ 145,608	$ 52,000	9.1	20.7	1	31	-1	2
35	035S_SH1702A	0	130	67	131	25	1	60	$ 235,213	$ 84,000	6.7	19.6	1	24	-1	2
35	035S_SH1703A	290	120	56	316	50	1	59	$ 168,010	$ 60,000	8.7	20.2	1	31	-1	2

Reach ID	USACE_ID	REF lot front	Lot length	Lot width	REF struc front	Struc length	AA Ratio	Flood Curve	Replacement Value of Structure in Dollars	Value of Contents in Dollars	G_elev	FF_elev	Active	Erosion Curve	Armor	Erosion Indicator
35	035S_SH1704A	0	130	67	125	30	1	59	$ 123,207	$ 44,000	7	19.3	1	2	-1	2
35	035S_SH1706A	0	130	67	159	14	1	60	$ 78,404	$ 28,000	7.7	21.6	1	5	-1	2
35	035S_SH1707A	290	120	56	346	25	1	59	$ 179,210	$ 64,000	14	22.7	1	31	-1	0.5
35	035S_SH1708A	0	130	67	141	30	1	59	$ 161,289	$ 57,600	8.5	23.2	1	22	-1	2
35	035S_SH1709A	290	120	56	325	30	1	59	$ 336,019	$ 120,000	13	23.1	1	31	-1	0.5
35	035S_SH1710A	0	130	67	160	25	1	60	$ 113,001	$ 40,355	16	24.7	1	19	-1	0.5
35	035S_SH1711A	290	120	56	320	35	1	60	$ 196,011	$ 70,000	8.6	19.2	1	31	-1	2
35	035S_SH1713A	290	120	56	314	35	1	59	$ 104,838	$ 37,440	8.5	18.6	1	31	-1	2
35	035S_SH1715A	290	120	56	340	30	1	60	$ 302,417	$ 108,000	13	22.8	1	31	-1	0.5
35	035S_SH1716A	0	130	67	143	25	1	59	$ 201,611	$ 72,000	13.6	23.9	1	10	-1	2
35	035S_SH1801A	290	120	56	347	25	1	60	$ 224,013	$ 80,000	13	22.3	1	31	-1	0.5
35	035S_SH1802A	0	130	67	140	35	1	59	$ 246,414	$ 88,000	11.5	22	1	3	-1	2
35	035S_SH1803A	290	120	56	338	40	1	59	$ 92,965	$ 33,200	9.8	17.7	1	31	-1	2
35	035S_SH1806A	0	130	67	140	20	1	60	$ 336,019	$ 120,000	12.5	22.2	1	4	-1	2
35	035S_SH1806X	0	130	67	138	20	1	60	$ 113,001	$ 40,355	19	23.4	1	1	-1	0.5
35	035S_SH1807A	290	120	56	341	20	1	60	$ 184,811	$ 66,000	13	21.2	1	31	-1	0.5
35	035S_SH1812A	0	130	67	138	40	1	60	$ 448,026	$ 160,000	11.4	21.1	1	6	-1	2
35	035S_SHFF03A	0	130	67	165	40	1	56	$ 315,125	$ 109,150	7	19	1	24	-1	2
35	035S_SHFF05A	290	120	56	330	40	1	56	$ 315,125	$ 109,150	7	19	1	31	-1	2
35	035S_SH1627A	290	120	56	320	40	1	56	$ 250,000	$ 105,000	7	19	1	31	-1	2
35	035S_SHFF01A	290	120	56	340	40	1	56	$ 315,125	$ 109,150	7	19	1	31	-1	2
35	035S_SHFF07A	290	120	56	310	40	1	56	$ 315,125	$ 109,150	7	19	1	31	-1	2
35	035S_SH1712A	0	130	67	160	40	1	56	$ 325,000	$ 97,500	7	19	1	29	-1	2
35	035S_SHFF02A	290	120	56	340	40	1	56	$ 315,125	$ 109,150	7	19	1	31	-1	2
35	035S_SHHWY	220	64	1000	235	34	1	64	$ 105,868	$ -	8.5	8.5	1	34	-1	0.5
-999																
36	036S_SH1519A	310	125	59	356	35	1	59	$ 156,809	$ 56,000	16	23.9	1	31	-1	0.5
36	036S_SH1520A	0	150	77	172	30	1	60	$ 179,210	$ 64,000	11.7	22.6	1	23	-1	2
36	036S_SH1521A	310	125	59	354	30	1	60	$ 263,215	$ 94,000	15	23.5	1	31	-1	0.5
36	036S_SH1522A	0	150	77	163	30	1	60	$ 224,013	$ 80,000	8.8	19.2	1	6	-1	2
36	036S_SH1523A	310	125	59	349	35	1	60	$ 332,659	$ 118,800	15	14.7	1	31	-1	0.5
36	036S_SH1524A	0	150	77	163	45	1	59	$ 336,019	$ 120,000	10	19.5	1	3	-1	2
36	036S_SH1525A	310	125	59	355	20	1	60	$ 240,814	$ 86,000	15	23.9	1	31	-1	0.5
36	036S_SH1526A	0	150	77	190	30	1	60	$ 285,616	$ 102,000	14	21.6	1	22	-1	0.5
36	036S_SH1527A	310	125	59	345	30	1	60	$ 241,486	$ 86,240	14	24	1	31	-1	0.5
36	036S_SH1528A	0	150	77	189	25	1	60	$ 301,073	$ 107,520	15	21.7	1	22	-1	0.5
36	036S_SH1529A	310	125	59	347	35	1	1	$ 77,284	$ 27,600	10.7	10.7	1	31	-1	2

Reach ID	USACE_ID	REF lot front	Lot length	Lot width	REF struc front	Struc length	AA Ratio	Flood Curve	Replacement Value of Structure in Dollars	Value of Contents in Dollars	G_elev	FF_elev	Active	Erosion Curve	Armor	Erosion Indicator
36	036S_SH1530A	0	150	77	211	25	1	60	$ 113,001	$ 40,355	14	21.9	1	22	-1	0.5
36	036S_SH1531A	310	125	59	334	45	1	1	$ 98,566	$ 35,200	10.7	10.7	1	31	-1	2
36	036S_SH1534A	0	150	77	177	25	1	60	$ 616,035	$ 220,000	11.6	23	1	6	-1	2
36	036S_SH1535A	310	125	59	341	45	1	59	$ 96,325	$ 34,400	11	23.6	1	31	-1	2
36	036S_SH1538A	0	150	77	129	40	1	59	$ 168,010	$ 60,000	9.6	19.7	1	2	-1	2
36	036S_SH1539A	310	125	59	347	35	1	55	$ 291,217	$ 104,000	9.1	22.5	1	31	-1	2
36	036S_SH1540A	0	150	77	145	45	1	59	$ 145,608	$ 52,000	11.7	19.9	1	21	-1	2
36	036S_SH1601A	310	125	59	358	45	1	59	$ 294,577	$ 105,200	19	25.4	1	31	-1	0.5
36	036S_SH1605A	310	125	59	344	25	1	60	$ 196,011	$ 70,000	11.6	22.9	1	31	-1	2
36	036S_SH1606A	0	150	77	140	35	1	59	$ 128,807	$ 46,000	11.2	21	1	21	-1	2
36	036S_SH1609A	310	125	59	336	40	1	56	$ 197,131	$ 70,400	18.1	18.1	1	31	-1	0.5
36	036S_SH1610A	0	150	77	145	45	1	59	$ 526,430	$ 188,000	8.2	21.3	1	11	-1	2
36	036S_SH1613A	310	125	59	334	30	1	60	$ 227,373	$ 81,200	10.1	20	1	31	-1	2
36	036S_SH1615A	310	125	59	322	30	1	60	$ 392,022	$ 140,000	14	23.1	1	31	-1	0.5
36	036S_SH1614A	0	150	77	125	40	1	56	$ 600,000	$ 180,000	7.8	19.1	1	29	-1	2
36	036S_SHFF01A	310	125	59	350	40	1	56	$ 315,125	$ 109,150	10	22	1	31	-1	2
36	036S_SHFF04A	310	125	59	360	40	1	56	$ 315,125	$ 109,150	10	22	1	31	-1	2
36	036S_SHFF03A	0	150	77	185	40	1	56	$ 315,125	$ 109,150	10	22	1	24	-1	2
36	036S_SH1604A	0	125	59	350	40	1	56	$ 320,000	$ 96,000	10	22	1	29	-1	2
36	036S_SHHWY	250	64	1000	270	24	1	64	$ 105,868	$ -	9.3	9.3	1	34	-1	0.5
-999																
37	037S_SH1403A	290	140	77	280	35	1	59	$ 89,605	$ 32,000	9.3	20.2	1	31	-1	2
37	037S_SH1405A	290	140	77	282	40	1	59	$ 113,001	$ 40,355	13	23	1	31	-1	0.5
37	037S_SH1404A	0	230	63	125	30	1	60	$ 156,809	$ 56,000	13	25.2	1	22	-1	0.5
37	037S_SH1407A	290	140	77	284	40	1	56	$ 113,001	$ 40,355	14	23	1	31	-1	0.5
37	037S_SH1406A	0	230	63	127	20	1	59	$ 201,611	$ 72,000	12.1	21.7	1	19	-1	0.5
37	037S_SH1410A	0	230	63	144	40	1	56	$ 170,000	$ 51,000	12.8	24	1	28	-1	0.5
37	037S_SH1408A	0	230	63	151	25	1	60	$ 201,611	$ 72,000	10.9	20.2	1	6	-1	2
37	037S_SH1411A	290	140	77	298	35	1	60	$ 168,010	$ 60,000	11	22.4	1	31	-1	2
37	037S_SH1412A	0	230	63	140	30	1	60	$ 263,215	$ 94,000	12	21.9	1	1	-1	0.5
37	037S_SH1414A	0	230	63	138	30	1	60	$ 190,411	$ 68,000	10.4	20.9	1	6	-1	2
37	037S_SH1416A	0	230	63	134	40	1	59	$ 134,408	$ 48,000	10.3	19.7	1	21	-1	2
37	037S_SH1420A	0	230	63	142	30	1	59	$ 448,026	$ 160,000	10.3	21.5	1	3	-1	2
37	037S_SH1421A	290	140	77	338	30	1	1	$ 87,365	$ 31,200	9.2	9.2	1	31	-1	2
37	037S_SH1502A	0	230	63	151	20	1	60	$ 234,093	$ 83,600	12.3	21.6	1	4	-1	0.5
37	037S_SH1504A	0	230	63	149	20	1	60	$ 224,013	$ 80,000	10.4	20.4	1	24	-1	2
37	037S_SH1505A	290	140	77	340	25	1	55	$ 151,209	$ 54,000	13.5	18.3	1	31	-1	0.5

Reach ID	USACE_ID	REF lot front	Lot length	Lot width	REF struc front	Struc length	AA Ratio	Flood Curve	Replacement Value of Structure in Dollars	Value of Contents in Dollars	G_elev	FF_elev	Active	Erosion Curve	Armor	Erosion Indicator
37	037S_SH1506A	0	230	63	145	40	1	59	$ 96,325	$ 34,400	9.3	19	1	21	-1	2
37	037S_SH1507A	290	140	77	324	45	1	59	$ 156,809	$ 56,000	13.1	23.9	1	31	-1	0.5
37	037S_SH1508A	0	230	63	151	40	1	59	$ 108,646	$ 38,800	10.2	20.4	1	21	-1	2
37	037S_SH1509A	290	140	77	360	25	1	60	$ 181,450	$ 64,800	15.2	25.2	1	31	-1	0.5
37	037S_SH1510A	0	230	63	159	40	1	59	$ 145,608	$ 52,000	10.7	20.3	1	21	-1	2
37	037S_SH1511A	290	140	77	364	25	1	60	$ 126,567	$ 45,200	14.4	21.5	1	31	-1	0.5
37	037S_SH1512A	0	230	63	168	35	1	59	$ 280,016	$ 100,000	12.8	23.4	1	1	-1	0.5
37	037S_SH1515A	290	140	77	351	30	1	60	$ 179,210	$ 64,000	12.2	21.2	1	31	-1	0.5
37	037S_SH1516A	0	230	63	170	30	1	56	$ 260,975	$ 93,200	12.1	22.3	1	28	-1	0.5
37	037S_SH1517A	290	140	77	340	40	1	59	$ 123,207	$ 44,000	12	21	1	31	-1	0.5
37	037S_SH1518A	0	230	63	170	40	1	56	$ 580,000	$ 174,000	11.4	23	1	29	-1	2
37	037S_SHFF01A	290	140	77	290	40	1	56	$ 315,125	$ 109,150	10	22	1	31	-1	2
37	037S_SHFF02A	290	140	77	325	40	1	56	$ 315,125	$ 109,150	10	22	1	31	-1	2
37	037S_SHFF03A	0	125	70	135	40	1	56	$ 315,125	$ 109,150	10	22	1	31	-1	2
37	037S_SHHWY1	250	64	200	265	34	1	64	$ 21,169	$ -	8.8	8.8	1	34	-1	0.5
37	037S_SHHWY2	220	64	300	235	34	1	64	$ 31,765	$ -	8.8	8.8	1	34	-1	0.5
37	037S_SHHWY3	200	64	500	215	34	1	64	$ 52,934	$ -	8.8	8.8	1	34	-1	0.5
-999																
38	038KARE0104A	370	70	100	377	25	1	60	$ 192,651	$ 68,800	11	11.2	1	31	-1	2
38	038LORE0104A	370	70	100	374	25	1	56	$ 184,811	$ 66,000	14	24	1	31	-1	0.5
38	038ROSE0103A	370	70	100	375	30	1	59	$ 178,090	$ 63,600	11	10.5	1	31	-1	2
38	038S_SH1318A	0	210	56	143	35	1	55	$ 123,207	$ 44,000	13	21.8	1	28	-1	0.5
38	038S_SH1320A	0	210	56	128	45	1	59	$ 240,814	$ 86,000	10.7	24	1	3	-1	2
38	038S_SH1323A	270	100	67	303	25	1	60	$ 268,815	$ 96,000	8.8	17.8	1	31	-1	2
38	038S_SH1322A	0	210	56	113	40	1	59	$ 252,014	$ 90,000	10.4	20.2	1	3	-1	2
38	038S_SH1325A	270	100	67	307	35	1	59	$ 134,408	$ 48,000	8.1	16.9	1	31	-1	2
38	038S_SH1326A	0	210	56	152	35	1	60	$ 267,695	$ 95,600	13	22.2	1	4	-1	0.5
38	038S_SH1324A	0	210	56	128	35	1	59	$ 224,013	$ 80,000	8.9	17.5	1	3	-1	2
38	038S_SH1327A	270	100	67	316	25	1	59	$ 156,809	$ 56,000	7.9	17.3	1	31	-1	2
38	038S_SH1329A	270	100	67	294	25	1	60	$ 240,814	$ 86,000	8.7	20.6	1	31	-1	2
38	038S_SH1328A	0	210	56	104	30	1	60	$ 201,611	$ 72,000	14	20.8	1	4	-1	0.5
38	038S_SH1331A	270	100	67	290	40	1	59	$ 184,811	$ 66,000	9.1	19.6	1	31	-1	2
38	038S_SH1330A	0	210	56	123	45	1	59	$ 194,891	$ 69,600	11.2	20.9	1	3	-1	2
38	038S_SH1333A	270	100	67	308	25	1	56	$ 222,893	$ 79,600	9	19	1	31	-1	2
38	038S_SH1332A	0	210	56	136	35	1	60	$ 138,888	$ 49,600	12.5	23.3	1	4	-1	0.5
38	038S_SH1334A	0	210	56	124	45	1	59	$ 112,006	$ 40,000	10.3	18.8	1	21	-1	2
38	038S_SH1336A	0	210	56	125	35	1	60	$ 140,008	$ 50,000	11.1	24.1	1	23	-1	2

Reach ID	USACE_ID	REF lot front	Lot length	Lot width	REF struc front	Struc length	AA Ratio	Flood Curve	Replacement Value of Structure in Dollars	Value of Contents in Dollars	G_elev	FF_elev	Active	Erosion Curve	Armor	Erosion Indicator
38	038S_SH1338A	0	210	56	104	40	1	59	$ 201,611	$ 72,000	9.2	19.3	1	8	-1	2
38	038S_SH1340A	0	210	56	120	45	1	55	$ 112,006	$ 40,000	8.9	18.4	1	29	-1	2
38	038S_SH1342A	0	210	56	125	45	1	55	$ 154,569	$ 55,200	8.5	18.1	1	29	-1	2
38	038S_SH1344A	0	210	56	132	40	1	59	$ 190,411	$ 68,000	9.1	19.6	1	3	-1	2
38	038S_SH1346A	0	210	56	99	35	1	59	$ 125,447	$ 44,800	8	17.3	1	2	-1	2
38	038S_SH1348A	0	210	56	98	40	1	56	$ 328,000	$ 98,400	7.7	20	1	29	-1	2
38	038S_SH1401A	270	170	115	281	30	1	60	$ 302,417	$ 108,000	12	22.5	1	31	-1	0.5
38	038S_SH1350A	0	210	56	117	35	1	59	$ 179,210	$ 64,000	11	20.7	1	2	-1	2
38	038S_SH1402A	0	210	56	131	40	1	56	$ 710,000	$ 213,000	11.8	24.5	1	29	-1	2
38	038S_SHFF04A	270	170	115	280	40	1	56	$ 315,125	$ 109,150	9	21	1	24	-1	2
38	038S_SHFF05A	270	170	115	300	40	1	56	$ 315,125	$ 109,150	9	21	1	31	-1	2
38	038S_SHFF01A	270	170	140	320	40	1	56	$ 315,125	$ 109,150	9	21	1	31	-1	2
38	038S_SHFF02A	370	70	100	380	40	1	56	$ 315,125	$ 109,150	9	21	1	31	-1	2
38	038S_SHFF03A	270	170	115	290	40	1	56	$ 315,125	$ 109,150	9	21	1	31	-1	2
38	038S_SHHWY	190	64	1000	215	34	1	64	$ 105,868	$ -	7.8	7.8	1	34	-1	0.5
-999																
39	039S_SH1202A	0	230	59	93	35	1	59	$ 302,417	$ 108,000	10.4	21.5	1	20	-1	2
39	039S_SH1203A	290	170	125	315	50	1	59	$ 212,812	$ 76,000	7.9	16.8	1	31	-1	2
39	039S_SH1204A	0	230	59	108	30	1	59	$ 204,972	$ 73,200	9.9	21.6	1	20	-1	2
39	039S_SH1205A	290	170	125	323	30	1	60	$ 224,013	$ 80,000	7	19.1	1	31	-1	2
39	039S_SH1206A	0	230	59	83	35	1	2	$ 392,022	$ 140,000	10.6	10.6	1	31	-1	2
39	039S_SH1210A	0	230	59	155	45	1	59	$ 234,093	$ 83,600	12	21.4	1	19	-1	0.5
39	039S_SH1212A	0	230	59	108	60	1	59	$ 201,611	$ 72,000	8.8	17.9	1	3	-1	2
39	039S_SH1214A	0	230	59	121	45	1	59	$ 224,013	$ 80,000	9.7	17.9	1	3	-1	2
39	039S_SH1216A	0	230	59	100	55	1	59	$ 336,019	$ 120,000	10.1	22.3	1	20	-1	2
39	039S_SH1218A	0	230	59	118	35	1	55	$ 120,967	$ 43,200	8.3	19.6	1	30	-1	2
39	039S_SH1220A	0	230	59	127	40	1	56	$ 380,000	$ 114,000	8.4	20.6	1	29	-1	2
39	039S_SH1222A	0	230	59	141	30	1	60	$ 385,302	$ 137,600	7.2	19.2	1	6	-1	2
39	039S_SH1224A	0	230	59	149	30	1	60	$ 362,901	$ 129,600	10	20.9	1	15	-1	2
39	039S_SH1226A	0	230	59	171	30	1	60	$ 316,978	$ 113,200	14	22.6	1	4	-1	0.5
39	039S_SH1306A	0	230	59	176	45	1	59	$ 250,894	$ 89,600	16	23.6	1	10	-1	0.5
39	039S_SH1308A	0	230	59	180	25	1	60	$ 259,855	$ 92,800	16	23.6	1	13	-1	0.5
39	039S_SH1311A	290	170	125	397	30	1	56	$ 201,611	$ 72,000	15	24.5	1	31	-1	0.5
39	039S_SH1313A	290	170	125	388	30	1	56	$ 208,332	$ 74,400	13	26	1	31	-1	0.5
39	039S_SH1314A	0	230	59	160	40	1	56	$ 350,000	$ 105,000	8	20	1	29	-1	2
39	039S_SHFF03A	290	170	125	325	40	1	56	$ 315,125	$ 109,150	8	20	1	31	-1	2
39	039S_SH1310A	0	230	59	160	40	1	56	$ 250,000	$ 75,000	8	20	1	29	-1	2

Reach ID	USACE_ID	REF lot front	Lot length	Lot width	REF struc front	Struc length	AA Ratio	Flood Curve	Replacement Value of Structure in Dollars	Value of Contents in Dollars	G_elev	FF_elev	Active	Erosion Curve	Armor	Erosion Indicator
39	039S_SHFF05A	290	170	125	365	40	1	56	$ 315,125	$ 109,150	8	20	1	31	-1	2
39	039S_SHFF04A	0	230	59	170	40	1	56	$ 315,125	$ 109,150	8	20	1	24	-1	2
39	039S_SHFF02A	290	170	125	320	40	1	56	$ 315,125	$ 109,150	8	20	1	31	-1	2
39	039S_SHFF01A	290	170	125	320	40	1	56	$ 315,125	$ 109,150	0	20	1	31	-1	2
39	039N_TOHWY	350	64	600	365	34	1	64	$ 63,519	$ -	8.7	8.7	1	34	-1	0.5
39	039S_SHHWY1	220	64	200	335	34	1	64	$ 21,169	$ -	8.7	8.7	1	34	-1	0.5
39	039S_SHHWY2	250	64	200	265	34	1	64	$ 21,169	$ -	8.7	8.7	1	34	-1	0.5
39	039S_SHHWY3	240	64	600	255	34	1	64	$ 63,519	$ -	8.7	8.7	1	34	-1	0.5
-999																
40	040S_SH1105A	300	115	55	341	25	1	60	$ 236,333	$ 84,400	18.5	29.6	1	31	-1	0.5
40	040S_SH1108A	0	240	53	165	40	1	56	$ 420,000	$ 126,000	8.5	16.6	1	29	-1	2
40	040S_SH1107A	300	115	55	344	30	1	60	$ 113,001	$ 40,355	9	20.4	1	31	-1	2
40	040S_SH1110A	0	240	53	164	30	1	60	$ 268,815	$ 96,000	11	20	1	6	-1	2
40	040S_SH1111A	300	115	55	334	30	1	60	$ 212,812	$ 76,000	8	19.8	1	31	-1	2
40	040S_SH1112A	0	240	53	119	45	1	59	$ 134,408	$ 48,000	8.8	17.3	1	2	-1	2
40	040S_SH1113A	300	115	55	336	45	1	59	$ 134,408	$ 48,000	8.1	16.6	1	31	-1	2
40	040S_SH1114A	0	240	53	126	20	1	60	$ 246,414	$ 88,000	10.9	19.4	1	24	-1	2
40	040S_SH1117A	300	115	55	327	50	1	59	$ 267,695	$ 95,600	7.9	16	1	31	-1	2
40	040S_SH1115A	300	115	55	324	30	1	60	$ 267,695	$ 95,600	8	19.8	1	31	-1	2
40	040S_SH1116A	0	240	53	147	30	1	56	$ 302,417	$ 108,000	11	22.6	1	29	-1	2
40	040S_SH1118A	0	240	53	106	40	1	59	$ 95,205	$ 34,000	9	17.8	1	23	-1	2
40	040S_SH1119A	300	115	55	331	45	1	59	$ 145,608	$ 52,000	7.6	15.7	1	31	-1	2
40	040S_SH1120A	0	240	53	89	45	1	59	$ 108,646	$ 38,800	8.7	17.5	1	2	-1	2
40	040S_SH1121A	300	115	55	322	30	1	60	$ 225,133	$ 80,400	7	19	1	31	-1	2
40	040S_SH1122A	0	240	53	116	40	1	59	$ 134,408	$ 48,000	12.3	23.4	1	1	-1	0.5
40	040S_SH1123A	300	115	55	316	40	1	59	$ 96,325	$ 34,400	6.7	15.2	1	31	-1	2
40	040S_SH1124A	0	240	53	106	45	1	59	$ 168,010	$ 60,000	11.4	19.7	1	3	-1	2
40	040S_SH1126A	0	240	53	111	45	1	59	$ 89,605	$ 32,000	10.8	20.7	1	2	-1	2
40	040S_SH1127A	300	140	56	322	30	1	59	$ 113,001	$ 40,355	6.1	16.2	1	31	-1	2
40	040S_SH1128A	0	240	53	117	40	1	59	$ 201,611	$ 72,000	10.8	20.7	1	3	-1	2
40	040S_SH1129A	300	140	56	309	45	1	59	$ 192,651	$ 68,800	6.6	15.7	1	31	-1	2
40	040S_SH1130A	0	240	53	112	40	1	59	$ 190,411	$ 68,000	10.7	24.3	1	11	-1	2
40	040S_SH1132A	0	240	53	103	45	1	55	$ 145,608	$ 52,000	9.1	19.3	1	30	-1	2
40	040S_SH1136A	0	240	53	106	20	1	60	$ 280,016	$ 100,000	12	23.3	1	22	-1	0.5
40	040S_SH1138A	0	240	53	104	40	1	59	$ 313,618	$ 112,000	11.3	22.1	1	3	-1	2
40	040S_SH1139A	300	140	56	312	40	1	59	$ 224,013	$ 80,000	6.6	15.5	1	20	-1	2
40	040S_SH1140A	0	240	53	98	50	1	59	$ 224,013	$ 80,000	11.3	22.1	1	3	-1	2

Reach ID	USACE_ID	REF lot front	Lot length	Lot width	REF struc front	Struc length	AA Ratio	Flood Curve	Replacement Value of Structure in Dollars	Value of Contents in Dollars	G_elev	FF_elev	Active	Erosion Curve	Armor	Erosion Indicator
40	040S_SH1142A	0	240	53	97	30	1	2	$ 224,013	$ 80,000	9.8	9.8	1	30	-1	2
40	040S_TO1126A	415	25	55	401	30	1	59	$ 68,324	$ 24,400	5	14.1	1	31	-1	2
40	040S_SH1334A	0	240	53	145	40	1	56	$ 155,000	$ 46,500	7	19	1	29	-1	2
40	040S_SHFF03A	300	115	55	320	40	1	56	$ 315,125	$ 109,150	7	19	1	31	-1	2
40	040S_SH1106A	0	240	53	150	40	1	56	$ 360,000	$ 108,000	7	19	1	29	-1	2
40	040S_SHFF02A	300	115	55	340	40	1	56	$ 315,125	$ 109,150	7	19	1	31	-1	2
40	040S_SHFF08A	300	140	56	330	40	1	56	$ 315,125	$ 109,150	7	19	1	31	-1	2
40	040S_SHFF04A	300	140	56	325	40	1	56	$ 315,125	$ 109,150	7	19	1	31	-1	2
40	040S_SHFF06A	300	140	56	330	40	1	56	$ 315,125	$ 109,150	7	19	1	31	-1	2
40	040S_SHFF07A	300	140	56	320	40	1	56	$ 315,125	$ 109,150	7	19	1	31	-1	2
40	040S_SHHWY	230	64	1000	245	34	1	64	$ 105,868	$ -	9.2	9.2	1	34	-1	0.5
-999																
41	041S_SH1003A	340	150	67	373	25	1	60	$ 280,016	$ 100,000	11.4	21.7	1	31	-1	2
41	041S_SH1004A	0	150	50	153	40	1	59	$ 201,611	$ 72,000	9.7	18.4	1	31	-1	2
41	041S_SH1007A	340	150	67	375	30	1	59	$ 246,414	$ 88,000	12.6	21.3	1	31	-1	0.5
41	041S_SH1008A	0	225	50	142	55	1	59	$ 222,893	$ 79,600	15.2	24.4	1	10	-1	0.5
41	041S_SH1010A	0	225	50	132	35	1	59	$ 134,408	$ 48,000	12.5	24.2	1	19	-1	0.5
41	041S_SH1011A	340	150	67	388	30	1	60	$ 212,812	$ 76,000	8.9	17.4	1	31	-1	2
41	041S_SH1012A	0	225	50	189	30	1	60	$ 268,815	$ 96,000	13	23.5	1	22	-1	0.5
41	041S_SH1013A	340	150	67	376	35	1	59	$ 168,010	$ 60,000	9.9	18.8	1	31	-1	2
41	041S_SH1014A	0	225	50	168	50	1	60	$ 224,013	$ 80,000	7.2	18.6	1	24	-1	2
41	041S_SH1015A	340	150	67	367	30	1	60	$ 194,891	$ 69,600	10.7	19.8	1	31	-1	2
41	041S_SH1016A	0	225	50	142	45	1	59	$ 336,019	$ 120,000	11	21.4	1	3	-1	2
41	041S_SH1018A	0	225	50	142	35	1	60	$ 282,256	$ 100,800	11	20.2	1	6	-1	2
41	041S_SH1019A	340	150	67	365	25	1	60	$ 162,409	$ 58,000	11.7	21.4	1	31	-1	2
41	041S_SH1020A	0	225	50	134	45	1	60	$ 181,450	$ 64,800	12.7	22.4	1	4	-1	0.5
41	041S_SH1022A	0	225	50	138	35	1	59	$ 339,379	$ 121,200	13.3	21.4	1	1	-1	0.5
41	041S_SH1023A	340	150	67	363	25	1	60	$ 263,215	$ 94,000	8	18.7	1	31	-1	2
41	041S_SH1024A	0	225	50	157	40	1	60	$ 263,215	$ 94,000	13.3	21.7	1	4	-1	2
41	041S_SH1025A	340	150	67	339	35	1	59	$ 168,010	$ 60,000	14	22.9	1	31	-1	0.5
41	041S_SH1026A	0	225	50	137	30	1	60	$ 201,611	$ 72,000	13	22.5	1	4	-1	0.5
41	041S_SH1026X	0	225	50	138	30	1	60	$ 201,611	$ 72,000	13	22.5	1	4	-1	0.5
41	041S_SH1027A	340	150	67	328	40	1	59	$ 201,611	$ 72,000	15.4	24.3	1	31	-1	0.5
41	041S_SH1032A	0	225	50	136	45	1	59	$ 241,934	$ 86,400	10.1	22.4	1	20	-1	2
41	041S_SH1100A	0	225	50	139	25	1	60	$ 336,019	$ 120,000	9.3	19.7	1	3	-1	2
41	041S_SH1102A	0	225	50	124	45	1	60	$ 436,825	$ 156,000	9.6	21.3	1	24	-1	2
41	041S_SH1103A	340	150	67	334	45	1	55	$ 96,325	$ 34,400	16.2	25.1	1	31	-1	0.5

Reach ID	USACE_ID	REF lot front	Lot length	Lot width	REF struc front	Struc length	AA Ratio	Flood Curve	Replacement Value of Structure in Dollars	Value of Contents in Dollars	G_elev	FF_elev	Active	Erosion Curve	Armor	Erosion Indicator
41	041S_SH0918A	0	225	50	170	25	1	60	$ 224,013	$ 80,000	16	23.4	1	4	-1	0.5
41	041S_SH0919A	340	150	67	383	30	1	59	$ 114,247	$ 40,800	11.9	22	1	31	-1	2
41	041S_SH0920A	0	225	50	160	50	1	60	$ 336,019	$ 120,000	13.6	24.1	1	4	-1	0.5
41	041S_SH0922A	0	225	50	152	40	1	59	$ 201,611	$ 72,000	12.2	23.7	1	1	-1	0.5
41	041S_SH1006A	0	225	50	175	40	1	56	$ 302,000	$ 90,600	9	21	1	29	-1	2
41	041S_SHFF04A	340	150	67	370	40	1	56	$ 315,125	$ 109,150	9	21	1	31	-1	2
41	041S_SHFF05A	340	150	67	360	40	1	56	$ 315,125	$ 109,150	9	21	1	31	-1	2
41	041S_SH1002A	0	225	50	180	40	1	56	$ 248,000	$ 74,400	9	21	1	29	-1	2
41	041S_SHFF03A	340	150	67	370	40	1	56	$ 315,125	$ 109,150	9	21	1	31	-1	2
41	041S_SHFF06A	340	150	67	360	40	1	56	$ 315,125	$ 109,150	9	21	1	31	-1	2
41	041S_SHHWY	250	64	1000	265	34	1	64	$ 105,868	$ -	8.3	8.3	1	34	-1	0.5
-999																
42	042CROS0101A	350	70	77	445	40	1	60	$ 113,001	$ 40,355	9	18.7	1	31	-1	2
42	042CROS0107A	350	70	77	373	40	1	60	$ 113,001	$ 40,355	9	18.6	1	31	-1	2
42	042CROS0201A	350	80	77	369	40	1	60	$ 113,001	$ 40,355	9	18.1	1	31	-1	2
42	042S_SH0712A	0	200	71	166	30	1	60	$ 280,016	$ 100,000	14.7	24.9	1	4	-1	0.5
42	042S_SH0713A	350	180	77	383	45	1	59	$ 138,888	$ 49,600	16.5	25.7	1	31	-1	0.5
42	042S_SH0801A	350	180	77	371	30	1	60	$ 201,611	$ 72,000	17	27.2	1	31	-1	0.5
42	042S_SH0802A	0	200	71	151	40	1	56	$ 525,000	$ 157,500	16	25.2	1	28	-1	0.5
42	042S_SH0803A	350	180	77	382	30	1	60	$ 224,013	$ 80,000	18	28.1	1	31	-1	0.5
42	042S_SH0804A	0	200	71	144	50	1	59	$ 179,210	$ 64,000	15.5	24.8	1	19	-1	0.5
42	042S_SH0805A	350	180	77	377	30	1	60	$ 224,013	$ 80,000	18.9	29	1	31	-1	0.5
42	042S_SH0806A	0	200	71	179	30	1	60	$ 291,217	$ 104,000	15	24.5	1	1	-1	0.5
42	042S_SH0807A	350	180	77	381	35	1	59	$ 123,207	$ 44,000	19.4	28.1	1	31	-1	0.5
42	042S_SH0809A	350	180	77	391	30	1	60	$ 263,215	$ 94,000	8.9	18.6	1	31	-1	2
42	042S_SH0810A	0	200	71	178	30	1	60	$ 268,815	$ 96,000	11.5	20.8	1	14	-1	2
42	042S_SH0814A	0	200	71	217	30	1	60	$ 301,073	$ 107,520	13	21.3	1	4	-1	0.5
42	042S_SH0904A	0	230	71	164	40	1	60	$ 716,841	$ 256,000	10.4	18.8	1	20	-1	2
42	042S_SH0906A	0	230	71	166	40	1	60	$ 716,841	$ 256,000	10.5	18.9	1	20	-1	2
42	042S_SH0908A	0	230	71	167	40	1	60	$ 716,841	$ 256,000	10.4	18.6	1	20	-1	2
42	042S_SH0910A	0	200	71	168	40	1	60	$ 716,841	$ 256,000	10.2	18.4	1	20	-1	2
42	042S_SH0914A	0	230	71	219	35	1	60	$ 113,001	$ 40,355	13	21.4	1	4	-1	0.5
42	042S_SH0915A	350	370	77	379	35	1	56	$ 113,001	$ 40,355	9	18.7	1	31	-1	2
42	042S_SH0915X	350	100	77	378	35	1	56	$ 113,001	$ 40,355	10	18.7	1	31	-1	2
42	042S_SH0916A	0	200	71	160	70	1	59	$ 278,896	$ 99,600	11.6	20.5	1	11	-1	2
42	042S_SHFF01A	0	230	71	180	40	1	56	$ 315,125	$ 109,150	10	22	1	24	-1	2
42	042S_SH0812A	0	230	71	200	40	1	56	$ 630,000	$ 189,000	10	22	1	29	-1	2

Reach ID	USACE_ID	REF lot front	Lot length	Lot width	REF struc front	Struc length	AA Ratio	Flood Curve	Replacement Value of Structure in Dollars	Value of Contents in Dollars	G_elev	FF_elev	Active	Erosion Curve	Armor	Erosion Indicator
42	042S_SHFF03A	350	200	77	40	40	1	56	$ 315,125	$ 109,150	10	22	1	31	-1	2
42	042S_SHFF04A	350	200	77	40	40	1	56	$ 315,125	$ 109,150	10	22	1	31	-1	2
42	042S_SHHWY	280	64	1000	295	34	1	64	$ 105,868	$ -	8.1	8.1	1	34	-1	0.5
42	042CROSHWY	420	64	300	435	34	1	64	$ 42,966	$ -	8.1	8.1	1	34	-1	0.5
-999																
43	043S_SH0506A	0	200	63	125	40	1	60	$ 435,705	$ 155,600	14	25.2	1	4	-1	0.5
43	043S_SH0507A	320	150	64	297	40	1	1	$ 100,806	$ 36,000	17.1	17.1	1	31	-1	0.5
43	043S_SH0508A	0	200	63	131	40	1	60	$ 582,433	$ 208,000	14	24.8	1	4	-1	0.5
43	043S_SH0510A	0	200	63	136	30	1	60	$ 376,677	$ 134,520	14	24.7	1	4	-1	0.5
43	043S_SH0512A	0	200	63	141	35	1	60	$ 368,501	$ 131,600	13	24.8	1	4	-1	0.5
43	043S_SH0608A	0	200	63	156	30	1	60	$ 200,491	$ 71,600	10.3	21.5	1	14	-1	2
43	043S_SH0609A	320	150	64	359	30	1	60	$ 280,016	$ 100,000	11.5	21.9	1	31	-1	2
43	043S_SH0610A	0	200	63	129	60	1	59	$ 201,611	$ 72,000	11.8	20.3	1	3	-1	2
43	043S_SH0612A	0	200	63	138	40	1	59	$ 113,001	$ 40,355	11.2	19.7	1	12	-1	2
43	043S_SH0612G	0	0	0	220	30	1	59	$ 113,001	$ 40,355	10	17.5	1	12	-1	2
43	043S_SH0613A	320	150	64	380	30	1	59	$ 235,213	$ 84,000	8	19	1	31	-1	2
43	043S_SH0614A	0	200	63	145	35	1	59	$ 285,616	$ 102,000	9	17.5	1	3	-1	2
43	043S_SH0701A	320	150	64	378	45	1	59	$ 392,022	$ 140,000	9	17	1	31	-1	2
43	043S_SH0702A	0	45	63	119	40	1	56	$ 680,000	$ 204,000	16.8	28	1	28	-1	0.5
43	043S_SH0703A	320	150	64	377	40	1	60	$ 336,019	$ 120,000	13.1	21.6	1	31	-1	0.5
43	043S_SH0704A	0	200	63	139	25	1	60	$ 133,288	$ 47,600	15.2	24	1	4	-1	0.5
43	043S_SH0706A	0	200	63	154	35	1	60	$ 434,585	$ 155,200	14.1	24.2	1	4	-1	0.5
43	043S_SH0708A	10	200	63	155	50	1	59	$ 113,001	$ 40,355	13.5	24.7	1	10	-1	0.5
43	043S_SH0709A	320	150	64	384	30	1	60	$ 113,001	$ 40,355	14.5	24.7	1	31	-1	0.5
43	043S_SH0710A	0	200	63	157	50	1	60	$ 560,032	$ 200,000	14.3	24.8	1	4	-1	0.5
43	043CHARFF01A	400	150	100	405	40	1	56	$ 315,125	$ 109,150	11	23	1	31	-1	2
43	043S_SHFF11A	320	150	64	380	40	1	56	$ 315,125	$ 109,150	11	23	1	31	-1	2
43	043S_SHFF01A	320	150	64	300	40	1	56	$ 315,125	$ 109,150	11	23	1	31	-1	2
43	043S_SHFF07A	0	200	63	150	40	1	56	$ 315,125	$ 109,150	11	23	1	24	-1	2
43	043S_SHFF04A	320	150	50	350	40	1	56	$ 315,125	$ 109,150	11	23	1	31	-1	2
43	043S_SHFF06A	320	150	64	350	40	1	56	$ 315,125	$ 109,150	11	23	1	31	-1	2
43	043S_SHFF10A	320	150	64	380	40	1	56	$ 315,125	$ 109,150	11	23	1	31	-1	2
43	043S_SHFF05A	0	200	63	150	40	1	56	$ 315,125	$ 109,150	11	23	1	24	-1	2
43	043S_SHFF03A	0	200	63	145	40	1	56	$ 315,125	$ 109,150	11	23	1	24	-1	2
43	043S_SHFF12A	320	150	64	380	40	1	56	$ 315,125	$ 109,150	11	23	1	31	-1	2
43	043S_SHFF08A	320	150	64	370	40	1	56	$ 315,125	$ 109,150	11	23	1	31	-1	2
43	043S_SHFF02A	320	150	50	330	40	1	56	$ 315,125	$ 109,150	11	23	1	31	-1	2

Reach ID	USACE_ID	REF lot front	Lot length	Lot width	REF struc front	Struc length	AA Ratio	Flood Curve	Replacement Value of Structure in Dollars	Value of Contents in Dollars	G_elev	FF_elev	Active	Erosion Curve	Armor	Erosion Indicator
43	043S_SHFF01A	320	150	64	310	40	1	56	$ 315,125	$ 109,150	11	23	1	31	-1	2
43	043S_SHFF13A	320	150	64	390	40	1	56	$ 315,125	$ 109,150	11	23	1	31	-1	2
43	043S_SHHWY	220	64	1000	235	34	1	64	$ 105,868	$ -	7.3	7.3	1	34	-1	0.5
-999																
44	044DURH0103A	400	50	133	365	25	1	60	$ 113,001	$ 40,355	6	16.7	1	31	-1	2
44	044DURH0104G	360	50	75	371	25	1	1	$ 12,195	$ 4,355	6	6.5	1	31	-1	2
44	044DURH0104A	400	50	133	376	30	1	1	$ 113,001	$ 40,355	6	8.4	1	31	-1	2
44	044HIGH0105A	400	50	67	407	35	1	1	$ 113,001	$ 40,355	8	10.9	1	31	-1	2
44	044HIGH0105X	400	50	67	430	20	1	1	$ 113,001	$ 40,355	7	10.7	1	31	-1	2
44	044RALE0105A	400	50	133	411	40	1	1	$ 113,001	$ 40,355	7	8.7	1	31	-1	2
44	044RALE0106A	400	50	133	408	30	1	2	$ 113,001	$ 40,355	6	10.3	1	31	-1	2
44	044S_SH0301A	300	90	74	316	40	1	60	$ 247,534	$ 88,400	8	19	1	31	-1	2
44	044S_SH0302A	0	180	77	140	35	1	60	$ 358,420	$ 128,000	18	25.2	1	4	-1	0.5
44	044S_SH0303A	300	90	74	331	30	1	60	$ 265,455	$ 94,800	8	17.4	1	31	-1	2
44	044S_SH0304A	0	180	77	128	30	1	60	$ 255,375	$ 91,200	17	26.8	1	4	-1	0.5
44	044S_SH0305A	300	120	48	334	30	1	60	$ 227,373	$ 81,200	7	17.3	1	31	-1	2
44	044S_SH0306A	0	190	77	128	30	1	60	$ 280,016	$ 100,000	16	24.4	1	4	-1	0.5
44	044S_SH0307A	300	125	48	328	30	1	2	$ 78,404	$ 28,000	7	10.3	1	31	-1	0.5
44	044S_SH0309G	0	0	0	373	25	1	1	$ 67,204	$ 24,000	6	7.3	1	31	-1	0.5
44	044S_SH0309A	300	125	48	318	30	1	1	$ 68,324	$ 24,400	7	9.9	1	31	-1	0.5
44	044S_SH0310A	0	190	77	124	45	1	2	$ 115,367	$ 41,200	13	11	1	31	-1	0.5
44	044S_SH0311A	300	100	74	316	55	1	1	$ 100,806	$ 36,000	7	11	1	31	-1	0.5
44	044S_SH0312A	0	190	77	114	45	1	59	$ 201,611	$ 72,000	16	10.4	1	1	-1	0.5
44	044S_SH0313A	300	100	74	325	30	1	60	$ 267,695	$ 95,600	7	18.3	1	31	-1	2
44	044S_SH0401A	300	120	74	314	75	1	1	$ 103,046	$ 36,800	11.6	11.6	1	31	-1	0.5
44	044S_SH0402A	0	190	77	108	45	1	59	$ 179,210	$ 64,000	12.4	20.8	1	1	-1	0.5
44	044S_SH0404A	0	190	77	108	50	1	59	$ 212,812	$ 76,000	12.6	22.1	1	19	-1	0.5
44	044S_SH0403A	300	125	48	305	50	1	2	$ 84,005	$ 30,000	12.7	12.7	1	31	-1	0.5
44	044S_SH0405S	0	0	0	400	25	1	60	$ 224,013	$ 80,000	6	7.5	1	31	-1	2
44	044S_SH0406A	0	200	77	173	45	1	55	$ 113,001	$ 40,355	13	20.4	1	28	-1	0.5
44	044S_SH0408A	0	200	77	120	40	1	59	$ 134,408	$ 48,000	10.9	21	1	2	-1	2
44	044S_SH0405A	300	125	48	307	50	1	1	$ 224,013	$ 80,000	13.4	13.4	1	31	-1	0.5
44	044S_SH0410A	0	200	77	103	40	1	59	$ 134,408	$ 48,000	10.5	18.6	1	2	-1	2
44	044S_SH0412A	0	200	77	161	30	1	60	$ 262,095	$ 93,600	13	23.2	1	4	-1	0.5
44	044S_SH0413A	300	75	74	304	45	1	1	$ 69,444	$ 24,800	14.2	14.2	1	31	-1	0.5
44	044S_SH0501A	300	70	74	301	30	1	60	$ 246,414	$ 88,000	7	18.5	1	31	-1	2
44	044S_SH0503A	300	75	74	298	30	1	60	$ 209,452	$ 74,800	15.2	25.5	1	31	-1	0.5

Reach ID	USACE_ID	REF lot front	Lot length	Lot width	REF struc front	Struc length	AA Ratio	Flood Curve	Replacement Value of Structure in Dollars	Value of Contents in Dollars	G_elev	FF_elev	Active	Erosion Curve	Armor	Erosion Indicator
44	044S_SH0504A	0	200	77	89	30	1	59	$ 156,809	$ 56,000	19	28.5	1	19	-1	0.5
44	044S_SH0505A	300	200	48	294	40	1	1	$ 89,605	$ 32,000	16	16	1	31	-1	0.5
44	044S_SHFF01A	300	125	48	320	40	1	56	$ 315,125	$ 109,150	10	22	1	31	-1	2
44	044S_SHFF03A	0	200	77	160	40	1	56	$ 315,125	$ 109,150	10	22	1	24	-1	2
44	044S_SHFF02A	290	75	74	300	40	1	56	$ 315,125	$ 109,150	10	22	1	31	-1	2
44	044S_SHHWY	230	64	1000	245	34	1	64	$ 105,868	$ -	8.5	8.5	1	34	-1	0.5
-999																
45	045HIGH0106A	395	50	84	399	30	1	60	$ 113,001	$ 40,355	8	18.8	1	31	-1	2
45	045N_SH0102A	0	110	133	151	40	1	38	$ 422,264	$ 150,800	19	18.7	1	28	-1	0.5
45	045ROLA0204X	330	210	45	376	30	1	1	$ 113,001	$ 40,355	13	12.8	1	31	-1	0.5
45	045ROLA0204A	330	210	45	398	65	1	1	$ 113,001	$ 40,355	14	12.8	1	31	-1	0.5
45	045ROLA0205A	430	100	180	427	80	1	1	$ 113,001	$ 40,355	9	7.9	1	31	-1	0.5
45	045S_SH0101A	0	110	100	137	40	1	38	$ 113,001	$ 40,355	18	18.8	1	28	-1	2
45	045S_SH0103A	325	55	108	356	30	1	55	$ 67,204	$ 24,000	9	11.3	1	31	-1	2
45	045S_SH0110A	0	120	51	169	45	1	59	$ 201,611	$ 72,000	15	27.1	1	22	-1	2
45	045S_SH0112A	0	120	51	197	40	1	59	$ 113,001	$ 40,355	13	19	1	13	-1	2
45	045S_SH0116A	0	60	96	133	30	1	59	$ 112,006	$ 40,000	18	16.5	1	10	-1	2
45	045S_SH0116X	200	50	48	215	25	1	59	$ 112,006	$ 40,000	13	15.8	1	31	-1	2
45	045S_SH0116Y	200	50	48	207	30	1	59	$ 112,006	$ 40,000	12	15.8	1	31	-1	2
45	045S_SH0120A	0	120	52	151	25	1	60	$ 324,819	$ 116,000	15	24.8	1	4	-1	2
45	045S_SH0122X	0	125	52	156	12	1	25	$ 20,161	$ 7,200	15	14.2	1	4	-1	2
45	045S_SH0002P	0	110	70	137	20	1	1	$ 113,001	$ 40,355	17	18.9	1	4	-1	2
45	045S_SH0202A	0	180	52	153	25	1	60	$ 324,819	$ 116,000	17	14.7	1	4	-1	2
45	045S_SH0204A	0	180	52	151	30	1	60	$ 257,615	$ 92,000	17	14.7	1	4	-1	2
45	045S_SH0205A	313	100	49	336	35	1	1	$ 113,001	$ 40,355	7	9.2	1	31	-1	0.5
45	045S_SH0205X	380	100	49	396	30	1	1	$ 113,001	$ 40,355	7	10.1	1	31	-1	0.5
45	045S_SH0206A	0	180	52	169	40	1	60	$ 324,819	$ 116,000	12	22	1	22	-1	2
45	045S_SH0207A	313	100	51	317	40	1	60	$ 113,001	$ 40,355	7	20	1	31	-1	2
45	045S_SH0208A	0	45	52	159	45	1	60	$ 369,621	$ 132,000	14	22.6	1	4	-1	0.5
45	045S_SH0209A	313	100	54	334	30	1	1	$ 113,001	$ 40,355	7	10.4	1	31	-1	0.5
45	045S_SH0210A	0	180	52	153	35	1	60	$ 320,338	$ 114,400	15	23.6	1	22	-1	2
45	045S_SH0211A	305	100	42	317	35	1	60	$ 240,814	$ 86,000	7	19	1	31	-1	2
45	045S_SH0212A	0	180	52	157	40	1	60	$ 357,300	$ 127,600	13	24.9	1	22	-1	2
45	045S_SH0213A	305	90	42	311	40	1	60	$ 240,814	$ 86,000	7	18.9	1	31	-1	2
45	045S_SH0214A	0	180	52	165	35	1	60	$ 313,618	$ 112,000	14	22.5	1	4	-1	0.5
45	045S_TO0116A	430	100	180	438	40	1	35	$ 232,973	$ 83,200	8	9.7	1	31	-1	0.5
45	045S_TO0210A	420	125	54	429	30	1	1	$ 135,494	$ 48,388	7	8.7	1	31	-1	0.5

Reach ID	USACE_ID	REF lot front	Lot length	Lot width	REF struc front	Struc length	AA Ratio	Flood Curve	Replacement Value of Structure in Dollars	Value of Contents in Dollars	G_elev	FF_elev	Active	Erosion Curve	Armor	Erosion Indicator
45	045S_SHFF01A	325	60	108	340	40	1	56	$ 315,125	$ 109,150	12	24	1	31	-1	2
45	045S_SHFF02A	205	50	100	215	40	1	56	$ 315,125	$ 109,150	9	24	1	31	-1	2
45	045S_SHFF05A	325	100	108	340	40	1	56	$ 315,125	$ 109,150	9	24	1	31	-1	2
45	045S_TOFF01A	430	100	180	450	40	1	56	$ 315,125	$ 109,150	9	24	1	31	-1	2
45	045S_SHFF03A	0	125	51	200	40	1	56	$ 315,125	$ 109,150	9	24	1	24	-1	2
45	045S_SHFF06A	325	100	108	340	40	1	56	$ 315,125	$ 109,150	9	24	1	31	-1	2
45	045S_SHFF07A	325	100	108	330	40	1	56	$ 315,125	$ 109,150	9	24	1	31	-1	2
45	045S_SHFF08A	313	200	132	350	40	1	56	$ 315,125	$ 109,150	9	24	1	31	-1	2
45	045S_SHFF04A	0	125	51	190	40	1	56	$ 315,125	$ 109,150	9	24	1	24	-1	2
45	045S_SHHWY	250	64	1000	265	34	1	64	$ 105,868	$ -	8.2	8.2	1	34	-1	0.5
-999																
46	046GREE0203A	372	50	140	368	35	1	1	$ 113,001	$ 40,355	10	12	1	31	-1	0.5
46	046N_SH0107A	321	120	63	319	50	1	1	$ 201,611	$ 72,000	12	15.6	1	31	-1	0.5
46	046N_SH0107S	0	0	0	396	20	1	1	$ 113,001	$ 40,355	11	17	1	31	-1	0.5
46	046N_SH0108A	0	180	68	149	60	1	2	$ 784,045	$ 280,000	20	13.8	1	31	-1	0.5
46	046N_SH0111A	321	100	63	344	45	1	59	$ 333,779	$ 119,200	12	18.7	1	31	-1	2
46	046N_SH0114A	0	100	68	206	40	1	59	$ 160,169	$ 57,200	16	13.1	1	1	-1	2
46	046N_SH0121A	321	100	63	334	40	1	1	$ 92,965	$ 33,200	11	14.2	1	31	-1	0.5
46	046N_SH0123A	300	70	70	316	25	1	60	$ 257,615	$ 92,000	11	20.2	1	31	-1	2
46	046N_SH0124A	0	170	68	180	20	1	60	$ 134,408	$ 48,000	16	12.8	1	22	-1	2
46	046N_SH0202A	0	170	68	188	25	1	60	$ 280,016	$ 100,000	12	21.8	1	22	-1	2
46	046N_SH0204A	0	170	68	185	25	1	60	$ 280,016	$ 100,000	11	21.5	1	23	-1	2
46	046N_SH0206A	0	170	68	182	20	1	60	$ 280,016	$ 100,000	11	21.4	1	23	-1	2
46	046N_SH0207A	281	90	73	284	30	1	1	$ 72,804	$ 26,000	8	10.9	1	31	-1	0.5
46	046N_SH0208A	0	170	68	147	35	1	60	$ 287,856	$ 102,800	14	22.3	1	22	-1	2
46	046N_SH0209A	281	90	73	288	55	1	59	$ 226,253	$ 80,800	8	10	1	31	-1	2
46	046N_SH0211S	0	80	0	329	15	1	59	$ 226,253	$ 80,800	7	8.6	1	31	-1	2
46	046N_SH0211A	281	80	73	269	35	1	2	$ 336,019	$ 120,000	6	8.9	1	31	-1	0.5
46	046N_SH0212A	0	170	68	112	45	1	60	$ 252,014	$ 90,000	16	20.4	1	4	-1	2
46	046N_SH0213A	0	50	50	261	35	1	1	$ 179,210	$ 64,000	6	9.5	1	31	-1	0.5
46	046N_SH0213M	148	50	50	310	30	1	1	$ 179,210	$ 64,000	6	9.7	1	31	-1	0.5
46	046N_SH0214A	148	170	50	159	30	1	1	$ 82,885	$ 29,600	9	17.3	1	31	-1	0.5
46	046N_SH0214X	0	170	50	104	30	1	1	$ 113,001	$ 40,355	17	18.6	1	31	-1	0.5
46	046N_TO0106A	432	100	56	475	40	1	53	$ 156,809	$ 56,000	10	8.9	1	31	-1	0.5
46	046N_TO0114A	432	100	56	412	40	1	60	$ 148,968	$ 53,200	10	13.3	1	31	-1	2
46	046N_TO0118A	432	100	56	454	40	1	53	$ 67,204	$ 24,000	9	10.3	1	31	-1	2
46	046N_TO0206A	376	90	150	367	35	1	60	$ 113,001	$ 40,355	7	13.4	1	31	-1	2

Reach ID	USACE_ID	REF lot front	Lot length	Lot width	REF struc front	Struc length	AA Ratio	Flood Curve	Replacement Value of Structure in Dollars	Value of Contents in Dollars	G_elev	FF_elev	Active	Erosion Curve	Armor	Erosion Indicator
46	046N_TOFF04A	432	100	56	440	40	1	56	$ 315,125	$ 109,150	11	23	1	31	-1	2
46	046S_SHFF02A	281	90	73	300	40	1	56	$ 315,125	$ 109,150	11	23	1	31	-1	2
46	046N_SHFF07A	321	100	63	350	40	1	56	$ 315,125	$ 109,150	11	23	1	31	-1	2
46	046N_TOFF07A	432	100	56	460	40	1	56	$ 315,125	$ 109,150	11	23	1	31	-1	2
46	046N_TOFF02A	422	80	70	440	40	1	56	$ 315,125	$ 109,150	11	23	1	31	-1	2
46	046N_SHFF12A	321	110	63	360	40	1	56	$ 315,125	$ 109,150	11	23	1	31	-1	2
46	046N_TOFF05A	432	100	56	440	40	1	56	$ 315,125	$ 109,150	11	23	1	31	-1	2
46	046N_TOFF06A	432	100	56	450	40	1	56	$ 315,125	$ 109,150	11	23	1	31	-1	2
46	046N_SHFF05A	321	100	63	340	40	1	56	$ 315,125	$ 109,150	11	23	1	31	-1	2
46	046S_SHFF03A	300	70	70	310	40	1	56	$ 315,125	$ 109,150	11	23	1	31	-1	2
46	046N_TOFF09A	432	100	56	480	40	1	56	$ 315,125	$ 109,150	11	23	1	31	-1	2
46	046N_TOFF08A	432	100	56	480	40	1	56	$ 315,125	$ 109,150	11	23	1	31	-1	2
46	046S_SHFF01A	0	170	68	155	40	1	56	$ 315,125	$ 109,150	11	23	1	24	-1	2
46	046N_TOFF03A	422	80	70	450	40	1	56	$ 315,125	$ 109,150	11	23	1	31	-1	2
46	046N_SHFF09A	321	110	63	350	40	1	56	$ 315,125	$ 109,150	11	23	1	31	-1	2
46	046N_SHFF08A	0	180	68	180	40	1	56	$ 315,125	$ 109,150	11	23	1	24	-1	2
46	046N_SHFF13A	321	110	63	350	40	1	56	$ 315,125	$ 109,150	11	23	1	31	-1	2
46	046N_SHFF11A	0	180	68	180	40	1	56	$ 315,125	$ 109,150	11	23	1	24	-1	2
46	046N_SHFF04A	0	180	68	180	40	1	56	$ 315,125	$ 109,150	11	23	1	24	-1	2
46	046N_SHFF06A	0	180	68	180	40	1	56	$ 315,125	$ 109,150	11	23	1	24	-1	2
46	046N_SHFF10A	0	180	68	180	40	1	56	$ 315,125	$ 109,150	11	23	1	24	-1	2
46	046GOLDFF01A	401	50	70	410	40	1	56	$ 315,125	$ 109,150	11	23	1	31	-1	2
46	046GRENFF01A	380	50	140	390	40	1	56	$ 315,125	$ 109,150	11	23	1	31	-1	2
46	046GOLDFF02A	357	50	70	365	40	1	56	$ 315,125	$ 109,150	11	23	1	31	-1	2
46	046N_TOFF01A	447	50	140	430	40	1	56	$ 315,125	$ 109,150	11	23	1	31	-1	2
46	046N_SHHWY	230	64	1000	245	34	1	64	$ 105,868	$ -	10.8	10.8	1	34	-1	0.5
-999																
47	047N_SH0302A	0	190	59	105	45	1	59	$ 134,408	$ 48,000	16	19.4	1	1	-1	2
47	047N_SH0302F	200	190	59	166	20	1	59	$ 22,401	$ 8,000	11	22.2	1	31	-1	2
47	047N_SH0302A	0	190	200	282	170	1	59	$ 672,038	$ 240,000	7	10.6	1	3	-1	2
47	047N_SH0304A	0	190	59	126	40	1	59	$ 168,010	$ 60,000	13	25.1	1	19	-1	2
47	047N_SH0305S	300	90	62	345	20	1	2	$ 22,401	$ 8,000	7	8.5	1	31	-1	0.5
47	047N_SH0306G	0	190	0	163	45	1	55	$ 113,001	$ 40,355	10	19.5	1	30	-1	2
47	047N_SH0306A	0	190	59	110	30	1	55	$ 113,001	$ 40,355	17	14.3	1	30	-1	2
47	047N_SH0307A	300	90	62	277	45	1	1	$ 89,605	$ 32,000	7	12.6	1	31	-1	0.5
47	047N_SH0308A	0	190	59	108	40	1	55	$ 58,243	$ 20,800	16	18.6	1	28	-1	2
47	047N_SH0311A	300	90	62	301	40	1	1	$ 106,406	$ 38,000	8	12.5	1	31	-1	0.5

Reach ID	USACE_ID	REF lot front	Lot length	Lot width	REF struc front	Struc length	AA Ratio	Flood Curve	Replacement Value of Structure in Dollars	Value of Contents in Dollars	G_elev	FF_elev	Active	Erosion Curve	Armor	Erosion Indicator
47	047N_SH0312A	0	190	59	119	50	1	59	$ 201,611	$ 72,000	17	22.5	1	1	-1	2
47	047N_SH0313A	300	90	62	288	35	1	1	$ 94,085	$ 33,600	8	11.1	1	31	-1	0.5
47	047N_SH0314A	0	190	59	129	35	1	59	$ 112,006	$ 40,000	15	14.2	1	31	-1	2
47	047N_SH0315A	300	80	62	302	25	1	60	$ 235,213	$ 84,000	7	18.9	1	31	-1	2
47	047N_SH0316A	0	190	59	116	40	1	1	$ 113,001	$ 40,355	17	21.6	1	31	-1	0.5
47	047N_SH0316G	0	190	59	164	30	1	60	$ 113,001	$ 40,355	12	26.8	1	4	-1	2
47	047N_SH0317A	300	80	62	308	35	1	60	$ 218,412	$ 78,000	7	18	1	31	-1	2
47	047N_SH0318A	0	190	59	130	45	1	55	$ 280,016	$ 100,000	17	27.6	1	28	-1	2
47	047N_SH0320A	0	190	59	184	25	1	60	$ 344,980	$ 123,200	11	23.2	1	24	-1	2
47	047N_SH0322A	0	190	59	168	25	1	55	$ 96,325	$ 34,400	17	23.9	1	28	-1	2
47	047N_SH0324A	0	190	59	131	30	1	60	$ 190,411	$ 68,000	18	24.2	1	4	-1	2
47	047N_SH0326X	200	190	59	188	40	1	1	$ 113,001	$ 40,355	12	14.3	1	31	-1	0.5
47	047N_SH0326A	0	190	59	104	40	1	1	$ 113,001	$ 40,355	17	21	1	31	-1	0.5
47	047N_SH0327A	300	80	62	314	35	1	2	$ 147,848	$ 52,800	8	9.8	1	31	-1	0.5
47	047N_SH0328A	0	190	59	176	35	1	60	$ 392,022	$ 140,000	14	23.6	1	22	-1	2
47	047N_SH0330A	0	190	59	151	30	1	60	$ 280,016	$ 100,000	16	24.9	1	4	-1	2
47	047N_SH0331A	300	80	62	311	25	1	1	$ 71,684	$ 25,600	8	11	1	31	-1	0.5
47	047N_SH0332X	0	190	59	138	30	1	60	$ 280,016	$ 100,000	18	20.7	1	4	-1	2
47	047N_SH0332A	200	190	59	188	25	1	60	$ 96,325	$ 34,400	17	26.6	1	4	-1	2
47	047N_SH0333A	300	80	62	307	30	1	60	$ 134,408	$ 48,000	9	9.7	1	31	-1	2
47	047N_SH0334A	0	190	59	201	30	1	1	$ 313,618	$ 112,000	13	22.1	1	31	-1	0.5
47	047N_TO0306A	390	75	67	398	40	1	1	$ 113,001	$ 40,355	7	10.4	1	31	-1	0.5
47	047N_TO0312A	390	75	67	382	20	1	1	$ 48,163	$ 17,200	7	10	1	31	-1	0.5
47	047N_TO0314A	390	75	67	415	35	1	1	$ 112,006	$ 40,000	7	11	1	31	-1	0.5
47	047N_TO0316A	390	75	67	382	14	1	1	$ 113,001	$ 40,355	7	9.7	1	31	-1	0.5
47	047N_TO0322A	390	75	67	415	30	1	1	$ 134,408	$ 48,000	7	10.8	1	31	-1	0.5
47	047N_TO0324A	390	75	67	402	40	1	55	$ 118,727	$ 42,400	7	10.9	1	30	-1	2
47	047N_TO0326A	390	75	67	414	30	1	55	$ 78,404	$ 28,000	8	10.4	1	29	-1	2
47	047N_TO0328A	390	75	67	387	35	1	1	$ 144,488	$ 51,600	8	12.1	1	31	-1	0.5
47	047N_TO0330A	390	75	67	413	25	1	55	$ 67,204	$ 24,000	8	10.2	1	31	-1	2
47	047N_TO0334A	390	75	67	408	55	1	60	$ 162,409	$ 58,000	9	10.9	1	31	-1	2
47	047NEW_0201A	300	70	62	323	45	1	1	$ 113,001	$ 40,355	9	10.5	1	31	-1	0.5
47	047N_SHFF04A	300	80	62	320	40	1	56	$ 315,125	$ 109,150	8	20	1	31	-1	2
47	047N_SHFF03A	0	180	59	155	40	1	56	$ 315,125	$ 109,150	8	20	1	21	-1	2
47	047N_SHFF01A	300	80	62	340	40	1	56	$ 315,125	$ 109,150	8	20	1	31	-1	2
47	047N_SHFF02A	300	80	62	330	40	1	56	$ 315,125	$ 109,150	8	20	1	31	-1	2
47	047N_TOFF01A	390	80	67	410	40	1	56	$ 315,125	$ 109,150	8	20	1	31	-1	2

Reach ID	USACE_ID	REF lot front	Lot length	Lot width	REF struc front	Struc length	AA Ratio	Flood Curve	Replacement Value of Structure in Dollars	Value of Contents in Dollars	G_elev	FF_elev	Active	Erosion Curve	Armor	Erosion Indicator
47	047N_TOFF02A	390	80	67	400	40	1	56	$ 315,125	$ 109,150	8	20	1	31	-1	2
47	047N_SHHWY	220	64	1000	235	34	1	64	$ 105,868	$ -	9.7	9.7	1	34	-1	0.5
47	047N_TOHWY	450	64	1000	465	34	1	64	$ 105,868	$ -	9.7	9.7	1	34	-1	0.5
-999																
48	048N_SH0401A	320	80	56	326	35	1	1	$ 61,604	$ 22,000	8	9.9	1	31	-1	0.5
48	048N_SH0402A	0	200	62	162	30	1	60	$ 357,300	$ 127,600	16	24.9	1	1	-1	2
48	048N_SH0403A	320	80	56	329	30	1	1	$ 44,803	$ 16,000	8	8.7	1	31	-1	0.5
48	048N_SH0404A	0	200	62	153	30	1	60	$ 492,828	$ 176,000	17	20.3	1	4	-1	2
48	048N_SH0405A	320	80	56	331	35	1	1	$ 67,204	$ 24,000	8	10.4	1	31	-1	0.5
48	048N_SH0406A	0	200	62	154	35	1	60	$ 436,825	$ 156,000	17	14.3	1	4	-1	2
48	048N_SH0408A	0	200	62	132	45	1	59	$ 153,449	$ 54,800	18	14	1	1	-1	2
48	048N_SH0409A	320	80	56	328	25	1	2	$ 134,408	$ 48,000	8	9.3	1	31	-1	0.5
48	048N_SH0411A	320	80	56	323	45	1	59	$ 257,615	$ 92,000	8	10.8	1	31	-1	2
48	048N_SH0412A	0	200	62	109	40	1	59	$ 61,604	$ 22,000	18	20.8	1	1	-1	2
48	048N_SH0413A	320	80	56	317	30	1	1	$ 56,003	$ 20,000	9	9.7	1	31	-1	0.5
48	048N_SH0414G	0	200	62	177	12	1	55	$ 113,001	$ 40,355	15	15	1	31	-1	2
48	048N_SH0414A	0	200	62	115	30	1	55	$ 268,815	$ 96,000	18	21	1	28	-1	2
48	048N_SH0414X	170	80	62	206	30	1	55	$ 113,001	$ 40,355	13	12.7	1	31	-1	2
48	048N_SH0415A	320	80	56	309	35	1	55	$ 113,001	$ 40,355	9	18.5	1	31	-1	2
48	048N_SH0415X	355	80	56	352	30	1	1	$ 113,001	$ 40,355	7	9.5	1	31	-1	0.5
48	048N_SH0416A	0	200	62	114	35	1	55	$ 123,207	$ 44,000	18	20.6	1	28	-1	2
48	048N_SH0416G	0	200	62	220	20	1	1	$ 11,201	$ 4,000	12	13.6	1	31	-1	0.5
48	048N_SH0417A	320	80	56	317	30	1	1	$ 56,003	$ 20,000	9	11.2	1	31	-1	0.5
48	048N_SH0418A	0	200	62	105	35	1	2	$ 113,001	$ 40,355	17	19.8	1	31	-1	0.5
48	048N_SH0418G	0	80	62	219	25	1	2	$ 22,401	$ 8,000	12	17.7	1	31	-1	0.5
48	048N_SH0419P	0	80	62	327	55	1	11	$ 44,803	$ 16,000	9	10.2	1	31	-1	2
48	048N_SH0420A	0	200	62	158	35	1	60	$ 369,621	$ 132,000	16	26.3	1	4	-1	2
48	048N_SH0422A	0	200	62	121	40	1	59	$ 194,891	$ 69,600	18	24.9	1	1	-1	2
48	048N_SH0424A	0	200	62	167	30	1	60	$ 380,822	$ 136,000	16	25.7	1	4	-1	2
48	048N_SH0426A	0	200	62	178	30	1	60	$ 113,001	$ 40,355	16	26	1	25	-1	2
48	048N_SH0502A	0	200	62	100	35	1	55	$ 156,809	$ 56,000	16	21.7	1	28	-1	2
48	048N_SH0504A	0	200	62	172	45	1	55	$ 235,213	$ 84,000	13	23.4	1	28	-1	2
48	048N_SH0508A	0	200	62	113	45	1	59	$ 312,498	$ 111,600	17	23.3	1	1	-1	2
48	048N_SH0509A	320	80	50	331	20	1	60	$ 113,001	$ 40,355	10	20.4	1	31	-1	2
48	048N_TO0402A	390	65	62	412	30	1	1	$ 28,002	$ 10,000	8	9.7	1	31	-1	0.5
48	048N_TO0404A	390	65	62	413	50	1	1	$ 11,761	$ 4,200	7	10.7	1	31	-1	0.5
48	048N_TO0406A	390	65	62	394	40	1	2	$ 160,169	$ 57,200	7	9.5	1	31	-1	0.5

Reach ID	USACE_ID	REF lot front	Lot length	Lot width	REF struc front	Struc length	AA Ratio	Flood Curve	Replacement Value of Structure in Dollars	Value of Contents in Dollars	G_elev	FF_elev	Active	Erosion Curve	Armor	Erosion Indicator
48	048N_TO0408A	390	65	62	413	30	1	1	$ 109,766	$ 39,200	7	9.3	1	31	-1	0.5
48	048N_TO0410A	390	65	62	413	30	1	1	$ 81,765	$ 29,200	7	10.1	1	31	-1	0.5
48	048N_TO0412A	390	65	62	401	40	1	1	$ 62,724	$ 22,400	7	9.7	1	31	-1	0.5
48	048N_TO0414A	390	65	62	389	35	1	2	$ 134,408	$ 48,000	7	7.7	1	31	-1	0.5
48	048N_TO0418A	390	65	62	400	30	1	2	$ 168,010	$ 60,000	7	10.8	1	31	-1	0.5
48	048N_TO0420A	320	65	200	396	30	1	17	$ 168,010	$ 60,000	8	10.4	1	31	-1	2
48	048N_TO0420S	0	0	0	412	20	1	25	$ 22,401	$ 8,000	10	10.6	1	31	-1	2
48	048WILM0200A	320	125	200	341	80	1	24	$ 280,016	$ 100,000	11	13.2	1	31	-1	2
48	048N_SHFF01A	320	125	50	340	40	1	56	$ 315,125	$ 109,150	12	24	1	31	-1	2
48	048S_SHFF03A	320	200	56	325	40	1	56	$ 315,125	$ 109,150	12	24	1	31	-1	2
48	048N_SHFF02A	0	200	62	170	40	1	56	$ 315,125	$ 109,150	12	24	1	19	-1	2
48	048N_SHHWY	260	64	1000	275	34	1	64	$ 105,868	$ -	11.3	11.3	1	34	-1	0.5
-999																
49	049N_SH0511A	310	120	50	342	30	1	60	$ 252,014	$ 90,000	9	21.2	1	31	-1	2
49	049N_SH0512A	185	50	150	205	35	1	56	$ 449,020	$ 160,355	16	24.7	1	31	-1	2
49	049N_SH0513A	310	120	50	336	30	1	1	$ 33,602	$ 12,000	10	11.7	1	31	-1	0.5
49	049N_SH0514A	0	140	75	116	30	1	55	$ 133,064	$ 47,520	22	27.6	1	28	-1	2
49	049N_SH0516A	0	140	75	114	30	1	55	$ 460,221	$ 164,355	21	27.6	1	28	-1	2
49	049N_SH0518A	0	75	50	184	30	1	60	$ 113,001	$ 40,355	15	25.3	1	19	-1	2
49	049N_SH0519A	310	120	50	319	30	1	1	$ 69,444	$ 24,800	10	11.6	1	31	-1	0.5
49	049N_SH0519S	0	0	0	381	12	1	1	$ 22,401	$ 8,000	9	9.6	1	31	-1	0.5
49	049N_SH0520A	0	220	50	167	40	1	60	$ 851,249	$ 304,000	15	25.3	1	22	-1	2
49	049N_SH0521A	310	60	75	308	40	1	59	$ 113,001	$ 40,355	10	19.2	1	31	-1	2
49	049N_SH0522A	0	190	50	102	35	1	55	$ 78,404	$ 28,000	20	21.5	1	28	-1	2
49	049N_SH0602A	0	170	81	149	30	1	60	$ 280,016	$ 100,000	18	25.9	1	22	-1	2
49	049N_SH0605A	225	90	81	242	35	1	1	$ 58,243	$ 20,800	11	13.6	1	31	-1	0.5
49	049N_SH0606A	0	150	81	101	30	1	59	$ 168,010	$ 60,000	20	27.9	1	19	-1	2
49	049N_SH0607A	225	90	81	241	35	1	1	$ 70,564	$ 25,200	11	14.1	1	31	-1	0.5
49	049N_SH0608A	0	140	81	86	40	1	59	$ 162,409	$ 58,000	17	25.5	1	19	-1	2
49	049N_SH0610A	0	150	81	95	35	1	2	$ 162,409	$ 58,000	19	15.1	1	31	-1	0.5
49	049N_SH0611A	225	80	81	246	20	1	1	$ 44,803	$ 16,000	12	13.6	1	31	-1	0.5
49	049N_SH0611W	0	0	0	288	8	1	1	$ 44,803	$ 16,000	9	10.2	1	31	-1	0.5
49	049N_SH0614A	0	140	81	114	35	1	2	$ 179,210	$ 64,000	19	22.3	1	31	-1	0.5
49	049N_SH0616A	0	140	81	99	35	1	2	$ 168,010	$ 60,000	18	15	1	31	-1	0.5
49	049N_SH0617A	225	100	81	223	35	1	1	$ 67,204	$ 24,000	13	15.3	1	31	-1	0.5
49	049N_SH0618A	0	140	81	101	25	1	2	$ 291,217	$ 104,000	19	24.1	1	31	-1	0.5
49	049N_SH0620A	0	140	81	105	25	1	2	$ 252,014	$ 90,000	17	24.4	1	31	-1	0.5

Reach ID	USACE_ID	REF lot front	Lot length	Lot width	REF struc front	Struc length	AA Ratio	Flood Curve	Replacement Value of Structure in Dollars	Value of Contents in Dollars	G_elev	FF_elev	Active	Erosion Curve	Armor	Erosion Indicator
49	049N_SH0702A	0	220	50	119	40	1	60	$ 441,305	$ 157,600	12	22.6	1	22	-1	2
49	049N_TO0515A	310	120	50	326	70	1	1	$ 11,201	$ 4,000	11	11	1	31	-1	0.5
49	049N_TO0522A	370	60	75	382	35	1	1	$ 113,001	$ 40,355	9	9.6	1	31	-1	0.5
49	049N_TO0606A	310	100	81	327	40	1	1	$ 113,001	$ 40,355	8	9.6	1	31	-1	0.5
49	049N_TO0608A	310	100	81	321	40	1	1	$ 113,001	$ 40,355	8	9.6	1	31	-1	0.5
49	049N_TO0610A	310	100	81	302	45	1	1	$ 113,001	$ 40,355	9	10.3	1	31	-1	0.5
49	049N_TO0612A	310	100	81	320	40	1	59	$ 113,001	$ 40,355	8	16.8	1	31	-1	2
49	049N_TO0618A	310	180	81	329	30	1	2	$ 113,001	$ 40,355	8	15.3	1	31	-1	0.5
49	049N_TO0620A	210	100	110	284	35	1	59	$ 304,657	$ 108,800	10	10.8	1	31	-1	2
49	049N_TO0710A	250	140	50	292	40	1	60	$ 441,305	$ 157,600	10	20.8	1	31	-1	2
49	049N_TOFF03A	310	80	81	350	40	1	56	$ 315,125	$ 109,150	10	22	1	31	-1	2
49	049N_SHFF01A	225	90	81	240	40	1	56	$ 315,125	$ 109,150	10	22	1	31	-1	2
49	049N_TOFF01A	310	100	81	320	40	1	56	$ 315,125	$ 109,150	10	22	1	31	-1	2
49	049N_TOFF02A	310	100	81	325	40	1	56	$ 315,125	$ 109,150	10	22	1	31	-1	2
49	049N_SHFF03A	225	85	81	250	40	1	56	$ 315,125	$ 109,150	10	22	1	31	-1	2
49	049N_TOFF04A	310	110	50	350	40	1	56	$ 315,125	$ 109,150	10	22	1	31	-1	2
49	049N_SHFF04A	225	100	81	270	40	1	56	$ 315,125	$ 109,150	10	22	1	31	-1	2
49	049N_SHFF02A	225	80	81	240	40	1	56	$ 315,125	$ 109,150	10	22	1	31	-1	2
49	049N_SHHWY1	250	64	200	265	34	1	64	$ 21,169	$ -	12	12	1	34	-1	0.5
49	049N_SHHWY2	200	64	150	215	34	1	64	$ 15,883	$ -	12	12	1	34	-1	0.5
49	049N_SHHWY3	150	64	650	165	34	1	64	$ 68,817	$ -	12	12	1	34	-1	0.5
49	049N_TOHWY	380	64	1000	395	34	1	64	$ 105,868	$ -	12	12	1	34	-1	0.5
-999																
50	050N_SH0706A	0	230	54	123	35	1	60	$ 441,305	$ 157,600	13	22.7	1	19	-1	0.5
50	050N_SH0710A	0	230	54	117	40	1	60	$ 441,305	$ 157,600	13	22.7	1	22	-1	0.5
50	050N_SH0714A	0	270	54	134	30	1	60	$ 113,001	$ 40,355	13	22.9	1	22	-1	0.5
50	050N_SH0716A	0	210	54	137	30	1	60	$ 364,021	$ 130,000	13	23.3	1	22	-1	0.5
50	050N_SH0718A	0	250	54	131	35	1	60	$ 113,001	$ 40,355	13	23.3	1	22	-1	0.5
50	050N_SH0720A	0	250	54	132	30	1	60	$ 268,815	$ 96,000	13	22.9	1	22	-1	0.5
50	050N_SH0726A	0	250	54	149	30	1	60	$ 322,578	$ 115,200	13	22.8	1	22	-1	0.5
50	050N_SH0728A	0	250	54	151	25	1	60	$ 504,029	$ 180,000	13	22.5	1	22	-1	0.5
50	050N_TO0017A	320	50	150	327	12	1	62	$ 12,195	$ 4,355	9	11.7	1	33	-1	2
50	050N_TO0018A	275	50	150	287	14	1	62	$ 12,195	$ 4,355	9	12.1	1	33	-1	2
50	050N_TO0019A	230	50	150	244	12	1	62	$ 12,195	$ 4,355	10	12.4	1	33	-1	2
50	050N_TO0020A	180	50	150	205	14	1	62	$ 12,195	$ 4,355	10	12.7	1	33	-1	2
50	050N_TO0022A	0	50	75	104	12	1	62	$ 12,195	$ 4,355	11	13.2	1	33	-1	2
50	050N_TO0023A	285	50	150	300	40	1	62	$ 12,195	$ 4,355	8	12.1	1	33	-1	2

Reach ID	USACE_ID	REF lot front	Lot length	Lot width	REF struc front	Struc length	AA Ratio	Flood Curve	Replacement Value of Structure in Dollars	Value of Contents in Dollars	G_elev	FF_elev	Active	Erosion Curve	Armor	Erosion Indicator
50	050N_TO0024A	240	50	150	264	14	1	62	$ 12,195	$ 4,355	9	12.6	1	33	-1	2
50	050N_TO0025A	200	50	150	207	16	1	62	$ 12,195	$ 4,355	10	16.7	1	33	-1	2
50	050N_TO0026A	180	50	150	187	14	1	62	$ 12,195	$ 4,355	10	13.2	1	33	-1	2
50	050N_TO0027A	0	50	75	138	16	1	62	$ 12,195	$ 4,355	11	15.8	1	33	-1	2
50	050N_TO0028A	285	50	150	301	45	1	62	$ 12,195	$ 4,355	9	12	1	33	-1	2
50	050N_TO0029A	240	50	150	255	50	1	62	$ 12,195	$ 4,355	9	12	1	33	-1	2
50	050N_TO0030A	0	50	75	139	45	1	62	$ 12,195	$ 4,355	11	13.7	1	33	-1	2
50	050N_TO0031A	0	50	75	127	45	1	62	$ 12,195	$ 4,355	13	14.4	1	33	-1	0.5
50	050N_TO0702A	240	150	60	292	40	1	60	$ 441,305	$ 157,600	10	20.9	1	31	-1	2
50	050N_TO0706A	240	150	60	296	40	1	60	$ 504,029	$ 180,000	10	20.9	1	31	-1	2
50	050N_TO0804A	0	250	100	170	75	1	60	$ 337,014	$ 120,355	9	19.6	1	24	-1	2
50	050N_SHFF02A	0	250	54	290	40	1	56	$ 315,125	$ 109,150	9	21	1	24	-1	2
50	050N_SHFF01A	0	200	54	140	40	1	56	$ 315,125	$ 109,150	9	21	1	24	-1	2
50	050N_TOFF07A	240	110	60	300	40	1	56	$ 315,125	$ 109,150	9	21	1	31	-1	2
50	050N_SHFF03A	0	250	54	150	40	1	56	$ 315,125	$ 109,150	9	21	1	24	-1	2
50	050N_TOFF02A	240	110	60	290	40	1	56	$ 315,125	$ 109,150	9	21	1	31	-1	2
50	050N_TOFF05A	240	110	60	270	40	1	56	$ 315,125	$ 109,150	9	21	1	31	-1	2
50	050N_TOFF08A	240	110	60	290	40	1	56	$ 315,125	$ 109,150	9	21	1	31	-1	2
50	050N_TOFF09A	240	110	60	300	40	1	56	$ 315,125	$ 109,150	9	21	1	31	-1	2
50	050N_TOFF06A	240	110	60	290	40	1	56	$ 315,125	$ 109,150	9	21	1	31	-1	2
50	050N_TOFF04A	240	110	60	280	40	1	56	$ 315,125	$ 109,150	9	21	1	31	-1	2
50	050N_TOFF03A	240	110	60	290	40	1	56	$ 315,125	$ 109,150	9	21	1	31	-1	2
50	050N_TOFF01A	240	110	100	290	40	1	56	$ 315,125	$ 109,150	9	21	1	31	-1	2
50	050N_SHHWY2	250	64	350	265	34	1	64	$ 37,052	$ -	8	8	1	34	-1	0.5
50	050N_SHHWY1	210	64	200	225	34	1	64	$ 21,169	$ -	8	8	1	34	-1	0.5
50	050N_TOHWY	350	64	1000	365	34	1	64	$ 105,868	$ -	8	8	1	34	-1	0.5
-999																
51	051N_NE0918A	0	130	225	100	60	1	5	$ 113,001	$ 40,355	13	18.3	1	25	-1	0.5
51	051N_NE0918Z	200	250	225	194	200	1	5	$ 113,001	$ 40,355	10	17.7	1	31	-1	2
51	051N_NE0918T	0	130	225	102	60	1	5	$ 113,001	$ 40,355	15	18.8	1	25	-1	0.5
51	051N_NE0918Y	375	250	225	425	200	1	5	$ 113,001	$ 40,355	8	16.3	1	31	-1	2
51	051N_NE0918U	200	250	225	183	150	1	5	$ 113,001	$ 40,355	10	18.5	1	31	-1	2
51	051N_NE0918A	0	120	100	110	70	1	5	$ 113,001	$ 40,355	8	13.6	1	26	-1	2
51	051N_NE0918V	375	250	225	357	200	1	5	$ 113,001	$ 40,355	8	17.4	1	31	-1	2
51	051N_NE0918X	580	120	225	603	80	1	5	$ 113,001	$ 40,355	8	16.3	1	31	-1	2
51	051N_NE0918W	580	120	225	581	80	1	5	$ 113,001	$ 40,355	8	16.4	1	31	-1	2
51	051N_SH1003A	260	150	50	288	40	1	60	$ 113,001	$ 40,355	9	19.1	1	31	-1	2

Reach ID	USACE_ID	REF lot front	Lot length	Lot width	REF struc front	Struc length	AA Ratio	Flood Curve	Replacement Value of Structure in Dollars	Value of Contents in Dollars	G_elev	FF_elev	Active	Erosion Curve	Armor	Erosion Indicator
51	051N_SH1004A	0	220	75	168	40	1	60	$ 144,488	$ 51,600	12	21.4	1	22	-1	2
51	051N_SH1005A	260	140	50	286	65	1	60	$ 224,013	$ 80,000	8	17.5	1	31	-1	2
51	051N_SH1006A	0	180	75	128	40	1	60	$ 255,375	$ 91,200	16	25.6	1	7	-1	2
51	051N_SH1007A	260	140	50	282	40	1	60	$ 169,130	$ 60,400	9	8.1	1	31	-1	2
51	051N_TO1004A	400	100	50	409	50	1	60	$ 246,414	$ 88,000	6	18.3	1	31	-1	2
51	051N_TO1006A	400	100	50	405	60	1	2	$ 156,809	$ 56,000	7	5.9	1	31	-1	0.5
51	051N_TO1008A	400	100	50	413	40	1	60	$ 162,409	$ 58,000	6	16.1	1	31	-1	2
51	051N_TO0808A	0	240	67	171	35	1	60	$ 113,001	$ 40,355	11	23.2	1	24	-1	2
51	051N_TO0810A	0	230	67	189	40	1	60	$ 113,001	$ 40,355	11	22.3	1	24	-1	2
51	051N_TO0812A	270	100	80	291	40	1	60	$ 113,001	$ 40,355	10	20.9	1	31	-1	2
51	051N_TO0814A	270	120	80	275	30	1	60	$ 113,001	$ 40,355	10	20.6	1	31	-1	2
51	051N_TO0818A	270	90	80	300	30	1	60	$ 113,001	$ 40,355	10	21	1	31	-1	2
51	051N_TO0820A	0	230	67	176	30	1	60	$ 113,001	$ 40,355	12	22.6	1	22	-1	2
51	051N_TO0822A	270	100	80	298	35	1	60	$ 113,001	$ 40,355	9	21.9	1	31	-1	2
51	051N_TO0824A	0	220	67	171	35	1	60	$ 113,001	$ 40,355	13	18.8	1	22	-1	0.5
51	051N_TO0826A	0	210	67	180	25	1	60	$ 113,001	$ 40,355	11	18.3	1	24	-1	2
51	051N_TO0828A	270	100	80	295	30	1	60	$ 113,001	$ 40,355	12	21.3	1	31	-1	2
51	051N_TOFF01A	0	220	67	220	40	1	56	$ 315,125	$ 109,150	8	0	1	24	-1	2
51	051N_SHHWY	370	64	100	390	34	1	64	$ 10,585	$ -	6.8	6.8	1	34	-1	0.5
51	051N_TOHWY	370	64	350	390	34	1	64	$ 37,052	$ -	6.8	6.8	1	34	-1	0.5
-999																
52	052N_SH1008A	0	150	77	131	35	1	59	$ 145,160	$ 51,840	14	18.1	1	19	-1	0.5
52	052N_SH1009A	260	130	56	286	50	1	59	$ 217,292	$ 77,600	9	17	1	31	-1	2
52	052N_SH1010A	0	150	77	138	30	1	60	$ 263,215	$ 94,000	14	19.3	1	4	-1	2
52	052N_SH1011A	260	130	56	298	40	1	60	$ 168,010	$ 60,000	8	16.8	1	31	-1	2
52	052N_SH1013A	260	130	56	291	40	1	59	$ 166,890	$ 59,600	8	16.6	1	31	-1	2
52	052N_SH1014A	0	150	77	129	40	1	1	$ 156,809	$ 56,000	16	20.3	1	31	-1	0.5
52	052N_SH1101A	260	130	56	297	45	1	59	$ 96,325	$ 34,400	9	16.5	1	31	-1	2
52	052N_SH1102A	0	150	77	128	40	1	59	$ 144,488	$ 51,600	18	20.8	1	19	-1	2
52	052N_SH1103A	260	130	56	296	60	1	59	$ 134,408	$ 48,000	9	16.6	1	31	-1	2
52	052N_SH1104A	0	150	77	120	30	1	55	$ 100,806	$ 36,000	17	18.7	1	28	-1	2
52	052N_SH1105A	260	130	56	299	40	1	60	$ 145,608	$ 52,000	9	19.5	1	31	-1	2
52	052N_SH1106A	0	150	77	130	30	1	60	$ 221,773	$ 79,200	13	19.4	1	19	-1	2
52	052N_SH1108A	0	150	77	138	40	1	59	$ 92,965	$ 33,200	14	18.7	1	19	-1	2
52	052N_SH1109A	260	130	56	299	30	1	2	$ 190,411	$ 68,000	9	17	1	31	-1	0.5
52	052N_SH1111A	260	130	56	292	45	1	59	$ 156,809	$ 56,000	9	16.9	1	31	-1	2
52	052N_SH1112A	0	150	77	140	40	1	55	$ 106,406	$ 38,000	15	19.6	1	28	-1	2

Reach ID	USACE_ID	REF lot front	Lot length	Lot width	REF struc front	Struc length	AA Ratio	Flood Curve	Replacement Value of Structure in Dollars	Value of Contents in Dollars	G_elev	FF_elev	Active	Erosion Curve	Armor	Erosion Indicator
52	052N_SH1114A	0	150	77	130	35	1	55	$ 224,013	$ 80,000	16	19.7	1	28	-1	2
52	052N_SH1115A	260	130	56	288	50	1	60	$ 324,819	$ 116,000	9	16.6	1	6	-1	2
52	052N_SH1116A	0	150	77	138	30	1	55	$ 62,724	$ 22,400	13	18.2	1	28	-1	2
52	052N_SH1117A	260	130	56	288	45	1	59	$ 96,325	$ 34,400	9	16.6	1	31	-1	2
52	052N_SH1118A	0	150	77	168	30	1	60	$ 168,010	$ 60,000	15	17.7	1	22	-1	2
52	052N_SH1119A	260	130	56	287	45	1	55	$ 96,325	$ 34,400	9	16.3	1	31	-1	2
52	052N_SH1120A	0	150	77	126	40	1	56	$ 250,000	$ 75,000	16	28	1	28	-1	0.5
52	052N_SH1121A	260	130	56	286	45	1	55	$ 96,325	$ 34,400	9	16.4	1	31	-1	2
52	052N_SH1203A	260	100	56	284	30	1	60	$ 284,496	$ 101,600	10	20.3	1	31	-1	2
52	052N_SH1205A	260	100	56	278	30	1	59	$ 179,210	$ 64,000	9	15	1	31	-1	2
52	052N_SH1206A	0	150	77	139	45	1	55	$ 106,406	$ 38,000	18	18.2	1	28	-1	2
52	052N_SH1207A	260	100	56	271	35	1	59	$ 72,804	$ 26,000	9	14.4	1	31	-1	2
52	052N_TO1010A	390	100	56	420	40	1	59	$ 162,409	$ 58,000	6	16	1	31	-1	2
52	052N_TO1012A	390	100	56	431	40	1	2	$ 125,447	$ 44,800	6	14.4	1	31	-1	0.5
52	052N_TO1014A	390	100	56	417	45	1	55	$ 134,408	$ 48,000	7	14.6	1	31	-1	2
52	052N_TO1104A	390	110	56	415	50	1	2	$ 168,010	$ 60,000	8	14.7	1	31	-1	0.5
52	052N_TO1114A	390	110	56	407	45	1	59	$ 96,325	$ 34,400	8	15.7	1	31	-1	2
52	052N_TO1116A	390	110	56	431	40	1	56	$ 179,210	$ 64,000	8	18.2	1	31	-1	2
52	052N_TO1118A	390	110	56	411	45	1	59	$ 235,213	$ 84,000	8	19.1	1	31	-1	2
52	052N_TO1120A	390	120	56	413	30	1	60	$ 166,890	$ 59,600	8	16	1	31	-1	2
52	052N_TO1122A	390	120	56	422	35	1	60	$ 190,411	$ 68,000	8	16	1	31	-1	2
52	052N_TO1204A	390	110	56	400	50	1	59	$ 156,809	$ 56,000	11	15.4	1	31	-1	2
52	052N_TO1208A	390	110	56	392	40	1	55	$ 101,590	$ 36,280	9	14.7	1	31	-1	2
52	052N_SHFF02A	260	120	56	300	40	1	56	$ 315,125	$ 109,150	8	20	1	31	-1	2
52	052N_TOFF03A	390	115	56	420	40	1	56	$ 315,125	$ 109,150	8	20	1	31	-1	2
52	052N_TOFF07A	390	110	56	440	40	1	56	$ 315,125	$ 109,150	8	20	1	31	-1	2
52	052N_TOFF04A	390	110	56	415	40	1	56	$ 315,125	$ 109,150	8	20	1	31	-1	2
52	052N_SHFF01A	260	100	56	310	40	1	56	$ 315,125	$ 109,150	8	20	1	31	-1	2
52	052N_TOFF02A	390	110	56	410	40	1	56	$ 315,125	$ 109,150	8	20	1	31	-1	2
52	052N_TOFF06A	390	110	56	420	40	1	56	$ 315,125	$ 109,150	8	20	1	31	-1	2
52	052N_TOFF01A	390	110	56	410	40	1	56	$ 315,125	$ 109,150	8	20	1	31	-1	2
52	052N_SHFF03A	260	125	56	300	40	1	56	$ 315,125	$ 109,150	8	20	1	31	-1	2
52	052N_TOFF05A	390	110	56	420	40	1	56	$ 315,125	$ 109,150	8	20	1	31	-1	2
52	052N_SH1202A	0	150	50	115	40	1	56	$ 315,125	$ 109,150	8	20	1	31	-1	2
52	052N_SH1204A	0	150	50	115	40	1	56	$ 315,125	$ 109,150	8	20	1	31	-1	2
52	052N_SH1122A	0	150	50	115	40	1	56	$ 315,125	$ 109,150	8	20	1	31	-1	2
52	052N_SH1110A	0	150	50	115	40	1	56	$ 315,125	$ 109,150	8	20	1	31	-1	2

Reach ID	USACE_ID	REF lot front	Lot length	Lot width	REF struc front	Struc length	AA Ratio	Flood Curve	Replacement Value of Structure in Dollars	Value of Contents in Dollars	G_elev	FF_elev	Active	Erosion Curve	Armor	Erosion Indicator
52	052MISCHWY	350	40	200	36	34	1	64	$ 21,169	$ -	9.2	9.2	1	34	-1	0.5
52	052N_SHHWY	200	64	1000	215	34	1	64	$ 105,868	$ -	9.2	9.2	1	34	-1	0.5
52	052N_TOHWY	480	64	1000	500	34	1	64	$ 105,868	$ -	9.2	9.2	1	34	-1	0.5
-999																
53	053JONE0104A	320	100	56	359	30	1	55	$ 75,044	$ 26,800	6	13.9	1	31	-1	2
53	053N_SH1209A	200	100	59	264	45	1	59	$ 112,006	$ 40,000	9	15.7	1	31	-1	2
53	053N_SH1211A	200	100	59	258	40	1	55	$ 84,005	$ 30,000	9	15.6	1	31	-1	2
53	053N_SH1212A	0	140	111	106	30	1	55	$ 62,724	$ 22,400	14	16.1	1	28	-1	2
53	053N_SH1213A	200	100	59	253	45	1	55	$ 107,526	$ 38,400	9	16.1	1	31	-1	2
53	053N_SH1214A	0	140	111	106	30	1	55	$ 90,277	$ 32,240	16	17.4	1	28	-1	2
53	053N_SH1215A	200	100	59	239	55	1	55	$ 203,852	$ 72,800	9	15.9	1	31	-1	2
53	053N_SH1216A	0	110	111	96	55	1	59	$ 302,417	$ 108,000	16	15.6	1	1	-1	2
53	053N_SH1217A	200	100	59	234	40	1	59	$ 134,408	$ 48,000	9	16.1	1	31	-1	2
53	053N_SH1218A	0	110	111	97	35	1	59	$ 156,809	$ 56,000	14	16.8	1	19	-1	2
53	053N_SH1219A	200	100	59	227	40	1	60	$ 77,284	$ 27,600	9	14.9	1	31	-1	2
53	053N_SH1222A	0	140	111	120	30	1	60	$ 166,890	$ 59,600	12	18.1	1	22	-1	2
53	053N_SH1223A	200	100	59	219	45	1	2	$ 140,008	$ 50,000	9	14.5	1	31	-1	0.5
53	053N_SH1225A	200	100	59	214	55	1	59	$ 190,411	$ 68,000	9	16.8	1	31	-1	2
53	053N_SH1226A	0	140	111	103	30	1	55	$ 156,809	$ 56,000	14	16.1	1	28	-1	2
53	053N_SH1301A	200	100	59	225	35	1	59	$ 84,005	$ 30,000	8	15.9	1	31	-1	2
53	053N_SH1303A	200	100	59	207	35	1	59	$ 126,567	$ 45,200	7	16	1	31	-1	2
53	053N_SH1304A	0	140	111	61	30	1	55	$ 78,404	$ 28,000	6	18.1	1	29	-1	2
53	053N_SH1305A	200	100	59	204	35	1	60	$ 145,608	$ 52,000	7	17.1	1	31	-1	2
53	053N_SH1307A	200	100	59	199	40	1	59	$ 100,806	$ 36,000	7	16.5	1	31	-1	2
53	053N_SH1309A	200	100	59	193	40	1	59	$ 95,205	$ 34,000	7	17	1	31	-1	2
53	053N_SH1310A	0	130	111	50	35	1	55	$ 156,809	$ 56,000	6	17.1	1	29	-1	2
53	053N_SH1311A	200	100	59	188	45	1	55	$ 95,205	$ 34,000	7	14.7	1	31	-1	2
53	053N_SH1313A	200	100	59	182	40	1	59	$ 145,608	$ 52,000	7	16.9	1	31	-1	2
53	053N_SH1314A	0	130	111	46	40	1	55	$ 201,611	$ 72,000	6	15.7	1	29	-1	2
53	053N_SH1317A	200	100	59	169	40	1	59	$ 112,006	$ 40,000	7	16.8	1	31	-1	2
53	053N_SH1318P	0	130	0	77	20	1	1	$ 11,201	$ 4,000	11	17.2	1	31	-1	0.5
53	053N_TO1210A	320	110	56	392	45	1	2	$ 208,332	$ 74,400	9	14.7	1	31	-1	0.5
53	053N_TO1212A	320	110	56	383	45	1	2	$ 179,210	$ 64,000	9	14.9	1	31	-1	0.5
53	053N_TO1216A	320	110	56	363	55	1	59	$ 146,728	$ 52,400	9	14.8	1	31	-1	2
53	053N_TO1218A	320	110	56	370	40	1	2	$ 168,010	$ 60,000	9	6.6	1	31	-1	0.5
53	053N_TO1222A	320	110	56	354	45	1	60	$ 302,417	$ 108,000	8	18.5	1	31	-1	2
53	053N_TO1224A	320	110	56	351	30	1	60	$ 302,417	$ 108,000	8	17.1	1	31	-1	2

Reach ID	USACE_ID	REF lot front	Lot length	Lot width	REF struc front	Struc length	AA Ratio	Flood Curve	Replacement Value of Structure in Dollars	Value of Contents in Dollars	G_elev	FF_elev	Active	Erosion Curve	Armor	Erosion Indicator
53	053N_TO1226A	320	110	56	337	30	1	60	$ 246,414	$ 88,000	8	16.5	1	31	-1	2
53	053N_TO1306A	320	100	56	326	40	1	60	$ 257,615	$ 92,000	6	17	1	31	-1	2
53	053N_TO1308A	320	100	56	320	40	1	2	$ 324,819	$ 116,000	6	15.1	1	31	-1	0.5
53	053N_TO1310A	320	100	56	302	40	1	59	$ 134,408	$ 48,000	6	16.1	1	31	-1	2
53	053N_TO1312A	320	100	56	303	30	1	59	$ 77,284	$ 27,600	7	16.2	1	31	-1	2
53	053N_TO1314A	320	100	56	297	40	1	59	$ 145,608	$ 52,000	7	16.7	1	31	-1	2
53	053N_TO1316A	320	100	56	300	50	1	55	$ 106,406	$ 38,000	6	15.7	1	31	-1	2
53	053N_TO1320A	320	100	56	280	35	1	59	$ 81,765	$ 29,200	7	16	1	31	-1	2
53	053N_TOFF01A	320	100	56	300	40	1	56	$ 315,125	$ 109,150	9	21	1	31	-1	2
53	053N_TOFF03A	320	100	56	360	40	1	56	$ 315,125	$ 109,150	9	21	1	31	-1	2
53	053N_SHFF01A	200	90	59	190	40	1	56	$ 315,125	$ 109,150	9	21	1	31	-1	2
53	053N_TOFF02A	320	100	56	335	40	1	56	$ 315,125	$ 109,150	9	21	1	31	-1	2
53	053N_TOHWY	460	64	1000	475	34	1	64	$ 105,868	$ -	6.9	6.9	1	34	-1	0.5
53	053N_SHHWY	180	64	1000	195	34	1	64	$ 105,868	$ -	6.9	6.9	1	34	-1	0.5
-999																
54	054EASY1506A	300	90	59	336	30	1	60	$ 212,812	$ 76,000	8	15.8	1	31	-1	2
54	054LENO0103A	300	100	59	273	40	1	59	$ 113,001	$ 40,355	7	16	1	31	-1	2
54	054N_SH1319A	190	90	71	169	40	1	59	$ 201,611	$ 72,000	7	16.7	1	31	-1	2
54	054N_SH1401A	190	90	71	201	30	1	59	$ 100,806	$ 36,000	9	17.3	1	31	-1	2
54	054N_SH1409A	190	90	71	198	45	1	55	$ 88,485	$ 31,600	10	18.7	1	31	-1	2
54	054N_SH1411A	190	90	71	208	25	1	60	$ 257,615	$ 92,000	9	21.1	1	31	-1	2
54	054N_SH1413A	190	90	71	204	40	1	59	$ 77,284	$ 27,600	9	19.3	1	31	-1	2
54	054N_SH1417A	190	90	71	205	35	1	59	$ 84,005	$ 30,000	8	18.5	1	31	-1	2
54	054N_SH1419A	190	90	71	197	50	1	59	$ 132,168	$ 47,200	8	16.4	1	31	-1	2
54	054N_SH1420A	0	125	500	82	35	1	59	$ 119,847	$ 42,800	11	17.5	1	20	-1	2
54	054N_SH1421A	190	90	71	205	40	1	60	$ 209,452	$ 74,800	8	18.9	1	31	-1	2
54	054N_SH1422A	0	125	500	77	35	1	55	$ 150,089	$ 53,600	12	17.1	1	28	-1	0.5
54	054N_SH1501A	190	90	71	213	35	1	59	$ 77,284	$ 27,600	8	17.7	1	31	-1	2
54	054N_SH1503A	190	90	71	212	40	1	60	$ 380,822	$ 136,000	9	17.9	1	31	-1	2
54	054N_TO1402A	300	85	59	302	35	1	2	$ 100,806	$ 36,000	7	16.1	1	31	-1	0.5
54	054N_TO1404A	300	85	59	309	30	1	60	$ 197,131	$ 70,400	8	19.4	1	31	-1	2
54	054N_TO1406A	300	85	59	311	30	1	60	$ 89,605	$ 32,000	8	16.7	1	31	-1	2
54	054N_TO1408A	300	85	59	309	35	1	2	$ 100,806	$ 36,000	7	8.7	1	31	-1	0.5
54	054N_TO1410A	300	85	59	312	40	1	2	$ 179,210	$ 64,000	8	8.7	1	31	-1	0.5
54	054N_TO1412A	300	85	59	302	35	1	55	$ 212,812	$ 76,000	9	20.6	1	31	-1	2
54	054N_TO1416A	300	85	59	292	40	1	55	$ 89,605	$ 32,000	9	17.1	1	31	-1	2
54	054N_TO1418A	300	85	59	305	35	1	59	$ 112,006	$ 40,000	9	18.3	1	31	-1	2

Reach ID	USACE_ID	REF lot front	Lot length	Lot width	REF struc front	Struc length	AA Ratio	Flood Curve	Replacement Value of Structure in Dollars	Value of Contents in Dollars	G_elev	FF_elev	Active	Erosion Curve	Armor	Erosion Indicator
54	054N_TO1420A	300	85	59	305	25	1	60	$ 222,893	$ 79,600	8	19.3	1	31	-1	2
54	054PEND0201A	300	80	59	297	45	1	2	$ 113,001	$ 40,355	8	16.2	1	31	-1	0.5
54	054N_SHFF04A	0	90	71	210	40	1	56	$ 315,125	$ 109,150	9	21	1	24	-1	2
54	054N_TOFF04A	300	80	59	320	40	1	56	$ 315,125	$ 109,150	9	21	1	31	-1	2
54	054N_SHFF01A	0	80	71	210	40	1	56	$ 315,125	$ 109,150	9	21	1	24	-1	2
54	054N_TOFF03A	300	80	59	320	40	1	56	$ 315,125	$ 109,150	9	21	1	31	-1	2
54	054N_SHFF02A	0	80	71	210	40	1	56	$ 315,125	$ 109,150	9	21	1	24	-1	2
54	054N_SHFF03A	0	90	71	210	40	1	56	$ 315,125	$ 109,150	9	21	1	24	-1	2
54	054N_TOFF05A	300	80	59	310	40	1	56	$ 315,125	$ 109,150	9	21	1	31	-1	2
54	054EASYFF01A	300	90	59	330	40	1	56	$ 315,125	$ 109,150	9	21	1	31	-1	2
54	054EASYFF02A	300	90	59	340	40	1	56	$ 315,125	$ 109,150	9	21	1	31	-1	2
54	054N_TOHWY	380	64	1000	375	34	1	64	$ 105,868	$ -	8.3	8.3	1	34	-1	0.5
54	054N_SHHWY	120	64	1000	135	34	1	64	$ 105,868	$ -	8.3	8.3	1	34	-1	0.5
-999																
55	055EASY1512A	315	90	78	324	50	1	49	$ 179,210	$ 64,000	8	16.3	1	31	-1	2
55	055EASY1514A	315	90	78	329	35	1	59	$ 134,408	$ 48,000	9	16.2	1	31	-1	2
55	055EASY1516A	315	90	78	328	35	1	59	$ 134,408	$ 48,000	9	15.9	1	31	-1	2
55	055EASY1518A	315	90	56	314	50	1	2	$ 207,212	$ 74,000	9	16	1	31	-1	0.5
55	055N_NE1702A	375	100	76	446	60	1	38	$ 113,001	$ 167,474	9	10	1	31	-1	0.5
55	055N_NE1702S	375	140	76	467	30	1	38	$ 113,001	$ 40,355	9	8.4	1	31	-1	0.5
55	055N_NE1708S	0	0	0	397	40	1	59	$ 113,001	$ 40,355	10	8.5	1	31	-1	2
55	055N_NE1708A	375	140	76	444	40	1	1	$ 113,001	$ 40,355	9	7.4	1	31	-1	0.5
55	055N_NE1712A	375	140	76	434	40	1	59	$ 113,001	$ 40,355	9	14.7	1	31	-1	2
55	055N_NE1710A	375	140	76	439	45	1	59	$ 113,001	$ 40,355	9	15.2	1	31	-1	2
55	055N_SH1701A	0	125	70	135	40	1	56	$ 315,125	$ 109,150	9	21	1	31	-1	2
55	055N_SH1703A	0	125	70	135	40	1	56	$ 315,125	$ 109,150	9	21	1	31	-1	2
55	055N_SH1705A	0	125	70	135	40	1	56	$ 315,125	$ 109,150	9	21	1	31	-1	2
55	055N_SH1505A	0	100	78	220	35	1	60	$ 204,972	$ 73,200	9	21.8	1	31	-1	2
55	055N_SH1507A	0	100	78	232	45	1	59	$ 100,806	$ 36,000	9	17.3	1	31	-1	2
55	055N_SH1511A	0	100	78	222	45	1	59	$ 190,411	$ 68,000	9	16.8	1	31	-1	2
55	055N_SH1513A	0	100	78	219	25	1	59	$ 134,408	$ 48,000	9	16.9	1	31	-1	2
55	055N_SH1515A	0	100	78	224	40	1	59	$ 336,019	$ 120,000	9	18	1	31	-1	2
55	055N_SH1601A	0	60	78	219	30	1	60	$ 145,608	$ 52,000	9	19.1	1	31	-1	2
55	055N_SH1603A	0	100	78	202	40	1	55	$ 89,605	$ 32,000	9	16.7	1	31	-1	2
55	055N_SH1707A	0	140	63	276	30	1	55	$ 67,204	$ 24,000	10	15.9	1	31	-1	2
55	055N_SH1709A	0	140	63	272	40	1	59	$ 113,001	$ 40,355	10	19.7	1	31	-1	2
55	055N_SH1711A	0	140	63	265	45	1	59	$ 113,001	$ 40,355	9	19.1	1	31	-1	2

Reach ID	USACE_ID	REF lot front	Lot length	Lot width	REF struc front	Struc length	AA Ratio	Flood Curve	Replacement Value of Structure in Dollars	Value of Contents in Dollars	G_elev	FF_elev	Active	Erosion Curve	Armor	Erosion Indicator
55	055NEPT0106A	315	45	100	314	25	1	59	$ 190,411	$ 68,000	9	18.9	1	31	-1	2
55	055NEPTFF01A	365	50	100	360	40	1	56	$ 315,125	$ 109,150	9	21	1	31	-1	2
55	055EASYFF01A	315	90	78	330	40	1	56	$ 315,125	$ 109,150	9	21	1	31	-1	2
55	055EASYFF02A	315	90	78	340	40	1	56	$ 315,125	$ 109,150	9	21	1	31	-1	2
55	055BROAFF01A	315	100	78	330	40	1	56	$ 315,125	$ 109,150	9	21	1	31	-1	2
55	055N_SHFF04A	0	100	78	225	40	1	56	$ 315,125	$ 109,150	9	21	1	29	-1	2
55	055N_SH1701A	0	190	63	300	40	1	56	$ 244,300	$ 73,200	9	21	1	29	-1	2
55	055N_SH1703A	0	190	63	280	40	1	56	$ 244,300	$ 73,200	9	21	1	29	-1	2
55	055N_SH1705A	0	190	63	320	40	1	56	$ 244,300	$ 73,200	9	21	1	29	-1	2
55	055N_SH1707A	0	190	63	320	40	1	56	$ 244,300	$ 73,200	9	21	1	29	-1	2
55	055N_SHHWY	130	64	1000	145	34	1	64	$ 105,868	$ -	8.7	8.7	1	34	-1	0.5
-999																
56	056N_NE1714A	380	130	59	446	40	1	59	$ 113,001	$ 40,355	9	15.7	1	31	-1	2
56	056N_NE1718A	380	130	59	439	40	1	59	$ 113,001	$ 40,355	9	16.4	1	31	-1	2
56	056N_NE1720A	380	130	59	421	45	1	2	$ 113,001	$ 40,355	8	7	1	31	-1	0.5
56	056N_NE1802A	380	130	59	438	30	1	55	$ 113,001	$ 40,355	9	14.9	1	31	-1	2
56	056N_NE1804A	380	130	59	417	30	1	55	$ 113,001	$ 40,355	8	17.9	1	31	-1	2
56	056N_NE1806A	380	130	59	423	40	1	59	$ 113,001	$ 40,355	9	18.6	1	31	-1	2
56	056N_NE1810A	380	130	59	412	40	1	59	$ 113,001	$ 40,355	9	16.3	1	31	-1	2
56	056N_NE1812A	380	130	59	413	50	1	59	$ 113,001	$ 40,355	9	17.3	1	31	-1	2
56	056N_NE1814A	380	130	59	413	45	1	2	$ 113,001	$ 40,355	9	15.3	1	31	-1	0.5
56	056N_NE1816A	380	130	59	430	35	1	60	$ 113,001	$ 40,355	9	17.7	1	31	-1	2
56	056N_NE1818A	380	130	59	421	40	1	59	$ 113,001	$ 40,355	9	14.9	1	31	-1	2
56	056N_NE1820A	380	130	59	411	45	1	59	$ 113,001	$ 40,355	8	14.8	1	31	-1	2
56	056N_NE1822A	380	130	59	404	40	1	60	$ 113,001	$ 40,355	8	15.4	1	31	-1	2
56	056N_NE1824A	380	150	59	394	55	1	55	$ 113,001	$ 40,355	9	15.8	1	31	-1	2
56	056N_SH1713A	245	130	59	260	60	1	59	$ 113,001	$ 40,355	9	17	1	31	-1	2
56	056N_SH1714A	0	130	500	96	40	1	55	$ 113,001	$ 40,355	11	17.6	1	30	-1	2
56	056N_SH1717A	245	130	59	269	35	1	59	$ 113,001	$ 40,355	9	17.1	1	31	-1	2
56	056N_SH1719A	245	130	59	268	45	1	59	$ 113,001	$ 40,355	9	16.5	1	31	-1	2
56	056N_SH1801A	245	130	59	266	35	1	59	$ 113,001	$ 40,355	9	15.5	1	31	-1	2
56	056N_SH1804A	0	130	500	128	40	1	55	$ 113,001	$ 40,355	12	19.1	1	30	-1	0.5
56	056N_SH1805A	245	130	59	275	35	1	60	$ 113,001	$ 40,355	9	18.7	1	31	-1	2
56	056N_SH1807A	245	130	59	315	35	1	60	$ 113,001	$ 40,355	9	16.7	1	31	-1	2
56	056N_SH1809A	245	130	59	281	30	1	59	$ 113,001	$ 40,355	9	16.7	1	31	-1	2
56	056N_SH1811A	245	130	59	268	45	1	59	$ 113,001	$ 40,355	9	16.6	1	31	-1	2
56	056N_SH1813A	245	130	59	269	40	1	59	$ 113,001	$ 40,355	9	15.3	1	31	-1	2

Reach ID	USACE_ID	REF lot front	Lot length	Lot width	REF struc front	Struc length	AA Ratio	Flood Curve	Replacement Value of Structure in Dollars	Value of Contents in Dollars	G_elev	FF_elev	Active	Erosion Curve	Armor	Erosion Indicator
56	056N_SH1815A	245	130	59	267	40	1	60	$ 113,001	$ 40,355	9	17.3	1	31	-1	2
56	056N_SH1817A	245	130	59	263	45	1	60	$ 113,001	$ 40,355	9	17.4	1	31	-1	2
56	056N_SH1819A	245	130	59	284	50	1	55	$ 113,001	$ 40,355	10	20.9	1	31	-1	2
56	056N_SH1821A	245	130	59	277	40	1	60	$ 113,001	$ 40,355	11	22	1	31	-1	2
56	056N_SH1825A	245	130	59	267	40	1	59	$ 113,001	$ 40,355	9	16.4	1	31	-1	2
56	056N_SHFF03A	0	140	59	290	40	1	56	$ 315,125	$ 109,150	9	21	1	31	-1	2
56	056N_NEFF03A	380	135	59	430	40	1	56	$ 315,125	$ 109,150	9	21	1	31	-1	2
56	056N_NEFF02A	380	130	59	415	40	1	56	$ 315,125	$ 109,150	9	21	1	31	-1	2
56	056N_SHFF02A	245	130	59	280	40	1	56	$ 315,125	$ 109,150	9	21	1	31	-1	2
56	056N_NEFF01A	0	100	59	270	40	1	56	$ 315,125	$ 109,150	9	21	1	24	-1	2
56	056N_SHFF01A	245	120	59	415	40	1	60	$ 315,125	$ 109,150	9	21	1	31	-1	2
56	056N_SHHWY	180	64	1000	195	34	1	64	$ 105,868	$ -	7.5	7.5	1	34	-1	0.5
-999																
57	057N_NE1902A	360	120	59	399	40	1	59	$ 113,001	$ 40,355	9	16	1	31	-1	2
57	057N_NE1904A	360	120	59	397	40	1	55	$ 113,001	$ 40,355	9	16.6	1	31	-1	2
57	057N_NE1906A	360	120	59	403	45	1	59	$ 113,001	$ 40,355	9	16.4	1	31	-1	2
57	057N_NE1908A	360	120	59	404	45	1	59	$ 113,001	$ 40,355	9	15.9	1	31	-1	2
57	057N_NE1914A	360	120	59	388	45	1	59	$ 113,001	$ 40,355	9	15.9	1	31	-1	2
57	057N_NE1916A	360	120	59	377	55	1	59	$ 113,001	$ 40,355	9	15.7	1	31	-1	2
57	057N_NE1918A	360	120	59	382	50	1	59	$ 113,001	$ 40,355	9	16.1	1	31	-1	2
57	057N_NE1920A	360	120	59	375	50	1	59	$ 113,001	$ 40,355	9	16.1	1	31	-1	2
57	057N_NE1922A	360	120	59	389	40	1	59	$ 113,001	$ 40,355	9	15.5	1	31	-1	2
57	057N_NE2002A	360	110	59	389	40	1	2	$ 113,001	$ 40,355	9	7.9	1	31	-1	0.5
57	057N_NE2008A	360	110	59	382	40	1	2	$ 113,001	$ 40,355	9	15.5	1	31	-1	0.5
57	057N_NE2010A	360	110	59	386	40	1	59	$ 113,001	$ 40,355	9	7.8	1	31	-1	2
57	057N_NE2012A	360	110	59	381	40	1	2	$ 113,001	$ 40,355	9	17	1	31	-1	0.5
57	057N_SH1901A	0	120	59	275	45	1	59	$ 113,001	$ 40,355	9	16.4	1	31	-1	2
57	057N_SH1903A	0	120	59	271	30	1	59	$ 113,001	$ 40,355	9	17.8	1	31	-1	2
57	057N_SH1905A	0	120	59	263	50	1	59	$ 113,001	$ 40,355	9	15.4	1	31	-1	2
57	057N_SH1907A	0	120	59	269	45	1	59	$ 113,001	$ 40,355	9	18.9	1	31	-1	2
57	057N_SH1909A	0	120	59	264	45	1	59	$ 113,001	$ 40,355	9	16	1	31	-1	2
57	057N_SH1911A	0	120	59	264	55	1	59	$ 113,001	$ 40,355	9	15.7	1	31	-1	2
57	057N_SH1913A	0	120	59	266	45	1	55	$ 113,001	$ 40,355	9	15.5	1	31	-1	2
57	057N_SH1915A	0	120	59	266	45	1	59	$ 113,001	$ 40,355	9	15.7	1	31	-1	2
57	057N_SH1917A	0	120	59	269	40	1	59	$ 113,001	$ 40,355	9	15.9	1	31	-1	2
57	057N_SH1919A	0	120	59	271	40	1	59	$ 113,001	$ 40,355	9	16.6	1	31	-1	2
57	057N_SH2001A	245	120	59	266	35	1	55	$ 113,001	$ 40,355	9	16.7	1	31	-1	2

Reach ID	USACE_ID	REF lot front	Lot length	Lot width	REF struc front	Struc length	AA Ratio	Flood Curve	Replacement Value of Structure in Dollars	Value of Contents in Dollars	G_elev	FF_elev	Active	Erosion Curve	Armor	Erosion Indicator
57	057N_SH2003A	245	110	59	276	30	1	55	$ 113,001	$ 40,355	9	16.5	1	31	-1	2
57	057N_SH2004A	0	135	200	117	30	1	56	$ 113,001	$ 40,355	13	17.9	1	28	-1	0.5
57	057N_SH2005A	245	110	59	277	30	1	59	$ 113,001	$ 40,355	9	18.9	1	31	-1	2
57	057N_SH2006A	0	135	200	123	30	1	60	$ 113,001	$ 40,355	13	17.5	1	22	-1	0.5
57	057N_SH2007A	245	110	59	274	25	1	60	$ 113,001	$ 40,355	10	18.8	1	31	-1	2
57	057N_SH2008A	0	135	200	123	30	1	60	$ 113,001	$ 40,355	13	17.7	1	22	-1	0.5
57	057N_SH2009A	245	110	59	267	25	1	60	$ 113,001	$ 40,355	9	16.5	1	31	-1	2
57	057N_SH2010A	0	135	200	120	25	1	55	$ 113,001	$ 40,355	16	17	1	28	-1	0.5
57	057N_SH2011A	245	110	59	271	35	1	59	$ 113,001	$ 40,355	9	16.8	1	31	-1	2
57	057N_SH2012A	0	135	200	117	30	1	56	$ 113,001	$ 40,355	16	19.2	1	28	-1	0.5
58	058N_SH2014A	0	135	200	120	25	1	56	$ 315,125	$ 40,355	9	21	1	30	-1	2
57	057N_SHFF01A	0	110	59	270	40	1	56	$ 315,125	$ 109,150	9	21	1	24	-1	2
57	057N_NEFF03A	360	110	59	400	40	1	56	$ 315,125	$ 109,150	9	21	1	31	-1	2
57	057N_NEFF02A	360	110	59	390	40	1	56	$ 315,125	$ 109,150	9	21	1	31	-1	2
57	057N_NEFF04A	360	110	59	400	40	1	56	$ 315,125	$ 109,150	9	21	1	31	-1	2
57	057N_NEFF01A	360	110	59	390	40	1	56	$ 315,125	$ 109,150	9	21	1	31	-1	2
57	057N_SHHWY	180	64	1000	180	34	1	64	$ 113,001	$ -	6.6	6.6	1	34	-1	0.5
-999																
58	058E_NI9001A	375	50	140	390	30	1	60	$ 113,001	$ 40,355	9	16.6	1	31	-1	2
58	058E_NI9002A	330	125	95	307	185	1	38	$ 168,010	$ 60,000	8	9.5	1	31	-1	2
58	058E_NI9005A	300	50	140	304	40	1	60	$ 113,001	$ 40,355	9	17.1	1	31	-1	2
58	058N_NE2016A	350	100	54	380	35	1	60	$ 113,001	$ 40,355	8	16.1	1	31	-1	2
58	058N_NE2018A	350	110	54	382	35	1	59	$ 113,001	$ 40,355	9	18.2	1	31	-1	2
58	058N_NE2108A	0	120	225	322	30	1	33	$ 280,016	$ 100,000	8	9.4	1	31	-1	2
58	058N_NE2112A	330	120	42	352	55	1	38	$ 168,010	$ 60,000	8	8.2	1	31	-1	2
58	058N_SH2013A	230	110	50	261	35	1	60	$ 113,001	$ 40,355	9	16.8	1	31	-1	2
58	058N_SH2014A	0	120	530	123	30	1	56	$ 113,001	$ 40,355	15	19.9	1	28	-1	0.5
58	058N_SH2015A	230	130	50	250	40	1	59	$ 113,001	$ 40,355	9	18.1	1	31	-1	2
58	058N_SH2017A	200	150	80	233	35	1	59	$ 113,001	$ 40,355	10	15.9	1	31	-1	2
58	058N_SH2020A	0	120	140	73	45	1	59	$ 113,001	$ 40,355	10	18.4	1	21	-1	2
58	058N_SH2021A	230	100	125	211	40	1	35	$ 113,001	$ 40,355	10	10.9	1	31	-1	2
58	058N_SH2111A	0	120	73	223	55	1	35	$ 113,001	$ 40,355	9	7.6	1	31	-1	2
58	058N_SHFF04A	200	120	73	230	40	1	56	$ 315,125	$ 109,150	8	20	1	24	-1	2
58	058N_SHFF03A	200	120	73	230	40	1	56	$ 315,125	$ 109,150	8	20	1	24	-1	2
58	058N_SHFF02A	200	120	73	225	40	1	56	$ 315,125	$ 109,150	8	20	1	24	-1	2
58	058N_NEFF01A	350	120	54	380	40	1	56	$ 315,125	$ 109,150	8	20	1	31	-1	2
58	058N_SHFF01A	200	120	73	240	40	1	56	$ 315,125	$ 109,150	8	20	1	24	-1	2

Reach ID	USACE_ID	REF lot front	Lot length	Lot width	REF struc front	Struc length	AA Ratio	Flood Curve	Replacement Value of Structure in Dollars	Value of Contents in Dollars	G_elev	FF_elev	Active	Erosion Curve	Armor	Erosion Indicator
58	058N_SHHWY1	170	64	150	185	34	1	64	$ 15,883	$ -	10.1	10.1	1	34	-1	0.5
58	058N_SHHWY2	120	64	500	135	34	1	64	$ 52,934	$ -	10.1	10.1	1	34	-1	0.5
58	058ISLAFF01A	0	412	60	110	40	1	56	$ 315,125	$ 94,537	11	23	1	31	-1	2
58	058ISLAFF02A	0	412	60	110	40	1	56	$ 315,125	$ 94,537	11	23	1	31	-1	2
58	058ISLAFF03A	0	412	60	200	40	1	56	$ 315,125	$ 94,537	11	23	1	31	-1	2
58	058ISLAFF04A	0	412	60	205	40	1	56	$ 315,125	$ 94,537	11	23	1	31	-1	2
58	058ISLAFF05A	0	412	60	200	40	1	56	$ 315,125	$ 94,537	11	23	1	31	-1	2
58	058S_SHHWY	137	64	827	152	34	1	64	$ 87,555	$ -	10.12	10.12	1	34	-1	0.5
-999																
59	059ISLAFF01A	0	420	88	195	40	1	56	$ 315,125	$ 94,537	8	20	1	31	-1	2
59	059ISLAFF02A	0	420	88	200	40	1	56	$ 315,125	$ 94,537	8	20	1	31	-1	2
59	059ISLAFF03A	0	420	88	190	40	1	56	$ 315,125	$ 94,537	8	20	1	31	-1	2
59	059ISLAFF04A	0	420	88	185	40	1	56	$ 315,125	$ 94,537	8	20	1	31	-1	2
59	059ISLAFF06A	216	115	130	240	40	1	56	$ 315,125	$ 94,537	8	20	1	31	-1	2
59	059ISLAFF07A	332	106	108	370	40	1	56	$ 315,125	$ 94,537	8	20	1	31	-1	2
59	059ISLAFF08A	216	115	130	235	40	1	56	$ 315,125	$ 94,537	8	20	1	31	-1	2
59	059ISLAFF09A	332	106	108	375	40	1	56	$ 315,125	$ 94,537	8	20	1	31	-1	2
59	059ISLAFF10A	216	115	130	235	40	1	56	$ 315,125	$ 94,537	8	20	1	31	-1	2
59	059ISLAFF11A	332	106	108	370	40	1	56	$ 315,125	$ 94,537	8	20	1	31	-1	2
59	059ISLAFF12A	216	115	130	240	40	1	56	$ 315,125	$ 94,537	8	20	1	31	-1	2
59	059ISLAFF13A	332	106	108	375	40	1	56	$ 315,125	$ 94,537	8	20	1	31	-1	2
59	059ISLAFF14A	332	106	108	375	40	1	56	$ 315,125	$ 94,537	8	20	1	31	-1	2
59	059SEA_0196A	0	181	108	105	36	1	56	$ 134,679	$ 36,073	8.1	20.6	1	30	-1	2
59	059SEA_0198A	0	181	108	105	36	1	56	$ 134,679	$ 36,073	8.4	20.4	1	31	-1	2
59	059SEA_0200A	0	181	108	108	36	1	56	$ 134,679	$ 36,073	8.5	20.8	1	30	-1	2
59	059SEA_0202A	0	181	108	110	36	1	56	$ 134,679	$ 36,073	8.1	20.6	1	30	-1	2
59	059SEA_0206A	0	181	108	96	40	1	59	$ 65,229	$ 17,471	7.8	20.7	1	21	-1	2
59	059SEA_0209A	216	115	130	266	31	1	60	$ 213,668	$ 57,229	6.1	13.2	1	31	-1	2
59	059SEA_0210A	0	181	108	99	44	1	59	$ 80,711	$ 21,618	0	17.8	1	12	-1	2
59	059SEA_FF0215	A 332	106	108	280	40	1	60	$ 315,125	$ 94,537	7.6	19.2	1	31	-1	2
59	059S_SHHWY	182	64	535	197	34	1	64	$ 56,642	$ -	4.21	4.21	1	34	-1	0.5
-999																
60	060ISLA2372A	353	95	73	368	32	1	59	$ 49,340	$ 13,215	6.5	18.5	1	31	-1	2
60	060ISLA2376A	353	95	73	403	32	1	60	$ 93,353	$ 25,004	6.5	16	1	31	-1	2
60	060ISLAFF01A	353	95	73	395	40	1	56	$ 315,125	$ 94,537	6.5	18.5	1	31	-1	2
60	060SEA_0219A	244	186	87	289	40	1	59	$ 71,162	$ 19,060	7.4	17	1	31	-1	2
60	060SEA_0220A	0	179	83	115	40	1	2	$ 98,912	$ 26,493	10.4	19.5	1	31	-1	0.5

Reach ID	USACE_ID	REF lot front	Lot length	Lot width	REF struc front	Struc length	AA Ratio	Flood Curve	Replacement Value of Structure in Dollars	Value of Contents in Dollars	G_elev	FF_elev	Active	Erosion Curve	Armor	Erosion Indicator
60	060SEA_0224A	0	179	83	110	46	1	60	$ 127,001	$ 34,016	7.4	16	1	6	-1	2
60	060SEA_0225A	244	186	87	316	61	1	2	$ 90,808	$ 24,322	7.6	16.2	1	31	-1	0.5
60	060SEA_0231A	244	186	87	286	43	1	60	$ 213,831	$ 57,273	7	17.5	1	31	-1	2
60	060SEA_0231G	0	0	0	406	43	1	60	$ 213,831	$ 57,273	6.5	18.5	1	31	-1	2
60	060SEA_0232A	0	179	83	136	30	1	59	$ 100,949	$ 27,039	7.3	17.3	1	2	-1	2
60	060SEA_0236A	0	179	83	107	40	1	59	$ 69,977	$ 18,743	7.8	17.4	1	12	-1	2
60	060SEA_0237A	244	186	87	288	33	1	2	$ 251,047	$ 67,241	7.2	15.8	1	31	-1	0.5
60	060SEA_0242A	0	179	83	107	40	1	59	$ 70,842	$ 18,975	9	18	1	21	-1	2
60	060SEA_0243A	244	186	87	287	33	1	60	$ 434,701	$ 116,431	7.2	16.2	1	31	-1	2
60	060SEA_0248A	0	179	83	105	40	1	59	$ 58,053	$ 15,549	8.5	17.8	1	20	-1	2
60	060SEA_0252A	0	179	83	107	40	1	59	$ 97,105	$ 26,009	7.4	16.9	1	3	-1	2
60	060SEA_0253A	244	186	87	284	34	1	60	$ 277,398	$ 74,299	7.8	21.3	1	31	-1	2
60	060SEA_0256A	0	179	83	107	46	1	59	$ 128,056	$ 34,299	8.5	17.8	1	3	-1	2
60	060SEA_0266A	0	179	83	121	32	1	60	$ 201,678	$ 54,018	6.5	18.5	1	6	-1	2
60	060SEA_0274A	0	179	83	106	46	1	59	$ 40,778	$ 10,922	11.7	17.7	1	20	-1	2
60	060SEA_0283A	260	93	73	277	32	1	59	$ 135,946	$ 36,412	8	17.1	1	31	-1	2
60	060SEA_0284A	0	179	83	45	40	1	56	$ 315,125	$ 94,537	8	20	1	31	-1	2
60	060SEA_0292A	0	179	83	45	40	1	56	$ 315,125	$ 94,537	8	20	1	31	-1	2
60	060SEA_0288A	0	179	83	123	24	1	60	$ 125,464	$ 33,605	11.2	12.2	1	15	-1	2
60	060SEA_0296A	0	179	83	110	52	1	59	$ 101,059	$ 27,068	6.7	17.7	1	3	-1	2
60	060SEA_FF02A	260	93	73	285	40	1	56	$ 315,125	$ 94,537	6.5	18.5	1	31	-1	2
60	060SEA_FF03A	260	93	73	285	40	1	56	$ 315,125	$ 94,537	6.5	18.5	1	31	-1	2
60	060WICK2006A	244	186	87	268	50	1	60	$ 212,775	$ 56,990	6.5	18.5	1	31	-1	2
60	060WICK2006X	244	186	87	352	50	1	60	$ 226,728	$ 60,727	6.5	18.5	1	31	-1	2
60	060WICK2006Y	244	186	87	281	45	1	60	$ 221,765	$ 59,398	6.5	18.5	1	31	-1	2
60	060S_SHHWY	200	64	1000	215	34	1	64	$ 105,868	$ -	6.95	6.95	1	34	-1	0.5
-999																
61	061ISLA2398A	338	113	78	391	40	1	1	$ 48,848	$ 13,083	7	19	1	31	-1	0.5
61	061ISLA2414A	338	113	78	399	26	1	59	$ 44,616	$ 11,950	7	19	1	31	-1	2
61	061ISLA2416A	338	113	78	388	26	1	60	$ 169,400	$ 45,372	7.2	18.2	1	31	-1	2
61	061ISLA2422A	248	113	78	385	40	1	60	$ 230,235	$ 61,667	9	15	1	15	-1	2
61	061ISLA2426A	338	113	78	363	42	1	55	$ 91,672	$ 24,553	7	19	1	31	-1	2
61	061ISLA2430A	248	214	220	279	60	1	62	$ 45,085	$ 12,075	7	19	1	31	-1	2
61	061ISLAFF01A	248	113	78	385	40	1	56	$ 315,125	$ 94,537	7	19	1	31	-1	2
61	061ISLAFF02A	248	113	78	385	40	1	56	$ 315,125	$ 94,537	7	19	1	31	-1	2
61	061ISLAFF03A	248	113	78	385	40	1	56	$ 315,125	$ 94,537	7	19	1	31	-1	2
61	061ISLAFF04A	248	113	78	390	40	1	56	$ 315,125	$ 94,537	7	19	1	31	-1	2

Reach ID	USACE_ID	REF lot front	Lot length	Lot width	REF struc front	Struc length	AA Ratio	Flood Curve	Replacement Value of Structure in Dollars	Value of Contents in Dollars	G_elev	FF_elev	Active	Erosion Curve	Armor	Erosion Indicator
61	061ISLAFF05A	248	113	78	390	40	1	56	$ 315,125	$ 94,537	7	19	1	31	-1	2
61	061SEA_0299A	248	90	78	273	32	1	59	$ 46,053	$ 12,335	8.4	16.3	1	31	-1	2
61	061SEA_0300A	0	188	100	96	40	1	59	$ 87,842	$ 23,528	7	15.5	1	11	-1	2
61	061SEA_0303A	248	90	78	284	20	1	59	$ 50,417	$ 13,504	8.7	14.2	1	31	-1	2
61	061SEA_0304A	0	188	100	99	42	1	59	$ 70,062	$ 18,766	6.9	15.4	1	20	-1	2
61	061SEA_0307A	248	90	78	259	28	1	60	$ 86,756	$ 23,237	8.5	17.2	1	31	-1	2
61	061SEA_0310A	0	188	100	110	51	1	60	$ 171,878	$ 46,036	8.6	17.4	1	6	-1	2
61	061SEA_0311A	248	90	78	265	30	1	60	$ 113,001	$ 30,266	9.3	18.6	1	31	-1	2
61	061SEA_0315A	248	90	78	265	25	1	59	$ 47,465	$ 12,713	7	19	1	31	-1	2
61	061SEA_0316A	0	188	100	118	28	1	60	$ 229,593	$ 61,494	8.6	17.2	1	24	-1	2
61	061SEA_0319A	248	90	78	276	38	1	60	$ 130,142	$ 34,858	8.7	19.2	1	31	-1	2
61	061SEA_0326A	0	188	100	119	30	1	59	$ 66,608	$ 17,841	7	16.8	1	2	-1	2
61	061SEA_0330A	0	75	100	60	40	1	56	$ 315,125	$ 94,537	8	20	1	31	-1	2
61	061SEA_0331A	248	90	78	268	54	1	59	$ 122,365	$ 32,774	7.5	17.3	1	31	-1	2
61	061SEA_0333A	248	90	78	269	45	1	59	$ 182,371	$ 48,847	7.7	19	1	31	-1	2
61	061SEA_0335A	248	90	78	260	36	1	59	$ 53,727	$ 14,390	6.4	7.5	1	31	-1	2
61	061SEA_0338A	0	188	100	125	34	1	60	$ 188,609	$ 50,517	8.9	21.4	1	14	-1	2
61	061SEA_0339A	248	90	78	278	56	1	59	$ 162,515	$ 43,528	6.6	13.8	1	31	-1	2
61	061SEA_0342A	0	188	100	137	26	1	60	$ 100,909	$ 27,028	6.8	19.3	1	24	-1	2
61	061SEA_0346A	0	188	100	123	34	1	60	$ 202,169	$ 54,149	6.8	19.8	1	6	-1	2
61	061SEA_0350A	0	188	100	124	21	1	56	$ 103,748	$ 27,788	6.9	19.9	1	29	-1	2
61	061SEA_0354A	0	188	100	125	24	1	56	$ 117,487	$ 31,468	6.7	19.7	1	29	-1	2
61	061S_SHHWY	193	64	655	208	34	1	64	$ 69,343	$ -	6.57	6.57	1	34	-1	0.5
-999																
62	062S_PE0100A	350	138	67	399	36	1	2	$ 241,885	$ 64,787	8.4	16.1	1	31	-1	0.5
62	062S_PE0101A	0	155	143	159	60	1	25	$ 113,001	$ 30,266	10	22	1	31	-1	2
62	062S_PE0102A	350	138	67	388	26	1	60	$ 200,663	$ 53,746	8.3	18.3	1	31	-1	2
62	062S_PE0103A	0	155	143	154	38	1	60	$ 378,255	$ 101,312	9.8	18.6	1	5	-1	2
62	062S_PE0104A	350	138	67	387	34	1	60	$ 195,295	$ 52,308	8.5	17.5	1	31	-1	2
62	062S_PE0106A	350	138	67	414	24	1	60	$ 151,900	$ 40,685	10	22	1	31	-1	2
62	062S_PE0107A	0	155	143	151	32	1	60	$ 238,399	$ 63,853	10.6	20.5	1	6	-1	2
62	062S_PE0108A	350	138	67	401	28	1	60	$ 160,221	$ 42,914	10	22	1	31	-1	2
62	062S_PE0109A	157	76	91	265	25	1	60	$ 1,044	$ 280	11	20.1	1	31	-1	2
62	062S_PE0112A	350	138	67	380	35	1	60	$ 202,416	$ 54,215	10.1	19.4	1	31	-1	2
62	062S_PE0113A	157	76	91	240	42	1	60	$ 380,769	$ 101,986	9.8	18.9	1	31	-1	2
62	062S_PE0114A	350	138	67	374	45	1	60	$ 258,394	$ 69,209	10.3	19.8	1	31	-1	2
62	062S_PE0115A	0	155	143	158	36	1	60	$ 188,065	$ 50,372	11.6	20	1	15	-1	2

Reach ID	USACE_ID	REF lot front	Lot length	Lot width	REF struc front	Struc length	AA Ratio	Flood Curve	Replacement Value of Structure in Dollars	Value of Contents in Dollars	G_elev	FF_elev	Active	Erosion Curve	Armor	Erosion Indicator
62	062S_PE0116A	350	138	67	373	42	1	60	$ 309,049	$ 82,776	11.1	20.3	1	31	-1	2
62	062S_PE0117A	157	76	91	249	28	1	60	$ 154,689	$ 41,432	10.2	20.7	1	31	-1	2
62	062S_PE0118A	350	138	67	365	33	1	59	$ 167,312	$ 44,813	15.7	26.4	1	31	-1	0.5
62	062S_PE0120A	350	138	67	369	26	1	60	$ 153,822	$ 41,200	14.9	22	1	31	-1	0.5
62	062S_PE0122A	350	138	67	380	30	1	60	$ 376,341	$ 100,800	14.8	25.6	1	31	-1	0.5
62	062S_PE0125A	157	76	91	226	26	1	60	$ 248,226	$ 66,486	11.8	21.7	1	31	-1	2
62	062S_PE0126A	350	138	67	386	29	1	56	$ 143,192	$ 38,353	9.6	20	1	31	-1	2
62	062S_PE0127A	0	155	143	158	30	1	60	$ 251,338	$ 67,319	12.3	23.6	1	6	-1	0.5
62	062S_PE0128A	350	138	67	402	43	1	56	$ 216,778	$ 58,062	9.8	19.1	1	31	-1	2
62	062S_PE0129A	157	76	91	238	28	1	60	$ 184,015	$ 49,287	14.7	24.2	1	31	-1	0.5
62	062S_PE0133A	157	76	91	250	30	1	60	$ 1,044	$ 280	15	23.5	1	31	-1	0.5
62	062S_PE0135A	0	155	143	177	28	1	60	$ 224,190	$ 60,047	17.1	23.2	1	16	-1	0.5
62	062S_PE0137A	157	76	91	234	30	1	60	$ 203,794	$ 54,585	13	22.6	1	31	-1	0.5
62	062S_PEFF01A	0	76	91	235	40	1	56	$ 315,125	$ 94,537	10	22	1	31	-1	2
62	062S_PEFF02A	0	76	91	245	40	1	56	$ 315,125	$ 94,537	10	22	1	31	-1	2
62	062S_PEFF03A	350	138	67	375	40	1	56	$ 315,125	$ 94,537	10	22	1	31	-1	2
62	062S_PEFF05A	0	155	143	185	40	1	56	$ 315,125	$ 94,537	10	22	1	31	-1	2
62	062S_PEFF06A	157	76	91	260	40	1	56	$ 315,125	$ 94,537	10	22	1	31	-1	2
62	062S_PEFF07A	350	138	67	390	40	1	56	$ 315,125	$ 94,537	10	22	1	31	-1	2
62	062S_PEFF08A	0	155	143	280	40	1	56	$ 315,125	$ 94,537	10	22	1	31	-1	2
62	062S_PEFF09A	157	76	91	255	40	1	56	$ 315,125	$ 94,537	10	22	1	31	-1	2
62	062S_PE0137A	0	50	50	55	40	1	56	$ 315,125	$ 94,537	10	22	1	31	-1	2
62	062S_PE0131A	0	50	50	55	40	1	56	$ 315,125	$ 94,537	10	22	1	31	-1	2
62	062S_PE0117A	0	50	50	55	40	1	56	$ 315,125	$ 94,537	10	22	1	31	-1	2
62	062S_PEHWY	318	64	905	333	34	1	64	$ 95,810	$ -	6.6	6.6	1	34	-1	0.5
-999																
63	063ISLAFF01A	373	150	60	400	40	1	56	$ 315,125	$ 94,537	8	20	1	31	-1	2
63	063ISLAFF02A	373	150	60	400	40	1	56	$ 315,125	$ 94,537	8	20	1	31	-1	2
63	063ISLAFF03A	373	150	60	400	40	1	56	$ 315,125	$ 94,537	8	20	1	31	-1	2
63	063ISLAFF04A	373	150	60	400	40	1	56	$ 315,125	$ 94,537	8	20	1	31	-1	2
63	063ISLAFF05A	373	150	60	400	40	1	56	$ 315,125	$ 94,537	8	20	1	31	-1	2
63	063N_PE0102A	0	237	67	170	40	1	60	$ 113,001	$ 30,266	10	18.8	1	14	-1	2
63	063N_PE0103A	385	134	70	399	36	1	60	$ 189,211	$ 50,679	7.2	18.4	1	31	-1	2
63	063N_PE0104A	240	113	85	255	28	1	60	$ 184,015	$ 49,287	7.7	18.1	1	31	-1	2
63	063N_PE0105A	385	134	70	396	30	1	60	$ 180,592	$ 48,370	7.8	19.4	1	31	-1	2
63	063N_PE0106A	0	237	67	139	34	1	2	$ 303,319	$ 81,242	9.2	19.1	1	8	-1	0.5
63	063N_PE0107A	385	134	70	400	30	1	2	$ 113,001	$ 30,266	8	18.4	1	31	-1	0.5

Reach ID	USACE_ID	REF lot front	Lot length	Lot width	REF struc front	Struc length	AA Ratio	Flood Curve	Replacement Value of Structure in Dollars	Value of Contents in Dollars	G_elev	FF_elev	Active	Erosion Curve	Armor	Erosion Indicator
63	063N_PE0108A	240	113	85	240	30	1	60	$ 113,001	$ 30,266	10.1	21.2	1	5	-1	2
63	063N_PE0109A	385	134	70	400	32	1	60	$ 232,372	$ 62,239	8	20	1	31	-1	2
63	063N_PE0110A	0	237	67	150	24	1	60	$ 216,337	$ 57,944	10	19	1	5	-1	2
63	063N_PE0111A	385	134	70	388	24	1	60	$ 204,918	$ 54,886	5.7	16.5	1	31	-1	2
63	063N_PE0112A	240	113	85	247	30	1	60	$ 191,217	$ 51,216	8.8	18.2	1	31	-1	2
63	063N_PE0113A	385	134	70	443	435	1	60	$ 113,001	$ 30,266	8	20	1	31	-1	2
63	063N_PE0114A	0	237	67	145	26	1	60	$ 214,830	$ 57,541	8.8	16	1	15	-1	2
63	063N_PE0115A	385	134	70	447	34	1	60	$ 257,927	$ 69,084	16.1	18.1	1	31	-1	0.5
63	063N_PE0116A	240	113	85	240	30	1	60	$ 1,194	$ 320	9.8	16.4	1	31	-1	2
63	063N_PE0117A	385	134	70	453	34	1	60	$ 142,110	$ 38,063	5.2	14.1	1	31	-1	2
63	063N_PEFF0119	A 385	134	70	385	40	1	56	$ 315,125	$ 94,537	6.5	18.3	1	31	-1	2
63	063N_PE0120A	240	113	85	250	41	1	60	$ 229,313	$ 61,420	7.4	17.5	1	31	-1	2
63	063N_PE0122A	0	237	67	156	45	1	60	$ 181,752	$ 48,681	10.1	19.5	1	15	-1	2
63	063N_PE0124A	240	113	85	253	28	1	60	$ 162,137	$ 43,427	8	20	1	31	-1	2
63	063N_PE0126A	0	237	67	172	30	1	60	$ 272,536	$ 72,996	8.6	18.6	1	23	-1	2
63	063N_PE0128A	0	220	100	166	24	1	60	$ 192,444	$ 51,544	8.8	18.6	1	23	-1	2
63	063N_PEFF01A	240	113	85	260	40	1	56	$ 315,125	$ 94,537	8	20	1	31	-1	2
63	063N_PEFF02A	385	134	70	405	40	1	56	$ 315,125	$ 94,537	8	20	1	31	-1	2
63	063N_PEFF04A	0	237	67	185	40	1	56	$ 315,125	$ 94,537	8	20	1	31	-1	2
63	063N_PEFF05A	223	70	100	245	40	1	56	$ 315,125	$ 94,537	8	20	1	31	-1	2
63	063N_PEFF06A	293	80	100	310	40	1	56	$ 315,125	$ 94,537	8	20	1	31	-1	2
63	063OCEA0408A	0	210	200	66	58	1	56	$ 9,596	$ 2,570	6.9	14.5	1	31	-1	2
63	063OCEAFF01A	213	160	60	285	40	1	56	$ 315,125	$ 94,537	8	20	1	31	-1	2
63	063OCEAFF02A	213	160	60	285	40	1	56	$ 315,125	$ 94,537	8	20	1	31	-1	2
63	063OCEAFF03A	213	160	60	285	40	1	56	$ 315,125	$ 94,537	8	20	1	31	-1	2
63	063OCEAFF04A	0	160	60	285	40	1	56	$ 315,125	$ 94,537	8	20	1	31	-1	2
63	063OCEAFF05A	0	160	60	285	40	1	56	$ 315,125	$ 94,537	8	20	1	31	-1	2
63	063N_PEHWY	339	64	821	354	34	1	64	$ 86,917	$ -	5.21	5.21	1	34	-1	0.5
-999																
64	064GREE3003A	380	99	59	423	28	1	59	$ 28,212	$ 7,556	5.3	6.3	1	31	-1	2
64	064GREE3003X	0	0	0	381	35	1	60	$ 11,201	$ 3,000	8	18	1	31	-1	2
64	064ISLA2656A	380	99	59	420	28	1	60	$ 81,612	$ 21,859	8	18	1	31	-1	2
64	064ISLA2660A	380	99	59	408	40	1	55	$ 63,036	$ 16,884	8	18	1	31	-1	2
64	064ISLA2672A	380	99	59	404	48	1	1	$ 40,943	$ 10,966	8	18	1	31	-1	0.5
64	064ISLA2676A	380	99	59	401	32	1	59	$ 83,468	$ 22,356	8.1	8.1	1	31	-1	2
64	064ISLA2684A	380	99	59	401	30	1	2	$ 75,828	$ 20,310	7.4	14	1	31	-1	0.5
64	064ISLA2688A	380	99	59	430	25	1	1	$ 50,226	$ 13,452	6.9	9.1	1	31	-1	0.5

Reach ID	USACE_ID	REF lot front	Lot length	Lot width	REF struc front	Struc length	AA Ratio	Flood Curve	Replacement Value of Structure in Dollars	Value of Contents in Dollars	G_elev	FF_elev	Active	Erosion Curve	Armor	Erosion Indicator
64	064ISLA2692A	380	99	59	385	36	1	59	$ 99,197	$ 26,569	8	18	1	31	-1	2
64	064ISLA2704A	380	99	59	377	37	1	59	$ 50,106	$ 13,420	8	18	1	31	-1	2
64	064ISLAFF01A	380	99	59	390	40	1	56	$ 315,125	$ 94,537	8	18	1	31	-1	2
64	064ISLAFF02A	380	99	59	395	40	1	56	$ 315,125	$ 94,537	8	18	1	31	-1	2
64	064ISLAFF03A	380	99	59	395	40	1	56	$ 315,125	$ 94,537	8	18	1	31	-1	2
64	064ISLAFF04A	380	99	59	395	40	1	56	$ 315,125	$ 94,537	8	18	1	31	-1	2
64	064ISLAFF05A	380	99	59	395	40	1	56	$ 315,125	$ 94,537	8	18	1	31	-1	2
64	064ISLAFF06A	380	99	59	405	40	1	56	$ 315,125	$ 94,537	8	18	1	31	-1	2
64	064ISLAFF07A	380	99	59	410	40	1	56	$ 315,125	$ 94,537	8	18	1	31	-1	2
64	064ISLAFF08A	380	99	59	400	40	1	56	$ 315,125	$ 94,537	8	18	1	31	-1	2
64	064OCEA0442A	0	207	91	113	26	1	55	$ 35,665	$ 9,553	9.1	16.1	1	30	-1	2
64	064OCEA0448A	0	207	91	111	35	1	60	$ 129,155	$ 34,593	9.7	17.9	1	14	-1	2
64	064OCEA0454A	0	207	91	109	32	1	2	$ 102,538	$ 27,464	8.4	16	1	31	-1	0.5
64	064OCEA0457A	271	109	63	282	38	1	59	$ 69,355	$ 18,576	8.3	8.3	1	31	-1	2
64	064OCEA0460A	0	207	91	101	30	1	2	$ 58,688	$ 15,719	8.7	16	1	31	-1	0.5
64	064OCEA0462A	0	207	91	106	24	1	2	$ 63,741	$ 17,072	10	16.4	1	31	-1	0.5
64	064OCEA0464A	0	207	91	111	38	1	55	$ 60,765	$ 16,275	8.5	18.3	1	29	-1	2
64	064OCEA0465A	271	109	63	283	24	1	2	$ 52,538	$ 14,072	8.1	15.6	1	31	-1	0.5
64	064OCEA0469A	271	109	63	285	42	1	59	$ 77,548	$ 20,771	8.2	16.7	1	31	-1	2
64	064OCEA0470A	0	207	91	109	26	1	55	$ 52,837	$ 14,152	8.3	16.4	1	30	-1	2
64	064OCEA0473A	271	109	63	285	24	1	59	$ 67,474	$ 18,072	8.4	12	1	31	-1	2
64	064OCEA0476A	0	207	91	107	28	1	59	$ 95,307	$ 25,527	8.5	16.7	1	12	-1	2
64	064OCEA0477A	271	109	63	289	36	1	59	$ 43,877	$ 11,752	7.9	19.7	1	31	-1	2
64	064OCEA0481A	271	109	63	295	36	1	2	$ 89,353	$ 23,932	7.7	12	1	31	-1	0.5
64	064OCEA0485A	271	109	63	285	28	1	2	$ 47,036	$ 12,598	7.9	14.8	1	31	-1	0.5
64	064OCEA0486A	0	207	91	96	34	1	59	$ 55,221	$ 14,791	8.6	16.4	1	20	-1	2
64	064OCEA0489A	271	109	63	291	40	1	59	$ 88,498	$ 23,703	8.5	16.5	1	31	-1	2
64	064OCEA0492A	0	207	91	99	30	1	59	$ 98,532	$ 26,391	8.4	16	1	20	-1	2
64	064OCEA0493A	271	109	63	294	30	1	1	$ 25,189	$ 6,747	8.2	10.2	1	31	-1	0.5
64	064OCEAFF01A	0	109	63	285	40	1	56	$ 315,125	$ 94,537	8	18	1	31	-1	2
64	064OCEAFF02A	0	109	63	285	40	1	56	$ 315,125	$ 94,537	8	18	1	31	-1	2
64	064OCEAFF03A	0	109	63	285	40	1	56	$ 315,125	$ 94,537	8	18	1	31	-1	2
64	064OCEAFF04A	271	109	63	285	40	1	56	$ 315,125	$ 94,537	8	18	1	31	-1	2
64	064OCEAFF05A	271	109	63	285	40	1	56	$ 315,125	$ 94,537	8	18	1	31	-1	2
64	064OCEAFF06A	271	109	63	285	40	1	56	$ 315,125	$ 94,537	8	18	1	31	-1	2
64	064OCEAFF07A	0	207	91	145	40	1	56	$ 315,125	$ 94,537	8	18	1	31	-1	2
64	064OCEAFF08A	271	109	63	310	40	1	56	$ 315,125	$ 94,537	8	18	1	31	-1	2

Reach ID	USACE_ID	REF lot front	Lot length	Lot width	REF struc front	Struc length	AA Ratio	Flood Curve	Replacement Value of Structure in Dollars	Value of Contents in Dollars	G_elev	FF_elev	Active	Erosion Curve	Armor	Erosion Indicator
64	064OCEAHWY	205	64	1000	220	34	1	64	$ 105,868	$ -	7.36	7.36	1	34	-1	0.5
-999																
65	065GREY3200A	326	82	56	349	32	1	1	$ 35,855	$ 9,604	8.1	15.7	1	31	-1	0.5
65	065ISLA2708A	326	82	56	399	32	1	55	$ 47,124	$ 12,622	8	20	1	31	-1	2
65	065ISLA2712A	326	82	56	390	24	1	2	$ 56,518	$ 15,138	8	20	1	31	-1	0.5
65	065ISLA2716A	326	82	56	389	22	1	56	$ 117,102	$ 31,365	7.3	0	1	31	-1	2
65	065ISLA2720A	326	82	56	376	28	1	60	$ 104,071	$ 27,874	8	20	1	31	-1	2
65	065ISLA2728A	326	82	56	360	28	1	60	$ 79,814	$ 21,378	8	20	1	31	-1	2
65	065ISLA2734A	326	82	56	369	44	1	2	$ 78,689	$ 21,076	8	20	1	31	-1	0.5
65	065ISLA2752A	326	82	56	330	24	1	59	$ 64,192	$ 17,193	8	20	1	31	-1	2
65	065ISLA2768A	326	82	56	289	38	1	59	$ 50,999	$ 13,659	8.3	16	1	31	-1	2
65	065ISLA2772A	326	82	56	278	38	1	2	$ 67,475	$ 18,073	8.1	8.1	1	31	-1	0.5
65	065ISLA2776A	326	82	56	270	40	1	2	$ 101,552	$ 27,200	8	8	1	31	-1	0.5
65	065ISLA2780A	326	82	56	273	28	1	60	$ 133,965	$ 35,882	8	20	1	31	-1	2
65	065ISLA2784A	326	82	56	290	30	1	60	$ 113,001	$ 30,266	8	20	1	31	-1	2
65	065ISLAFF01A	326	82	56	390	40	1	56	$ 315,125	$ 94,537	8	20	1	31	-1	2
65	065ISLAFF02A	326	82	56	350	40	1	56	$ 315,125	$ 94,537	8	20	1	31	-1	2
65	065ISLAFF03A	326	82	56	325	40	1	56	$ 315,125	$ 94,537	8	20	1	31	-1	2
65	065ISLAFF04A	326	82	56	315	40	1	56	$ 315,125	$ 94,537	8	20	1	31	-1	2
65	065ISLAFF05A	326	82	56	315	40	1	56	$ 315,125	$ 94,537	8	20	1	31	-1	2
65	065OCEA0508A	0	171	333	155	40	1	59	$ 80,451	$ 21,548	8.1	18.1	1	11	-1	2
65	065OCEA0509A	235	91	59	306	35	1	59	$ 39,532	$ 10,588	7.7	12	1	31	-1	2
65	065OCEA0512A	0	82	56	85	40	1	56	$ 315,125	$ 94,537	8	20	1	31	-1	2
65	065OCEA0516A	0	171	333	105	32	1	55	$ 67,647	$ 18,119	8	20	1	29	-1	2
65	065OCEA0521A	235	91	59	288	36	1	59	$ 54,576	$ 14,618	7.8	16.1	1	31	-1	2
65	065OCEA0533A	235	91	59	255	38	1	59	$ 65,798	$ 17,623	9.1	17.4	1	31	-1	2
65	065OCEA0538A	0	171	333	126	44	1	59	$ 74,876	$ 20,055	7	15.8	1	12	-1	2
65	065OCEA0539A	235	91	59	229	35	1	59	$ 113,001	$ 30,266	8	20	1	31	-1	2
65	065OCEA0549A	235	91	59	237	36	1	59	$ 67,212	$ 18,002	7.7	17	1	31	-1	2
65	065OCEA0553A	235	91	59	240	25	1	55	$ 113,291	$ 30,344	9.7	17.9	1	31	-1	2
65	065OCEA0559A	235	91	59	211	37	1	60	$ 141,633	$ 37,935	8.3	16.7	1	31	-1	2
65	065OCEA0563A	235	91	59	186	40	1	59	$ 64,972	$ 17,402	7.6	8.6	1	31	-1	2
65	065OCEA0569A	235	91	59	182	47	1	2	$ 45,066	$ 12,070	8.7	8.7	1	31	-1	0.5
65	065OCEA0569S	235	93	56	220	10	1	60	$ 12,195	$ 3,266	8	20	1	31	-1	2
65	065OCEA0575A	235	91	59	182	28	1	59	$ 93,407	$ 25,018	8.8	8.8	1	31	-1	2
65	065OCEAFF01A	235	91	59	315	40	1	56	$ 315,125	$ 94,537	8	20	1	31	-1	2
65	065OCEAFF02A	235	91	59	310	40	1	56	$ 315,125	$ 94,537	8	20	1	31	-1	2

Reach ID	USACE_ID	REF lot front	Lot length	Lot width	REF struc front	Struc length	AA Ratio	Flood Curve	Replacement Value of Structure in Dollars	Value of Contents in Dollars	G_elev	FF_elev	Active	Erosion Curve	Armor	Erosion Indicator
65	065OCEAFF03A	235	91	59	295	40	1	56	$ 315,125	$ 94,537	8	20	1	31	-1	2
65	065OCEAFF04A	235	91	59	298	40	1	56	$ 315,125	$ 94,537	8	20	1	31	-1	2
65	065OCEAFF05A	235	91	59	290	40	1	56	$ 315,125	$ 94,537	8	20	1	31	-1	2
65	065OCEAFF06A	235	91	59	190	40	1	56	$ 315,125	$ 94,537	8	20	1	31	-1	2
65	065OCEAFF07A	235	91	59	190	40	1	56	$ 315,125	$ 94,537	8	20	1	31	-1	2
65	065OCEAHWY	201	64	1006	216	34	1	64	$ 106,507	$ -	7.06	7.06	1	34	-1	0.5
-999																
66	066ISLA0627A	205	102	58	211	38	1	59	$ 66,653	$ 17,852	11.3	11.3	1	31	-1	2
66	066ISLA0631A	205	102	58	221	30	1	60	$ 111,260	$ 29,800	11.5	11.9	1	31	-1	2
66	066ISLA0641A	205	102	58	230	32	1	55	$ 39,125	$ 10,479	9.4	18.4	1	31	-1	2
66	066ISLA0645A	205	102	58	234	32	1	59	$ 36,618	$ 9,808	9.3	17.7	1	31	-1	2
66	066ISLA0649A	205	102	58	233	33	1	55	$ 45,513	$ 12,190	9.1	18.8	1	31	-1	2
66	066ISLA0653A	205	102	58	230	38	1	55	$ 53,353	$ 14,290	9.9	19.1	1	31	-1	2
66	066ISLA0657A	205	102	58	237	32	1	56	$ 73,966	$ 19,811	9.4	17.5	1	31	-1	2
66	066ISLA0665A	205	102	58	232	25	1	59	$ 72,124	$ 19,318	8.8	17.9	1	31	-1	2
66	066ISLA2794A	257	72	95	267	32	1	60	$ 65,439	$ 17,527	9	17.2	1	31	-1	2
66	066ISLA2798A	257	72	95	264	24	1	2	$ 53,940	$ 14,448	9	21	1	31	-1	0.5
66	066ISLA2806A	257	72	95	265	38	1	59	$ 82,249	$ 22,029	9	21	1	31	-1	2
66	066ISLA2810A	257	72	95	269	30	1	2	$ 39,470	$ 10,572	9	21	1	31	-1	0.5
66	066ISLA2865A	427	114	125	476	18	1	60	$ 15,838	$ 4,242	9	21	1	31	-1	2
66	066ISLAFF01A	257	72	95	280	40	1	56	$ 315,125	$ 94,537	9	21	1	31	-1	2
66	066ISLAFF02A	427	114	125	450	40	1	56	$ 315,125	$ 94,537	9	21	1	31	-1	2
66	066ISLAFF03A	427	114	125	440	40	1	56	$ 315,125	$ 94,537	9	21	1	31	-1	2
66	066ISLAFF04A	427	114	125	440	40	1	56	$ 315,125	$ 94,537	9	21	1	31	-1	2
66	066ISLAFF05A	427	114	125	425	40	1	56	$ 315,125	$ 94,537	9	21	1	31	-1	2
66	066ISLAFF06A	427	114	125	420	40	1	56	$ 315,125	$ 94,537	9	21	1	31	-1	2
66	066ISLAFF07A	427	114	125	415	40	1	56	$ 315,125	$ 94,537	9	21	1	31	-1	2
66	066ISLAFF08A	427	114	125	425	40	1	56	$ 315,125	$ 94,537	9	21	1	31	-1	2
66	066ISLAFF09A	0	102	59	235	40	1	56	$ 315,125	$ 94,537	9	21	1	31	-1	2
66	066OCEA0597A	205	52	59	189	37	1	59	$ 61,168	$ 16,383	9.3	16.6	1	31	-1	2
66	066OCEA0603A	205	52	59	189	36	1	2	$ 72,561	$ 19,435	9.4	9.4	1	31	-1	0.5
66	066OCEA0607A	205	52	59	196	26	1	59	$ 55,123	$ 14,764	11	17.3	1	31	-1	2
66	066OCEA0611A	205	52	59	193	28	1	59	$ 47,608	$ 12,752	10.2	17.6	1	31	-1	2
66	066OCEA0615A	205	52	59	212	34	1	59	$ 56,149	$ 15,039	9	21	1	31	-1	2
66	066OCEA0623A	205	52	59	207	30	1	59	$ 69,191	$ 18,532	10.7	18.7	1	31	-1	2
66	066OCEAFF01A	0	168	1000	100	40	1	56	$ 10	$ 3	9	21	1	31	-1	2
66	066OCEAFF02A	205	52	59	195	40	1	56	$ 315,125	$ 94,537	9	21	1	31	-1	2

Reach ID	USACE_ID	REF lot front	Lot length	Lot width	REF struc front	Struc length	AA Ratio	Flood Curve	Replacement Value of Structure in Dollars	Value of Contents in Dollars	G_elev	FF_elev	Active	Erosion Curve	Armor	Erosion Indicator
66	066OCEAFF03A	205	52	59	200	40	1	56	$ 315,125	$ 94,537	9	21	1	31	-1	2
66	066OCEAHWY	137	64	1000	152	34	1	64	$ 105,868	$ -	9.96	9.96	1	34	-1	0.5
66	066ISLAHWY	316	64	1003	331	34	1	64	$ 106,182	$ -	9.96	9.96	1	34	-1	0.5
-999																
67	067ISLA0671A	0	285	167	227	44	1	2	$ 82,618	$ 22,128	9.6	10.5	1	31	-1	0.5
67	067ISLA2928A	0	285	167	156	20	1	56	$ 128,743	$ 34,483	11.1	21.4	1	30	-1	2
67	067ISLAFF01A	0	285	167	225	40	1	56	$ 315,125	$ 94,537	9	21	1	31	-1	2
67	067ISLAFF02A	368	128	193	405	40	1	56	$ 315,125	$ 94,537	9	21	1	31	-1	2
67	067LATE0301A	368	128	193	403	30	1	60	$ 113,001	$ 30,266	9	21	1	31	-1	2
67	067LATE0309A	438	70	250	457	30	1	60	$ 113,001	$ 30,266	9	16.3	1	31	-1	2
67	067LATEFF01A	368	70	250	0	40	1	56	$ 315,125	$ 94,537	9	21	1	31	-1	2
67	067OCEA0210A	0	285	167	187	24	1	60	$ 118,256	$ 31,674	9	21	1	23	-1	2
67	067OCEA0224A	0	285	167	146	34	1	60	$ 232,539	$ 62,284	8.8	19.4	1	23	-1	2
67	067OCEA0236A	0	285	167	166	35	1	60	$ 232,899	$ 62,380	9.4	19.4	1	23	-1	2
67	067OCEA0202A	0	100	50	90	40	1	56	$ 315,125	$ 94,537	9	21	1	31	-1	2
67	067OCEA0206A	0	100	50	90	40	1	56	$ 315,125	$ 94,537	9	21	1	31	-1	2
67	067OCEA0212A	0	100	50	90	40	1	56	$ 315,125	$ 94,537	9	21	1	31	-1	2
67	067OCEA0216A	0	100	50	90	40	1	56	$ 315,125	$ 94,537	9	21	1	31	-1	2
67	067OCEA0230A	0	100	50	90	40	1	56	$ 315,125	$ 94,537	9	21	1	31	-1	2
67	067PORT0200A	368	128	193	399	40	1	60	$ 113,001	$ 30,266	9	21	1	31	-1	2
67	067ISLAHWY1	240	64	568	255	34	1	64	$ 60,136	$ -	5.77	5.77	1	34	-1	0.5
67	067ISLAHWY2	296	64	1000	311	34	1	64	$ 105,868	$ -	5.77	5.77	1	34	-1	0.5
-999																
68	06824TH4503A	365	189	62	424	42	1	59	$ 86,229	$ 23,096	6	18	1	31	-1	2
68	068ERNE0200A	0	283	83	133	34	1	56	$ 94,860	$ 25,408	6.1	17.8	1	30	-1	2
68	068ERNE0202A	0	283	83	127	30	1	55	$ 181,019	$ 48,484	6.5	18.3	1	30	-1	2
68	068ERNE0204A	0	283	83	144	34	1	56	$ 49,695	$ 13,310	2.7	5.7	1	30	-1	2
68	068ISLA2950A	0	283	83	149	35	1	53	$ 113,001	$ 168,483	5.4	18.1	1	30	-1	2
68	068ISLA2978A	0	283	83	153	40	1	60	$ 106,366	$ 28,489	9.8	14.8	1	5	-1	2
68	068ISLA2998A	0	283	83	145	24	1	55	$ 52,642	$ 14,100	6	18	1	31	-1	2
68	068ISLA2999A	365	189	62	166	30	1	60	$ 49,173	$ 13,171	6.9	13.7	1	31	-1	2
68	068ISLA3000A	0	283	83	164	20	1	60	$ 169,857	$ 45,495	10.1	21.4	1	5	-1	2
68	068ISLA3004A	0	283	83	146	30	1	60	$ 114,705	$ 30,723	7.2	19	1	5	-1	2
68	068ISLA3010A	0	283	83	205	32	1	60	$ 141,932	$ 38,015	6	18	1	23	-1	2
68	068ISLA3017A	365	189	62	437	28	1	1	$ 67,419	$ 18,058	4.8	7.2	1	31	-1	0.5
68	068ISLA3021A	365	189	62	430	154	1	59	$ 101,409	$ 27,162	5.5	13.3	1	31	-1	2
68	068ISLA3028A	0	283	83	205	32	1	60	$ 120,925	$ 32,389	6	18	1	5	-1	2

Reach ID	USACE_ID	REF lot front	Lot length	Lot width	REF struc front	Struc length	AA Ratio	Flood Curve	Replacement Value of Structure in Dollars	Value of Contents in Dollars	G_elev	FF_elev	Active	Erosion Curve	Armor	Erosion Indicator
68	068ISLAFF01A	365	189	62	390	40	1	56	$ 315,125	$ 94,537	6	18	1	31	-1	2
68	068ISLAFF02A	365	189	62	390	40	1	56	$ 315,125	$ 94,537	6	18	1	31	-1	2
68	068ISLAFF03A	365	189	62	395	40	1	56	$ 315,125	$ 94,537	6	18	1	31	-1	2
68	068ISLAFF04A	365	189	62	395	40	1	56	$ 315,125	$ 94,537	6	18	1	31	-1	2
68	068ISLAFF05A	365	189	62	405	40	1	56	$ 315,125	$ 94,537	6	18	1	31	-1	2
68	068ISLAFF06A	0	283	83	205	40	1	56	$ 315,125	$ 94,537	6	18	1	31	-1	2
68	068ISLAFF07A	0	283	83	215	40	1	56	$ 315,125	$ 94,537	6	18	1	31	-1	2
68	068SUMM0101A	365	86	220	375	25	1	56	$ 132,542	$ 35,500	5.2	14.2	1	31	-1	2
68	068SUMM0102A	365	86	220	370	32	1	60	$ 110,255	$ 29,531	4.7	14.4	1	31	-1	2
68	068SUMM0111A	451	103	220	459	32	1	2	$ 118,357	$ 31,701	6	18	1	31	-1	0.5
68	068SUMMFF01A	451	103	220	470	40	1	56	$ 315,125	$ 94,537	6	18	1	31	-1	2
68	068ISLAHWY	280	64	1000	295	34	1	64	$ 105,868	$ -	5.91	5.91	1	34	-1	0.5
-999																
69	06922ND4903A	362	172	111	509	14	1	62	$ 23,657	$ 6,336	5	8	1	31	-1	2
69	06923RD4701A	362	172	111	441	40	1	59	$ 55,900	$ 14,972	5	13.6	1	31	-1	2
69	06923RD4706A	362	172	111	509	26	1	59	$ 66,250	$ 17,744	5.5	14	1	31	-1	2
69	06924TH4502A	362	172	111	417	31	1	59	$ 57,860	$ 15,497	4.5	12.8	1	31	-1	2
69	069ISLA3032A	0	279	67	198	30	1	56	$ 126,155	$ 33,790	0	0	1	30	-1	2
69	069ISLA3041A	362	172	111	425	30	1	59	$ 53,016	$ 14,200	4.9	13.4	1	31	-1	2
69	069ISLA3044A	0	279	67	201	20	1	56	$ 199,389	$ 53,405	4.9	13.1	1	30	-1	2
69	069ISLA3045A	362	172	111	432	30	1	59	$ 52,655	$ 14,103	4.9	13.1	1	31	-1	2
69	069ISLA3060A	0	279	67	206	32	1	60	$ 256,931	$ 68,817	12.4	20.8	1	13	-1	0.5
69	069ISLA3064A	0	279	67	208	32	1	60	$ 254,622	$ 68,198	7.6	20.6	1	5	-1	2
69	069ISLA3068A	0	279	67	187	64	1	59	$ 125,632	$ 33,650	8.8	18.4	1	12	-1	2
69	069ISLAFF01A	0	279	67	210	40	1	56	$ 315,125	$ 94,537	5	17	1	31	-1	2
69	069ISLAFF02A	0	279	67	205	40	1	56	$ 315,125	$ 94,537	5	17	1	31	-1	2
69	069ISLAFF03A	0	279	67	210	40	1	56	$ 315,125	$ 94,537	5	17	1	31	-1	2
69	069ISLAFF04A	0	279	67	215	40	1	56	$ 315,125	$ 94,537	5	17	1	31	-1	2
69	069TOPS0110A	0	279	67	139	32	1	60	$ 137,501	$ 36,829	7.1	18.9	1	15	-1	2
69	069TOPS0114A	0	279	67	209	24	1	60	$ 131,358	$ 35,183	11	23	1	23	-1	2
69	069TOPS0115A	362	172	111	361	30	1	59	$ 87,627	$ 23,470	8.3	17.2	1	21	-1	2
69	069TOPS0122A	0	279	67	211	34	1	60	$ 166,065	$ 44,479	9.5	21.6	1	5	-1	2
69	069TOPS0128A	0	279	67	169	30	1	60	$ 114,375	$ 30,635	8.1	20.1	1	5	-1	2
69	069TOPSFF01A	0	279	67	210	40	1	56	$ 315,125	$ 94,537	5	17	1	31	-1	2
69	069TOPSFF02A	0	279	67	215	40	1	56	$ 315,125	$ 94,537	5	17	1	31	-1	2
69	069TOPSFF03A	362	172	111	365	40	1	56	$ 315,125	$ 94,537	5	17	1	31	-1	2
69	069TOPSFF04A	362	172	111	375	40	1	56	$ 315,125	$ 94,537	5	17	1	31	-1	2

Reach ID	USACE_ID	REF lot front	Lot length	Lot width	REF struc front	Struc length	AA Ratio	Flood Curve	Replacement Value of Structure in Dollars	Value of Contents in Dollars	G_elev	FF_elev	Active	Erosion Curve	Armor	Erosion Indicator
69	069ISLAHWY	325	64	627	340	34	1	64	$ 66,375	$ -	6.86	6.86	1	34	-1	0.5
69	069TOPSHWY	287	64	341	302	34	1	64	$ 36,100	$ -	6.86	6.86	1	34	-1	0.5
-999																
70	07018TH5605A	398	72	82	390	10	1	62	$ 6,958	$ 1,864	7	19	1	31	-1	2
70	07018TH5611A	291	107	57	315	32	1	1	$ 127,557	$ 34,165	7	19	1	31	-1	0.5
70	070ISLA3184A	398	72	82	386	66	1	62	$ 20,828	$ 5,579	7	19	1	31	-1	2
70	070ISLA3188A	398	72	82	386	10	1	62	$ 16,306	$ 4,368	7	19	1	31	-1	2
70	070ISLAFF01A	398	72	82	430	40	1	56	$ 315,125	$ 94,537	7	19	1	31	-1	2
70	070ISLAFF02A	398	72	82	430	40	1	56	$ 315,125	$ 94,537	7	19	1	31	-1	2
70	070ISLAFF03A	398	72	82	425	40	1	56	$ 315,125	$ 94,537	7	19	1	31	-1	2
70	070ISLAFF04A	398	72	82	420	40	1	56	$ 315,125	$ 94,537	7	19	1	31	-1	2
70	070ISLAFF05A	398	72	82	420	40	1	56	$ 315,125	$ 94,537	7	19	1	31	-1	2
70	070ISLAFF06A	398	72	82	415	40	1	56	$ 315,125	$ 94,537	7	19	1	31	-1	2
70	070TOPS0142A	0	249	125	193	28	1	60	$ 124,069	$ 33,231	7	19	1	15	-1	2
70	070TOPS0151A	328	141	65	346	31	1	60	$ 235,199	$ 62,996	9.7	20.1	1	31	-1	2
70	070TOPS0153A	328	141	65	330	30	1	60	$ 188,412	$ 50,464	8.6	19.3	1	31	-1	2
70	070TOPS0154A	0	249	125	190	41	1	60	$ 155,201	$ 41,569	11.3	23.1	1	23	-1	2
70	070TOPS0155A	291	107	57	326	36	1	59	$ 87,932	$ 23,552	7.6	16.7	1	31	-1	2
70	070TOPS0159A	291	107	57	325	40	1	60	$ 277,270	$ 74,264	3.8	15.6	1	31	-1	2
70	070TOPS0160A	0	249	125	187	28	1	60	$ 138,701	$ 37,150	7	19	1	23	-1	2
70	070TOPS0163A	291	107	57	336	34	1	2	$ 257,625	$ 69,003	6.5	15.1	1	31	-1	0.5
70	070TOPS0167A	291	107	57	336	36	1	2	$ 287,946	$ 77,124	6	15.3	1	31	-1	0.5
70	070TOPS0168A	0	249	125	151	32	1	60	$ 83,345	$ 22,323	7.7	19.2	1	15	-1	2
70	070TOPS0171A	291	107	57	326	34	1	2	$ 257,187	$ 68,885	6.2	15.5	1	31	-1	0.5
70	070TOPS0174A	0	249	125	162	28	1	56	$ 94,715	$ 25,368	7.5	19.7	1	30	-1	2
70	070TOPS0180A	0	249	125	160	22	1	60	$ 183,586	$ 49,172	8.1	21	1	23	-1	2
70	070TOPS0183A	291	107	57	340	25	1	59	$ 64,554	$ 17,290	5.6	13.7	1	31	-1	2
70	070TOPS0191A	291	107	57	320	30	1	60	$ 113,001	$ 30,266	10.2	0	1	31	-1	2
70	070TOPS0193A	291	107	57	289	28	1	60	$ 144,722	$ 38,763	7	19	1	31	-1	2
70	070TOPS0194A	0	249	125	162	28	1	56	$ 87,317	$ 23,387	8.3	22.1	1	30	-1	2
70	070TOPS0204A	0	249	125	150	30	1	56	$ 67,426	$ 18,059	7.1	19	1	30	-1	2
70	070TOPS0205A	291	107	57	294	12	1	62	$ 8,887	$ 2,380	7.1	9	1	31	-1	2
70	070TOPS0213A	291	107	57	272	78	1	1	$ 64,941	$ 17,394	7.1	9	1	31	-1	0.5
70	070TOPSFF01A	328	141	65	370	40	1	56	$ 315,125	$ 94,537	6	18	1	31	-1	2
70	070TOPSFF02A	328	141	65	365	40	1	56	$ 315,125	$ 94,537	6	18	1	31	-1	2
70	070TOPSFF03A	291	107	57	320	40	1	56	$ 315,125	$ 94,537	6	18	1	31	-1	2
70	070TOPSFF04A	291	107	57	325	40	1	56	$ 315,125	$ 94,537	6	18	1	31	-1	2

Reach ID	USACE_ID	REF lot front	Lot length	Lot width	REF struc front	Struc length	AA Ratio	Flood Curve	Replacement Value of Structure in Dollars	Value of Contents in Dollars	G_elev	FF_elev	Active	Erosion Curve	Armor	Erosion Indicator
70	070TOPSFF05A	0	100	57	190	40	1	56	$ 315,125	$ 94,537	6	18	1	31	-1	2
70	070TOPSFF06A	0	100	57	190	40	1	56	$ 315,125	$ 94,537	6	18	1	31	-1	2
70	070TOPSHWY	248	64	1000	263	34	1	64	$ 105,868	$ -	10.27	10.27	1	34	-1	0.5
-999																
71	07113TH6602A	345	51	100	330	40	1	59	$ 82,413	$ 22,074	8.1	10.3	1	31	-1	2
71	07113TH6604A	297	48	100	293	12	1	62	$ 4,758	$ 1,274	8.2	10.8	1	31	-1	2
71	07114TH6400A	345	51	100	358	14	1	62	$ 12,195	$ 3,266	7.7	11.4	1	31	-1	2
71	07114TH6404A	297	48	100	296	40	1	59	$ 59,005	$ 15,804	8.3	16.1	1	31	-1	2
71	07114TH6411A	226	105	63	205	12	1	62	$ 6,780	$ 1,816	10.1	11.5	1	31	-1	2
71	07114TH6412A	226	105	63	188	33	1	55	$ 52,936	$ 14,179	9.8	17.1	1	31	-1	2
71	07114TH6503A	345	51	100	343	14	1	62	$ 12,195	$ 3,266	8.4	10.3	1	31	-1	2
71	07114TH6504A	297	48	100	293	22	1	1	$ 32,782	$ 8,780	8.4	10.3	1	31	-1	0.5
71	07115TH6200A	331	92	60	336	44	1	59	$ 112,842	$ 30,224	7.7	9.9	1	31	-1	2
71	07115TH6201A	345	51	100	363	14	1	62	$ 32,398	$ 8,677	7.7	11	1	31	-1	2
71	07115TH6205A	297	48	100	320	46	1	62	$ 10,510	$ 2,815	8.4	10.3	1	31	-1	2
71	07115TH6210A	226	105	63	239	38	1	60	$ 109,584	$ 29,351	8	20	1	31	-1	2
71	07115TH6211A	226	105	63	221	22	1	55	$ 25,563	$ 6,847	9.4	16.5	1	31	-1	2
71	071ISLA3192A	331	92	60	394	14	1	62	$ 13,607	$ 3,644	8	10	1	31	-1	2
71	071ISLA3200A	331	92	60	385	30	1	60	$ 164,803	$ 44,141	7	19.1	1	31	-1	2
71	071ISLA3210A	331	92	60	358	60	1	59	$ 12,195	$ 3,266	8	20	1	31	-1	2
71	071ISLA3212A	0	0	0	363	38	1	59	$ 124,171	$ 33,258	7.7	15	1	31	-1	2
71	071ISLA3222A	331	92	60	338	42	1	59	$ 99,072	$ 26,536	7.2	17.6	1	31	-1	2
71	071ISLAFF01A	331	92	60	385	40	1	56	$ 315,125	$ 94,537	8	20	1	31	-1	2
71	071ISLAFF02A	331	92	60	365	40	1	56	$ 315,125	$ 94,537	8	20	1	31	-1	2
71	071ISLAFF03A	331	92	60	345	40	1	56	$ 315,125	$ 94,537	8	20	1	31	-1	2
71	071TOPS0213S	226	105	63	300	40	1	60	$ 5,600	$ 1,500	8	20	1	31	-1	2
71	071TOPS0220A	0	174	250	158	24	1	56	$ 113,001	$ 30,266	6.9	20.8	1	30	-1	2
71	071TOPS0221A	226	105	63	269	62	1	59	$ 32,829	$ 8,793	6.6	9.1	1	31	-1	2
71	071TOPS0229A	226	105	63	273	24	1	60	$ 161,409	$ 43,232	9	18.4	1	31	-1	2
71	071TOPS0230A	0	174	250	144	26	1	55	$ 88,628	$ 23,738	6.6	19.7	1	30	-1	2
71	071TOPS0233A	226	105	63	268	32	1	60	$ 216,130	$ 57,889	9.3	19.4	1	31	-1	2
71	071TOPS0237A	226	105	63	281	26	1	60	$ 134,400	$ 35,998	9.1	16.4	1	31	-1	2
71	071TOPS0238A	0	174	250	141	20	1	55	$ 90,145	$ 24,144	6.4	18	1	30	-1	2
71	071TOPS0241A	226	105	63	277	26	1	60	$ 116,431	$ 31,185	8.9	18	1	31	-1	2
71	071TOPS0247A	226	105	63	248	32	1	59	$ 51,126	$ 13,694	8.8	17.7	1	31	-1	2
71	071TOPS0265A	226	105	63	220	28	1	59	$ 59,128	$ 15,837	9.3	18.6	1	31	-1	2
71	071TOPS0269A	226	105	63	200	28	1	59	$ 36,584	$ 9,798	9.3	17	1	31	-1	2

Reach ID	USACE_ID	REF lot front	Lot length	Lot width	REF struc front	Struc length	AA Ratio	Flood Curve	Replacement Value of Structure in Dollars	Value of Contents in Dollars	G_elev	FF_elev	Active	Erosion Curve	Armor	Erosion Indicator
71	071TOPS0285A	226	105	63	197	14	1	59	$ 17,919	$ 4,800	8	20	1	31	-1	2
71	071TOPS0290A	0	174	250	72	26	1	59	$ 46,413	$ 12,432	7.5	21	1	12	-1	2
71	071TOPSFF01A	226	105	63	330	40	1	56	$ 315,125	$ 94,537	8	20	1	31	-1	2
71	071TOPSFF02A	226	105	63	285	40	1	56	$ 315,125	$ 94,537	8	20	1	31	-1	2
71	071TOPSHWY	173	64	998	188	34	1	64	$ 105,656	$ -	7.15	7.15	1	34	-1	0.5
-999																
72	07210TH7202A	319	49	125	321	12	1	1	$ 9,228	$ 2,472	8	20	1	31	-1	0.5
72	07210TH7204A	268	51	125	262	46	1	59	$ 99,975	$ 26,778	8.2	17.4	1	31	-1	2
72	07210TH7211A	169	99	59	154	24	1	59	$ 48,781	$ 13,065	8.8	16.4	1	31	-1	2
72	07210THFF01A	268	51	125	270	40	1	56	$ 315,125	$ 94,537	8	20	1	31	-1	2
72	07211TH01A	268	51	125	270	40	1	56	$ 315,125	$ 94,537	8	20	1	31	-1	2
72	07211TH7002A	319	49	125	322	40	1	60	$ 113,704	$ 30,455	8	20	1	31	-1	2
72	07211TH7003A	319	49	125	325	40	1	56	$ 315,125	$ 94,537	8	20	1	31	-1	2
72	07211TH7003P	319	100	111	323	40	1	1	$ 4,480	$ -	8	20	1	31	-1	0.5
72	07211TH7007A	268	51	125	266	40	1	2	$ 65,408	$ 17,519	7.6	15.2	1	31	-1	0.5
72	07212TH6803A	319	49	125	335	35	1	56	$ 113,001	$ 30,266	8	20	1	31	-1	2
72	07212TH6804A	268	51	125	284	25	1	1	$ 13,441	$ 3,600	8	20	1	31	-1	0.5
72	07212TH6805A	268	51	125	285	35	1	59	$ 113,001	$ 30,266	8	20	1	31	-1	2
72	07213TH6603A	319	49	125	331	14	1	62	$ 5,600	$ 1,500	8	20	1	31	-1	2
72	07213TH6605A	268	51	125	290	16	1	62	$ 5,600	$ 1,500	8	20	1	31	-1	2
72	0729TH_7400A	319	49	125	314	28	1	59	$ 25,714	$ 6,888	7.8	14.9	1	31	-1	2
72	0729TH_7402A	268	51	125	264	24	1	59	$ 28,339	$ 7,590	7.9	14.9	1	31	-1	2
72	0729TH_7414A	169	99	59	149	24	1	59	$ 34,507	$ 9,242	9.6	16.3	1	31	-1	2
72	072ISLAFF01A	319	49	125	335	40	1	56	$ 315,125	$ 94,537	8	20	1	31	-1	2
72	072ISLAFF02A	319	49	125	320	40	1	56	$ 315,125	$ 94,537	8	20	1	31	-1	2
72	072TOPS0303A	169	99	59	180	40	1	62	$ 28,871	$ 7,733	10.9	11.9	1	31	-1	2
72	072TOPS0306A	0	117	333	68	24	1	2	$ 45,351	$ 12,147	8	19.3	1	31	-1	0.5
72	072TOPS0307A	169	99	59	177	40	1	56	$ 224,013	$ 60,000	8	20	1	31	-1	2
72	072TOPS0311A	169	99	59	196	32	1	56	$ 174,120	$ 46,637	10	18.6	1	31	-1	2
72	072TOPS0315A	169	99	59	175	35	1	62	$ 15,613	$ 4,182	7.6	11	1	31	-1	2
72	072TOPS0321A	169	99	59	187	30	1	60	$ 168,038	$ 45,008	8	20	1	31	-1	2
72	072TOPS0325A	169	99	59	161	31	1	59	$ 85,907	$ 23,009	8.7	16.2	1	31	-1	2
72	072TOPS0329A	169	99	59	204	38	1	59	$ 117,743	$ 31,537	8.9	18.1	1	31	-1	2
72	072TOPS0333A	169	99	59	185	39	1	56	$ 106,303	$ 28,472	7.8	16.9	1	31	-1	2
72	072TOPS0340A	0	117	333	46	24	1	59	$ 67,205	$ 18,000	6.6	16.6	1	12	-1	2
72	072TOPS0341A	169	99	59	180	50	1	59	$ 108,841	$ 29,152	8.9	18.2	1	31	-1	2
72	072TOPS0345A	169	99	59	163	36	1	56	$ 80,055	$ 21,442	8	20	1	31	-1	2

Reach ID	USACE_ID	REF lot front	Lot length	Lot width	REF struc front	Struc length	AA Ratio	Flood Curve	Replacement Value of Structure in Dollars	Value of Contents in Dollars	G_elev	FF_elev	Active	Erosion Curve	Armor	Erosion Indicator
72	072TOPS0349A	169	99	59	155	37	1	59	$ 88,655	$ 23,746	8.6	16.3	1	31	-1	2
72	072TOPS0353A	169	99	59	175	44	1	60	$ 109,168	$ 29,240	9.4	17.4	1	31	-1	2
72	072TOPS0364A	0	117	333	46	24	1	59	$ 73,170	$ 19,598	6.3	16.8	1	12	-1	2
72	072TOPSFF01A	169	99	59	175	40	1	56	$ 315,125	$ 94,537	8	20	1	31	-1	2
72	072TOPSFF01A	169	99	59	220	40	1	56	$ 315,125	$ 94,537	8	20	1	31	-1	2
72	072TOPSFF02A	169	99	59	180	40	1	56	$ 315,125	$ 94,537	8	20	1	31	-1	2
72	072TOPSHWY	119	64	999	134	34	1	64	$ 105,756	$ -	7.8	7.8	1	34	-1	0.5
-999																
73	0735TH_8202A	308	54	125	335	35	1	56	$ 113,001	$ 30,266	9	21	1	31	-1	2
73	0735TH_8210A	163	98	62	204	26	1	2	$ 70,156	$ 18,791	8.5	12.8	1	31	-1	0.5
73	0735TH_FF01A	261	47	125	275	40	1	56	$ 315,125	$ 94,537	9	21	1	31	-1	2
73	0736TH_8000A	308	54	125	314	14	1	1	$ 24,189	$ 6,479	8.8	11.8	1	31	-1	0.5
73	0736TH_8003A	308	54	125	330	40	1	56	$ 315,125	$ 94,537	9	21	1	31	-1	2
73	0736TH_8003S	0	0	0	323	8	1	60	$ 504	$ 135	9	21	1	31	-1	2
73	0736TH_8004A	261	47	125	269	50	1	1	$ 39,462	$ 10,570	9.3	11.8	1	31	-1	0.5
73	0736TH_8004S	0	0	0	265	12	1	60	$ 1,344	$ 360	9	21	1	31	-1	2
73	0736TH_8005A	261	47	125	261	53	1	55	$ 76,509	$ 20,492	12.9	15.2	1	31	-1	0.5
73	0736TH_8011A	163	98	62	169	32	1	60	$ 54,639	$ 14,635	9.7	19.2	1	31	-1	2
73	0737TH_7800A	308	54	125	326	32	1	59	$ 70,395	$ 18,855	8.7	10.7	1	31	-1	2
73	0737TH_7800S	334	0	111	325	12	1	60	$ 952	$ 255	9	21	1	31	-1	2
73	0737TH_7803A	308	54	125	308	34	1	59	$ 96,221	$ 25,772	9.1	20.4	1	31	-1	2
73	0737TH_7806A	261	47	125	262	34	1	59	$ 67,465	$ 18,070	8.9	16.6	1	31	-1	2
73	0737TH_7807A	261	47	125	261	30	1	59	$ 69,415	$ 18,592	9.8	11.7	1	31	-1	2
73	0737TH_7812A	163	98	62	157	41	1	59	$ 78,904	$ 21,134	8.5	16.2	1	31	-1	2
73	0738TH_7605A	261	47	125	268	30	1	59	$ 76,990	$ 20,621	9	21	1	31	-1	2
73	0738TH_7605S	308	54	125	328	12	1	60	$ 1,680	$ 450	9	21	1	31	-1	2
73	0738TH_7612A	163	98	62	163	40	1	60	$ 96,554	$ 25,861	9.3	17.3	1	31	-1	2
73	0738TH_FF01A	261	47	125	275	40	1	56	$ 315,125	$ 94,537	9	21	1	31	-1	2
73	0739TH_7401A	308	54	125	313	42	1	60	$ 107,468	$ 28,785	5.2	7.4	1	31	-1	2
73	0739TH_7405A	261	47	125	266	24	1	59	$ 47,997	$ 12,856	9	21	1	31	-1	2
73	0739TH_7415A	163	98	62	164	48	1	60	$ 100,908	$ 27,027	9.3	16.4	1	31	-1	2
73	073ISLAFF01A	308	54	125	330	40	1	56	$ 315,125	$ 94,537	9	21	1	31	-1	2
73	073TOPS0383A	163	98	62	162	57	1	1	$ 19,597	$ 5,249	8.8	11.8	1	31	-1	0.5
73	073TOPS0387A	163	98	62	180	30	1	59	$ 54,026	$ 14,471	9.4	16.7	1	31	-1	2
73	073TOPS0403A	163	98	62	191	24	1	60	$ 158,061	$ 42,335	9.1	17.1	1	31	-1	2
73	073TOPS0419A	163	98	62	175	36	1	59	$ 55,637	$ 14,902	9.7	19.2	1	31	-1	2
73	073TOPS0423A	163	98	62	181	40	1	59	$ 59,171	$ 15,848	11.2	18.7	1	31	-1	2

Reach ID	USACE_ID	REF lot front	Lot length	Lot width	REF struc front	Struc length	AA Ratio	Flood Curve	Replacement Value of Structure in Dollars	Value of Contents in Dollars	G_elev	FF_elev	Active	Erosion Curve	Armor	Erosion Indicator
73	073TOPS0425A	163	98	62	181	26	1	59	$ 44,579	$ 11,940	11	19.5	1	31	-1	2
73	073TOPSFF01A	0	116	1000	62	40	1	56	$ 315,125	$ 94,537	9	21	1	31	-1	2
73	073TOPSFF02A	163	98	62	185	40	1	56	$ 315,125	$ 94,537	9	21	1	31	-1	2
73	073TOPSFF03A	163	98	62	165	40	1	56	$ 315,125	$ 94,537	9	21	1	31	-1	2
73	073TOPSFF04A	163	98	62	180	40	1	56	$ 315,125	$ 94,537	9	21	1	31	-1	2
73	073TOPSFF05A	163	98	62	180	40	1	56	$ 315,125	$ 94,537	9	21	1	31	-1	2
73	073TOPSFF06A	163	98	62	185	40	1	56	$ 315,125	$ 94,537	9	21	1	31	-1	2
73	073TOPSHWY	115	64	1000	130	34	1	64	$ 105,868	$ -	8.93	8.93	1	34	-1	0.5
-999																
74	0742ND_8800A	296	53	143	298	34	1	1	$ 26,382	$ 7,066	9	21	1	31	-1	0.5
74	0742ND_8800G	0	0	0	317	12	1	1	$ 1,344	$ 360	9	21	1	31	-1	2
74	0742ND_8801A	296	53	143	291	40	1	59	$ 88,832	$ 23,793	9	21	1	31	-1	2
74	0742ND_8804A	245	51	143	247	40	1	1	$ 113,001	$ 30,266	9	21	1	31	-1	0.5
74	0742ND_8804G	0	0	0	247	25	1	1	$ 5,600	$ 1,500	9	21	1	31	-1	2
74	0742ND_8805A	245	51	143	244	24	1	55	$ 17,388	$ 4,657	9	21	1	31	-1	2
74	0742ND_8805S	0	0	0	265	30	1	1	$ 2,240	$ 600	9	21	1	31	-1	2
74	0742ND_8806A	146	99	59	166	30	1	55	$ 113,001	$ 30,266	9	21	1	31	-1	2
74	0742ND_8811A	146	99	59	151	32	1	55	$ 43,849	$ 11,745	9	21	1	30	-1	2
74	0742ND_8904A	437	92	125	460	28	1	55	$ 89,029	$ 23,846	9	21	1	31	-1	2
74	0743RD_8603A	245	51	143	310	30	1	60	$ 113,001	$ 30,266	9	21	1	23	-1	2
74	0743RD_8607A	245	51	143	241	36	1	59	$ 87,675	$ 23,483	9	21	1	31	-1	2
74	0743RD_8610A	146	99	59	185	30	1	60	$ 113,001	$ 30,266	9	21	1	15	-1	2
74	0744TH_8404A	245	51	143	275	32	1	56	$ 113,001	$ 30,266	9	21	1	31	-1	2
74	0744TH_8409A	245	51	143	264	46	1	1	$ 42,817	$ 11,468	9	21	1	31	-1	0.5
74	0744TH_8411A	146	99	59	177	32	1	59	$ 113,252	$ 30,334	9	21	1	31	-1	2
74	0745TH_8203A	296	53	143	304	38	1	59	$ 66,993	$ 17,943	9	21	1	31	-1	2
74	0745TH_8205A	245	51	143	253	42	1	59	$ 105,488	$ 28,254	7.2	16.3	1	31	-1	2
74	0745TH_8211A	146	99	59	173	40	1	59	$ 51,404	$ 13,768	8.3	15.8	1	31	-1	2
74	0746TH_8803A	296	53	143	315	40	1	56	$ 315,125	$ 94,537	9	21	1	31	-1	2
74	074ISLA3504A	146	99	59	157	32	1	60	$ 252,987	$ 67,760	8.6	18.7	1	23	-1	2
74	074ISLA3507A	437	92	125	434	32	1	60	$ 195,931	$ 52,478	4	14.2	1	31	-1	2
74	074ISLAFF01A	296	53	143	320	40	1	56	$ 315,125	$ 94,537	9	21	1	31	-1	2
74	074ISLAFF02A	296	53	143	315	40	1	56	$ 315,125	$ 94,537	9	21	1	31	-1	2
74	074ISLAFF03A	296	53	143	318	40	1	56	$ 315,125	$ 94,537	9	21	1	31	-1	2
74	074TOPS0464A	0	100	500	64	18	1	55	$ 63,515	$ 17,012	6	20.9	1	30	-1	2
74	074TOPS0465A	146	99	59	171	32	1	60	$ 41,268	$ 11,053	7.1	15.6	1	31	-1	2
74	074TOPS0469A	146	99	59	205	28	1	60	$ 132,579	$ 35,510	8.4	9.2	1	31	-1	2

Reach ID	USACE_ID	REF lot front	Lot length	Lot width	REF struc front	Struc length	AA Ratio	Flood Curve	Replacement Value of Structure in Dollars	Value of Contents in Dollars	G_elev	FF_elev	Active	Erosion Curve	Armor	Erosion Indicator
74	074TOPS0479A	146	99	59	185	30	1	59	$ 1,044	$ 280	9.9	17.1	1	31	-1	2
74	074TOPS0486A	0	100	500	39	24	1	59	$ 42,608	$ 11,412	7.2	18.2	1	2	-1	2
74	074TOPS0499A	146	99	59	185	35	1	55	$ 224,013	$ 60,000	9.1	21.1	1	31	-1	2
74	074TOPS0503A	146	99	59	178	40	1	55	$ 77,702	$ 20,812	9.9	18	1	30	-1	2
74	074TOPS0517A	146	99	59	151	30	1	55	$ 37,075	$ 9,930	11.1	17.8	1	31	-1	2
74	074TOPS0523A	146	99	59	152	66	1	60	$ 99,322	$ 26,603	10.4	14.9	1	31	-1	2
74	074TOPS0527A	146	99	59	149	34	1	59	$ 113,704	$ 30,455	9.8	18.2	1	31	-1	2
74	074TOPS0527G	0	0	0	200	40	1	60	$ 12,195	$ 3,266	9	21	1	31	-1	2
74	074TOPSFF01A	146	99	59	175	40	1	56	$ 315,125	$ 94,537	9	21	1	31	-1	2
74	074TOPSFF02A	146	99	59	180	40	1	56	$ 315,125	$ 94,537	9	21	1	31	-1	2
74	074TOPSFF03A	146	99	59	175	40	1	56	$ 315,125	$ 94,537	9	21	1	31	-1	2
74	074TOPSHWY	102	64	892	117	34	1	64	$ 94,433	$ -	8.06	8.06	1	34	-1	0.5
-999																
75	075CALI0101A	440	119	111	471	30	1	60	$ 392,497	$ 105,127	6.6	17	1	31	-1	2
75	075CALI0105A	440	119	111	486	30	1	60	$ 392,659	$ 105,170	6	18	1	31	-1	2
75	075HERO0101A	440	119	111	466	30	1	60	$ 100,689	$ 26,969	6.2	16.3	1	31	-1	2
75	075HERO0105A	440	119	111	466	30	1	60	$ 100,689	$ 26,969	6	18	1	31	-1	2
75	075ISLA3512A	0	353	67	159	28	1	60	$ 155,643	$ 41,688	7.8	18.1	1	5	-1	2
75	075ISLA3518A	0	353	67	165	34	1	60	$ 257,807	$ 69,052	8.9	21.4	1	5	-1	2
75	075ISLA3522A	0	353	67	182	25	1	60	$ 228,462	$ 61,192	7.9	19.7	1	5	-1	2
75	075ISLA3530A	0	353	67	163	32	1	60	$ 207,752	$ 55,644	16.1	16.3	1	5	-1	0.5
75	075ISLA3536A	0	353	67	215	30	1	55	$ 164,033	$ 43,935	6	18	1	30	-1	2
75	075ISLA3541A	440	119	111	484	30	1	60	$ 113,738	$ 30,464	5.4	14	1	31	-1	2
75	075ISLA3542A	0	353	67	135	40	1	60	$ 71,398	$ 19,124	6.9	19	1	15	-1	2
75	075ISLA3546A	0	353	67	198	28	1	60	$ 97,027	$ 25,988	11.2	24.4	1	23	-1	2
75	075ISLA3560A	0	353	67	264	26	1	60	$ 126,875	$ 33,983	6	18	1	23	-1	2
75	075ISLA3562A	0	353	67	133	47	1	60	$ 213,694	$ 57,236	6.6	21.1	1	5	-1	2
75	075ISLA3575A	440	119	111	530	24	1	59	$ 49,265	$ 13,195	6.1	14.2	1	31	-1	2
75	075ISLA3584A	0	353	67	227	32	1	60	$ 223,159	$ 59,772	6	18	1	23	-1	2
75	075ISLA3585A	440	119	111	528	32	1	55	$ 48,554	$ 13,005	6.1	13.9	1	31	-1	2
75	075ISLA3586A	0	353	67	239	33	1	59	$ 177,097	$ 47,434	9.8	0	1	12	-1	2
75	075ISLA3588A	0	353	67	227	52	1	60	$ 317,694	$ 85,092	7.1	22.4	1	5	-1	2
75	075ISLA3588G	0	0	0	264	30	1	60	$ 12,195	$ 3,266	6	18	1	31	-1	2
75	075ISLAFF01A	440	119	111	450	40	1	56	$ 315,125	$ 94,537	6	18	1	31	-1	2
75	075ISLAFF02A	0	353	67	260	40	1	56	$ 315,125	$ 94,537	6	18	1	31	-1	2
75	075ISLAFF03A	0	353	67	260	40	1	56	$ 315,125	$ 94,537	6	18	1	31	-1	2
75	075ISLAFF04A	440	119	111	450	40	1	56	$ 315,125	$ 94,537	6	18	1	31	-1	2

Reach ID	USACE_ID	REF lot front	Lot length	Lot width	REF struc front	Struc length	AA Ratio	Flood Curve	Replacement Value of Structure in Dollars	Value of Contents in Dollars	G_elev	FF_elev	Active	Erosion Curve	Armor	Erosion Indicator
75	075ISLAFF05A	0	353	67	400	40	1	56	$ 315,125	$ 94,537	6	18	1	31	-1	2
75	075_210HWY	353	64	1000	368	34	1	64	$ 105,868	$ -	6.87	6.87	1	34	-1	0.5
-999																
76	076ISLA3592A	0	360	71	233	65	1	60	$ 267,991	$ 71,779	6.9	11.6	1	23	-1	2
76	076ISLA3600A	0	360	71	278	28	1	2	$ 77,984	$ 20,888	8	20	1	31	-1	0.5
76	076ISLA3605A	449	145	167	509	38	1	59	$ 65,724	$ 17,604	5.7	13.3	1	31	-1	2
76	076ISLA3606A	0	360	71	226	40	1	59	$ 283,726	$ 75,993	14.3	24.1	1	10	-1	0.5
76	076ISLA3612A	0	360	71	171	26	1	60	$ 172,622	$ 46,236	9.2	12.2	1	5	-1	2
76	076ISLA3618A	0	360	71	172	32	1	60	$ 134,143	$ 35,929	7.6	19.2	1	15	-1	2
76	076ISLA3622A	0	360	71	177	30	1	60	$ 106,771	$ 28,598	8.1	18.9	1	5	-1	2
76	076ISLA3632A	0	360	71	255	24	1	60	$ 174,913	$ 46,849	8.4	18	1	23	-1	2
76	076ISLA3634A	0	360	71	258	24	1	56	$ 177,843	$ 47,634	8.4	17.9	1	30	-1	2
76	076ISLA3638A	0	360	71	261	28	1	56	$ 285,638	$ 76,506	8	20	1	30	-1	2
76	076ISLA3644A	0	360	71	162	32	1	60	$ 220,343	$ 59,017	8.7	15.2	1	5	-1	2
76	076ISLA3648A	0	360	71	248	24	1	60	$ 179,403	$ 48,052	17	21.1	1	13	-1	0.5
76	076ISLA3655A	449	145	167	482	27	1	2	$ 106,235	$ 28,454	8	20	1	31	-1	0.5
76	076ISLA3655G	0	0	0	500	40	1	1	$ 113,704	$ 30,455	8	20	1	31	-1	2
76	076ISLA3658A	0	360	71	181	32	1	60	$ 104,859	$ 28,086	8.1	10.2	1	17	-1	2
76	076ISLAFF01A	465	145	167	510	40	1	56	$ 315,125	$ 94,537	8	20	1	31	-1	2
76	076ISLAFF02A	449	145	167	510	40	1	56	$ 315,125	$ 94,537	8	20	1	31	-1	2
76	076ISLAFF03A	449	145	167	495	40	1	56	$ 315,125	$ 94,537	8	20	1	31	-1	2
76	076ISLAFF04A	449	145	167	480	40	1	56	$ 315,125	$ 94,537	8	20	1	31	-1	2
76	076ISLAFF05A	0	360	71	220	40	1	56	$ 315,125	$ 94,537	8	20	1	31	-1	2
76	076_210HWY	362	64	1000	377	34	1	64	$ 105,868	$ -	6.43	6.43	1	34	-1	0.5
-999																
77	077ISLA3674A	0	318	71	192	42	1	56	$ 131,103	$ 35,115	11.4	12.1	1	30	-1	2
77	077ISLA3720A	0	318	71	201	34	1	59	$ 314,031	$ 84,111	7	19	1	12	-1	2
77	077ISLA3730A	0	318	71	202	36	1	60	$ 155,075	$ 41,536	7	18.5	1	15	-1	2
77	077ISLA3734A	0	318	71	475	40	1	60	$ 163,722	$ 43,852	7	19	1	27	-1	2
77	077ISLA3735A	421	162	111	199	35	1	56	$ 113,001	$ 30,266	7	19	1	31	-1	2
77	077ISLA3740A	0	318	71	124	25	1	60	$ 164,795	$ 44,139	5.4	18.9	1	15	-1	2
77	077ISLA3744A	0	318	71	119	28	1	60	$ 210,300	$ 56,327	8.3	16.4	1	5	-1	2
77	077ISLA3748A	0	318	71	187	50	1	60	$ 137,118	$ 36,726	7	19	1	15	-1	2
77	077ISLAFF01A	0	318	71	200	40	1	56	$ 315,125	$ 94,537	7	19	1	31	-1	2
77	077ISLAFF02A	405	162	111	480	40	1	56	$ 315,125	$ 94,537	7	19	1	31	-1	2
77	077ISLAFF03A	0	318	71	215	40	1	56	$ 315,125	$ 94,537	7	19	1	31	-1	2
77	077ISLAFF04A	405	162	111	485	40	1	56	$ 315,125	$ 94,537	7	19	1	31	-1	2

Reach ID	USACE_ID	REF lot front	Lot length	Lot width	REF struc front	Struc length	AA Ratio	Flood Curve	Replacement Value of Structure in Dollars	Value of Contents in Dollars	G_elev	FF_elev	Active	Erosion Curve	Armor	Erosion Indicator
77	077ISLAFF05A	0	318	71	220	40	1	56	$ 315,125	$ 94,537	7	19	1	31	-1	2
77	077ISLAFF06A	405	162	111	475	40	1	56	$ 315,125	$ 94,537	7	19	1	31	-1	2
77	077ISLAFF07A	0	318	71	215	40	1	56	$ 315,125	$ 94,537	7	19	1	31	-1	2
77	077ISLAFF08A	405	162	111	470	40	1	56	$ 315,125	$ 94,537	7	19	1	31	-1	2
77	077ISLAFF09A	0	318	71	475	40	1	56	$ 315,125	$ 94,537	7	19	1	31	-1	2
77	077ISLAFF10A	405	162	111	425	40	1	56	$ 315,125	$ 94,537	7	19	1	31	-1	2
77	077ISLAFF11A	0	318	71	205	40	1	56	$ 315,125	$ 94,537	7	19	1	31	-1	2
77	077ISLAFF12A	405	162	111	465	40	1	56	$ 315,125	$ 94,537	7	19	1	31	-1	2
77	077ISLAFF13A	0	318	71	195	40	1	56	$ 315,125	$ 94,537	7	19	1	31	-1	2
77	077ISLAFF14A	405	162	111	440	40	1	56	$ 315,125	$ 94,537	7	19	1	31	-1	2
77	077ISLAFF15A	405	162	111	440	40	1	56	$ 315,125	$ 94,537	7	19	1	31	-1	2
77	077_210HWY	318	64	1000	333	34	1	64	$ 105,868	$ -	4.89	4.89	1	34	-1	0.5
-999																
78	078ISLA3752A	0	322	56	183	24	1	56	$ 113,722	$ 30,460	7	19	1	30	-1	2
78	078ISLA3756A	0	322	56	187	26	1	60	$ 120,166	$ 32,185	7	19	1	23	-1	2
78	078ISLA3759A	408	183	100	450	35	1	60	$ 113,001	$ 30,266	7	19	1	31	-1	2
78	078ISLA3760A	0	322	56	185	40	1	59	$ 104,715	$ 28,047	7	19	1	12	-1	2
78	078ISLA3764A	0	322	56	200	30	1	60	$ 1,044	$ 280	7	19	1	15	-1	2
78	078ISLA3767A	408	183	100	450	30	1	60	$ 113,001	$ 30,266	7	19	1	31	-1	2
78	078ISLA3768A	0	322	56	200	30	1	60	$ 1,044	$ 280	7	19	1	15	-1	2
78	078ISLA3775A	408	183	100	450	35	1	60	$ 113,001	$ 30,266	7	19	1	31	-1	2
78	078ISLA3776A	0	322	56	195	32	1	56	$ 94,689	$ 25,362	7.4	15.9	1	31	-1	2
78	078ISLA3801A	408	183	100	450	35	1	60	$ 113,001	$ 30,266	7	19	1	31	-1	2
78	078ISLA3802A	0	322	56	227	33	1	56	$ 84,302	$ 22,580	7	19	1	30	-1	2
78	078ISLA3803A	408	183	100	450	35	1	60	$ 113,001	$ 30,266	7	19	1	31	-1	2
78	078ISLA3804A	0	322	56	203	48	1	56	$ 172,820	$ 46,288	8	17.5	1	30	-1	2
78	078ISLA3805A	408	183	100	429	34	1	60	$ 83,304	$ 22,312	5.9	14.6	1	31	-1	2
78	078ISLA3808A	0	322	56	119	40	1	59	$ 83,703	$ 22,419	6.6	11.4	1	12	-1	2
78	078ISLA3814A	0	322	56	197	40	1	56	$ 126,815	$ 33,966	7	19	1	30	-1	2
78	078ISLA3824A	0	322	56	138	32	1	60	$ 193,948	$ 51,947	7.3	13.7	1	5	-1	2
78	078ISLA3825A	408	183	100	488	40	1	55	$ 58,126	$ 15,569	7	19	1	31	-1	2
78	078ISLA3828A	0	322	56	148	32	1	55	$ 60,259	$ 16,140	8.4	19.3	1	30	-1	2
78	078ISLAFF01A	408	183	100	450	40	1	56	$ 315,125	$ 94,537	7	19	1	31	-1	2
78	078ISLAFF02A	408	183	100	455	40	1	56	$ 315,125	$ 94,537	7	19	1	31	-1	2
78	078ISLAFF03A	0	322	56	200	40	1	56	$ 315,125	$ 94,537	7	19	1	31	-1	2
78	078ISLAFF04A	0	322	56	225	40	1	56	$ 315,125	$ 94,537	7	19	1	31	-1	2
78	078ISLAFF05A	0	322	56	240	40	1	56	$ 315,125	$ 94,537	7	19	1	31	-1	2

Reach ID	USACE_ID	REF lot front	Lot length	Lot width	REF struc front	Struc length	AA Ratio	Flood Curve	Replacement Value of Structure in Dollars	Value of Contents in Dollars	G_elev	FF_elev	Active	Erosion Curve	Armor	Erosion Indicator
78	078ISLAFF08A	0	80	50	175	40	1	56	$ 315,125	$ 94,537	7	19	1	31	-1	2
78	078MYRT0209A	0	322	56	188	40	1	55	$ 113,001	$ 30,266	7	19	1	31	-1	2
78	078MYRT0211A	0	322	56	191	35	1	59	$ 113,001	$ 30,266	7	19	1	31	-1	2
78	078MYRTFF01A	0	322	56	220	40	1	56	$ 113,704	$ 30,455	7	19	1	31	-1	2
78	078SEA_0100A	408	90	100	433	33	1	60	$ 80,180	$ 21,475	7	19	1	31	-1	2
78	078SEA_0110A	498	93	100	534	35	1	60	$ 80,180	$ 21,475	7	19	1	31	-1	2
78	078_210HWY	322	64	998	337	34	1	64	$ 105,656	$ -	4.69	4.69	1	34	-1	0.5
-999																

April 21, 2002

Erosion Damage Thresholds in North Carolina

by Spencer M. Rogers Jr.
North Carolina Sea Grant

INTRODUCTION

As the coast of North Carolina developed over the last century, coastal construction has experienced significant damage from hurricanes and other coastal storms, as well as long-term erosion. Construction practices have evolved due to changes in public perception of storm risk and several construction regulation programs. Several important changes in practice did not occur as a gradual process but instead in a series of identifiable steps in time. Significant events affecting construction practice include: a series of severe hurricanes and coastal storms in the 1950s; the mid-1960s adoption and later revision of the North Carolina State Building Code, the second oldest hurricane-resistant building code in the U.S.; and the 1978 implementation and later revisions of the NC Coastal Area Management Act. The evolution of coastal construction practice and general thresholds for damage has been described by Rogers (2001). This report applies to those observed changes to develop methods to estimate damage to coastal structures due to storm-induced erosion in North Carolina. A comprehensive inventory of building construction details and other structures can be combined with commonly unmeasurable construction details that can be inferred from the construction date and the known evolution of general construction practices.

The effect of construction regulations is always limited by the effectiveness of local enforcement and the speed of adoption as general construction practice. Experience from severe storms and long-term erosion in North Carolina has shown that the building code and regulatory enforcement has been generally good; regulatory compliance in coastal communities has been consistently high; and the adoption of new standards by local contractors timely. The use of construction dates to estimate hidden construction parameters affecting erosion resistance is therefore a reasonable assumption and an improvement over previous methods to estimate erosion damage.

North Carolina's buildings and other development have evolved due to a unique storm and regulatory history. The recommendations in this report will not directly apply to other coastal areas. However, locally-customized construction factors can be developed for any shoreline that could be used to significantly improve erosion damage predictions over previously used methods.

The most accurate method to predict future damage is to perform a building by building damage evaluation of historical severe storms on shorelines with similar development and construction standards. At this time detailed studies do not exist. Therefore, the damage thresholds suggested for North Carolina and the erosion damage curves in Appendix A are based on the opinion of the author, formed over 27 years of building damage evaluations, following most of the worst storms on the East and Gulf coasts, and for most of that time, observations of the North Carolina coast on a daily basis. A resume is included as Appendix B.

GENERAL APPROACH

To improve erosion damage estimates, buildings can be separated into two general classes: small buildings (primarily single family houses) and larger commercial buildings. Each class is further separated by construction details determined by a local building inventory and assumed local construction practice based on construction date. The erosion resistance of a building can seldom be determined by construction details alone. The local ground elevation significantly affects the effectiveness of the construction standards. Local topographical data can be used to separate shorelines into two general types with high or low elevation building sites.

SHORELINE TYPES

On ocean shorelines, zones of storm damage have been observed that can separated by ground elevation into two types (Rogers, 1990) shown in **Figure 1**. The high elevation type is defined as sufficiently elevated to prevent wave effects unless subject to erosion (**Figure 1-A**). The seaward of two damage zones is defined by the area subject to erosion. Buildings in the erosion zone are subject to combined damage from erosion, wave impacts and flooding. The high elevation of the more landward zone protects the buildings from erosion, waves and flooding. Both zones are subject to storm winds.

Low elevation shorelines with overtopped dunes have four building damage zones (**Figure 1B**). The seaward zone is defined as the area experiencing erosion but also subject to waves, and flooding. The next landward zone is defined as the area subject to breaking waves capable of destroying solid building walls and foundations. It includes the area subject to overwash deposition. The National Flood Insurance Program has traditionally identified the threshold for destructive wave heights as 3 feet (Corps of Engineers, 1975). More recent research indicates that a breaking wave of 1.5 feet will destroy common solid walls and foundations (Tung et al, 1999) . The next landward zone is defined by flooding but no significant wave damage. The landward-most zone has sufficient elevation to avoid erosion, waves and flooding but like the more seaward zones, may be subject to high winds.

Figure 1: SHORELINE TYPES

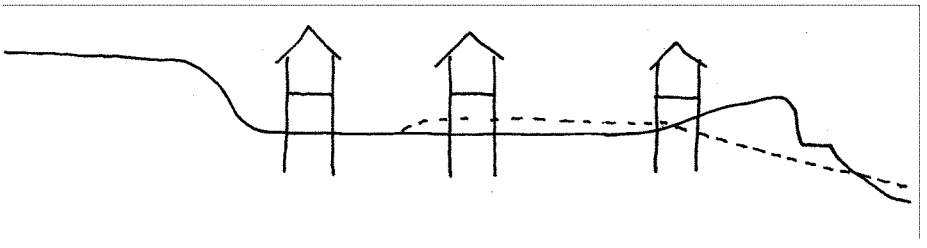
A. High dune, no overtopping
1. Erosion zone with waves and flooding
2. High ground (no erosion, waves or flooding)

HIGH GROUND **EROSION, WAVES & FLOODING**



B. Small overtopped dune
1. Erosion zone with waves and flooding
2. Waves zone with overwash deposition and flooding
3. Stable ground elevation with flooding
4. High ground: (no erosion, waves or flooding)

HIGH GROUND **FLOODING** **WAVES** **EROSION**



CLASSES OF STRUCTURES

To predict erosion damage within the described zones, it is useful to separate structures into several different classes as shown in **Figure 2.** Buildings are separated by general size, typically single-family houses and larger commercial buildings. Both classes of buildings commonly use breakaway walls and enclosures under piling supported, elevated buildings. The behavior of the enclosures is sufficiently different and often independent of the elevated buildings therefore justifying a separate class and damage calculations for the enclosures. A broad class of structures including mobile homes, swimming pools and other expendable structures, including decks seaward of oceanfront houses, are grouped as highly erosion sensitive structures. Dune walkways, roads and erosion control actions are listed as separate classes. It is useful to separate the buildings and several other classes into subclasses, based on similar construction characteristics. Suggested erosion damage tables for Classes 1-5 are included as an appendix.

Class 1: Single-Family Houses

Single-family houses are by far the most common class of buildings along the North Carolina coast. They are used as primary residences, second homes and rental property. The class includes similarly designed small buildings such as duplexes, small condos and some small commercial buildings. The class can be further divided by foundation type, determined by a detailed building inventory and the date of initial construction. Class 1a includes erosion-sensitive foundations including concrete slabs, shallow spread footings and most others not on pilings. Class 1b buildings are constructed on relatively shallow pilings. Building code requirements beginning in the mid-1960s led to the common use of pilings installed to a depth of 8 feet below grade. It includes most non-oceanfront houses up to present and oceanfront houses constructed through 1985. Class 1c consists of oceanfront houses constructed from 1986 to present, following an increase in the piling foundation standard to -5 feet NGVD or 16 feet below grade, whichever is shallower.

The shallow foundations in Class 1a are equally erosion damage prone in both shoreline elevation types. The shallow pilings in Class 1b are ineffective on high elevation, Type A shorelines, and perform like Class 1a (**Figure 3**). At lower ground elevations of Type B a moderate level of erosion resistance is provided (**Figure 4**). For short pilings, +12' NGVD is suggested as an effective ground elevation separation for shoreline type. Shallow piling foundations in Type A shorelines have a piling tip penetration above +4' or slightly above the mean high water elevation, too little embedment to improve the erosion-resistance over Class 1a. Significant damage to deeper imbedded pilings is likely to begin when the erosion depth exceeds 4', half the embedment depth of 8'.

On high elevation Type A shorelines the deeper pilings of Class 1c are limited in effectiveness by the 16' feet below grade requirement. The shoreline types can be separated by a ground elevation of +16' NGVD. On A shorelines, the piling embedment will be no deeper than 0.0' NGVD and can be expected to perform similar to the other grossly eroded foundations in 1a and 1b(A) (**Figure 5**). When piling embedment approaches or exceeds the -5' NGVD piling standard on lower ground elevations (Type B) the erosion resistance of 1986 piling standards proved very effective during Hurricane Fran (FEMA, 1997 and Woodward-Clyde, 1997.) See **Figure 6.** An erosion threshold of 4 feet is suggested.

Figure 2: CLASSES OF COASTAL BUILDINGS AND OTHER STRUCTURES

1. Single-family house (includes duplexes & small condos)
   a. Slab foundation or shallow perimeter footing and interior piers
   b. Shallow piling foundation (~ 8' below grade: oceanfront, 1965 thru 1985 and farther inland, all dates.)
   c. Deeper piling foundation (piling penetration to -5' NGVD or 16' below grade, whichever is shallower, 1986 and later, oceanfront only)

2. Commercial or large multi-family buildings
   a. Slab or other on-grade foundation
   b. Second floor and above piling supported, lowest floor on grade (common in hotel and condos)
   c. Fully piling supported, deep pilings, [some wood-frame, pre-1985 oceanfront condos may have shallow pilings as in 1b above]
   d. Building specific evaluation (fishing piers, etc.)

3. Underhouse enclosures: may be unfinished or finished interior
   Unfinished enclosures have fixed cost per either SF or linear wall footage
   Finished enclosure valued as ratio of total finished floor area
   a. None (parking slab?)
   b. Small (<300 SF)
   c. Partial (>300 SF, < full)
   d. Full enclosure

4. Mobile homes, utility buildings, detached garages, decks seaward of oceanfront houses, gazebos, pools etc

5. Dune walkways
   a. Houses
   b. Public/commercial

6. Paved roads and parking lots
   a. Damage
   b. Overwash excavation
   c. Sand sifting operations

7. Erosion control structures and actions
   a. Beach scraping
   b. Emergency sandbags



Figure 3: Short piling foundation failures (Class 1b) on high-elevation shoreline (Type A). Location: Kure Beach NC after Hurricane Fran.

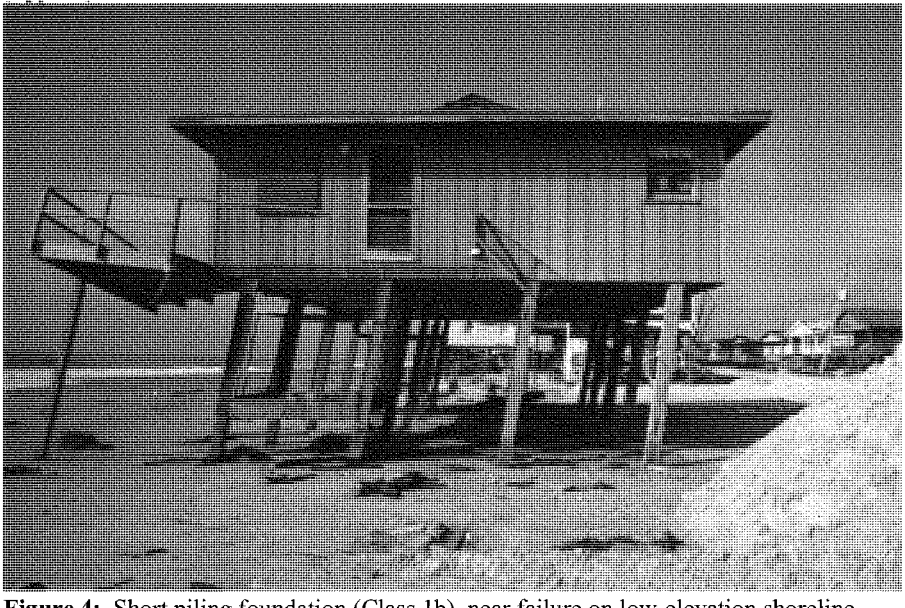


Figure 4: Short piling foundation (Class 1b) near failure on low-elevation shoreline (Type B). Location: Surf City NC after Hurricane Fran.



Figure 5: House under construction with piling 16 feet below grade (Class 1c) on high-elevation dune (Type A). Dune elevation above +16 feet NGVD makes erosion failure more likely. Location: Emerald Isle NC.

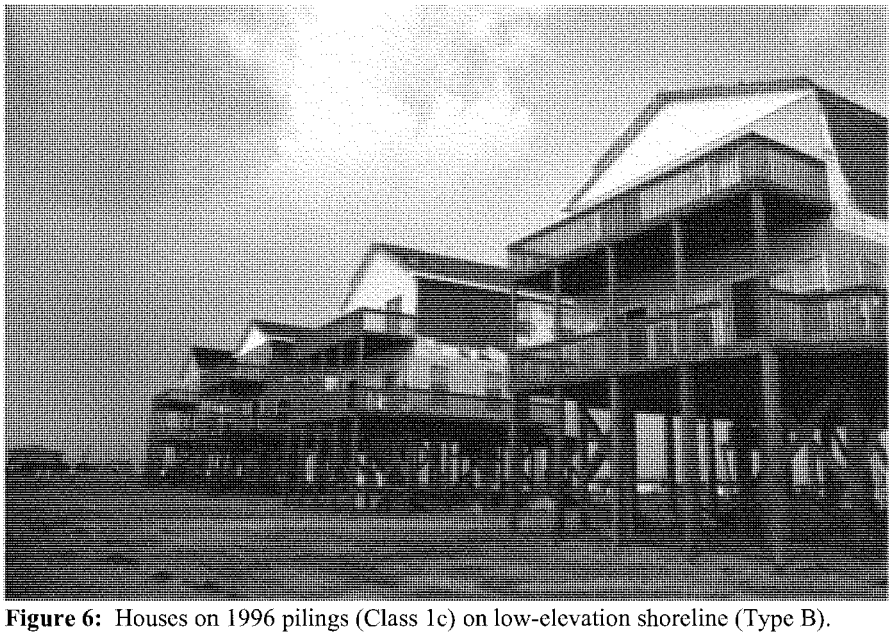


Figure 6: Houses on 1996 pilings (Class 1c) on low-elevation shoreline (Type B). Location: Topsail Island after Hurricane Fran.



Figure 7: Slab foundation failure (Class 1a & 2a) beside commercial/deep-piling structure (Class 2c) on high-elevation shoreline (Type A). Location: Surf City NC after Hurricane Fran.

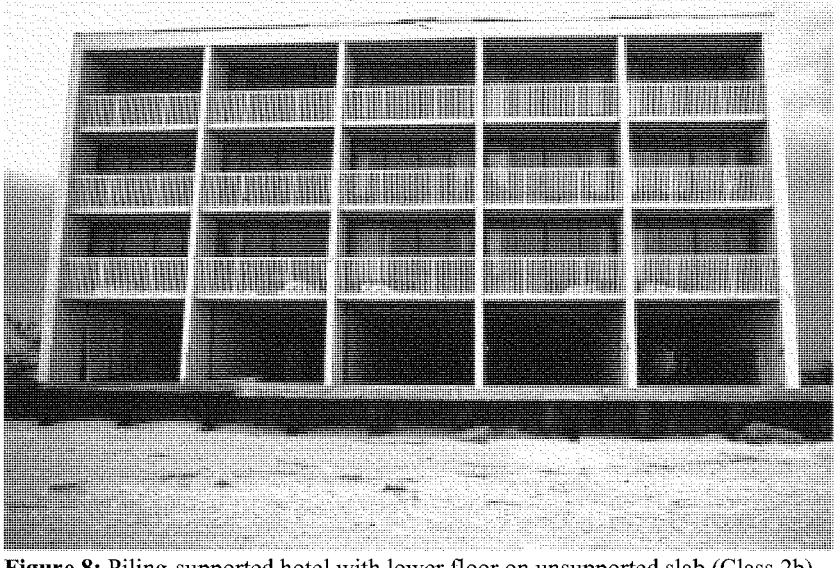


Figure 8: Piling-supported hotel with lower floor on unsupported slab (Class 2b) on low-elevation shoreline (Type B). Location: Wrightsville Beach NC after Hurricane Fran.

Class 2: Large Commercial Buildings

The class of large buildings includes hotels, large condos, restaurants, and most other commercial buildings. These generally larger buildings are constructed to a separate performance building code that does not include the specific piling depth requirements found in Class 1. The large mass of the buildings typically dictates, that where used, piling embedment depths are significantly greater than for small buildings. Class 2a buildings are constructed on shallow, erosion-sensitive foundations, typical of older commercial buildings (**Figure 7**). Class 2c is fully supported on a piling foundation and has an erosion tolerance as good or better than the best small buildings (**Figure 7.**) Class 2b is a hybrid foundation common in hotel construction. All of the building walls and all floors above the first floor are supported on pilings and buried grade beams that are relatively erosion tolerant (**Figure 8**). The lowest finished floor is supported on a slab foundation supported on grade between the foundation pilings (**Figure 9**). The lowest floor is therefore highly erosion sensitive. Wave and erosion damage occurs to the lowest floor where much of the value of the building is concentrated, but higher floors are relatively undamaged. It is suggested that total erosion damage be estimated by treating the lowest floor as a slab (Class 1a and 2a)but weighted for twice the average square-foot value for the building, and added to damage in higher floors as applied in Class 1c and 2c.

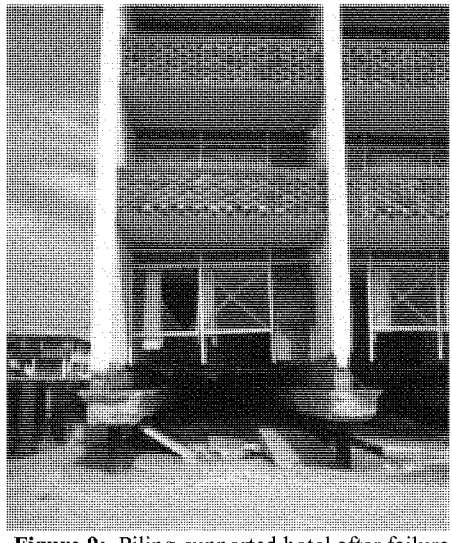


Figure 9: Piling-supported hotel after failure of unsupported, first-floor slab (Class 2b) on low-elevation shoreline (Type B). Location: Horry County after Hurricane Hugo.

Class 3: Under-building Enclosures

Many buildings of all ages enclose part or all of the area under piling-supported elevated buildings. Present regulations allow lower level enclosures for the purposes of parking, storage or access to the elevated building. Any enclosure must be unfinished and include no equipment such as a heat pump, water heater, washer or dryer. In some communities it is common for piling-supported houses constructed prior to adoption of minimum floor elevation requirements, to have fully finished underhouse enclosures supported on a slab foundation. Although prohibited in more recent construction, small finished enclosures and unauthorized equipment are not uncommon. Erosion or waves frequently destroy the lower level and equipment, leaving the elevated floors in place.

Some near-ocean buildings are required to use specific designs for breakaway enclosure walls. More recent research has shown that standard wood framing adequately functions to breakaway from the piling foundation and elevated building, negating the need for a specific

breakaway design (Tung et al, 1999). Whether it was designed to breakaway is a moot issue. Waves and/or erosion will predictably cause all enclosure walls to breakaway.

Enclosures are common in both Class 1 and Class 2 buildings. Enclosures are supported on slab foundations that behave quite differently in erosion than the rest of a piling-supported building. Recent building inventory collections have included separate descriptions of the size and finish of the enclosures. Therefore overall damage calculations can be simplified and improved by considering enclosures as Class 4 structures, separate from the rest of the elevated buildings. The National Flood Insurance premium rating system serves to encourage enclosure sizes into four groups as outlined in **Figure 2**. Open buildings with no enclosures may still have parking slabs that are subject to erosion damage. In NFIP V-zones, enclosures smaller than 300 SF can be rated by local flood insurance agents. Larger enclosures must submit information to Washington for rating. Full enclosures are common near some shorelines particularly in A-zones where flood insurance rates are not affected by the size or presence of the enclosures.

The value of the enclosure will vary depending on whether it is finished or unfinished. Finished areas can be reasonably valued at the SF rate of the elevated building. Unfinished enclosures are obviously lower in value.

Class 4: Mobile Homes and Other Expendable Structures

Mobile homes and a group of other expendable structures are highly erosion sensitive, failing quickly after only partial undermining. Mobile homes in this class use shallow, mortarless concrete block piers, tied down with screw anchors. A small number of mobile homes have recently been installed on traditional piling foundations and should be evaluated as Class 1 structures. North Carolina has historically considered expendable structures to include small utility buildings, parking surfaces, gazebos, swimming pools and tennis courts. Also included are the open decks seaward of most oceanfront houses. Building setback lines generally apply to the roofed building, but expendable decks of limited size are allowed to be constructed contiguous to the building, seaward of the setback line. The building code allows the common practice of using short pilings on the decks compared to required depth for the building (FEMA, 1997.) Oceanfront decks are therefore far more erosion-sensitive than the adjacent buildings and are more accurately grouped with Class 4. Detached garages are more common in older development and are affected similarly by erosion.

Class 5: Dune walkways

Dune walkways are permitted as expendable structures and restricted in piling depth to require erosion damage rather than interfering with access along the beach. Walkway damage differs from Class 4 only in the rate that erosion damage progresses. The relatively long, shore perpendicular structures can be assumed to experience a linear increase in damage with the percentage of erosion rather than a quick total loss as in Class 4. Houses and commercial/public walkways differ primarily in value per linear foot of walkway . Commercial/public walkways tend to be a few feet wider and use heavier materials, therefore have a higher value per unit length.

Class 6: Paved Roads and Parking Areas

On-grade paving is destroyed by shallow erosion, requiring replacement and/or relocation. In contrast overwash deposits bury the paving without significant damage. Damage values result from the effort required to excavate the surface, returning it to its intended function. Road repair and replacement costs should be available from the NC Department of Transportation. Overwash excavation costs may also be available from the same source for Highway 12 or from local governments. Most near-ocean overwash deposits that are excavated from roads or developed areas are required to be replaced on or near the beach. In our recent hurricanes, the abundance of construction debris excavated with overwash sand has led to major sand sifting projects before being returned to the beach. The cost of handling has been estimated in some communities to have exceed $15/CY of excavated sand. The cost of past efforts should be available from local governments or NC Emergency Management since they are included in FEMA Public Assistance reimbursements.

Class 7: Erosion control structures and responses

Most erosion control structures on the oceanfront are prohibited by NC regulations. However emergency sandbag revetments and several other practices are pre-authorized by general permits and are in common use. Most permanent structures, including buildings, are eligible for an emergency sand bag permit if erosion moves the vegetation line closer than 20 feet from the building. Roads and septic tanks are included. Mobile homes and detached garages would also qualify but most other expendable structures in Class 4, including oceanfront decks, would not be eligible. The emergency sandbag revetments are limited in time (two to five years, depending on building size, longer if beach nourishment is under study) and in size. The size limit is approximately 6 feet high and 20 feet wide. Typical practice uses bags filled to roughly 2 feet high by four feet wide in a sloping revetment three bags high and three wide for a total of 6 rows of bags. A property owner on Topsail Island recently received three bids of approximately $20 per linear foot of row of bags or $120 per linear foot for a typical 6-bag cross section. Cooperating adjacent owners pay for their oceanfront lot width. Isolated owners must pay for extra bags to protect the one or both sides of their structures.

Beach scraping, excavating sand from the berm or foreshore and pushing it to just landward of the vegetation line or erosion scarp is the most common erosion control response in use on the NC coast. Funding and permitting varies by community. Work is contracted by individual property owners, or in some cases by local government or homeowners associations for longer shorelines under their management. Several research projects have concluded that beach scraping within the limits of the state permit conditions has no significant positive or negative impact on the local erosion rate. Although proven to be of little benefit, beach scraping is a common and real cost, directly by the property owner or indirectly through government or homeowner association assessments. The frequency and cost of beach scraping can usually be determined by contacting the local government or building inspector.

USING SBEACH TO PREDICT BUILDING DAMAGE

SBEACH erosion model was developed to predict two-dimensional beach profile changes with varying storm surge, wave and sediment size conditions. It is intended to predict bar movement, overwash and shoreline recovery better than previously available models. It was not developed to predict erosion damage to buildings and has limitations if directly used for that purpose. Most of the model calibration came from large scale wave tank data and field studies following storms with moderate surge elevations. Calibration for design level storms (50 to 100-year events) appears to have been minimal.

Since SBEACH was designed to better model dune overtopping and overwash deposition it should better represent low elevation shorelines where dunes are flattened and overwash is deposited farther landward. The predicted overwash terrace should provide a better profile for predicting depth limited wave heights around buildings on the second row and farther inland. For predicting erosion threats to typical oceanfront buildings it is suspected that the model underestimates erosion depth. It may not be a significant issue on shallow foundations, such as slabs, but becomes a particular problem when predicting the erosion failure threshold for shallow pilings. Reasonable results are likely to be obtained by using a modeled erosion depth threshold that is shallower (2' maybe?) than observed in the field (on the order of 4' for 8' pilings in severe storms.) Several sections of Topsail Island that lost 150+ similar buildings on short pilings in Fran would be useful area to calibrate SBEACH for the erosion failure threshold for low elevation shorelines with overtopped dunes.

During extreme storms, those most likely to cause erosion damage to buildings, high dunes or unconsolidated bluffs are observed to retreat with near vertical erosion scarps. Slopes steeper than 75 degrees appear common. There is sufficient soil moisture in the dune sands to allow the steep slope to remain stable for a period of days to weeks. Eventually the bluff face will dry and avalanche to a slope flatter than the angle of repose for the sand. The severe erosion depth caused by the retreat of the bluff during the storm places extreme conditions on both shallow and deep piling foundations. However, after the storm there is usually sufficient time to stabilize the top of the bluff, avoiding the additional horizontal erosion that would otherwise occur by avalanching.

In contrast, SBEACH adjusts the erosion scarp by continuously avalanching the eroded scarp (SBEACH Report #1 VI, page 171.) When the slope exceeds 28 degrees the model retreats the top of the erosion scarp and redistributes the sand volume to a slope of 10 degrees at each time step. The assumptions appear to be coded into the software and are not variable parameters. The theoretical slope may approach 28 degrees, much flatter than observed following severe storms. However, a few sample runs in dunes higher than the wave runup limit, consistently resulted in slopes of only 8 to 9 degrees, far flatter than the roughly 75 degrees observed in the field. The model profile output gives the appearance of a steep eroded dune face but is misleading due to the horizontal to vertical distortions in the default profile scales. The affect is not unique to SBEACH. Report #1 VII p. 217-9 indicates the Kriebel model predicts even flatter slopes.

There is no obvious method to adjust SBEACH to generate a more realistic erosion scarp or to adjust the observed erosion threshold depths of the different foundation types to fit the model. Selection of an erosion threshold in the model is necessary to determine the

percentage of structure erosion in **Figure 2** before the percentage of damage can be estimated. Calibration tests in SBEACH Report #4 appear to indicate the model underestimates the horizontal dune retreat more often than overestimates. The best vertical erosion depth for the model is likely to be lower than observed for actual damage. For shallow foundation classes an erosion threshold of 0.5' to 1' appears reasonable. For the piling foundation classes, an erosion threshold of 4' is realistic in the field but 2' or less in SBEACH may generate more realistic damage estimates. It may be feasible to calibrate the damage estimates using the high ground elevations of Kure Beach during Hurricane Fran when 15 to 20 building were destroyed. The choice of an erosion threshold depth on the flat eroded dune slope from SBEACH is likely to result in extreme variations in the percentage of damage for each class of structure. It is likely additional calibration will be necessary to select an arbitrary erosion threshold depth for reasonable damage estimates. The selected threshold for piling supported buildings is likely to be considerably different than observed in the field, a necessary correction due to limitations in the model.

SUGGESTED HURRICANE FRAN CALIBRATION AREAS FOR SBEACH

Kure Beach, NC in the vicinity of Avenue E — Figure 3

1226 N. Shore Drive & Jones Avenue, Surf City, NC — Figure 4
Area includes: Severely leaning house on short pilings
Post-1986 house on long piles, undamaged
Multiple pre-1986 houses destroyed.

341 Topsail Road & 11th Avenue, North Topsail Beach, NC — Figure10
Second-row house has been protected by overwash deposit left in place after Hurricane Fran.



Figure 10: Second-row dune left after Hurricane Fran provided protection during Hurricanes Bonnie, Dennis and Floyd. Location North Topsail Beach after Hurricane Floyd.

References

Corps of Engineers, 1975. "Guidelines for Identifying Coastal High Hazard Zones." US Army Corps of Engineers, Galveston District.

Federal Emergency Management Agency, 1997. "Building Performance Assessment: Hurricane Fran in North Carolina." FEMA 290.

Rogers, Spencer, 2001. "Evaluating Potential Hurricane and Erosion Damage to Buildings in Coastal North Carolina," North Carolina Sea Grant, UNC-SG-01-04.

Rogers, Spencer M. Jr., 1990. "Designing for Storm Surge and Wave Damage in Coastal Buildings." Coastal Engineering Conference, Delft, The Netherlands. ASCE. pp. 2908-2921.

Tung, C.C., B. Kasal, Spencer M. Rogers, Jr., and S.C. Yeh, 1999. "Behavior of Breakaway Wall Subjected to Wave Forces: Analytical and Experimental Studies." NC Sea Grant (UNC-SG-99-03).

Woodward-Clyde Federal Services, 1997. "Pile Damage Assessment: Topsail Island, North Carolina." Federal Emergency Management Agency, Region IV, EMW-95-C-4678, Task Order # 111.

APPENDIX A: Erosion-Damage Curves

Contents damage assumed to be the same curve as structural damage

Class 1 Structures: Single-family residential buildings, duplexes and small condos

Structure Class	1a. Slab	1b. Short Pilings		1c. Long Pilings	
Shoreline Type	A & B All ground elevations	A: High Dune ground el >12' piling tip > el +4'	B: Low Elevation ground el <12' piling tip < el +4	A: High Dune ground el >16' piling tip > el 0	B: Low Elevation ground el <16' piling tip < el 0'
Erosion depth threshold	0.5 feet	4 feet		4 feet	
% Erosion	% Damage				
0	0.05	0.05	0.05	0.05	0
0.1	0.2	0.1	0.1	0.1	0.01
0.2	0.4	0.2	0.2	0.2	0.02
0.3	0.6	0.4	0.3	0.4	0.03
0.4	0.8	0.8	0.4	0.8	0.04
0.5	1	1	0.5	1	0.05
0.6	1	1	0.6	1	0.06
0.7	1	1	0.7	1	0.07
0.8	1	1	0.8	1	0.08
0.9	1	1	0.9	1	0.09
1	1	1	1	1	0.1

Class 2 Structures: Commercial buildings, hotels, large condos

Structure Class	2a non-piling foundation	2b piling foundation lowest floor slab	2c full piling foundation
	Same as 1a	f(# floors) * below	Same as Type B-1c
Erosion depth threshold	0.5 feet	0.5 feet	4 feet
% erosion	% Damage		
0	0.05	*	0
0.1	0.2	*	0.01
0.2	0.4	*	0.02
0.3	0.8	*	0.03
0.4	1	*	0.04
0.5	1	*	0.05
0.6	1	*	0.06
0.7	1	*	0.07
0.8	1	*	0.08
0.9	1	*	0.09
1	1	*	0.1

* Class 2b: % damage = [2 x (% erosion) / (# floors)] + (% damage Class 2c)

Class 3 Structures: Underhouse enclosures below piling supported buildings, equipment, utilities, etc.

Non-piling foundation	
	Same as 1a
% erosion	% Damage
0	0.05
0.1	0.2
0.2	0.4
0.3	0.8
0.4	1
0.5	1
0.6	1
0.7	1
0.8	1
0.9	1
1	1

Erosion depth threshold = 0.5 feet

Class 4 Structures: Mobile homes, utility buildings, oceanfront residential decks, detached decks, gazebos, pools, detached garages, buried public utilities

	Shallow foundations
% erosion	% Damage
0	0
0.1	0.5
0.2	1
0.3	1
0.4	1
0.5	1
0.6	1
0.7	1
0.8	1
0.9	1
1	1

Erosion depth threshold = 0.5 feet

Class 5 Structures: Dune walkways

	Shallow foundations
% erosion	% Damage
0	0
0.1	0.1
0.2	0.2
0.3	0.3
0.4	0.4
0.5	0.5
0.6	0.6
0.7	0.7
0.8	0.8
0.9	0.9
1	1

Erosion depth threshold = 2 feet

APPENDIX B: BUILDING DAMAGE ASSESSMENT EXPERIENCE

Spencer McMath Rogers, Jr.

ADDRESS: North Carolina Sea Grant & Coastal Services
5001 Masonboro Loop Road 233 Marsh Hen Drive
Wilmington, NC 28409 Wilmington, NC 28409
910-962-2491 910-799-6654

EDUCATION: M.S. Coastal & Oceanographic Engineering, 1975, University of Florida, Gainesville, FL
B.S. Engineering, 1973, University of Virginia, Charlottesville, Virginia

EMPLOYMENT:

1978 to Present: Job title: Coastal Engineering Specialist, NC Sea Grant. Work through the NC Sea Grant Marine Advisory Service to advise private property owners, builders, designers, and governmental agencies on hurricane-resistant construction methods, shoreline erosion alternatives and marine construction techniques. Faculty: University of North Carolina - Wilmington, Center for Marine Science. Adjunct faculty: North Carolina State University, Department of Civil Engineering in Raleigh NC.

1975-78: Coastal Engineer for the Bureau of Beaches and Shores, Florida Department of Natural Resources, Tallahassee. Conducted evaluations of proposed Atlantic and Gulf front development for variances of the coastal construction setback line. Evaluated erosion control alternatives and impacts.

AFFILIATIONS: National Association of Coastal Engineers
American Society of Civil Engineers
National Society of Professional Engineers
Professional Engineers of North Carolina
Association of State Floodplain Managers

REGISTRATIONS: Registered Geologist, State of North Carolina, # 684

APPOINTMENTS:

North Carolina Coastal Resources Advisory Council, 1992 to present.
Representing marine science and technology. The Council advises the NC Coastal Resources Commission on coastal management regulations in North Carolina.

NC Science Panel on Coastal Hazards, 1997 to present.
NC university coastal engineers and geologists advising the NC Coastal Resources Commission on technical issues related to coastal processes.

PERTINENT PUBLICATIONS: 35 selected from 47

Rogers, Spencer M. Jr. and Chris Jones, 2002. "Selecting Erosion Setbacks For Balanced Multi-hazard Risk." Solutions to Coastal Disasters Conference, San Diego CA, ASCE.

Jones, Chris and Spencer Rogers, 2002. "Establishing Standards for Building Setbacks: Incorporation of Erosion Rate Variability." Solutions to Coastal Disasters Conference, San Diego CA, ASCE.

Rogers, Spencer, 2001. "Evaluating Potential Hurricane and Erosion Damage to Buildings in Coastal North Carolina." North Carolina Sea Grant, UNC-SG-01-04.

Rogers, Spencer M. Jr., 2000. "Beach Nourishment For Hurricane Protection: North Carolina: Project Performance in Hurricanes Dennis and Floyd." National Beach Preservation Conference. August 2000.

Kriebel, David, Larry Buss and Spencer Rogers, 2000. "Impact Loads from Flood-bourne Debris" ASCE report for FEMA. Other research on floating debris is in progress.

Rogers, Spencer M. Jr., 1999. "Design and Construction Guidance for Breakaway Walls Below Elevated Coastal Buildings in accordance with the National Flood Insurance Program." FEMA_Technical Bulletin, FIA-TB 9-99.

Yeh, S. C., Spencer M. Rogers, Jr., C. C. Tung, and B. Kasal, 1999. " Behavior of Breakaway Walls Under Wave Action." Journal of Structural Engineering. ASCE. October 1999. pp. 1162-1169.

Tung, C. C., B. Kasal, S. C.Yeh, and Spencer M. Rogers, Jr., 1999. "Ultimate Capacity of Nailed Connections for Design of Breakaway Walls." Forest Products Journal. Vol. 49. No. 10. October 1999. pp. 76-81.

Tung, C.C., B. Kasal, Spencer M. Rogers, Jr., and S.C. Yeh, 1999. "Behavior of Breakaway Wall Subjected to Wave Forces: Analytical and Experimental Studies." NC Sea Grant (UNC-SG-99-03). February 2.

Work, Paul A., Spencer M. Rogers, Jr., and Robert Osborne, 1999. "Flood Retrofit of Coastal Residential Structures: Outer Banks, North Carolina." Journal of Water Resources Planning and_Management. March/April 1999.

Pratt, Anthony P., Christopher P. Jones, Spencer M. Rogers, Jr., and Darryl J. Hatheway, 1998. "Delaware Coastal Vulnerability and Construction Standards Study." Association of State Floodplain Managers Conference Proceedings.

Rogers, Spencer M., Jr. and Sam Houston, 1997. "Hurricane Surge and Wave Conditions: Research Needs." Waves '97 Conference Proceedings, ASCE.

Jones, Christopher P., Spencer M. Rogers, Jr., and Darryl Hatheway, 1997. "Coastal Vulnerability and Construction Standards Study." Delaware Department of Natural Resources and Environmental Control, Dewberry & Davis. September 17, 1997.

Clark, Walter, and Spencer M. Rogers, Jr., 1996. "Questions and Answers on Purchasing Coastal Real Estate in North Carolina." NC Sea Grant & NC Real Estate Commission. (UNC-SG-96-10).

Rogers, Spencer M., Jr., 1996. "Corrosion Protection for Metal Connectors in Coastal Areas," Technical Bulletin TB 8-96, FEMA.

Rogers, Spencer M., Jr., 1995. "The Effects of Corrosion on Sheet-Metal Connectors in Coastal Buildings: A Summary of Present Knowledge," FEMA.

Rogers, Spencer M., Jr. 1995. "Getting the Most from Oceanfront Setback Lines" Coastal Zone '95, Tampa, FL, ASCE.

Rogers, Spencer, M. 1995. "Preliminary Summary of Conditions and Damages: Hurricane Emily". *Shore & Beach*, Journal of the American Shore and Beach Preservation Association, Berkeley, CA. January 1995.

Rogers, Spencer M. Jr., 1995. "Coastal Hazard Analysis for North Carolina Aquarium/Fort Fisher." NC Sea Grant.

Rogers, Spencer M. Jr., 1994. "Hurricane Andrew & the South Florida Building Code: Relevance to the North Carolina Building Code." NC Sea Grant.

Rogers, Spencer, M. Jr. 1993. "Relocating Erosion-Threatened Buildings: A Study of NC Housemoving". Coastal Zone '93, New Orleans, LA, ASCE.

Rogers, Spencer M. Jr., 1991. "Foundations and Breakaway Walls of Small Coastal Buildings in Hurricane Hugo." Coastal Zone '91, Long Beach, CA, ASCE. Also published in National Hazard Center Quick Response Report, #37.

Rogers, Spencer, M., Jr. 1991. "Flood Insurance Construction Standards: Can They Work on the Coast?". Coastal Zone '91, Long Beach, CA, ASCE, and Natural Hazards Research Center, U. of Colorado, 1990.

Rogers, Spencer M. Jr. 1990. "Designing for Storm Surge and Wave Damage in Coastal Buildings." Coastal Engineering Conference, Delft, The Netherlands, ASCE.

Rogers, Spencer M., Jr., 1990. "Performance of Building Resistance to Water, Waves and Erosion." Proceedings from "Hugo: One Year After." Charleston, SC, ASCE.

Rogers, Spencer M., and Peter R. Sparks, 1991. "Damage to Buildings: Hurricane Hugo". *Shore & Beach*, Journal of the American Shore and Beach Preservation Association, Berkeley, CA. Oct. 1990.

Rogers, Spencer M. Jr., 1990. "The Cost of Oceanfront Erosion in North Carolina: An Analysis of Flood Insurance Claim Payments 1977-1989." NC Sea Grant.

Rogers, Spencer M., Jr., 1986. "Coastal Erosion Issues in Flood Hazard Mapping,". Report to the Coastal Committee, Association of State Floodplain Managers.

Rogers, Spencer M., Jr., Sparks, Peter R. and Sparks, Katharine M., 1985. "A Study of the Effectiveness of Building Legislation in Improving the Wind Resistance of Residential Construction", National Conference on Wind Engineering, Lubbock, TX, Wind Engineering Council.

Rogers, Spencer M., Jr., 1985. "Hurricane Diana: Impact on Coastal Development." Coastal Zone '85, Baltimore, MD, ASCE.

Stutts, Alan T., Chrystos D. Siderelis, and Spencer M. Rogers. 1985. "Effect of Ocean Setback Standards on the Location of Permanent Structures in Coastal North Carolina." Coastal Zone '85, Baltimore, ASCE.

Cox, John W., with Spencer M. Rogers, Jr., 1984. "Performance of Offshore and Coastal Structures During Alicia", Alicia: One Year Later, Galveston, TX, ASCE.

Rogers, Spencer M. Jr., 1982. "Coastal Environment and Site Characteristics." Coastal Residential Construction Workshop. FEMA, Emmitsburg, MD.

Rogers, Spencer M. Jr., 1982. "Coastal Flood Forces", Proceedings from Intergovernmental Seminar on Flood-Loss Reduction Through Improved Building Practices, FEMA, Emmitsburg, MD.

Tayfun, M. Aziz, Spencer M. Rogers, Jr. and Jay Langfelder, 1979. "Delineation of an Ocean Hazard Zone for North Carolina Department of Marine Science and Engineering", NC State University.

POST-STORM BUILDING DAMAGE ASSESSMENTS
(not including northeasters or other storms)

Named Storm	Year	Location	Support
Hurricane Floyd	1999	NC	NC Sea Grant
Hurricane Dennis	1999	NC	NC Sea Grant
Hurricane Bonnie	1997	NC	NC Sea Grant
Hurricane Fran	1996	NC	FEMA Building Performance Assessment Team
Hurricane Bertha	1996	NC	NC Sea Grant
Hurricane Opal	1995	FL	Florida State Emergency Response Team
Hurricane Emily	1993	NC	FEMA Damage Assessment Team
Hurricane Andrew	1992	FL	NC Sea Grant
Hurricane Hugo	1989	SC/NC	Natural Hazards Research Center
Hurricane Gloria	1985	NC	NC Sea Grant
Hurricane Diana	1984	NC	NC Sea Grant
Hurricane Alicia	1983	TX	NC Sea Grant
Hurricane Fredric	1979	AL/MS	NC Sea Grant
Hurricane David	1978	NC	NC Sea Grant
Hurricane Eloise	1975	FL	Florida Bureau of Beach and Coastal Systems

OTHER WORK

Project member for FEMA's 2001 revisions of the Coastal Construction Manual.

Flood Hazard Committee, HAZUS Flood Loss Estimation Model, National Institute of Building Sciences. Committee is guiding development of a flood damage assessment model to estimate economic losses from future floods.

Member, ASCE Standards Committee: Flood Damage Resistant Design and Construction, 1995 to 1999.

Project committee member, "Compatibility of Flood Loss Reduction Standards of the National Flood Insurance Program with the National Model Building Codes and Standards," National Institute of Building Sciences, Washington, D.C., 1992.

Congressional Testimony, on "Issues Relating to Erosion, Erosion Management and Erosion Insurance H.R. 3456, H.R. 4461 and Managing Coastal Erosion by the National Research Council". Before the Committee on Banking, Finance and Urban Affairs, Subcommittee on Policy Research and Insurance. Rehoboth, DE, July 1990.

Technical Consultant, "Property Eligibility Requirements for Wind Storm Coverage" Property Insurance Underwriting Association, State of New York, 1988. NY now requires existing buildings to be retrofitted to minimum storm resistance standards for coverage through the state-sponsored wind insurance pool for high risk coastal buildings.

Technical Editor, America's Vanishing Coastlines: A New Concern For The Voluntary And Residual Property Insurance Markets, National Committee on Property Insurance, 1988.

Co-author, "Coastal and Flood Plain Construction Standards," NC State Building Code, NC Dept. of Insurance, 1986.

FEASIBILITY REPORT
AND
ENVIRONMENTAL IMPACT STATEMENT

COASTAL STORM DAMAGE REDUCTION PROJECT
SURF CITY AND NORTH TOPSAIL BEACH
NORTH CAROLINA

Appendix C
Geotechnical Analysis

Note: The Appendix contains 3 attachments. These attachments are included in the electronic version of the document, but due to size are not being included in the printed version.

Appendix C: Geotechnical Analyses

Table of Contents

1. Regional Geology C-1
    A. Physiography and Geomorphology C-1
    B. Stratigraphy C-1
    C. Coastal Processes C-1

2. Site Geology C-2
    A. Topsail Island C-2
    B. Onslow Bay C-2

3. Subsurface Investigation C-3
    A. Historical Data C-3
    B. Geophysical Investigation C-4
        1. General C-4
        2. Sand Borrow Search Area C-4
        3. Geophysical Methods C-4
        4. Positioning System C-4
        5. Depth Sounder C-5
        6. CHIRP Sonar System C-5
        7. Seismic Reflection Profiling System C-5
        8. Summary of Geophysical Results C-5
            a. Stratigraphy C-5
            b. Vibracore Targets C-6
            c. Borrow Areas C-6
    C. Vibracore Investigation C-6
        1. Field Investigation C-6
        2. Laboratory Analysis C-7

4. Compatibility Analysis C-7

5. Archeological Resources Survey C-7

6. Hard Bottom Confirmation and Characterization Study C-8

7. Sand Borrow Areas C-8

Appendix C: Geotechnical Analyses

Table of Contents (cont.)

8. Conclusion C-10

9. References C-10

List of Tables

Table C-1 Surf City/North Topsail Beach Borrow Area Characteristics C-14

Attachments

Attachment 1 – Final Report Marine Geophysical Investigation for the Evaluation of Sand Resource Areas Offshore Topsail Island North Carolina, prepared by Greenhorne & O'Mara with Ocean Surveys, Inc.

Attachment 2 - Boring logs

Attachment 3 - Lab Data

Appendix C: Geotechnical Analyses

1. Regional Geology

A. Physiography and Geomorphology. The study area encompasses Topsail Island and nearshore Onslow Bay. Topsail Island is a 40 km long barrier island, which lies within the Atlantic Coastal Plain Physiographic Province. It is bounded by New River Inlet to the northeast, New Topsail Inlet to the southwest, Onslow Bay to the southeast, and the Atlantic Intracoastal Waterway (AIWW) to the northwest. Onslow Bay is a modern embayment of the Atlantic Ocean. It is bounded by Cape Lookout to the north and Cape Fear to the south. Present on Topsail Island are beaches, dunes, and marshes, landforms typical of barrier island complexes. On the nearshore floor of Onslow Bay are submarine scarps, shoals, and bars.

B. Stratigraphy. The Atlantic Coastal Plain and the inner continental shelf of Onslow Bay are both underlain by relatively flat-lying sedimentary units which gently dip and thicken to the southeast. This large sedimentary wedge includes both sediments which have not been indurated or cemented and rock units. The oldest (lowest units) were deposited during the Cretaceous Period, from 144 to 65 million years ago. The youngest part of the wedge dates to the Quaternary Period, from 1.8 million years ago to 10,000 years ago. This sediment and sedimentary rock wedge overlies pre-Mesozoic (older than 248 million years ago) crystalline basement rock (Horton and Zullo, 1991). A patchy veneer of Holocene (10,000 years ago to present) sand and gravel overlies the Quaternary strata in the project area.

C. Coastal Processes. Dynamic coastal processes continually shape the barrier islands of southeastern North Carolina. Rivers and streams entering Onslow Bay are generally small with low gradients. Their continentally derived sediment loads are therefore not very large. In addition, much of this fluvial sediment becomes trapped within the river estuaries. This lack of significant sediment discharge into Onslow Bay limits the build-up of nearshore continental shelf sand deposits. In other areas along the Atlantic coast these nearshore deposits are an important source of sand. When deprived of this source of sand as at Topsail Island, seasonal storms and longshore currents can cause episodic severe shoreface erosion and migration (Cleary, 1968; Sarle, 1977; Riggs and others, 1996; Cleary 2002).

2. Site Geology

A. Topsail Island. Several Oligocene formations outcrop on the nearshore floor of Onslow Bay. These strata extend westward under Topsail Island, vertically removed from the island surface. The stratigraphy and lithology of these strata are described below in paragraph "Onslow Bay." The geologic materials of concern to the project on Topsail Island are the surficial sand soils.

Sand soils encountered on the Topsail Island beaches are classified as fine- to medium-grained poorly-graded sands according to the Unified Soils Classification System. These sands are the result of a complex combination of factors. Part of the sand is accumulated from storm overwash and longshore drift. Another part results from the biological, chemical, and physical erosion of nearshore sedimentary rocks. Winnowing by wind and wave action results in the predominantly fine- to medium-grained poorly-graded sands on the beach today.

B. Onslow Bay. The continental shelf in Onslow Bay is composed of a complex sequence of seaward dipping Tertiary age (65 million to 1.8 million years ago) strata, which was deposited during an age of periodic sea-level fluctuations (Hine and Riggs, 1986; Snyder and others, 1985, 1986; Snyder and others, 1991).

The oldest rocks outcropping within the study area are Oligocene age (33.7 million to 23.8 million years ago) limestones submerged offshore of Topsail Island (Attachment 1, Figure 2). Riggs and others (1985) describe these limestones as the Belgrade and Trent formations, which consist of "moldic biomicrudite (Folk, 1974) limestones with interbedded calcarenite sands and grayish-green calcareous quartz sands." A stratigraphically similar unit named the River Bend Formation, which consists of olive green quartz sand and silt, is reported to also underlie areas offshore of Topsail Island (OSI, 2004). Northeast and east of the survey area lies a major unconformity separating the Oligocene rock and sediments from the younger Miocene (23.8 million to 5.3 million years ago) Pungo River Formation.

Quaternary paleofluvial channels, which generally trend normal to shore, crosscut the older strata offshore of Topsail Island. These channels were

down cut during a period of lower sea level elevation. The paleofluvial channels are remnant streambeds, which were infilled with sediments during Pliocene to Pleistocene times (1.8 million years ago to 10,000 years ago) (Hoffman, C. W. and others, 1994), and were drowned during the Holocene sea-level rise (Belknap, 1982; Hine and Snyder, 1985, Snyder and Snyder, 1992).

Surficial Holocene sedimentary deposits are scarce offshore of Topsail Island in Onslow Bay. Much of the native beach sand is derived from the physical and biological erosion of Oligocene rock and strata submerged in Onslow Bay. These sediments are then reworked, redistributed and deposited within submarine valleys and ridges, or along the shoreface of Topsail Island (Cleary, 1968; HDR, 2002; HDR, 2003; Meisburger, 1979; McQuarrie, 1998; Riggs and others, 1996; Snyder and Snyder, 1992).

3. Subsurface Investigation

A. Historical Data

Information in the offshore areas of Topsail has not been studied or documented in the past. HDR Engineering Inc. of the Carolinas (HDR) was hired in fall of 2002 to gather information about the area and to make recommendations of where the most promising areas are for borrow material for the Topsail Beach Coastal Storm Damage Reduction Project. HDR hired Dr. William Cleary of the University of North Carolina at Wilmington as a consultant to assist in the assessment. The area offshore of Topsail Island is one of the areas of interest for Dr. Cleary. The study included mapping (side scan sonar) and classifying the seafloor composition by collecting physical samples of the bottom. This information was used to locate areas with the most promise for use as borrow for beachfill. HDR along with Dr. Cleary submitted a report in March of 2003 outlining the recommended areas offshore of Topsail Beach for use as potential borrow sites. This report was titled "Assessment of the Availability of Beachfill Quality Sand Offshore Topsail Island, Topsail Beach, Pender County, North Carolina". The recommended offshore areas were the focus of the subsequent geophysical investigation.

B. Geophysical Investigation (Attachment 1)

1. General. A search for suitable beach fill materials for this project was begun offshore in Onslow Bay. A marine geophysical investigation was conducted by Ocean Surveys March 27 to April 17, 2004 in order to locate and evaluate potential sand resource areas. Approximately 315 miles of bathymetric and subbottom data were collected along 60 tracklines. Twenty-two (22) tracklines were shore-parallel and twenty-eight (28) tracklines were run perpendicular to shore along with 10 diagonal tie lines to insure thorough coverage.

2. Sand Borrow Search Area. Geophysical data was collected in the area between 0.5 nautical miles (30 foot isobath) to 5.0 nautical miles offshore of Topsail Island. The site stretches nearly 23 nautical miles from Rich Inlet to northeast of New River Inlet. Survey limits were established to further resolve sand resource areas identified by earlier surveys.

3. Geophysical Methods. Two types of sub-bottom methods were used: a "CHIRP Sonar" seismic reflection profiler, which generates a high frequency, short duration acoustic pulse providing high resolution of shallow sub-bottom strata; and a "Boomer" seismic reflection profiler which uses a low frequency pulse to achieve deeper penetration of the sub-bottom strata. These were run simultaneously to achieve the best possible resolution and penetration. Augmenting the seismic equipment was survey equipment that allowed real-time depth sounding, positioning, and motion (heave) corrections.

4. Positioning System. A differential global positioning system was used to determine position along the seismic lines. Equipment included a Trimble 4000 Global positioning System (GPS) and a Leica MX52R U.S. Coast Guard (USCG) Differential Beacon Receiver interfaced with HYPACK software. Navigation fixes were recorded on an onboard PC every second with an accuracy of better than 3 feet.

5. Depth Sounder. Bathymetric data was collected at a near continuous rate using an Innerspace Model 448 Digital Depth sounder, which operated at a frequency of 200 kHz. Tidal data from the NOAA station in Beaufort, North Carolina were used for tidal corrections.

6. CHIRP Sonar System. The Contractor accomplished the high-resolution subbottom profiling utilizing an EdgeTech Xstar Full Spectrum "CHIRP" Subbottom Profiler system operating with frequencies of 0.5-12 kHz. The system has three components: a deck unit that is comprised of a PC system and amplifier, an underwater cable, and a Model 512 towed vehicle that houses the transducers. The tow fish vehicle emits a high frequency FM pulse over the full spectrum range of 0.5-12 kHz for a 20 millisecond period, and the acoustic return is received by a hydrophone array, which allows high resolution of the shallow subsurface. The higher frequency yields higher resolution with a tradeoff in lesser depth penetration.

7. Seismic Reflection Profiling System. Deeper sub-bottom penetration was accomplished using an Applied Acoustics 100-300 joule "boomer" system comprised of a boomer plate, power supply, hydrophone array, TSS-model 360 filter and time-varied-gain system, and an EPC 1086 thermal paper recorder. The "boomer" employs a sound source that utilizes electrical energy discharged from a capacitor bank to rapidly move a metal plate in the transducer bed. The short duration motion of the metal plate creates a broad-band (500-8000 Hz) pressure wave capable of penetrating hundreds of feet of marine sediments under favorable site conditions.

8. Summary of Geophysical Results

a. Stratigraphy. The geophysical and bathymetric surveys showed that shallow rock scarps and outcrops dominate and control the submarine topography offshore of Topsail Island. A surficial sand horizon was resolved. However, it is very discontinuous and broken by Oligocene rock outcrops. Erosion and reworking of this rock contributes coarse and fine-grained materials to the surficial sand. This decreases its aesthetic value as beach fill. The thickest sequence of unconsolidated sediment occurs in or adjacent to the paleochannels. These sediments tend to be dominated by estuarine muds and fine

sands and thus unsuitable as beach fill. Borrow areas must generally be configured to avoid these channels.

b. Vibracore Targets. The subsurface investigation was performed between May and November 2003. The boring locations were based on the seismic data available from the geophysical investigation conducted by OSI.

c. Borrow Areas. The results of the 2004 geophysical survey in combination with vibracore data were used to identify potential borrow areas within the study area.

B. Vibracore Investigation

1. Field Investigation. The subsurface investigation was performed between May and November 2003. The criteria for the boring locations was between 1 and 6.5 miles from the beach, water depth greater than 30 feet Mean Lower Low Water (MLLW), and change in seismic profile, which could represent differing soil types. A total of 369 borings were performed in the Topsail Island area. Boring locations are shown in Appendix A, Figure A-6. The boring logs are included in Attachment 2. Borings were performed offshore of Topsail Island, in the Banks Channel behind Topsail Beach, in the connecting channel between the Atlantic Intracoastal Water Way (AIWW) and New Topsail Inlet, in New Topsail Inlet, and New River Inlet.

Borings were performed from the USACE Snagboat *SNELL* using a 3 7/8 inch diameter, 20-foot long, Alpine vibracore drill machine. The sampler consists of a metal barrel in which a plastic cylinder or tube is inserted. After the plastic tube was inserted, a metal shoe was screwed onto the plastic tube and then the metal barrel. The shoe provided a cutting edge for the sampler and retained the plastic tube. An air-powered vibrator was mounted at the upper-most end of the vibracore barrel, and the vibrator and the vibracore barrel was mounted to a stand. This stand was lowered to the ocean floor by the Snell's crane, the vibrator was activated and vibrated the vibracore barrel into the ocean sediment. The sediment sample is retained in the plastic tube. All borings were drilled to a depth of 20 feet below the ocean floor, unless vibracore refusal was encountered.

Vibracore refusal was defined as a penetration rate of less than 0.1 feet in 10 seconds.

2. Laboratory Analysis. The recovered vibracore tubes were visually classified by Wilmington District personnel in accordance with the Unified Soils Classification System (USCS). Samples were taken at a minimum of every two feet or at each change of material. A total of 1327 samples were collected in the Topsail Island area. Grain size tests were performed in accordance with ASTM D-422 using a fourteen-sieve test and visual classifications were performed in accordance with ASTM D-2488, by Wolf Technologies, Inc. The sieves used in these tests were the 3/4, 3/8, Number 4, Number 7, Number 10, Number 14, Number 18, Number 25, Number 35, Number 45, Number 60, Number 80, Number 120, and Number 230. Grain size test results are located in Attachment 3.

4. Compatibility Analysis

The compatibility analysis compares the grain size of the "native beach" or the "reference beach" with the material in the proposed borrow material. The procedure for calculating the overfill ratio for borrow areas in relation to the reference beach was performed in accordance with the U.S. Army Corps of Engineers Coastal and Hydraulics Laboratory Automated Coastal Engineering System (ACES) software version 4.01. This procedure is discussed in section V-4-1.e(3)(i) of the U.S. Army Corps of Engineers Engineer Manual (EM) 1110-2-1100, part V, dated 1 August 2008, titled Coastal Engineering Manual. As stated in this manual, the overfill ratio is the primary indicator of the compatibility of the borrow material to the beach material, with a value of 1.00 to 1.05 considered optimum for sediment compatibility. Obtaining this level of compatibility is not always possible due to limitations in available borrow sites and an overfill ratio of 1.5 is generally considered acceptable. See Appendix E for more information regarding the compatibility analysis.

5. Archeological Resources Survey

Mid-Atlantic Technology and Environmental Research, Inc. (MATER) conducted magnetometer and side-scan sonar (acoustic) surveys to identify archeological resources that may be present in the preliminary borrow areas from the fall 2004 to spring 2005. The side-scan sonar survey was used to further delineate hard bottom identified in the borrow areas in the geophysical investigation. Line

spacing for this survey was approximately 65 feet and the survey covered an area of approximately 14.1 square nautical miles. Hard bottom consisting of high, moderate, and low relief based on the elevation changes were identified in several of the preliminary borrow areas. As a result, three preliminary borrow areas (I, K, and M) were eliminated from further consideration as borrow sources.

6. Hard Bottom Resource Confirmation and Characterization Study

Anamar Environmental Consulting, Inc. conducted in-situ diver groundtruthing of several borrow areas in the spring 2008. Twelve transects were conducted to confirm and characterize hard bottom at five borrow areas (G, J, L, O, and T). Transects were planned for locations where hard bottom was identified by MATER in the archeological resources survey. Hard bottom of low and moderate relief were identified for all of the transects with the exception of one transect in borrow area J (J1), where no hard bottom was identified. Concurrently, applicability of the North Carolina hard bottom buffer rule (NCAC 07H. 0208(b)(12)(A(iv)), which identifies a 500 meter buffer for dredging operations around high relief hard bottom had been discussed for the coastal storm damage reduction projects potentially impacting hard bottom. In August 2008, State and Federal resource agencies concurred with a USACE, Wilmington District proposal to establish a hard bottom buffer consisting of 500 meters (1,640 feet) for high and moderate relief hard bottom and 122 meters (400 feet) for low relief bottom.

7. Sand Borrow Areas

After completion of the archeological resources survey, eleven offshore borrow areas were identified for the Surf City/North Topsail Beach project and are labeled as G, H, J, L, N, O, P, Q, R, S, and T (See Appendix A, Figure A-6). The material classification ranged from clean sand (SP), slightly silty sand (SP-SM), with minor amounts of silty sand (SM), silt (MH and ML), and clay (CH) (See attachment 2). The boundaries of the borrow areas have been limited to preclude material with classification of silty sand, silt, and clay by adjusting the depth of the borrow area at vibracore locations.

The State of North Carolina implemented new rules in 2007 governing sediment compatibility for beach nourishment. The rules are titled "Technical Standards for Beach Fill Projects" and are found in 15A North Carolina Administrative

Code (NCAC) 07H.0312. The standards require compatibility of the native beach with borrow sources in regards to the percentage of silt, granular sediment, gravel, and calcium carbonate (or shell content for existing projects). Borrow Area R was subsequently eliminated due to elevated silt concentration. Based on the results of the compatibility analysis, the total estimated volume in the remaining ten borrow areas is approximately 27.59 million cubic yards (yd^3). This amount of material is insufficient to meet the required volume for the NED plan of 32.3 million yd^3.

Therefore, borrow areas identified for the Topsail Beach Federal coastal storm damage reduction project were considered. By evaluating the borrow areas for all Topsail Island coastal storm damage reduction projects, sufficient material is available for the two Federal and two non-Federal projects. The six borrow areas identified for the Topsail Beach Federal coastal storm damage reduction project (A, B, C, D, E, and F) have been included with the aforementioned ten borrow areas for the Surf City/North Topsail Beach project. By evaluating all Topsail Island offshore borrow areas together, the sixteen borrow areas contain approximately 50.4 million yd^3 of borrow material. The two Federal and two non-Federal coastal storm damage reduction projects currently planning to use material from these borrow areas have volume requirements of approximately 46.3 million yd^3 or about 92% of the available borrow material in all of the borrow areas evaluated for the Federal projects.

All of the remaining borrow areas comply with the beach fill standards with the exception of borrow areas A F, L, S and P. Borrow areas A and L exceed the silt standard by 0.4 and 0.1% respectively. Borrow areas F and S exceed the granular sediment standard by 0.9 and 0.5% respectively. Borrow area F and P exceed the gravel standard by 3 and 1.1% respectively. See Appendix E for more information on the compatibility analysis of the borrow sources.

The borrow areas in which the standards were exceeded for the various characteristic (A, F, L, S, and P) have been retained as all borrow areas will be further characterized during the plans and specification phase of this project. Additional borings will be performed to comply with the NC beach fill standard of 1 core/acre or 1,000 feet spacing. The characteristics of the remaining ten borrow areas is shown in Table C-1. As shown in this table, the borrow areas are typically between 1 and 6 miles offshore and have pre-dredge bottom depths of 50 feet or less.

8. Conclusion

An extensive investigation was conducted for borrow sources for the Surf City/North Topsail Beach Federal coastal storm damage reduction project which included seismic and sonar studies, subsurface investigation using numerous vibracores, an archeological resources survey, and a hard bottom confirmation and characterization study. The number and configuration of borrow areas for the project has been continuously modified throughout the process to incorporate the additional data.

The borrow areas were re-evaluated after the North Carolina beach fill standards were implemented in 2007. At that time ten borrow areas were identified for the project. However, the volume of material in these borrow areas is insufficient to meet the project requirements. Therefore, borrow areas identified for the Topsail Beach Federal coastal storm damage reduction project were considered. By evaluating the borrow areas for all Topsail Island coastal storm damage reduction projects, sufficient material is available for the two Federal and one non-Federal projects.

Currently sixteen borrow areas have been identified for the Surf City/North Topsail Beach Federal coastal storm damage reduction project. Five of these borrow areas (A, F, L, P, and S) exceed the NC beach fill standards slightly for various characteristics. Because all borrow areas will be evaluated further during the plans and specifications phase of this project, these borrow areas have been retained. Additional vibracores will be performed in all borrow areas to comply with the NC beach fill standards of 1 core/acre or 1,000 feet spacing. For a complete description of the borrow area materials and the sand compatibility see Appendix E, Sand Compatibility Analysis.

9. References

Snyder, Stephan.W., Snyder, Scott., Riggs, S.R., Hine, A.C., 1991, Sequence Stratigraphy of Miocene Deposits, North Carolina Continental Margin; *The Geology of the Carolinas*, Carolina Geological Society, Fiftieth Anniversary Volume, p. 263-273.

Hine, A.C., and Riggs, S.R., 1986, Geologic Framework, Cenozoic History, and Modern Processes of Sedimentation on the North Carolina Continental Margin, in Textoris, D.A., ed., SEPM Field Guidebooks, Third Annual Midyear Meeting,

Southeastern United States: Society of Economic Paleontologists and Mineralogists, Field Trip No.5, p.129-194.

Snyder, Stephen W., Snyder, Scott, W., Waters, V.J., Steinmetz, J.C., Hine, A.C., and Riggs, S.R., 1985, More evidence for glacial world prior to the Middle Miocene Oxygen Isotope Enrichment Event: Resolution of Early Miocene Glacioeustatic Sea-level Cyclicity from North Carolina: Geological Society of America Abstracts with Programs, v.17, p. 721.

Snyder, Stephen W., Hine, A.C., and Riggs, S.R., and Snyder, Scott W., 1986, Miocene Unconformities, Chronostratigraphy, and Sea-level Cyclicity: Fine-tuning the Early Neogene Relative Coastal Onlap Curve for the North Carolina Continental Margin [abstract]: American Association of Petroleum Geologists Bulletin, v. 70, p. 651.

Harris, B.W., and Zullo, V.A., 1979, Structural and Stratigraphic Framework for the Coastal Plain of North Carolina, Field Trip Guidebook, Carolina Geological Society and Atlantic Coastal Plain Geological Association, 111 p.

Riggs, S.R., Snyder, Stephen, W., Hine, A.C., Snyder, Scott, W., Ellington, M.D., and Mallette, P.M., 1985, Geologic Framework of the Phosphate Resources in Onslow Bay, North Carolina Continental Shelf: Economic Geology, v. 80, p. 716-738.

Snyder, Scott, W., and Snyder, Stephen, W., 1992, Translating Biostratigraphic and High Resolution Seismic Data into a Sequence Stratigraphic Framework-Insights Gained from the Study of the NC Neogene, Third Bald Head Island Conference, Nov. 4-8, Hilton Head Beach and Tennis Resort, Hilton Head Is., SC, 67 p.

Folk, R.L., 1974, Petrology of Sedimentary Rocks, 190p.

Snyder, Stephen, W., Mallette, P.M., Snyder, Scott, W., Hine, A.C., and Riggs, S.R., 1988, Overview of Seismic Stratigraphy and Lithofacies Relationships in Pungo River Formation Sediments of Onslow Bay, North Carolina Continental Shelf. Cushman Foundation Special Publication No. 25, p. 1-14.

Belknap, D.F., 1982, Amino Acid Racemization from C14 Dated "Mid-Wisconsin" Mollusks of the Atlantic Coastal Plain, Geological Society of America Abstracts with Programs, v. 14, 4p.

Hine, A.C., and Snyder, S.W., 1985, Coastal Lithosome Preservation: Evidence from the Shoreface and Inner Continental Shelf off Bogue Banks, North Carolina: Marine Geology, v. 63, p. 307-330.

Sarle, L. L., 1977, Processes and Resulting Morphology of Sand Deposits within Beaufort Inlet, Carteret County, North Carolina, Duke University, MS, 150 p;

Riggs, S.R., Snyder, S.W., and others, 1996, Hardbottom Morphology and Relationship to the Geologic Framework: Mid-Atlantic Continental shelf, Journal of Sedimentology Research, vol. 66, no. 4, p 830-846.

HDR Engineering, Inc., 2002, An Assessment of the Availability of Beachfill Quality Sand Offshore Topsail Beach, Pender County, NC, Project Report for the U.S. Army Corps of Engineers, Wilmington District, 28p.

HDR Engineering, Inc., 2003, An Assessment of the Availability of Beachfill Quality Sand Offshore North Topsail Beach and Surf City, North Carolina, Project Report for the U.S. Army Corps of Engineers, Wilmington District, 41p.

Meisburger, E.P., 1979 Reconnaissance Geology of the Inner Continental Shelf, Cape Fear Region, North Carolina, U.S. Army Corps of Engineers, Coastal Engineering and Research Center, Technical Report TP79-3, 135p.

McQuarrie, M.E., 1998, Geologic Framework and Short-term, Storm Induced Changes in Shoreface Morphology: Topsail Beach, NC, unpublished M.S. Thesis, Department of the Environment, Duke University, Durham, 105p.

Ocean Surveys, Inc., 2004, Marine Geophysical Investigation for the Evaluation of Sand Resource Areas Offshore Topsail Island, North Carolina: Final Report prepared for the U.S. Army Corps of Engineers Wilmington District, 44p.

Mid-Atlantic Technology and Environmental Research (MATER), 2005, An Archaeological Remote Sensing Survey of Surf City – North Topsail Beaches Offshore Borrow Areas.

Boss, S.K., and Hoffman, C.W., 2000, Sand Resources of the North Carolina Outer Banks: Final Report, prepared for the Outer Banks Task Force and the North Carolina Department of Transportation, 87p.

Cleary, W.J., 1968, Marine Geology of Onslow Bay, Dept. Geology, Duke University, M.S. Thesis, 73p.

Table C-1
Borrow Area Characteristics

Borrow Area	Mean Grain Size	Estimated Volume (Million yd^3)	Distance offshore (miles)	Pre-Dredge Surface/Bottom Elevation (ft. MLLW)
A	2.36 phi (0.20 mm)	*	1 to 3	-38.5 to –49.0
B	2.17 phi (0.22 mm)	*	1.5 to 2.5	-42.2 to –43.2
C	2.32 phi (0.20 mm)	*	4 to 5.5	-45.5 to -47.7
D	2.13 phi (0.23 mm)	*	3.5 to 4.5	-43.5 to –46.9
E	2.15 phi (0.23 mm)	*	4.5 to 5.5	-49 to –50
F	1.09 phi (0.47 mm)	*	4.5 to 5.5	-47.2 to -48
G	2.05 phi (0.24 mm)	2.41	4 to 5.5	-46.5 to -49
H	2.21 phi (0.22 mm)	0.72	3.5 to 4.5	-44.4 to -45.2
J	2.12 phi (0.23 mm)	3.67	3 to 4.5	-42 to -47.4
L	2.05 phi (0.24 mm)	6.13	3 to 5.5	-42.3 to -47
N	1.86 phi (0.28 mm)	5.64	4 to 6	-43.6 to -46.7
O	2.12 phi (0.23 mm)	3.85	1.5 to 4	-40.6 to -43.9
P	2.01 phi (0.25 mm)	2.73	2 to 3.5	-39.5 to -40.5
Q	2.30 phi (0.20 mm)	0.73	1 to 1.5	-35.2 to -35.4
S	1.62 phi (0.32 mm)	1.46	3.5 to 4.5	-43.8 to -44.8
T	1.78 phi (0.29 mm)	0.25	2 to 4	-37.2 to -42

* - These borrow area are planned to be used for the Topsail Beach Federal and non-Federal projects. The excess material not used for these projects is expected to be available for the Surf City/North Topsail Beach project. This amount is approximately 9.29 million cubic yards.
yd^3 - cubic yards
mm - millimeter
MLLW – Mean Low Low Water

Feasibility Report
and
Environmental Impact Statement

Coastal Storm Damage Reduction

SURF CITY AND NORTH TOPSAIL BEACH, NORTH CAROLINA

Appendix D

Coastal Engineering

Appendix D: Coastal Engineering

Table of Contents

1. Plans Investigated D-1
   a. Dune-and-Berm Plans D-1
      1) Description D-1
      2) Dune-and-Berms Evaluated D-1
   b. Berm-Only Plans D-1
      1) Description D-1
      2) Berms Evaluated D-1
   c. Construction Line D-3

2. Description of Recommended Plan D-3
   a. Plan Description D-3
   b. Project Data D-6

3. Alternative Evaluation Process D-6
   a. Study Limits D-6
   b. Alternatives Addressed D-6
      1) Berm-Only Plans D-7
      2) Dune-and-Berm Plans D-7
      3) Refinement of Study Limits D-7
      4) Refinement of Alternatives D-7
      5) Nonstructural Alternative D-8

4. Shoreline Analysis D-9
   a. Closure Depth D-9
   b. Wave Climate D-9
   c. Local Bathymetry D-11
   d. Shoreline Adjustments D-12
   e. Long-Term Shoreline Change Rates D-13
      1) Computed Shoreline Change Rates D-13
      2) Comparison with Other Data D-14
      3) Sea Level Rise Impacts D-15

5. Shoreline Modeling D-15
   a. Sediment Budget D-15
   b. Regional Sediment Management Draft Results D-16
   c. Beachfill Evolution and Transition Modeling D-17
   d. Sensitivity of Erosion Rates in GRANDUC Simulations D-20

6. Storm Damage Analysis D-21
a. General D-21
b. SBEACH Analysis D-21
1) Beach Profiles D-22
2) Storm Surge D-23
3) Storm Waves D-24
c. Storm Response Parameters D-25
d. EST Analysis D-26
1) Frequency Curves D-26
2) Modifications to EST Frequency Curves D-27
e. Storm History Simulations D-27

7. Selection of the Periodic Renourishment Interval D-28
a. Optimum Periodic Renourishment Interval D-28
b. Periodic Renourishment Interval Considerations D-29
1) Dredging Window D-29
2) Scarping D-29
c. Recommended Renourishment Interval D-30

8. Borrow Sand Requirements D-30

9. Risk and Uncertainty D-31
a. Background D-31
b. Guidance D-31
c. Analysis Requirements D-32
d. Uncertainty D-32
e. Risk Results for Alternatives Evaluated D-32

Addendum D:1 - GRANDUC Documentation D-34
Addendum D:2 – Sea Level Rise Sensitivity Analysis D-50
Addendum D:3 – Dredging Research Program Storm Surge Database D-57
Addendum D:4 – Overview of EST Process D-61
Addendum D:5 – Beach Profiles D-65

List of Tables

Table D-1 Summary of Federal Coastal Storm Damage Reduction Projects in North Carolina D - 7
Table D-2 Summary of Erosion Rate Sensitivity D-20
Table D-3 SBEACH Input Parameters D-22
Table D-4 Summary of Total Costs & Net Benefits for Various Renourishment Intervals D-29
Table D-5 Borrow Sand Requirements D-31
Table D-6 Percent Chance of Having Positive Net Benefits D-33

List of Figures

Figure D-1	Typical "Dune-and-Berm" Template	D-2
Figure D-2	Typical "Berm-Only" Template	D-2
Figure D-3	Typical NED Plan Beachfill Profile	D-3
Figure D-4	Schematic of Transition Scenarios	D-5
Figure D-5	Location of WIS Station 292	D-9
Figure D-6	All WIS Data 1990-1999	D-10
Figure D-7	Seasonal Variation of Wave Direction/Height	D-11
Figure D-8	Nearshore Bathymetry Contours	D-12
Figure D-9	1963-2002 Shoreline Change Rates	D-13
Figure D-10	Shoreline Change Rate Comparison to NCDCM Rates	D-15
Figure D-11	Sediment Budget Cell Definition from 1989 report	D-16
Figure D-12	Sediment Budget From 1989 Report	D-16
Figure D-13	Preliminary Regional Sediment Transport Results	D-17
Figure D-14	Input Parameters for Planform Evolution Model	D-18
Figure D-15	Graphical Output from Planform Evolution Model	D-19
Figure D-16	Erosion Rates Used in GRANDUC Simulations	D-19
Figure D-17	With/Without Project Damages & Benefits with Reduced Erosion Rates	D-20
Figure D-18	Example SBEACH Input Profile	D-23
Figure D-19	Example SBEACH Storm Input Parameters	D-24
Figure D-20	Typical SBEACH Output Parameter Plot	D-26
Figure D-21	Example of Escarped Dune	D-28
Figure D-22	Escarpment Length vs. Renourishment Interval	D-30

Appendix D: Coastal Engineering

1. Plans Investigated

Two general alternative beachfill plans were evaluated for this study: 1) a dune-and-berm plan and 2) a berm-only plan. Numerous templates for each of these plans were evaluated and are described below.

a. Dune-and-Berm Plans

1) **Description.** Existing dunes were assumed to remain in place, with the design dunes tying into them where appropriate. The design dune templates were tied to a construction line, which is based on both the existing shoreline and the existing development. The landward slope of the dune template is 5 horizontal to 1 vertical; the top of the dune is 25 feet wide; and the seaward slope is 10 horizontal to 1 vertical. The berm elevation is 7 feet-NGVD, with berm width measured from the toe of the constructed dune. The seaward slope of the berm is 15 horizontal to 1 vertical extending down to MLW elevation (-1.9 feet-NGVD), below which the with-project profile parallels the existing profile out to a closure depth of -23 feet-NGVD. Fill material is expected to be fully compatible with existing beach material.

2) **Dune-and-Berms Evaluated.** Initially dune-and-berm templates with dune elevations of 11, 13, and 15 feet-NGVD were evaluated, each with 25-, 50-, and 75-foot berm widths at elevation 7 feet-NGVD. In order to envelop the NED plan, additional plans with dune elevations up to 17 feet-NGVD were evaluated. A typical dune-and-berm profile is shown in Figure D-1.

b. Berm-Only Plans

1) **Description.** The berm-only template is a fill extending seaward from the existing profile with an elevation of 7 feet-NGVD, which is approximately the elevation of the existing natural berm. Berm width is measured seaward along the top of the berm from the point where it intersects the natural profile. The seaward slope of the design berm is 15 horizontal to 1 vertical extending down to MLW elevation (-1.9 feet-NGVD), below which the with-project profile parallels the existing profile out to a closure depth of -23 feet-NGVD. Fill material is expected to be fully compatible with existing beach material.

2) **Berms Evaluated.** At the feasibility level, 50-, 100-, and 150-foot berm-only plans were evaluated. Each used a berm elevation of 7 feet-NGVD. A typical berm-only profile is shown in Figure D-2.

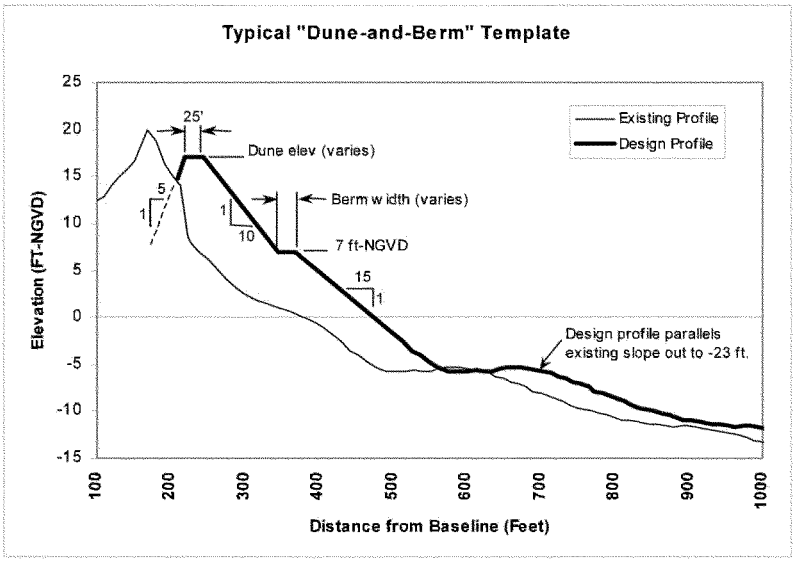


Figure D-1. Typical "Dune-and-Berm" Template

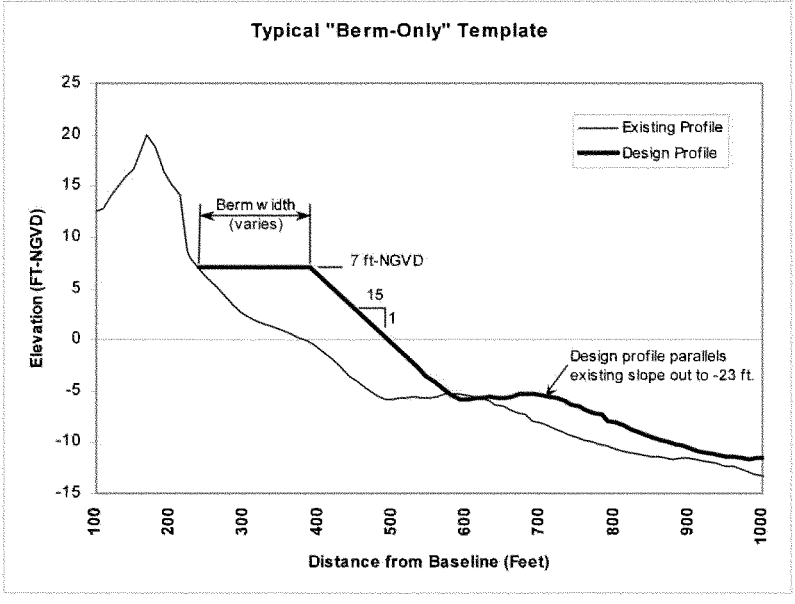


Figure D-2. Typical "Berm-Only" Template

c. Construction Line

The construction line was established to: a) minimize impacts on existing development and b) minimize erosion of the project by aligning the seaward edge of the berm parallel to the existing shoreline to the maximum extent practical. Additionally, the construction line needed to account for the easement line that is located an additional 20 feet landward of the construction tie-in line to ensure adequate room for initial project construction and re-construction in the event of severe storm damage. Another constraint was that the landward toe of the beachfill needed to tie into the existing profile at a minimum elevation of 7 feet-NGVD along the construction line. The resulting construction tie-in line is shown on the Beachfill Plan Layout plates (Appendix A, Figure A-8) as the landward edge of the hachured beachfill area.

2. Description of Recommended Plan

a. Plan Description

The recommended plan is the 1550 dune-and-berm template that consists of a 25-foot-wide dune crest at an elevation of 15 feet-NGVD and a 50-foot-wide berm at an elevation of 7 feet-NGVD. The dune has a landward side slope of 5 horizontal to 1 vertical and a seaward side slope of 10 horizontal to 1 vertical. A typical 1550 dune-and-berm profile for the NED plan is displayed on Figure D-3.

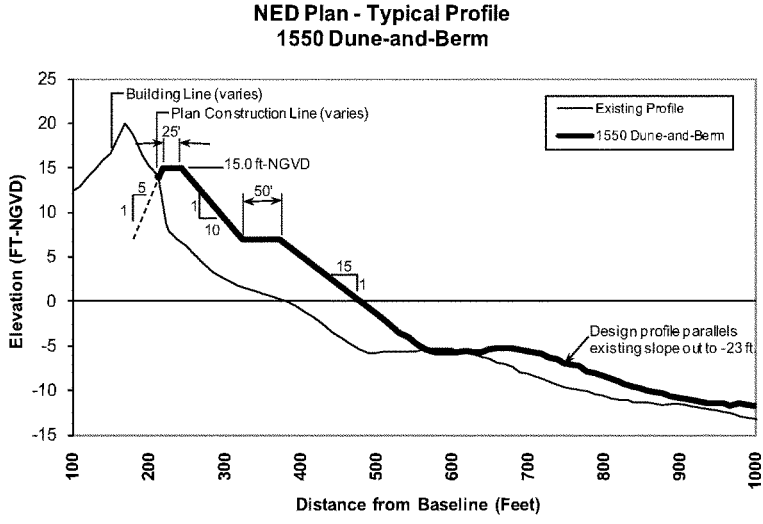


Figure D-3. Typical NED Plan Beachfill Profile

As shown on Figure A-7 (NED Plan, Plan View) in Appendix A, the recommended 1550 plan extends the full length of the 52,150-foot (9.88-mile) continuous non-CBRA portion of the study area, which includes all of Surf City (reaches 27-58) and the southern 3.8 miles of North Topsail Beach (reaches 59-78). No project could be justified in the two small non-CBRA areas in the northern end of North Topsail Beach (reaches 107-108 and 114-115). Initial scoping and optimizing of the beachfill design considered a stand-alone beachfill with a 2000-foot transition extending into reaches 25 and 26 in Topsail Beach on the south and a 2000-foot transition extending into reaches 79 and 80 in North Topsail Beach CBRA-zone. Transitions consist of a berm-only cross section that tapers down to a zero-width berm. For the recommended plan, a total of four transition scenarios were evaluated to account for project and environmental constraints.

The following transition scenarios (shown in Figure D-4) were evaluated in GRANDUC , which is the storm and hurricane damage model being used for this study. (See Addendum at end of Coastal Engineering Appendix for a description of GRANDUC.);

Transition T - assume Topsail Beach federal project and North Topsail Beach local project; build full dune and berm upon Topsail Beach transition in reaches 27 and 28 tying into federal project and north transition occurs in reach 78 tying dune and berm into local project.

Transition X – assume no Topsail Beach federal project and no North Topsail Beach local project; south transition extends in reaches 25 and 26 and north transition occurs in reaches 77 and 78 ending before CBRA boundary.

Transition Y - assume no Topsail Beach federal project and no North Topsail Beach local project; south transition extends in reaches 25 and 26 and north transition occurs in reaches 79 and 80 extending into CBRA boundary. (This is the scenario used during initial beachfill plan selection process).

Transition Z - assume no Topsail Beach federal project and no North Topsail Beach local project; south transition occurs in reaches 27 and 28 ending before Topsail Beach boundary and north transition occurs in reaches 77 and 78 ending before CBRA boundary.

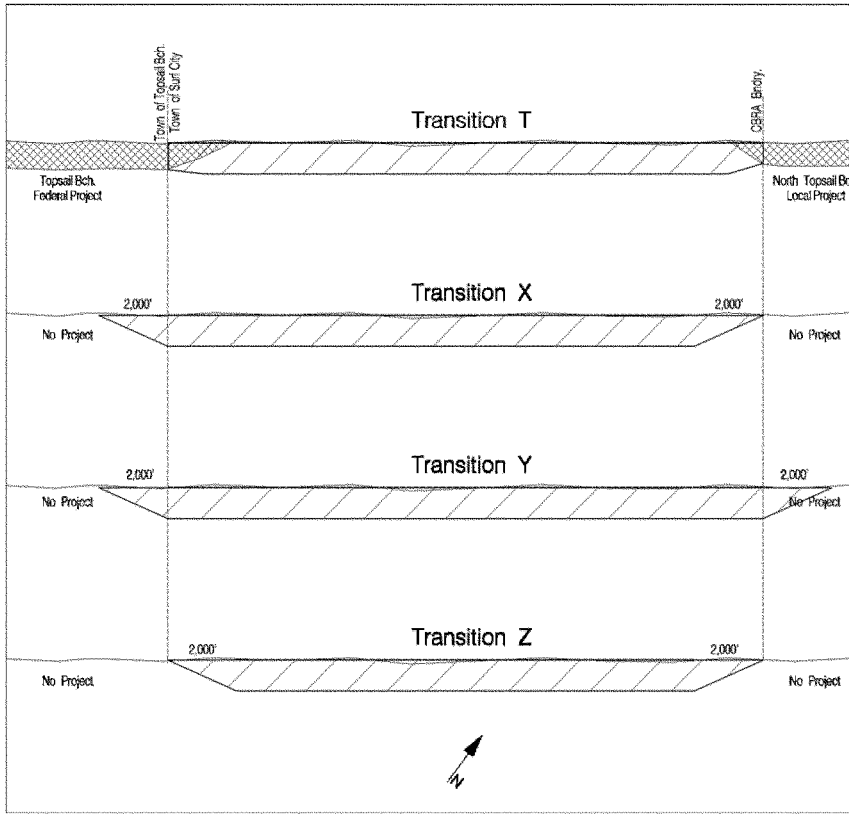


Figure D-4 Schematic of Transition Scenarios

The GRANDUC model was run on each of the scenarios and the benefits/cost statisitics provided for further economic evaluation. As expected, Transition T, which ties into beachfill projects on each end provides the most favorable benefits/cost ratio.

Appendix A also contains the more detailed Beachfill Plan Layout plates showing the physical location of the main project and transition on aerial photography of the study area. As shown on the typical NED plan profile in Figure D-3, the design profile is assumed to parallel the natural contour below MLW (-1.9 feet-NGVD) out to a closure depth of -23 feet-NGVD. The initial construction profile will extend seaward of the final design berm profile a variable distance (about 100 to 200 feet) providing the required material volume which will equilibrate and redistribute along the active profile (out to about -23 feet NGVD). This equilibration process is highly

dependent upon the wave climate during and after placement and therefore equilibration time will vary. Experience with nearby beachfill projects shows that the equilibration will take place within one-year of initial placement (Bogue Banks, NC, annual surveys). Once sand redistribution along the foreshore occurs, the equilibrated profile shape will resemble the design berm profile.

b. Project Data

The recommended plan requires about 11.8 million cubic yards of borrow material during initial construction. This borrow volume quantity is actually 15 percent greater than the desired in-place template volume to account for placement losses during initial construction, which equates to an average overfill factor of 1.15. This overfill factor is based upon the characteristics of the borrow material. Placement losses are defined as the extra volume of material that must be removed from the borrow area in order to realize the required in-place volume of material on the beach. Project maintenance requirements for each 6-year renourishment cycle are about 2.6 million cubic yards of borrow material, and that volume includes about 21 percent of additional borrow material to offset material characteristics and placement losses. In total, about 32.3 million cubic yards of borrow material will be required for the 50-year project.

3. Alternative Evaluation Process

a. Study Limits

The Surf City and North Topsail Beach study limits for preliminary assessment of alternatives included all of Surf City (6.0 miles) and the non-CBRA portion of North Topsail Beach's shoreline (4.6 miles), for a total shoreline length of 10.6 miles. North Topsail Beach's non-CBRA shoreline was comprised of its southern 3.8-mile section bordering Surf City and two smaller (less than one-half mile each) sections in the northern end of North Topsail Beach near New River Inlet.

The contiguous 9.8 miles of the study area consisting of Surf City and the southern portion of North Topsail Beach was divided into 52 reaches (27 through 78)—each of which were about 1000 feet wide, except for the southernmost reach (27) which was 1300 feet wide. The two separate, smaller non-CBRA sections were each divided into 2 smaller reaches of varying lengths (reaches 107-108 and 114-115).

b. Alternatives Addressed

With the study limits defined, a systematic procedure for evaluating alternatives was developed. Knowing that the volume of beachfill is a

strong indicator of storm and hurricane damage protection to be expected and knowing the history of optimum protection along the North Carolina coastline, an array of three berm-only plans and nine dune-and-berm plans were initially addressed.

1) **Berm-Only Plans.** The berm-only plans evaluated included the 50-, 100-, and 150-foot wide berms that tied directly into the existing dune face and relied solely on the existing dune protection. Evaluations were made using GRANDUC, which is the storm and hurricane damage model being used for this study. (See Addendum at end of Coastal Engineering Appendix for a description of GRANDUC.) In spite of a fairly substantial existing dune, these berm-only plans did not provide the level of storm damage protection as did the dune-and-berm plans, resulting in significantly lower total net benefits and did not warrant further consideration.

2) **Dune-and-Berm Plans.** Historical projects in place along the North Carolina coast have dune heights of about 13-feet above NGVD with a berm width of about 50 feet. Therefore, in addition to the 13-foot dune with a 50-foot berm, a higher 15-foot and lower 11-foot dune, each with a 25-, 50-, and 75-foot berm at 7 feet-NGVD, were selected for initial evaluation. A fixed dune width of 25 feet was used for all plans. See below table for a summary of other Federal Coastal Storm Damage Reduction projects along the North Carolina coast (for information only).

Project	Date Constructed	Dune Width/Elevation	Dune Foreslope	Berm Width/Elevation	Length, ft	Fill Density cy/lf		Borrow Volume, cy
						In-Place	Borrow Measure	
Wrightsville Beach	1965	25' / 13.5'	10H:1V	50' / 6.0' *	14,000	-	210	2,993,100
Carolina Beach	1965	25' / 13.5'	10H:1V	50' / 6.5' *	14,000	120	250	3,597,400
Kure Beach	1997	25' / 13.5'	10H:1V	50' / 6.5' *	18,000	-	190	3,372,000
Sea Turtle Habitat, Oak Island	2001	20' / 11.0'	5H:1V	70' / 8.0'	10,000	-	260	2,650,000
Dare County Beaches	N/A	25' / 13.0'	10H:1V	50' / 7.0'	75,000	147	180	12,340,000
Topsail Beach (NED)	N/A	25' / 15.0'	10H:1V	50' / 7.0'	25,000	140	-	3,420,000
Topsail Beach (LPP)	N/A	25' /12.0'	10H:1V	50' / 7.0'	25,000	100	-	2,387,000
* Berm elevation given represents construction berm since project designed with a stepped dune								

Table D-1 Summary of Federal Coastal Storm Damage Reduction Projects in NC

3) **Refinement of Study Limits.** The project limits were refined by evaluating the economic feasibility of constructing a project in every reach of the study area. As a result, the two separate study segments in the northern end of North Topsail Beach (reaches 107-108 and 114-114) were not shown to be feasible for a project due primarily to the expected high end losses of material from these short segments.

4) **Refinement of Alternatives.** The initial array of dune-and-berm plans using the reduced project limits was evaluated. Dune elevations of 11,

13, and 15 ft. were evaluated for berm widths of 25, 50, and 75 ft. That analysis was based on using identical unit construction costs across all plans. Although the initial analysis indicated that 25 ft. plans on average had the highest net benefits (about 2 percent higher on average than 50-ft. plans), it was determined that borrow unit costs for implementing a 25-ft. plan were underestimated by at least 8 percent as compared to 50-ft. and greater width plans. One of the primary reasons for the greater unit cost under a 25-ft. plan is the additional equipment and operators that are needed to move pipe along the beach as the dredge is pumping, because the narrow berm width does not allow pumping at one location for as long. For a pipeline, a 25-ft berm is too narrow to use a 'Y' valve (which would allow equipment time to prepare pipe for the next reach once adequate sand is placed on the beach template) to be in place on the beach. On a 25-ft berm, a 'T' valve used with hoppers means pipe would have to be added faster, require more 'T' setups and more often because of the switching back and forth between the 'T' valve on the beach for each Hopper pump out location. It is estimated that for at 25-ft berm, 3 dozers and 2 loaders would be needed for construction, as opposed to 2 dozers and 1 loader for the larger plans. Therefore, on the basis of that reassessment of unit costs, the 50–ft. berm plans had the highest net benefits. Next, additional dune elevations were evaluated with the 50-ft. berm width. Dune elevations between 11 and 17 ft. were all found to be economically feasible. The 15 ft dune, 50 ft berm plan was found to have the maximum net benefits.

5) **Nonstructural Alternative.** An alternative to beachfill that was evaluated is the nonstructural plan, which includes a combination of retreat, relocation, and demolition to avoid or delay damage to structures by removing them from the hazard area. For this GRANDUC analysis all of the oceanfront structures were eliminated from the structure database. The without project damages were then recomputed using this revised structure database to estimate residual damages for the nonstructural plan. Benefits were determined as the difference in residual damages between the without project GRANDUC runs for the original and modified structure database. However, the nonstructural plan yielded negative net benefits overall and was eliminated from continued consideration. For additional details of the nonstructural plan, including associated costs, refer to Section 5.05.1 and Appendix P.

4. Shoreline Analysis

a. Closure Depth

The seaward limit of changes in depth over long-time periods due to movement of sediment is referred to as the "closure depth" and this depth is used for several calculations in the coastal analysis. Ideally, several years of coastal profile data are compared to observe the depth at which the profile appears stable or constant. Historical profile data is not available so, this analysis used wave height data to calculate a closure depth (USACE Coastal Engineering Manual, EM 1110-2-1100 (Part III).

Closure depth = $1.57 * H_e$ (formula reference III-3-12)

Where H_e is the effective significant wave height, a relationship of the mean significant wave height (H), and standard deviation of significant wave height (σ_H)

$H_e = H + 5.6 * \sigma_H$ (formula reference III-3-11)

Significant wave height at WIS Phase II Station 43 is 3.28'with a standard deviation of 1.97' giving a closure depth of -23' NGVD. This value is in-line with nearby beaches at Wrightsville Beach (-24'), Carolina Beach (-24') and Kure Beach (-24') [all NGVD datum].

b. Wave Climate

The source of the wave information is from updated hindcast data for the period 1990-1999 for the WIS Level 3 Station 292, located about 10 miles offshore of Topsail Island as shown in the figure below.

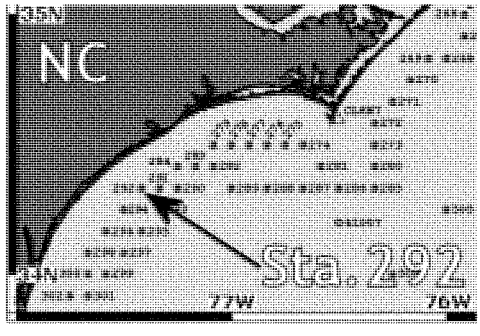


Figure D-5 Location of WIS Station 292

Statistical analysis results of the wave data are shown in the below graphs and show that the predominate wave direction is from the ESE.

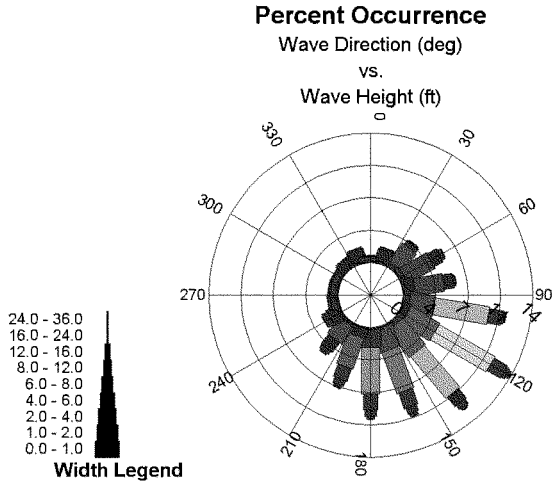


Figure D-6 All WIS Data 1990 - 1999

Seasonal wave statistics shown indicate Fall and Winter seasons typically experience larger waves more from the easterly direction while Spring and Summer seasons bring smaller waves from the more southerly directions.

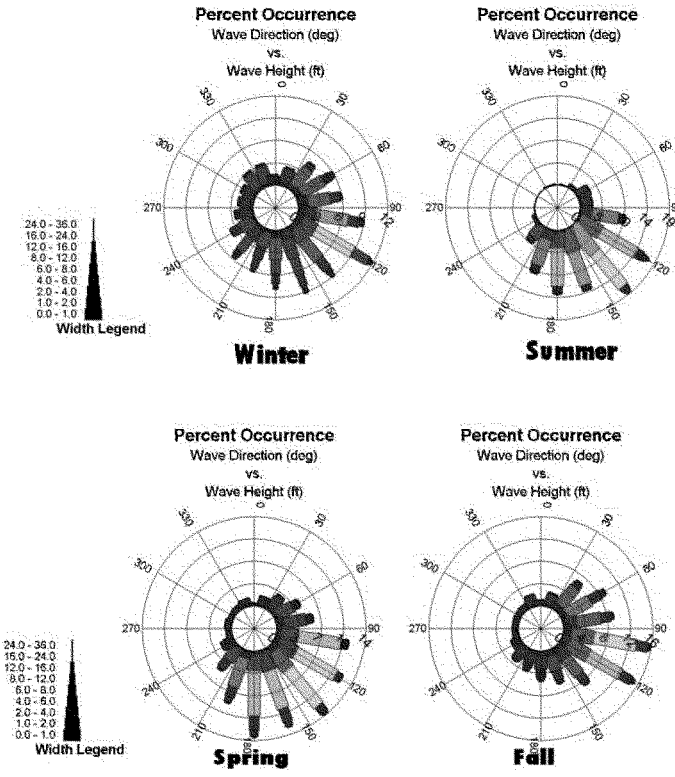


Figure D-7 Seasonal Variation of Wave Direction/Height

c. Local Bathymetry

The below map shows the project area and bathymetric contours (NGVD datum, 5-foot interval). The contours landward of the closure depth (-23 ft NGVD) are generally parallel.

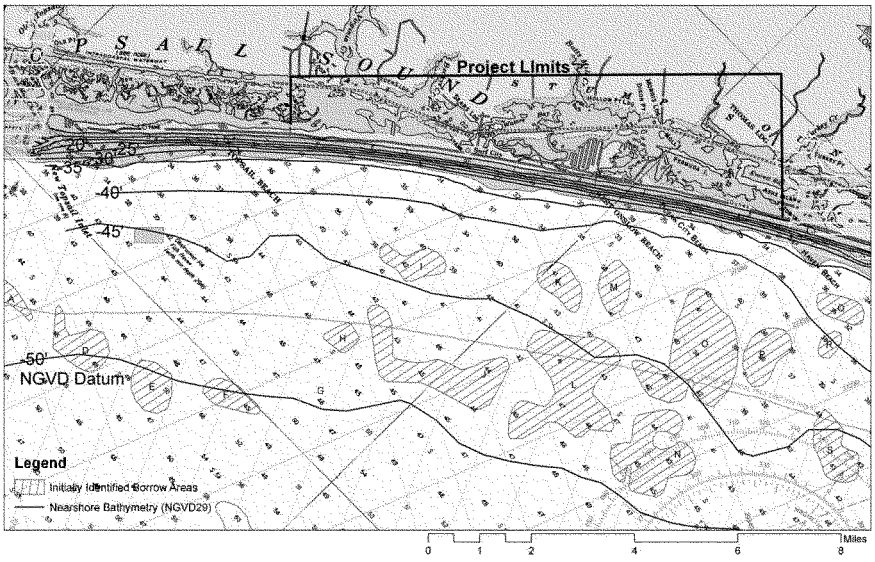


Figure D-8 Nearshore Bathymetry Contours

Localized deepening of offshore borrow areas can potentially have impacts on wave conditions; however, these changes are not expected to be significant as borrow areas are excavated. Simplified irregular wave transformation calculations were made to look at the sensitivity of deepening the ocean floor by 5-feet (to simulate excavating borrow) on wave heights (Goda's Method – Automated Coastal Engineering System (ACES) application package). Findings indicate absolute wave height differences of less than 0.1-feet due to deepening for a range of the most commonly occurring wave heights and periods. Even considering possible greater excavation depths up to 15 feet in the borrow areas, negligible changes in wave conditions were found in the analysis.

d. Shoreline Adjustments

Immediately after the project is constructed there will be major adjustments to the beachfill profile that will occur naturally in response to the existing wave environment and may take several months or longer to finally stabilize. (See Beachfill Evolution and Transition Modeling section later in this appendix). As explained earlier in the report, the initial construction berm width will extend 100 to 200 feet beyond the final design width. When stable, the final profile should approximate and parallel the pre-fill profile. Simultaneously, there will be erosion to the profile caused by longshore transport and offshore migration of the sand placed on the beach.

e. Long-Term Shoreline Change Rates

1) **Computed Shoreline Change Rates.** Long-term erosion rates were determined by comparing the 2002 MHW (+2.1 feet-NGVD) shoreline position for each reach to a historical 1963 Corps of Engineers shoreline survey of Topsail Island, a period of 40 years. The 1963 topographic survey was conducted during the month of August while the 2002 profile/photogrametric surveys were done in March. The 1963 MHW shoreline (approximated using the +2 feet-NGVD contour) was digitized using MicroStation to readily allow comparison of shoreline position for each reach. The 2002 MHW shoreline was available from photogrammetric digital mapping of Topsail Island conducted for this study at a scale of 1"=200' with 1.0' contour intervals, along with validation using 26 beach profile surveys taken every 1000 feet. Shoreline positions within each reach were determined every 250 feet and then averaged with shoreline positions in the two adjacent reaches to determine the average long-term shoreline change rate for each reach. Figure D-9 is a plot of the long-term shoreline change rates that were computed.

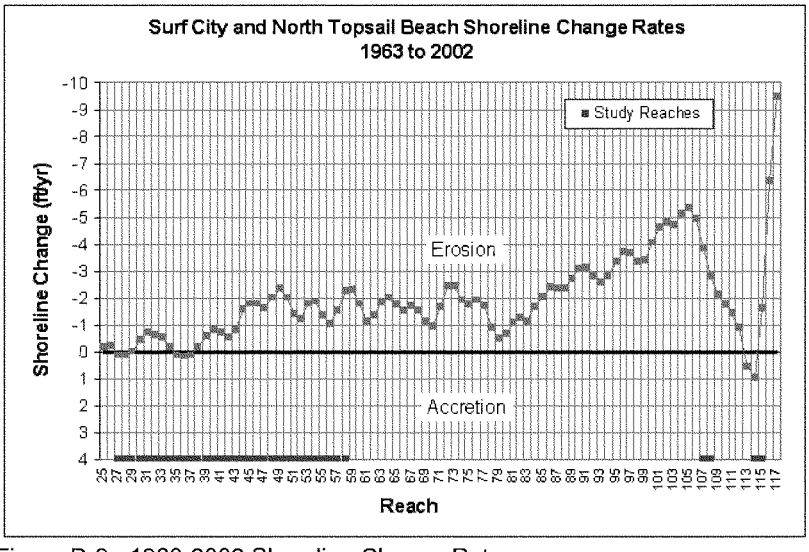


Figure D-9. 1963-2002 Shoreline Change Rates

Between 1963 and 2002, erosion rates were relatively low (less than one foot per year) in the southern half of the main study area (reaches 27-43); however, erosion rates in the northern half of the main study area (reaches 44-78) averaged nearly 2 feet per year. This change in

erosion rates may indicate the presence of a sediment transport reversal in this area. Section 5 of this appendix discusses ongoing regional sediment management studies which, when completed, will help clarify the sediment transport processes and the presence of transport reversals. Erosion rates increased significantly to over 5 feet per year in portions of the non-study CBRA area (reaches 79-106), but decreased to 2 to 3 feet per year in reaches 107-108 study segment. Shoreline changes in reaches 114-115 study segment begin to be significantly influenced by inlet processes as erosion precipitously changed to minor accretion and then back to significant erosion within a span of only a few reaches as you move towards New River Inlet. Other than the inlet area influence, erosion rates are relatively even. This, along with the parallel bathymetry contours indicates continuity of the shoreline along the project length.

2) **Comparison with Other Data.** Shoreline change rates computed for this study were compared to the North Carolina Division of Coastal Management's (NCDCM) long-term shoreline change rates, as shown in Figure D-10. The USACE analysis utilized measurements using actual survey data as opposed to the NCDCM data which was approximated with aerial photography. The NCDCM data shown is also based on end points (1940's to 1989, i.e. not including storms of the 1990's) and the accretionary areas are not corroborated by observed shoreline geometry (bulges or salient features along the shoreline). . The NCDCM rates generally show lower erosion rates than the 1963-2002 rates computed for this study, even showing significant accretion in the northern end of the main study area (reaches 50-58). Since the NCDCM data only extended through 1989 and do not reflect the severe storm activity the region experienced during the 1990s, this is not unreasonable.

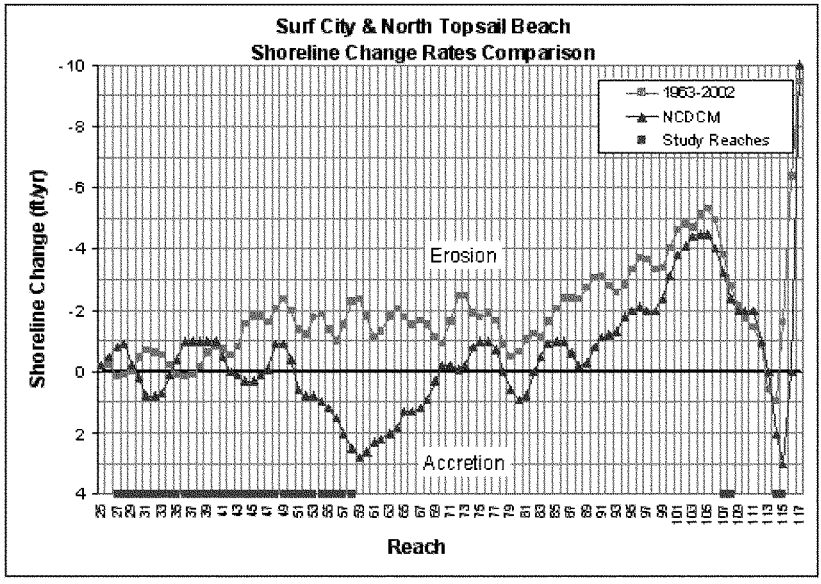


Figure D-10. Shoreline Change Rate Comparison to NCDCM Rates

3) **Sea Level Rise Impacts.** Inherent in these historic shoreline change rates is about 0.2 feet per year of shoreline erosion due to Sea Level Rise (SLR). This is based on NOS historical sea level rise for the Wilmington, NC station (No. 865810) which indicates sea level rise of about 0.008 feet per year from 1953 to 1993. Accelerated SLR scenarios would result in increased shoreline erosion and are discussed in more detail in Addendum D:2 *Sea Level Rise Sensitivity Analysis* at the end of this appendix.

5. Shoreline Modeling

a. Sediment Budget

A sediment budget for Topsail Island had been developed for the Final Feasibility Report and Environmental Impact Statement on Hurricane Protection and Beach Erosion Control, West Onslow Beach and New River Inlet North Carolina (Topsail Beach) dated November 1989 (Topsail Beach FR/EIS 1989). This sediment budget was not updated with this report, but is presented below to provide additional understanding of the shore processes along Topsail Island. This project study areas lie within Cells 2 and 3 and the resulting project lies within Cell 2. In Cell 2 (74,000 feet in length) the net sediment transport rate is about 48,000 cy/yr to the north/east and an

estimated 28,000 cy/yr lost offshore yielding a net deficient of about 76,000 cy/yr.

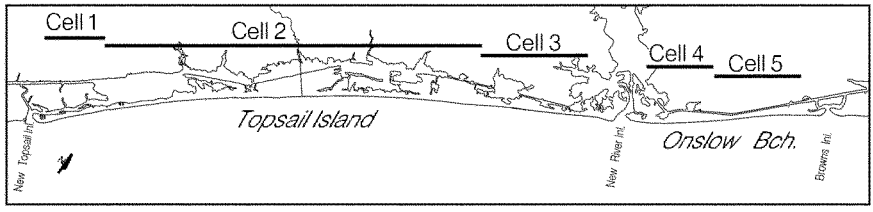


Figure D-11 Sediment Budget Cell Definition from 1989 report

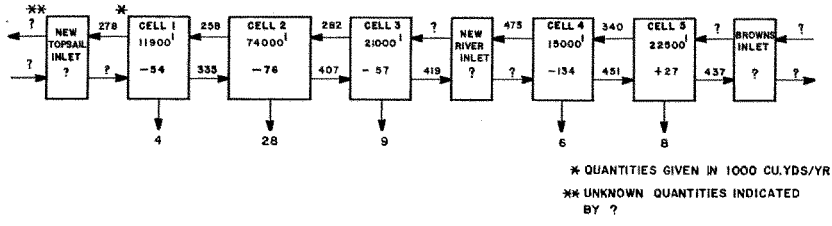


FIGURE C-7 (A)
SCHEMATIC OF STUDY AREA SHORELINE

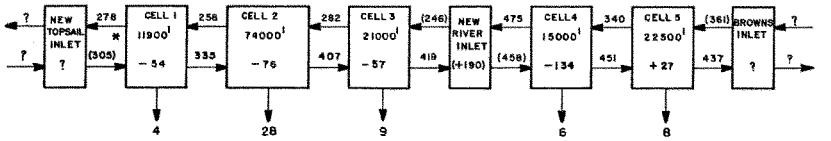


FIGURE C-7 (B)
RESULTS OF SEDIMENT BUDGET ANALYSIS

Figure D-12 Sediment Budget from 1989 report

b. Regional Sediment Management Draft Results

A regional sediment management study is currently underway for Onslow Bay, NC, covering more than 100 miles of beaches, 11 inlets, and five counties from Cape Lookout to Cape Fear, NC. This study is just beginning and results are very preliminary. These preliminary results indicate a sediment transport reversal along Topsail Island with an overall

rate of about 200,000 cy/yr to the south (west) and a generally increasing rate of about 400,000 cy/yr to the north (east). In Figure D-13 below, positive transport rates indicate transport to the south (west) and negative indicates transport to the north (east). Data and conclusions from this study will be utilized as the Coastal Storm Damage Reduction project progresses into the construction and renourishment phases.

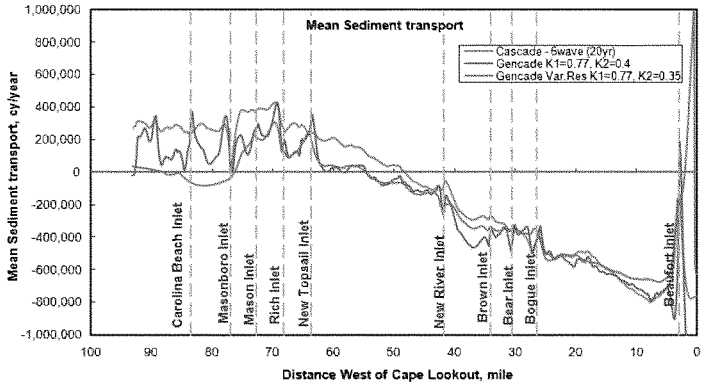


Figure D-13 Preliminary Regional Sediment Transport Results - Onslow Bay, NC

c. Beachfill Evolution and Transition Modeling

In general, when sand is placed for a beach nourishment project, this project represents an "anomaly" to the shoreline planform, and the natural processes will tend to smooth out this anomaly. Determining future shoreline geometry can be estimated using various automated coastal tools, including GENESIS and the Planform Evolution Model. GENESIS had been applied to Topsail Island where a terminal groin structure was being considered at New Topsail Inlet. However, difficulties encountered in calibrating the GENESIS model, likely due to the islands curvature and the islands inlet-dominated shoreline, prevented it's application being useful for the Surf City North Topsail Beach beachfill project. Instead, the Planform Evolution Model (within the Beach Fill Module developed by the Engineering Research and Development Center's Coastal and Hydraulics Laboratory) was used to simulate beachfill planform evolution. The model is a rapidly applied model that considers both background erosion rate, which is the normal rate in areas that have not been nourished, and shoreline retreat due to "spreading out" losses from the beach nourishment project. The model also requires input of sediment characteristics and effective wave conditions for longshore transport. The

effective wave conditions consist of a single set of the average wave parameters. Input data is displayed in the screen captures below.

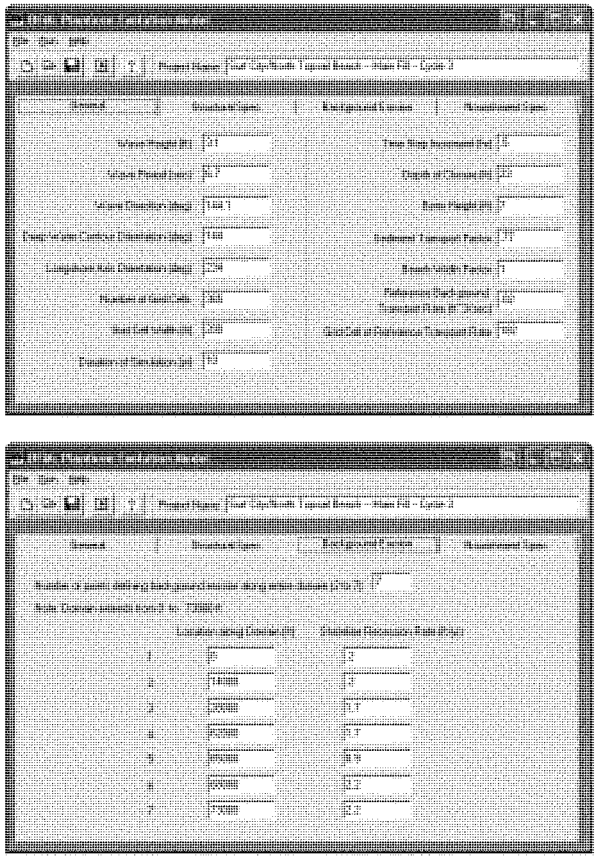


Figure D-14 Input Parameters for Planform Evolution Model

Model output consists of shoreline positions at user-specified time intervals along with sediment transport rates.

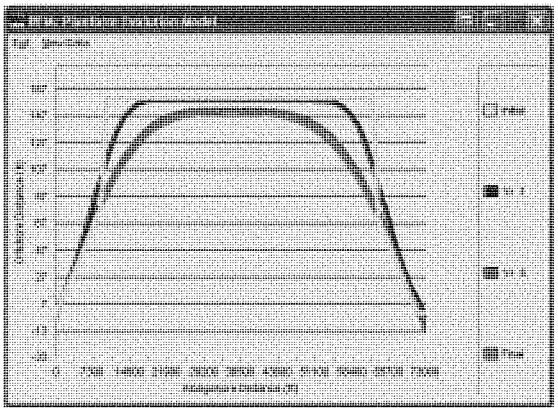


Figure D-15 Graphical Output from Planform Evolution Model, 6-Year Duration

Post-processing of the output was performed to compute shoreline change rates associated with the project. Based on typical transition lengths of 2000 feet, shoreline change rates and associated volumetric losses were determined over a 10 year period and this data used to derive an annual erosion rate. These erosion rates were then input to GRANDUC to determine the NED plan and optimum renourishment cycle. Figure D-15 shows the results of detailed planform evolution analysis performed on the selected plan (6-year renourishment). These losses were especially severe in the two separated and discontinuous short study reaches in the north end of North Topsail Beach, which resulted in elimination of these reaches.

Final erosion rates for GRANDUC simulations are shown in the figure below.

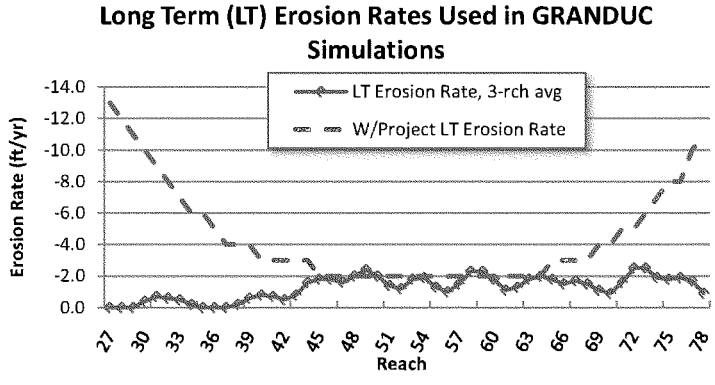


Figure D-16 Erosion Rates Used in GRANDUC Simulations

d. Sensitivity of Erosion Rates in GRANDUC Simulations

Because there is minimal detailed data to support erosion rates calculated with the end-point analysis mentioned earlier, a simplified sensitivity analysis of reduced erosion rates was conducted. In this analysis, the long-term erosion rate shown in the above graph was reduced to one-half and to one-quarter of the value and GRANDUC runs executed. For the with-project condition, the end loss erosion rates were maintained since the beachfill would continue to be seen as an anomaly to the shoreline and those erosion rates are calculated from the Planform Evolution Model; however the erosion rates near the middle portion of the project were reduced from 2 ft/yr to 1 ft/yr and 0.5 ft/yr in the analysis. Note that the analysis was conducted assuming a 4-year renourishment interval and with older cost data so some of the values for the selected plan may not agree with values shown elsewhere in this appendix and in the main report. However, the application of the results of this analysis is appropriate for renourishment intervals and costs. See the summary table (Table D-2) and graph (Figure D-17) below.

Table D-2 Summary of Erosion Rate Sensitivity Assuming 4-year Renourishment Interval

Summary of Erosion Rate Sensitivity								
	W/O Project Damages ($1,000)	With Project Damages ($1,000)	Benefits ($1,000)	Costs ($1,000)	Net Benefits ($1,000)	B/C Ratio	1550 Erosion Rate	Average Renourishment Volume (cy)
Selected Plan with historical Erosion Rates included	$370,522	$42,615	$327,907	$206,784	$121,123	1.59	2.0	1,770,183
Selected Plan with Half of the Erosion Rate	$314,130	$42,079	$272,051	$194,910	$77,141	1.40	1.0	1,492,526
Selected Plan with 1/4 of Erosion Rate	$287,049	$41,849	$245,200	$189,512	$55,688	1.29	0.5	1,366,318

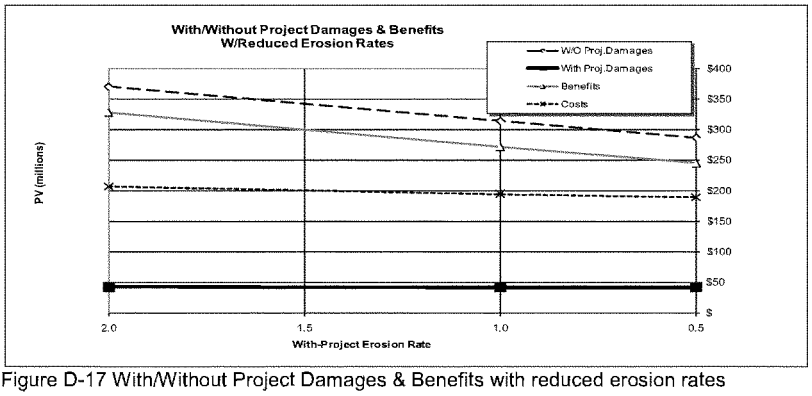


Figure D-17 With/Without Project Damages & Benefits with reduced erosion rates

It can be seen from the results that as erosion rate is decreased, the without-project damages and benefits are reduced at about the same rate. The costs and with-project damages are reduced at a much less rate. The smaller change in costs is due to the continued need for renourishment volumes which are not reduced in the same proportions as the erosion rates (1/2 and ¼). As mentioned, the end losses and spreading out losses would continue even if the long term erosion rate is reduced thus requiring renourishment to provide continued protection. The small change in with-project damages indicates that the project would continue to perform and the benefit-cost ratios in the table indicate the economics of the project would continue to be robust even with lower erosion rates.

6. Storm Damage Analysis

a. General

The economic analysis of storm damages for the range of beach conditions throughout the study area requires development of frequency-of-occurrence relationships for water levels, wave conditions, and erosion distances. In order to account for risks and uncertainties inherent to the analysis procedure, methods were selected to express storm damages in a probabilistic manner. In other words, the results were required in the form of erosion distance or water levels versus frequency-of-occurrence relationships. A suite of storm events was used to assess the performance of alternatives in reducing potential damages due to erosion, wave attack, and inundation. Profiles were developed to characterize the alternatives dimensions and serve as input to the storm damage calculations. The numerical model SBEACH (Storm Induced BEAch CHange) was used to transform the waves from an approximate depth of 30 feet into the nearshore across proposed alternatives and simulate beach profile change, including the formation and movement of major morphological features such as longshore bars, troughs, and berms, under varying storm waves and water levels. In addition to computing beach profile response, the wave transformation algorithms within SBEACH were utilized to characterize incident wave conditions and total water levels (including wave setup) for each storm. Key response parameters from the SBEACH output were extracted for each storm and used to generate frequency of occurrence relationships using the Empirical Simulation Technique (EST) model. The frequency of occurrence relationships for erosion distances and other parameters serve as input to the GRANDUC model for computation of storm damages.

b. SBEACH Analysis

The computer model SBEACH was used to estimate erosion expected to occur during various storm events for the without-project condition and the with-project templates considered. Additionally, the wave transformation routines in SBEACH provide transformed wave conditions and wave-induced setup values for each simulation. SBEACH simulations were performed for the suite of storm events against the range of beach profile conditions. Input data for the SBEACH model included onshore and offshore survey data, storm water elevations, and storm wave heights and periods as discussed previously. The results from SBEACH modeling (i.e., "response parameters") that are used in storm damage calculations include: erosion distances (landwardmost occurrence of 0.5-, 2.0-, and 4.0-ft vertical erosion), the ground elevations at these erosion points, erosion volumes, maximum dune elevation, maximum wave height at dune crest, and maximum total water level (including wave setup).

Additional input parameters are listed in the Table D-3 below.

Table D-3 SBEACH Input Parameters

SBEACH Input Parameters	Value	Unit
Landward surf zone depth:	1	ft
Effective grain size:	0.35	mm
Maximum slope prior to avalanching:	45	deg
Transport rate coefficient:	1.75E-06	m^4/N
Overwash transport parameter (K - unitless):	0.005	
Coefficient for slope dependent term:	0.002	m^2/sec
Water temperature in Degrees C:	20	deg C
Variable Grid	yes	
421@5' width / 193@20' width		
Position of landward boundary relative to input profile	-1000	
Contours used to track beach recession	0	ft NGVD
	2.1	ft NGVD
	7	ft NGVD
Erosion depths used to track erosion distances	0.5	ft
	2	ft
	4	ft
Reference Elevation	2.1	ft NGVD

No historical beach profile data was available to allow calibration of SBEACH so the standard coefficients developed for SBEACH were used. SBEACH simulations generally resulted in reasonable values for the erosion indicators that fell within the erosion category for moderate class storms (USACE Shore Protection Manual, 1973).

1) **Beach Profiles.** During the spring of 2002, beach profile data were collected along 56 transects at approximately 1000-foot spacing throughout the study areas in Surf City and North Topsail Beach. These surveys extended offshore to a depth of 30 feet, or a minimum of one mile. Photogrammetric one-foot contour maps and

digital orthophotos of the study areas were also generated to complement the beach profile surveys. Representative profile selection was conducted in a rather straightforward manner. The profiles were arranged sequentially and graphically compared and grouped with considerations of dune height, berm and nearshore profile. Groupings of profiles with similar features were further reviewed. The groupings generally consisted of profiles adjacent to one another. Groupings included as few as 2 profiles and as many as 7 profiles. One of the profiles from each of the grouping was selected as the representative profile. Of the 52 beach profiles within the selected plan limits, 16 were used as representative profiles. Although the 2002 profiles likely are continuing to show effects of the storms of the 1990's, no other profile data is available for comparison. Figure D-18 shows typical SBEACH profile input. Addendum D:5 –Beach Profiles shows all of the surveyed profiles grouped by the representative profile.

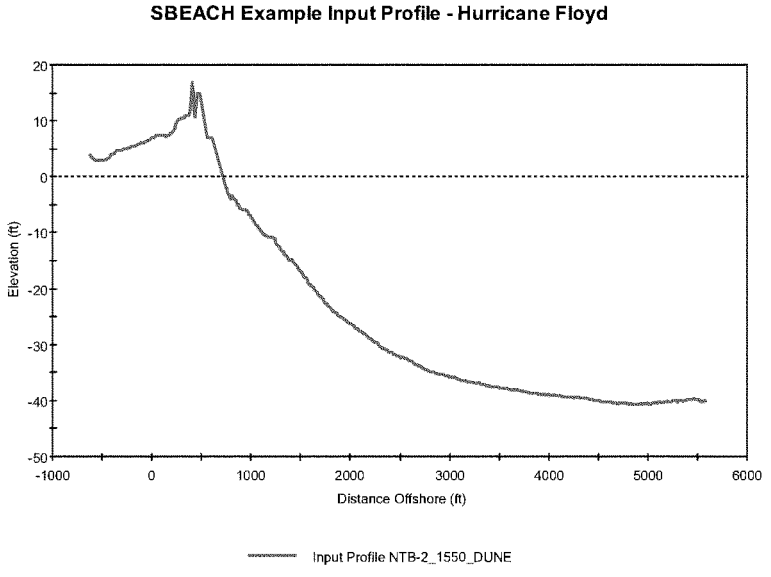


Figure D-18 Example SBEACH input profile

2) **Storm Surge.** Storm surges are storm-induced rises above normal water levels due to the action of wind stress on the water surface and also atmospheric pressure reduction during hurricanes. Storm surge time-series were developed for all significant hurricanes in the Atlantic Ocean from 1890 to 1990 as part of the Dredging Research Program (DRP-1-17, Scheffner, 1994). The ADCIRC

model was used to update the hindcast to include recent hurricanes through from 1999, including named hurricanes Bertha, Fran, Dennis, Floyd, Bonnie, and Irene. Time-series of storm surge were coupled with astronomical tide data to serve as input to SBEACH for the storm damage assessment. For the 100-plus years of coverage, 37 events were identified using a minimum storm surge threshold of one foot. In addition to the tropical storm surge database, extratropical storm surge values for 23 events were calculated for the dates from 1976 to 1993. See Addendum, *Dredging Research Program Storm Surge Database and Recent Hurricane Modeling* for additional details about storm surge modeling.

3) **Storm Waves.** Wave heights and periods corresponding to the storm surge events discussed above were determined from WIS hindcast data . Combined with the water level time-series, these wave height and period time-series will serve as the storm input to SBEACH for the damage analysis. See Figure D-19 for example storm input parameters.

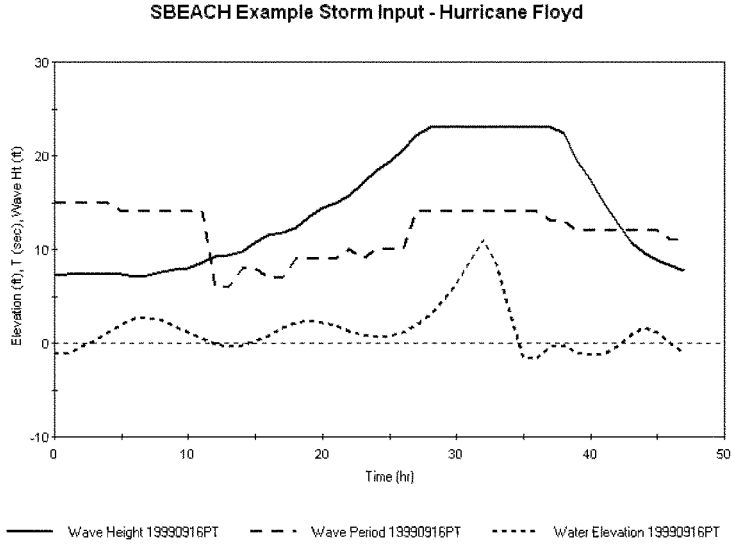
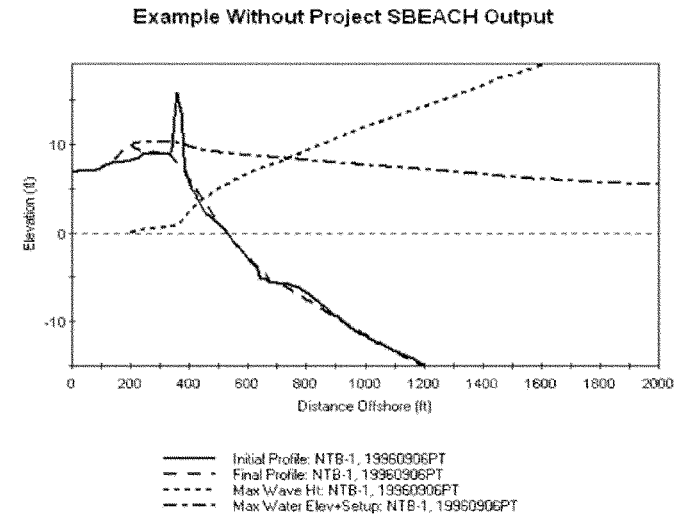


Figure D-19 Example SBEACH Storm input parameters

c. Storm Response Parameters

Simulation of storm events yields various responses. The parameters that directly impact storm damage include nearshore wave height, total water level, storm surge, wave setup, runup, erosion distances, dune lowering, dune recession, and volumetric changes above MHW. Select parameters were extracted from the SBEACH analysis and used to characterize the performance of the alternatives against each storm event. Figure D-20 displays example SBEACH output for an extreme event for existing conditions and with-project conditions at North Topsail Beach. The plots display initial and final profile conditions, along with maximum water elevations (includes storm surge and wave setup) and maximum wave height observed throughout the simulation. The profile response over the simulation, as indicated by the difference between initial and final profiles, provides an indicator of the severity of the storm on potential offshore losses.



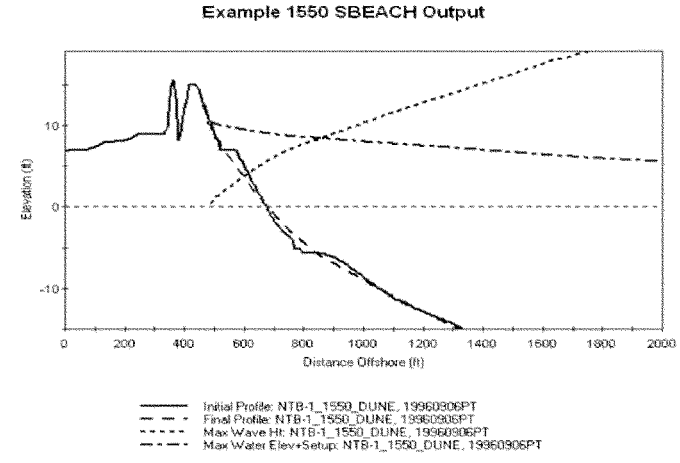


Figure D-20 Typical SBEACH Output Parameter Plot

d. EST Analysis

1) **Frequency Curves.** The EST (Empirical Simulation Technique, Scheffner and Borgman, 1992) utilizes observed and computed parameters associated with site-specific historical events as a basis for developing multiple life-cycle simulations of storm activity and the effects associated with each simulated event. The first step in EST is an analysis of historical events that have impacted a specific locale.

The storm events simulated (as described previously) were parameterized to define the characteristics of each event and the impacts of that event. Parameters that define the event are referred to as input vectors. Response vectors define storm-related impacts such as total water level and shoreline/dune erosion. These input and response vectors were then used as a basis for generating life-cycle simulations of storm-event activity with corresponding impacts. Results of the multiple repetitions were post-processed to generate frequency-of-occurrence relationships. These relationships were developed for all profile conditions (existing and alternatives) and all response parameters. Select return periods were extracted from each frequency-of-occurrence relationship and provided as input to the GRANDUC model used to calculate storm-induced damages. See the Addendum, *Overview of EST Process* at the end of this appendix for additional details.

2) **Modifications to EST Frequency Curves.** Water level frequency curves generated by EST for low frequency events (50-, 100-, and 500-year events) were unreasonable and exceed FEMA surge level estimates for Topsail Beach by 10 to 20 percent. Adjustments were made to these response curves so that they better reflected the FEMA surge elevations. Also, the EST erosion distance frequency curves were "smoothed" in some cases to result in more uniform and expected erosion responses. An additional analysis using Automated Coastal Engineering System (ACES) software module Extremal Significant Wave Height Analysis corroborated the FEMA extrapolated values.

e. Storm History Simulations

From the response frequency curves, one-thousand different equally-likely storm series were generated as actual input to GRANDUC. A program was written to use the response parameter frequency curves, a Poisson distribution with an average number of storms per year of one, and a random number generator to create the storm histories for the multitude of GRANDUC simulations to be run. For each year of a simulation, the program generates a random number and uses it with the Poisson distribution to determine the number of storms for that year. Then, for each storm, another random number is generated that is used with each of the variable frequency curves to determine the parameters for that storm.

7. Selection of the Periodic Renourishment Interval

a. Optimum Periodic Renourishment Interval

An analysis of various renourishment intervals from 2 to 7 years was conducted in the GRANDUC model. Longer renourishment intervals increase the risks between renourishment events of allowing accumulated erosion to create escarpments (for instance, it is projected that the escarpment would be nearly two miles longer under a 7 versus a 4 year renourishment cycle), narrow the non-dune portion of the beachfill, erode the toe of the dune, and damage dune vegetation, resulting in an unnatural beach profile. Large scarps also create potential safety hazards (Figure D-21). For renourishment cycles beyond 4 years, an additional hopper dredge would be needed in order to complete dredging during the environmental hopper dredging window of December 1 to March 31.

Net benefits increase as a function of renourishment interval from 2 to 4 years (Table D-4). Beyond 4 years, the differences in benefits are insignificant. Therefore, the 6 year renourishment interval, which had the lowest cost, was selected. (Note: this analysis was conducted with older cost data; however, the application of the results is appropriate for determining an optimum renourishment interval).



Figure D-21 Example of escarped dune and eroded berm

Table D-4. Summary of total costs and net benefits of various renourishment intervals

Renourishment interval (years)	Total cost ($)	Total net benefit ($)
2	129,594,587	158,481,504
3	115,058,012	165,298,498
4	111,479,241	168,712,045
5	111,931,664	167,731,332
6	109,549,340	169,771,051
7	109,637,064	169,032,905

b. Periodic Renourishment Interval Considerations

1) **Dredging Window.** Because of the limited sand thicknesses of the offshore borrow sites available for renourishment, it is likely that a hopper dredge will be used. The environmental dredging window for hopper dredging to avoid the possible presence of sea turtles in the borrow area is December 1 to March 31. Additional hopper dredge(s) would be needed to accommodate the renourishment volumes required for intervals greater than 4 years. These additional mob/demob costs were factored into the optimum analysis results shown in Table D-4.

2) **Scarping.** For such long renourishment intervals, impacts are likely on turtle nesting, recreation, and storm protection due to loss of the berm and scarping of the dune. This is particularly true for the reaches near the ends of the project, whose estimated with-project erosion rates are 10 to 13 feet per year based on planform evolution analysis. No advanced nourishment is included in this life-cycle design, so the storm berm erodes back to the base of the dune, escarping the dune. Based on a 6-yr renourishment cycle, over three times the length of scarping would occur compared to a 4-yr renourishment cycle. An example of an eroded berm with escarped dune is shown in the Figure D-21. This situation is more likely to occur under the longer renourishment intervals.

In addition, escarpment length jumps most rapidly when increasing the interval from 4- to 5-years (see below figure).

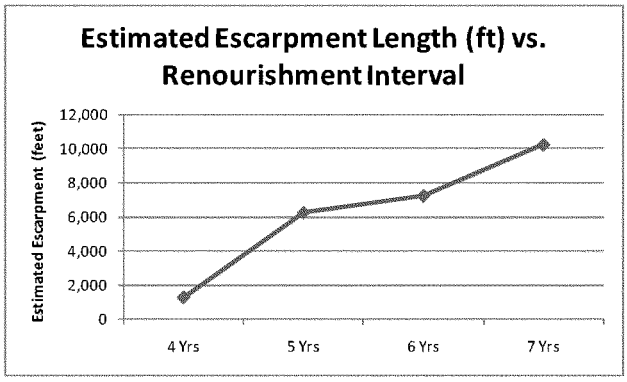


Figure D-22 Escarpment Length vs. Renourishment Interval

c. **Recommended Renourishment Interval.** The 6-year renourishment interval was chosen since it has the lowest cost. Annual surveys will also be used to monitor the project performance. Should monitoring indicate that renourishment is not needed after 6 years (perhaps due to less severe storm activity or other reasons), renourishment can be delayed beyond 6 years as appropriate provided factors such as excessive dune scarping or loss of sea turtle nesting habitat are adequately considered.

8. Borrow Sand Requirements

Table D-5 shows the borrow sand requirements for the initial construction volume and 6-year periodic nourishment volumes for the Surf City and North Topsail Beach NED plan (15 feet-NGVD dune elevation and 50-foot berm). Volumes shown are borrow quantities that have been adjusted for the required overfill factors. Initial beachfill volumes were computed geometrically using the representative profiles. The dune and berm profile was superimposed upon the representative profile (as shown in Figure D-1) and unit volumes computed (cy/lf). These unit volumes were increased by the overfill factor to account for losses and multiplied by the reach lengths to compute the borrow volume required. The recommended borrow plan for initial construction calls for 11,860,000 cubic yards of material to be pumped by hopper dredges from offshore borrow areas. Various transition scenarios result in a difference of no more than about 1 million cubic yards. During periodic renourishment, the plan calls for about 2,642,000 cubic yards of material to be hopper dredged from

multiple offshore borrow sites over the course of the periodic renourishments (based on a 6-year cycle).

Table D-5
Borrow Sand Requirements
(cubic yards)

Initial Construction Volume	6-Year Periodic Renourishment Volume	50-year Periodic Renourishment Volume	Total Project Volume
11,860,000	2,642,000	20,477,000	32,300,000

9. Risk and Uncertainty

a. Background

Analysis of coastal storm damage reduction projects has moved from the traditional deterministic approach to a more comprehensive probabilistic, risk-based methodology. Coastal storm damage reduction projects are now formulated to provide economical protection for storm and erosion prone areas, selecting the plan that maximizes net economic benefits consistent with acceptable risk and functional performance. The technical task of any risk-based analysis is to balance the risk of design exceedance with damages prevented, uncertainty of storm characteristics with design accommodations, and to provide for safe, predictable performance. Risk-based analysis enables risk issues and uncertainty in critical data to be explicitly included in project formulation and evaluation. The uncertainties associated with the sequencing of storms and natural recovery and those associated with storm damages and erosion losses can now take on a very large number of values. Evaluating the effects of each sequence of storms becomes a life cycle analysis problem and many lifecycles must be evaluated in order to quantify the distribution of economic losses both without a coastal storm damage reduction project and with each alternative formulated. The use of the lifecycle approach helps explain the evaluation process for erosion and nourishment much more easily since the lifecycle approach is more realistic and more closely mimics the dynamic coastal conditions.

b. Guidance

A major design consideration for this project was to incorporate risk and uncertainty as an integral part of the formulation process. Chapter 6 of ER 1105-2-100, entitled "Risk-Based Analysis for Evaluation of Hydrology/Hydraulics and Economics in Shore Protection Studies" specifies the analysis requirements for coastal storm damage reduction

projects, the fundamental requirement being that all shore protection analysis adopt a life cycle approach. The Wilmington District model, GRANDUC, which was used for this study incorporates the life cycle approach into the formulation process.

c. Analysis Requirements

ER 1105-2-100 also specifies that the analysis be risk-based and that the following variables be explicit in the analysis and some, by implication, be considered as uncertain:

1) the erosion damage function
2) the stage damage function
3) the wave damage function
4) storm-related parameters
5) wave height above the dune
6) wave penetration
7) shoreline retreat or eroded volume
8) natural post-storm recovery

All of these variables are explicitly covered in the GRANDUC model.

d. Uncertainty

The GRANDUC model is currently programmed to measure uncertainty using the following three variables:

1) erosion distance – plus or minus 5.0 feet
2) structure distance – plus or minus 2.0 feet
3) structure elevation – plus or minus 0.1 feet

These three variables utilized are considered a reasonable measure of uncertainty for this study. A triangular distribution has been chosen to represent the variance for each variable.

e. Risk Results for Alternatives Evaluated

Given the probabilistic nature of the analysis, dune-and-berm alternatives were evaluated to determine the percent chance that the given alternative would have positive net benefits. These evaluations are summarized below in Table D-6.

Table D-6
Percent Chance of Having Positive Net Benefits

Dune-and-Berm Plans	Percent Chance
11-ft Dune Elev / 50-ft Berm	100
13-ft Dune Elev / 50-ft Berm	100
14-ft Dune Elev / 50-ft Berm	100
15-ft Dune Elev / 50-ft Berm	99.8
16-ft Dune Elev / 50-ft Berm	99.8
17-ft Dune Elev / 50-ft Berm	99.4

For the above-listed alternatives, risk-based analysis using GRANDUC shows that a feasible project (i.e., net benefits greater than 0) could be justified in nearly all of the lifecycles performed. (GRANDUC performs a total of 1000 lifecycles for each run, with a lifecycle being the 50-year economic life of the project.) In fact, none of the lifecycles performed for the 11, 13, and 14 foot dunes resulted in negative net benefits. The NED plan (15-ft dune elevation with 50-ft berm) had a 99.8 percent chance of having positive net benefits.

Addendum D:1 - GRANDUC Documentation

Table of Contents

1.Introduction D-35

2.Data Requirements D-35
- a. Project Reaches D-35
- b. Structure Database D-37
- c. Life Cycle Storm Histories D-37
- d. Global Data D-39
- e. Reach Data D-39
- f. Flood Damage Curves D-40
- g. Erosion Damage Curves D-40

3.Program Operation D-40

4. Recent Model Enhancements D-45
- a. Storm Responses D-45
- b. Structure Replacement D-46

5.Surf City and North Topsail Beach GRANDUC Input D-47
- a. Global Data D-47
- b. Reach Data D-47
- c. Life Cycle Storm Histories D-48
- d. Structure Database D-48
- e. Flood Damage Curves D-49
- f. Erosion Damage Curves D-49

List of Tables

Table 1 Sample Life Cycle Storm Histories D-38
Table 2 Partial Results for the Sample Project D-43

List of Figures

Figure 1 Sample Reach D-36
Figure 2 Sample Flood Damage Curve D-40
Figure 3 Program Operation Flow Chart D-42
Figure 4 Sample Project Profile D-44
Figure 5 Sample Frequency Plot D-45
Figure 6 Sample Cumulative Probability Distribution D-46

Addendum D:1
GRANDUC Documentation

GRANDUC
Generalized Risk AND Uncertainty - Coastal

1. Introduction

GRANDUC is a group of numerical programs that estimates the benefits and costs associated with coastal storm damage reduction projects and provide a measure of the risk and uncertainty associated with them. The programs are driven by storm water elevation, the associated erosion distances, erosion volumes, and ground elevations. They calculate damages due to storm erosion, annual erosion (sea level rise, littoral sand deficits, etc.), inundation, and wave attack. Structure, contents, and land loss damages are determined along with nourishment costs. Present worth values for benefits and costs are calculated for each simulated life cycle. The life cycle storm data is generated by the Empirical Simulation Technique (EST). Armoring is modeled (if applicable) and an option to track all of the damages associated with one structure for one life cycle is available.

2. Data Requirements

The following is general information on data requirements for the programs. The specific information on running the programs is contained in the program documentation.

a. Project Reaches

The criteria for selecting reaches are as follows:

1) Straight Shoreline: The shoreline in each reach must be straight enough to satisfy the model assumption that the shoreline retreats uniformly.
2) Similar Beach Profile: The beach profile along the reach should not have large variations. This allows one set of storm response predictions to be applied to the reach.
3) Resolution: Long reaches make it difficult to determine the length of the project or how a limited quantity of sand should be distributed. Reach lengths of 500 to 1000 feet have been used satisfactorily.

Figure 1 is a sample reach that is 1000 feet long and contains 40 structures. A reference line and a shoreline are shown in the Figure 1. The reference line is the location from which the structure distances are measured, and the shoreline is the location from which the erosion is measured.

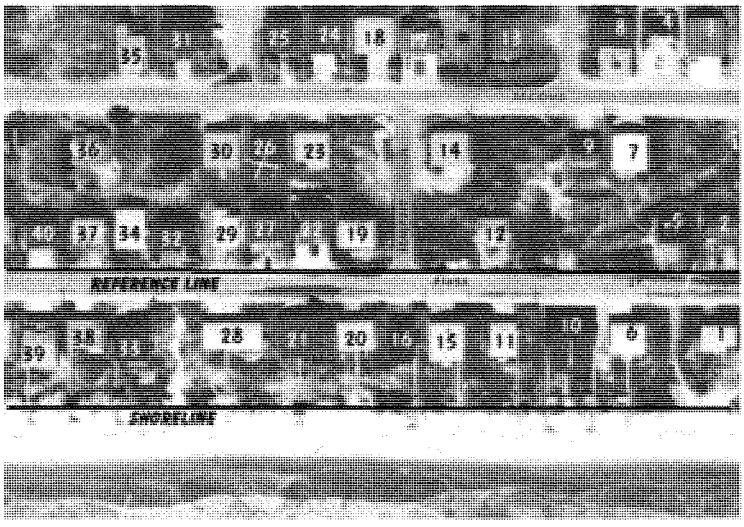


Figure 1. Sample Reach

b. Structure Database

The structure database contains the following information:

1) Reach Number
2) Structure ID
3) Distance from the Reference Line to the Ocean Front of the Lot
4) Lot Length
5) Lot Width
6) Distance from the Reference Line to the Front of the Structure
7) Structure Length
8) Attack Angle Ratio - this is the cosine of the angle between the lot orientation and the direction of erosion
9) Structure Type - determines which flood damage curve to use
10) Structure Value
11) Contents Value
12) Ground Elevation - at the structure
13) First Floor Elevation
14) Active Flag: +1 the structure is used in the damage calculations
-1 the structure is not used in the damage calculations
15) Erosion Type - determines which erosion damage curve to use
16) Armor Flag: +1 the structure is armored
-1 the structure is not armored
17) Erosion Indicator - indicates whether to use the 0.5-, 2.0-, or 4.0-foot erosion distances.

c. Life Cycle Storm Histories

Each of the 1000 life cycle simulations needs a sequence of storms and storm responses to be generated for it. These sequences are generated by the Empirical Simulation Technique (EST) which uses a historic storm data base, a storm response model such as SBEACH, and a multi-dimensional interpolation procedure to generate a multitude of new storm histories. The data generated for each storm is:

1) Simulation Number - the number of the life cycle to which the storm belongs (ranging from 0 to 999)
2) Life Cycle Year - the year in the life cycle in which the storm occurred
3) Erosion Distances – calculated using SBEACH; the landward most occurrence of 0.5-, 2.0-, and 4.0-foot vertical profile erosion measured from the specified shoreline reference.
4) Erosion Volume - the volume of sand eroded by the storm
5) Surge Elevation - the peak storm water elevation
6) Wave Setup - the nearshore setup as calculated in the Coastal Engineering Manual (formerly Shore Protection Manual)
7) Ground Elevation - the ground elevation at the erosion point

Table 1 contains a sample 50-year life cycle storm history.

Table 1. Sample Life Cycle Storm Histories

Simulation Nu	Life Cycle Year	Erosion Distance	Erosion Volume	Surge Elevation	Wave Setup	Ground Elevation
1	2	78	10.2	6.7	2.3	9.6
1	4	29	4.3	6.2	1.4	13.7
1	7	87	11.1	7.2	2.4	9.3
1	11	14	2.5	6.0	1.1	15.0
1	11	60	8.1	6.5	1.9	11.0
1	14	70	9.3	6.6	2.1	10.3
1	16	33	4.8	6.2	1.4	13.3
1	21	35	5.0	6.2	1.5	13.2
1	25	14	2.5	6.0	1.1	14.9
1	29	20	3.2	6.1	1.2	14.5
1	33	21	3.3	6.1	1.2	14.4
1	35	57	7.7	6.5	1.9	11.3
1	37	61	8.2	6.5	1.9	11.0
1	40	69	9.2	6.6	2.1	10.3
1	41	50	6.9	6.4	1.7	11.9
1	50	30	4.5	6.2	1.4	13.6
1	53	70	9.3	6.6	2.1	10.2

d. Global Data

The following data apply to all the reaches:

1) Run Title
2) The Number of Life Cycles to be Simulated
3) Interest Rate - the annual interest rate
4) Economic Period - the length of the life cycle
5) Base Year - the year to start the analysis. Storms that occur before the base year cause damage and can remove structures but the damages are not added to the output totals.
6) Total Initial Volume
7) Switches to Vary Erosion Distance, Structure Distance, and Structure Elevation - if a switch is on, the program will introduce some uncertainty into the calculations using a number selected from a distribution around the inputted number.
8) Nourishment Cycle in Years
9) Initial Benefits - such as benefits during construction
10) Annual Benefits - such as recreation
11) Initial Costs - construction, real estate, studies, etc.
12) Annual Costs - surveys, aerial photographs, and reports
13) Dredge Mobilization and Demobilization Costs - separate cost allowed for nourishment and renourishment, if different.
14) Costs Other than Dredging - separate cost allowed for nourishment and renourishment, if different.
15) ID of Structure to be traced - all of the damages incurred by this structure during the first life cycle will be stored in a file.
16) The Number of Reaches

e. Reach Data

The following data are repeated for each reach:

1) Reach Distribution - the portion of the initial volume applied to each reach; used to determine the fraction of the mobilization and other nourishment costs that should be applied to this reach.
2) Distance from the Shoreline to the Reference Line – erosion is measured from the shoreline and structures are measured from the reference line. This is a useful parameter when the project width shifts the shoreline seaward.
3) Long Term Erosion Rate for the Reach - this would be the rate calculated from historic data and is the result of all the different causes of erosion.
4) Annual Erosion Rate for the Reach - the erosion rate from non-storm related causes such as sea level rise.
5) Annual Volume Loss for the Reach - volume lost to non-storm related causes.
6) Storm Erosion Volume that Initiates Dune Repair - erosion volume associated with a storm that removes the dune. It is assumed that after a large storm some repairs to the dune, such as scraping or truck hauling, will take place.
7) Repair Volume - the volume needed to repair the dune.
8) Unit Repair Cost - the cost per cubic yard to repair the dune.
9) Unit Dredging Cost - dollars/cubic yard and does not include mobilization; separate cost allowed for nourishment and renourishment, if different.
10) Total Fill Placement Adjustment Ratio - overfill requirement and transport losses.
11) Land Value - dollars per square foot.
12) Reach Length
13) Parameters for Wave Attenuation - parameters relating drag losses and

obstructions.

14) Wave Zone - this is a 200 to 300 foot zone from the erosion line in which a wave reduction is applied for an effective row of structures. The wave reduction is calculated using all the structures located within this zone as a row of structures.

f. Flood Damage Curves

Two curves are given for each type of structure. One curve is for the structure damage and the second curve is for the content damage. The curves are the distance that the water is above or below the first floor elevation versus the percent damage. Figure 2 displays a sample curve.

g. Erosion Damage Curves

Two curves are given for each type of structure. One curve is for the structure damage and the second curve is for the content damage. The curves are a representation of the percent undermining of the structure (the ratio of the erosion distance under the structure over the structure length) versus the percent damage.

3. Program Operation

The program starts by reading the global data and damage curves. Next a reach loop is begun in which reach data is read and all of the simulations are performed on the structures in the reach before proceeding to the next reach. Then the data for the next reach is read and all of the simulations are repeated on this reach. The loop proceeds until all of the reaches are analyzed. See Figure 3.

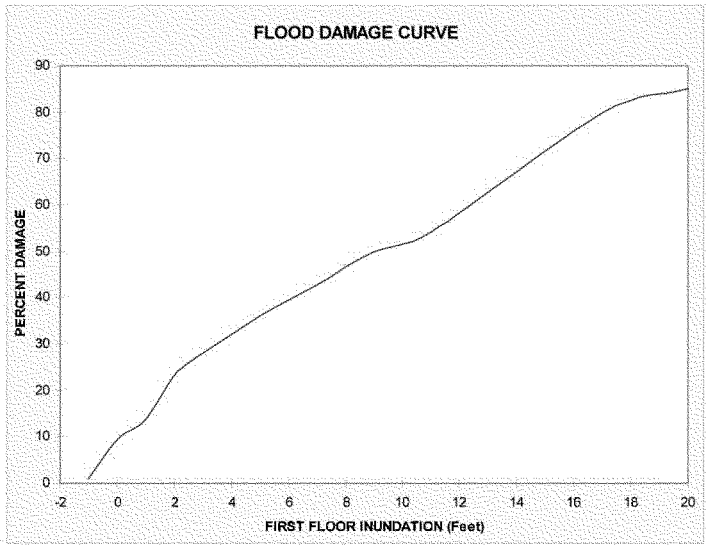


Figure 2. Sample Flood Damage Curve

At the beginning of the reach loop, the program reads in the long-term erosion data and the parameters used in calculating the flood profile. The structure is read in and the random number generators are reset.

The program then begins the life cycle simulation loop. Damage values are set to zero and all parameters are set to their initial value. All storms associated with this life cycle are then read in and for the without project runs the net storm erosion recovery factor is calculated as follows:

$$NetStormErosionFactor = \frac{(LongTermErosion - AnnualErosion)\ x\ LifeCycleDuration}{CumulativeStormErosion}$$

This equation forces the net storm erosion to be consistent with the observed long-term erosion rate. Project runs require this parameter to be entered as input data. Project profiles may have a different recovery factor, however, the average of the calculated net storm erosion values is printed out and can be used if other information is unavailable.

The program then enters a year loop. At the beginning of the loop all structures that can be repaired are restored to their original value. The program checks if there has been storm. If there has been a storm, the erosion value is varied if this option was chosen. The flood profile is calculated by going to the point of erosion and using the storm surge, wave setup, and ground elevation to calculate the water depth and largest wave that can exist at that point. The wave height and wave setups are then reduced at landward points on the profile using the drag coefficient and obstruction parameters read in for the reach. In order to calculate the wave reduction due to a row of structures, the structures are sorted according to distance from the reference line. The structure distances are then summed until the distance between two structures is greater than the row distance parameter. If a distance is greater than the row distance parameter, then the distances of the previously summed structures are averaged and a wave reduction factor is applied. This procedure continues until all structures are checked. Since most of the wave activity can happen in the first couple of hundred feet of the erosion point and structures can be staggered which could prevent the row distance from being exceeded, a wave reduction is calculated using the structures located in the wave zone as defined by the input parameter wave zone. The wave crest is used to define the flood profile. A wave impact profile is defined for areas where the wave height exceeds 3 feet and is two feet below the wave crest.

Having calculated the storm characteristics, a structure loop is begun. Erosion, flood, and wave damages are calculated for each structure. The maximum of these damages is multiplied by a present worth factor and is added to a cumulative variable. However, if the life cycle year is earlier than the base year, no damages are recorded. If the structure is armored, erosion is stopped at the armor line until the armor is outflanked. The value of the structure and its contents is reduced by the maximum storm damage amount. This is done to prevent double counting in case there are multiple storms in one year or if at the end of the year the structure is lost to long term erosion. Structures totally destroyed are assumed to be replaced only once during a life cycle. Future damages to these replacement structures for the remainder of the life cycle are based on updated erosion and flood damage curves appropriate for the replacement structure.

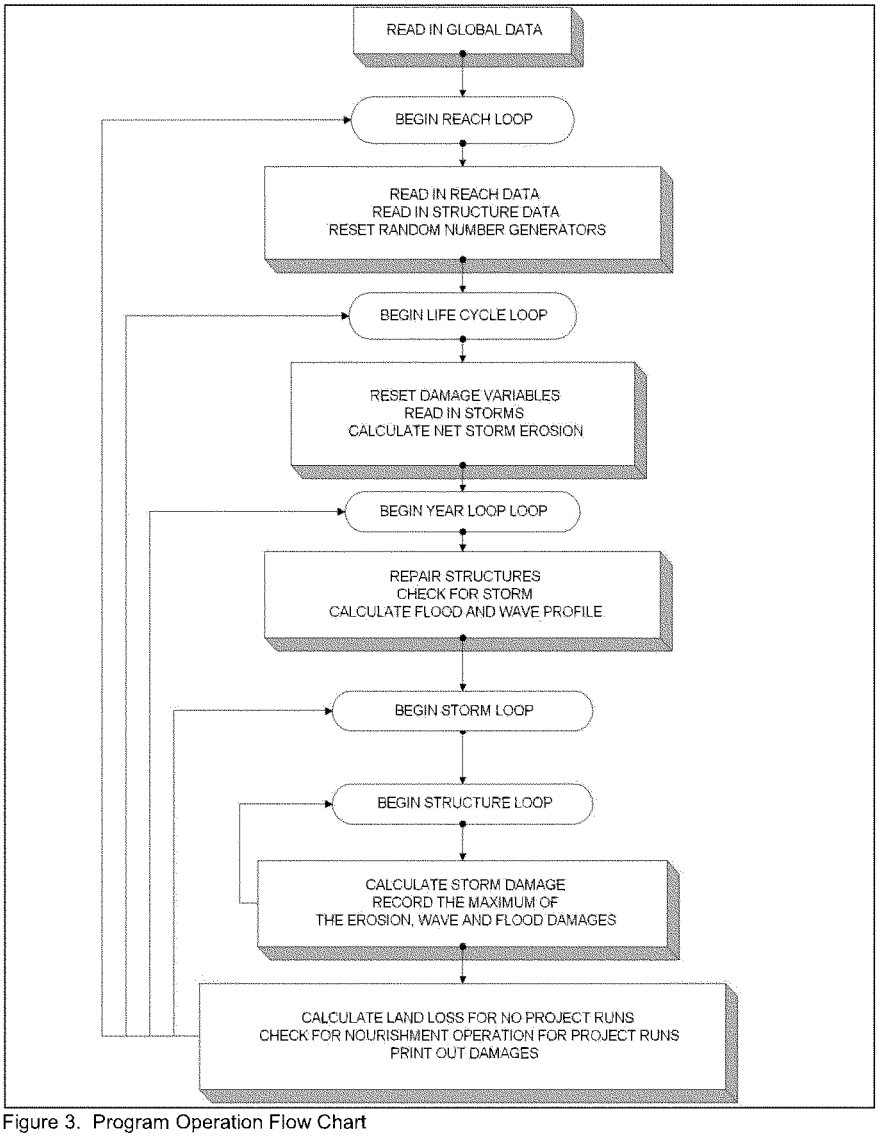


Figure 3. Program Operation Flow Chart

At the end of the year loop, the shoreline is adjusted for net storm erosion and annual erosion. Land losses are calculated and undermined structures are made inactive. At the end of each life cycle, the total damage is printed out.

Runs with projects differ from base condition runs in that there is no land loss and there is a periodic nourishment cycle. At the end of each periodic nourishment cycle, annual and storm erosion damage is repaired. During the periodic nourishment cycle, only minor repairs are made to the project after major storms that reduce project protection by causing the shoreline to retreat. The output for project runs includes project costs, partial benefits, and damages.

A separate program compares the damages from a project run and the base run to calculate benefits and outputs a probability versus net benefits table. Figure 4 contains a sample project profile, which was applied to the reach shown in Figure 1. Runs with and without the project are made and compared. Sample results for the first 15 life cycles are shown in Table 2.

Table 2. Partial Results for the Sample Project

Benefits	Costs	BCR	Net Benefits
1,758,779	723,043	2.43	1,035,736
1,922,766	710,440	2.71	1,212,326
1,758,698	714,167	2.46	1,044,531
2,699,991	783,825	3.44	1,916,166
1,662,882	714,438	2.33	948,444
1,859,573	710,070	2.62	1,149,503
2,672,781	724,054	3.69	1,948,727
1,942,507	70,8590	2.74	1,233,917
1,091,978	696,686	1.57	395,292
1,942,585	716,308	2.71	1,226,277
761,246	675,450	1.13	85,796
971,021	666,249	1.46	304,772
790,800	685,589	1.15	105,211
1,450,528	715,683	2.03	73,4845
1,041,401	683,001	1.52	358,400
1,880,998	710,466	2.65	1,170,532

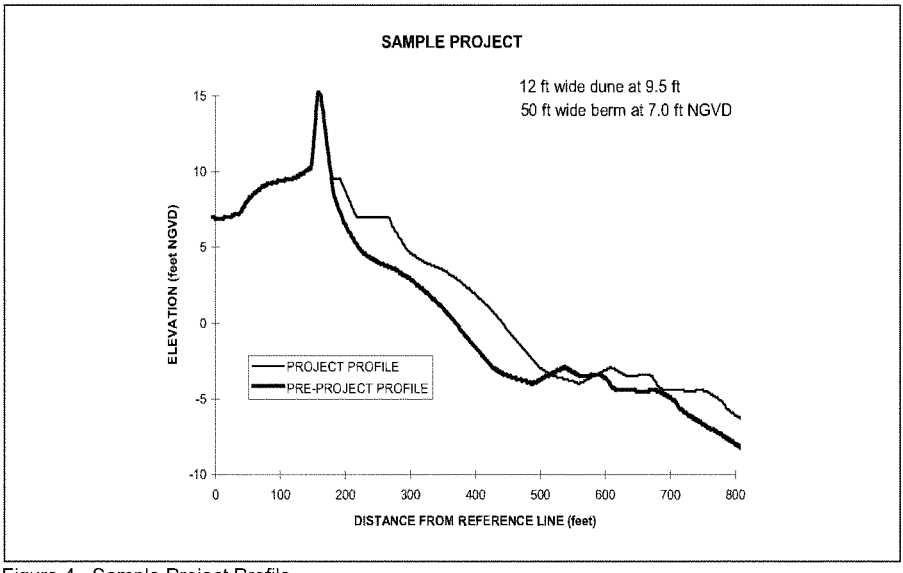


Figure 4. Sample Project Profile

Figure 5 is a sample frequency plot of the net benefits output for 7,000 life cycles. The range of the net benefit outputs was divided into $50,000 intervals. The number of times a net benefit result occurred within an interval was tallied to produce the frequency plot. The frequencies in Figure 5 can be converted into probabilities by dividing them by the total number of life cycles. The probabilities can then be totaled to produce a cumulative probability distribution as shown in Figure 6. There are some negative net benefits results in this sample. These negative net benefits result from life cycle simulations in which there are few storms and no years in which there are more than one storm. It is difficult to read the probability from the graph but the data for this sample shows that there is less than a 3% chance that the net benefits will be negative.

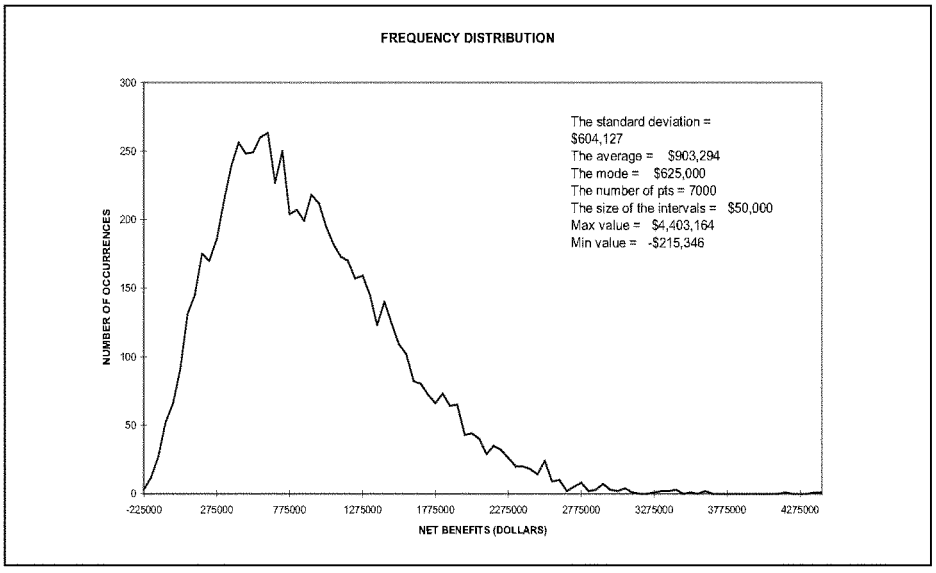


Figure 5. Sample Frequency Plot

4. Recent Model Enhancements

Significant enhancements made to the model since the Alternative Formulation Briefing have had a significant impact on plan formulation. These changes are summarized below.

a. Storm Responses

GRANDUC has been revised to allow for a secondary set of storm responses to be triggered for the remainder of a renourishment cycle, at

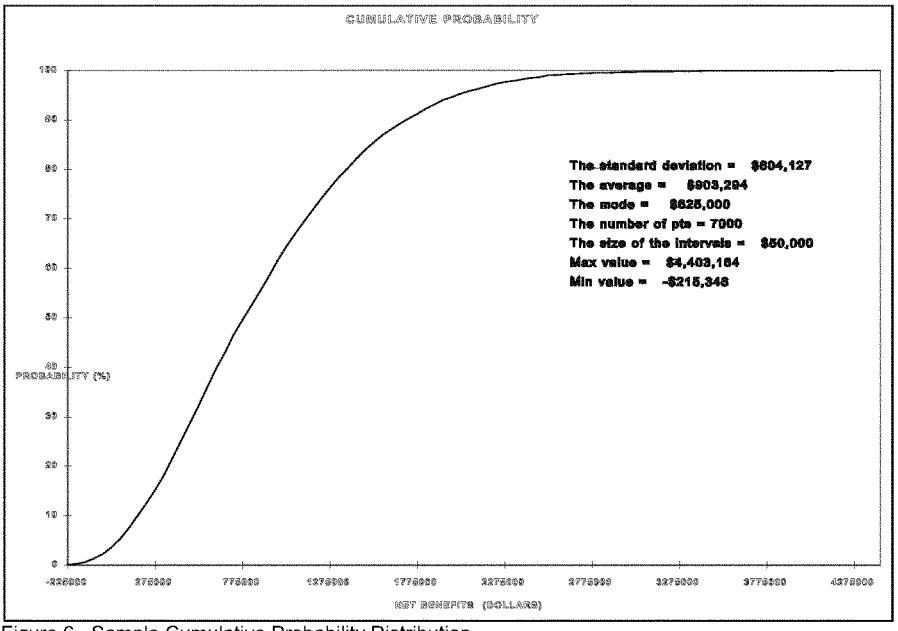


Figure 6. Sample Cumulative Probability Distribution

which time GRANDUC would revert then back to the primary set of storm responses. This allows for a switch-over from the primary "beachfill" responses to the secondary "existing condition" responses, triggered by either an erosion distance or a storm erosion volume. First, this allows for GRANDUC to more realistically model the diminished shore protection following major storm damage until the project template can be re-established during the subsequent renourishment. Second, since the "existing condition" at Surf City and North Topsail Beach is basically that of a reconstructed dune (following the extensive damage of hurricanes in the late 90s), switching over to these secondary responses allows GRANDUC to simulate this interim dune rebuilding as part of its operating scheme.

b. Structure Replacement

Previous versions of GRANDUC allowed for structures that were taken out by storm damage to be replaced multiple times with an identical structure, as long as the structure was not taken out by long-term erosion. GRANDUC has been revised to incorporate the following more realistic criteria:

- Structures are replaced only if adequate buildable lot depth remains (100-foot minimum distance from back of lot).
- Only one structure replacement per lot is allowed.
- Residential structures taken out by storm damage are replaced with new residential structures that conform to the latest building codes. While the replacement structures have a higher value, they are also more resistant to storm damage, which will be reflected in their revised erosion damage curve.

- Non-residential structures are replaced with structures of the same type and value, however, the first-floor elevation will be set at "ground" plus 10 feet. This assumption will exceed the 100-yr storm surge elevation and it is predicated on actual current building practices. Revised erosion damage curves will limit total structure damages to 20 percent maximum and only when the erosion indicator is 100 percent through the structure footprint.

5. Surf City and North Topsail Beach GRANDUC Input

a. Global Data

1) **Number of Life Cycles**: To achieve model stability, 1000 life cycles were simulated.

2) **Interest Rate:** An interest rate of 4.125% is used for this analysis.

3) **Economic Period:** A 50-year length of life cycle is used.

4) **Base Year:** The base year for GRANDUC analysis is the first year the project is in place. Adjustments were made to the shoreline and structure database to reflect project in-place conditions.

5) **Uncertainty**: Uncertainty was introduced into the model via three variables: erosion distance, structure distance, and first floor structure elevation. A variance of ± 5 feet is used for erosion distance, ± 2 feet for structure distance, and ± 0.1 feet for first-floor structure elevation.

6) **Nourishment Cycle:** A 6-year periodic nourishment cycle is used.

7) **Initial Benefits:** No initial benefits were included in the GRANDUC analyses.

8) **Initial Costs, Annual Costs, Dredging Mobilization and Demobilization Cost during Nourishment:** Study team members provided cost input data.

b. Reach Data

1) **Reaches:** The contiguous main portion of the Surf City and North Topsail Beach study area was subdivided into a total of 52 reaches—each of these reaches were approximately 1000 feet in length, except the southernmost reach at the Topsail Beach/Surf City town limit, which was about 1300 feet in length. The two smaller, separate non-CBRA areas in the northern end of North Topsail Beach both had lengths of less than 2000 feet and each was subdivided into two smaller reaches of varying lengths.

2) **Shoreline and Reference Line:** The existing mean high water line (+2.1 feet-NGVD) was used as both the shoreline and the reference line. Erosion is measured from the shoreline and structure setbacks are measured from the reference line.

3) **Long Term Erosion Rates:** For pre-project (base) conditions, long-term erosion rates were computed using historic surveys. For project conditions, long-term erosion losses were calibrated using the Planform Evolution Model.

4) **Annual Erosion:** An annual erosion rate of 0.2 feet per year was used to represent losses due to sea level rise.

5) **Dune Damage and Repair:** Scraping costs of $2.00 per cubic yard were input to the model to account for emergency repairs that may occur following severe storms.

6) **Unit Dredging Cost:** Initial construction dredging costs (assuming hopper dredging) varied slightly by reach from about $7.84 to $10.02 per cubic yard (depending on the particular borrow area), averaging about $8.38 per cubic yard. For the periodic renourishments, a slightly higher average dredging cost of about $9.20 per cubic yard was used.

7) **Total Fill Placement Adjustment Ratio:** Overfill ratios ranged from 1.15 to 1.19 (depending on the particular borrow area) for initial construction analysis. During periodic renourishment, overfill ratios averaged 1.21.

8) **Land Value:** An updated land value of $25 per square foot was used throughout the study area.

c. Life Cycle Storm Histories

1) **Erosion Distance:** Erosion distances for 0.5-, 2.0-, and 4.0-foot vertical erosion were determined using the SBEACH model.

2) **Surge Elevation and Wave Setup:** Surge elevation is the peak storm water elevation, and wave setup is the increase in nearshore water surface elevation due to wave action alone. Surge elevation and wave setup for each typical profile for 1-year to 500-year recurrence intervals were determined using EST analysis of SBEACH output.

d. Structure Database

The Economics Section of the Wilmington District developed all input data to the structure database. Most of the information in the database was determined by measuring distances from available project area GIS mapping. These measurements included distance from the reference line to the front of the lot and structure, lot width and length, and structure length. Values also had to be assigned to each structure for the following:

1) **Structure Type** selection determines which flood damage curve (piling, slab, etc.) is assigned to a given structure.
2) **Structure Value** is based on replacement value less depreciation.
3) **Content Value** is normally computed as a percentage of the structure value.
4) **Ground Elevation** (at the structure) was taken from field surveys and March 2002 contour mapping of the study area.
5) **First Floor Elevation** for each structure was taken from surveys.

The actual structure file is included in *Appendix B: Economic Analysis*, along with a detailed discussion of all structure-related inputs.

e. Flood Damage Curves

For each type of structure in the study area, flood damage curves were developed for both the structure and contents. Damages for each structure are tied to the first-floor elevation. A total of 65 flood/inundation type curves were selected by the Economics Section of the Wilmington District to present all the structures in the study area.

f. Erosion Damage Curves

For each type of structure in the study area, erosion damage curves were developed for both the structure and contents. A total of 34 erosion damage curves were selected by the Economics Section of the Wilmington District to represent all the structures in the study area. A more detailed description of the erosion damage curves is provided in *Appendix B: Economic Analysis*, along with the actual erosion damage curves.

Addendum D:2
Sea Level Rise Sensitivity Analysis

1. Introduction

The purpose of this sensitivity analysis is to verify that the project purpose of storm damage reduction is maintained even with accelerated sea level rise (SLR). SLR estimates are derived from historical trends in local mean sea level. Tidal records from nearby National Ocean Service (NOS) tidal station in Wilmington, NC (No. 865810) is about 0.008 feet per year from 1953 to 1993. The risk and uncertainty analysis for the scoping, optimizing and selection process included the historical sea level rise (SLR) as a function of constant shoreline change rates (0.3 ft/yr of shoreline recession). Because recent climate research predicts possible accelerated rise in global sea level, it is also important to look at the impacts and sensitivity of much greater SLR. This addendum describes the process to examine the sensitivity of the selected plan to an accelerated rate of SLR.

U.S. Army Corps of Engineers, Engineering Circular, EC 1165-2-211 provides the guidance for considerations of accelerated SLR in Civil Works programs. The guidance uses the updated National Research Council (NRC) projections (updated from 1987) as well as using the Intergovernmental Panel on Climate Change (IPCC 2007b) Fourth Assessment Report guidelines. These guidelines were used to bracket a range of possible SLR for the Surf City & North Topsail Beach area. In order to investigate the sensitivity of the selected plan to sea level rise, modified-NRC Curves 1 and 3 were used to bracket estimates in SLR. Curve 1 projection indicates a SLR of 0.8 feet 50 years after construction (year 2064), while Curve 3 indicates 2.2 feet of SLR in 2064. For comparison, the historic SLR rate projects about 0.4 feet of SLR in 2064. (see Figure D:2 - 1)

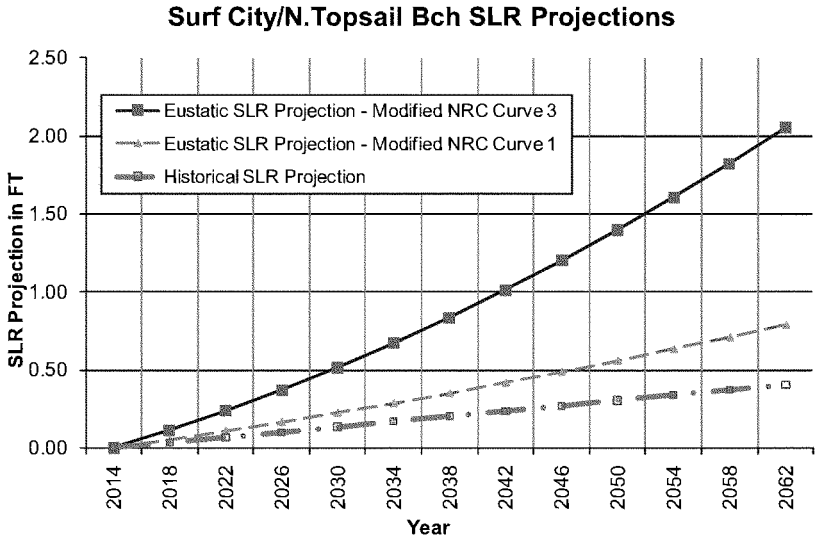


Figure D:2 – 1 Surf City & North Topsail Beach SLR Projections

2. Beach Profile Storm Response Sensitivity

The approach to simulating various SLR rates for the Surf City/North Topsail Beach project involved investigating the sensitivity of storm response changes due to SLR. According to the Bruun Rule (Bruun, 1962), as sea level rises, the beach profile will attempt to reestablish the same bottom depths relative to the surface of the sea that existed prior to sea level change. In other words, the natural profile will be translated upward and shoreward to maintain equilibrium (the beach berm rises).

In order to check the sensitivity of storm responses to a raised berm, storm responses of the original proposed project berm profile were compared with those of a proposed project with a raised berm. Two typical profiles from the project area were selected representing a healthy dune system and a weaker dune system. The original design template was modeled along with a modified template with a raised berm. Both large and moderate storms were selected for the simulation. SBEACH runs were made on the modified (raised berm) profile and compared with storm responses for the original profile. Figure D:2 - 2 shows typical graphical profile output from SBEACH for one of the runs. Results for all of the sample runs are tabulated in the below Table D:2 - 1. Results indicate that the storm responses are not significantly sensitive to the higher berm elevation.

Sample SBEACH Pre- and Post-Storm Profiles (Original & Raised Berm)

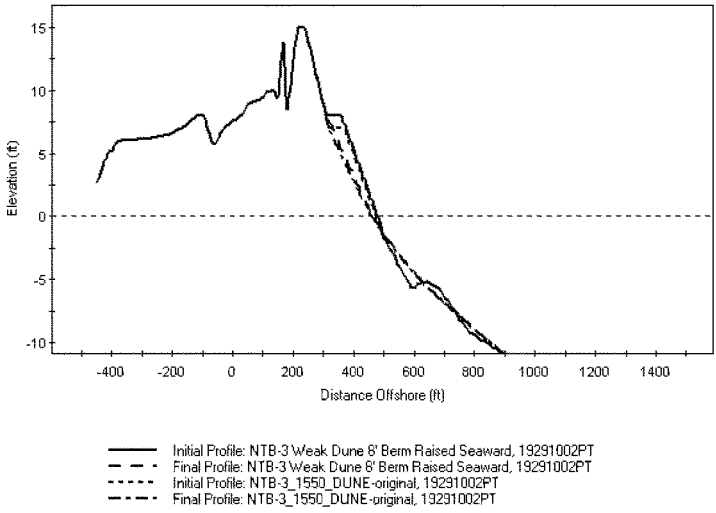


Figure D:2 - 2 – Sample SBEACH Profiles for Storm Response Sensitivity

Results of SBEACH Runs on Selected Storms & Profiles to Examine Beach Project Storm Responses of a Higher Berm due to Rise in Sea Level

Selected Storms and Profiles Tested	Volume Change (cy/ft)	Max H20 elev + setup (ft)	Max Runup elev (ft)	Position 0.5' Eros (ft) *	0.5' Eros Dist (ft) **	Position 2.0' Eros (ft) *	2.0 Eros Dist (ft) **	Position 4.0' Eros (ft) *	4.0 Eros Dist (ft) **	Max Recession of 0' contour (ft)	Max Recession of 2.1' contour (ft)	Max Recession of 7' contour (ft)
1929 storm												
NTB-3 Original	-1.5	8.23	10.66	331	111.5	356	86.5	n/a	n/a	17.69	29.69	47.37
NTB-3 Berm Raised 1'	-1.5	8.36	10.63	326	121.5	351	96.5	n/a	n/a	19.45	31.39	44.74
SC-2 Original	-1.5	8.23	10.45	265	102.5	295	72.5	n/a	n/a	6.83	19.56	42.95
SC-2 Berm Raised 1'	-1.5	8.33	10.46	255	117.5	285	87	n/a	n/a	7.81	20.95	36.3
1954 storm												
NTB-3 Original	0	15.79	18.11	56	386.5	151	291.5	166	276.5	3.02	12.46	32.92
NTB-3 Berm Raised 1'	0	15.89	18.84	51	396.5	156	291.5	166	281.5	4.2	12.8	34.88
SC-2 Original	0	16.25	19.69	50	317.5	n/a	n/a	n/a	n/a	1.99	5.44	32.22
SC-2 Berm Raised 1'	0	16.25	19.64	50	322.5	n/a	n/a	n/a	n/a	2.72	6.73	30.91
1960 storm												
NTB-3 Original	-0.1	11.8	14.25	346	96.5	n/a	n/a	n/a	n/a	11.53	23.22	33.32
NTB-3 Berm Raised 1'	-0.1	11.825	14.16	341	106.5	n/a	n/a	n/a	n/a	13.47	24.91	28.32
SC-2 Original	-0.1	11.8	14.15	275	92.5	n/a	n/a	n/a	n/a	3.01	14.3	30.85
SC-2 Berm Raised 1'	-0.1	11.81	13.95	270	102.5	n/a	n/a	n/a	n/a	3.76	15.42	20.23
1999 storm												
NTB-3 Original	-1.8	15.86	18.88	-149	591.5	41	491.5	161	281.5	6.29	17.74	85.49
NTB-3 Berm Raised 1'	-1.8	15.95	19.95	-174	621.5	-94	541.5	161	286.5	7.17	17.41	58.66
SC-2 Original	-1.7	16.75	20.86	25	342.5	45	322.5	n/a	n/a	0	7.8	30.42
SC-2 Berm Raised 1'	-1.7	16.73	20.87	25	347.5	45	327.5	n/a	n/a	0	9.11	30.73

* Position of landward most occurrence of xx ft. erosion depth
** Distance from position of reference elevation on initial profile to position of landward most occurrence of a xx ft erosion depth

Table D:2 - 1 – SBEACH Results

3. Shoreline Recession Due to Sea Level Rise

With a rise in sea level the beach berm will rise and the beach profile down to the depth of closure will adjust to the rise in sea level. The volume of sand needed for the profile adjustment will cause the beach to erode (Bruun Rule). Additionally, it is expected that the storm surge elevations of the accelerated SLR modeled storms would increase relative to those storm surge elevations originally modeled using historical SLR. To simulate the increase in storm surge elevation, the storm input used for the GRANDUC program was adjusted to reflect the increased storm elevations and therefore more frequent occurrence of all storm parameters.

The erosion rates input to GRANDUC required adjusting due to sea level rise. The Bruun Rule was applied to make adjustments to simulate accelerated SLR. As stated by Bruun, with a rise in sea level the storm berm will rise, and erosion of the shoreline will occur to make up sand volume needed for the higher storm berm. The quantity of material required to re-establish the nearshore slope must come from erosion of the shore (assuming longshore littoral transport in and out of the shoreline is equal). Bruun developed an equation to estimate shoreline recession, X, resulting from SLR.

$$X = S\,L\,/\,(h + B)$$

Where S is sea level rise, L is the width of the active profile (distance from depth of closure (B) to top of berm) and h is elevation of berm. In this case, L = 1,100 ft, h = 7 ft, and B = 23 ft. The resulting shoreline recession varies from 0.3 ft/yr, to 0.6 ft/yr, to 1.6 ft/yr for historical, modified-NRC Curve 1, and modified-NRC Curve 3 rates, respectively.

4. GRANDUC Simulations With Sea Level Rise

Sea level rise-adjusted shoreline erosion rates and sea level rise-adjusted storm input parameters were applied to GRANDUC for various SLR cases, with and without beach project, and output was compared with the selected plan output. Cost levels and interest rates were kept consistent with those of the initial plan selection analysis. Instead of the gradual increase of sea level as shown in Figure 1, these GRANDUC runs assumed a simplified, but worse-case scenario in that the erosion rates and storm response files were stepped immediately to the full extent of SLR. A range of total SLR values were tested. These values included 0.8' and 2.2' which correspond to modified-NRC Curves 1 and 3, respectively. Results are shown below in tabular and graphic form (see Table D:2 - 2 and Figure D:2 - 3)

The economic values, both costs and estimated damages over the period of analysis, are discounted to the present value using the same interest rate for all conditions. The amounts calculated in the GRANDUC model and shown in the comparative tables represent the accumulated present value of all amounts over the period of analysis. These values are valid for comparison purposes. In the feasibility report, however, values are converted to average annual equivalent amounts. The relative comparison of alternative SLR scenarios remains the same with both approaches. As present-worth economics is used in GRANDUC analyses, the worse-case scenario economics results are much more extreme compared to the present-worth results of a SLR that occurs gradually over 50 years.

Results show that the net benefits of a shoreline protection project increase as sea level rises. With any degree of SLR the without-project damages are on average six-times the with-project damages. For a SLR from 0.4 ft (historical projection) to 0.8 ft (modified-NRC Curve 1) the without-project damages increase $153 M while the with-project damages increase only $22 M. Estimated increase in with-project costs for the same SLR comes to about $19 M. Although costs increase as the renourishment volume increases with 0.8 ft of SLR, the damages prevented are about eight-times greater than the cost increase.

If projecting a 2.2 ft SLR using modified-NRC Curve 3, the without-project damages increase $497 M while with-project damages increase $91 M. With total cost increase estimated at $52 M, damages prevented are over nine-times greater than the cost increase.

Summary of Sea Level Rise GRANDUC Output						
	W/O Project Damages ($1,000)	With Project Damages ($1,000)	Benefits ($1,000)	Costs ($1,000)	Net Benefits ($1,000)	B/C Ratio
Selected Plan with historical SLR included	$400,852	$47,131	$353,722	$218,069	$135,653	1.6
Selected Plan with 0.8 ft SLR (NRC Curve 1)	$554,075	$69,489	$484,586	$237,286	$247,300	2.0
Selected Plan with 2.2 ft SLR (NRC Curve 3)	$897,554	$138,360	$759,194	$270,523	$488,671	2.8
Note: GRANDUC output not updated with most up to date benefits - no recreation benefits, etc.						

Table D:2 - 2 – Summary Table of Sea Level Rise GRANDUC Output

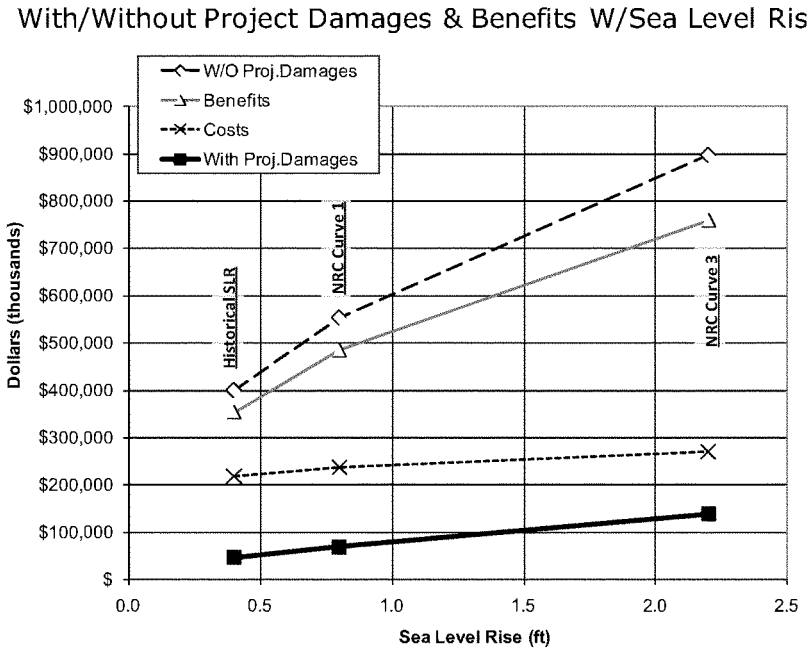


Figure D:2 – 3 – With/Without Project Damages & Benefits W/ Sea Level Rise

The proposed beach nourishment project is not a hard structure and adjusts to natural forces. Regardless of the rate of SLR, the beach fill project is monitored annually and renourished every 6-years. Monitoring data provides input to determining the details of each renourishment of the beach. If an accelerated SLR occurs, erosion volumes increase and renourishment volumes will increase, increasing borrow requirements and increasing renourishment costs. Total project costs output by the model show a cost increase of 24% (using the most extreme estimate of SLR in 50 years) but the project provides an additional 115% of damage reduction benefits. Note that limitations of the model require the SLR to be applied immediately, therefore the erosion volumes and costs would rise more slowly over the 50-year project life.

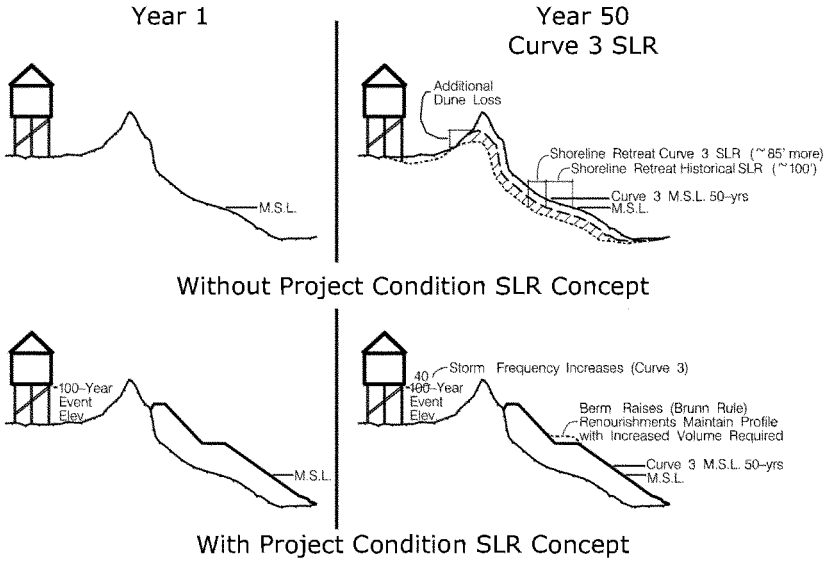


Figure D:2 – 4 – Conceptual Sketches Showing Effects of SLR With/Without Project

The figure above (D:2 – 4) shows how accelerated SLR affects the with and without project condition. Without the project the increased erosion and more frequent intense storms cause undermining and direct wave attack to structures. Also more structures further back from the retreated dune are subjected to damage. With the project damages increase at a rate much less than without the project. The beachfill template is maintained with renourishments and continues to provide damage reduction. Additional volume will be required but cost increases are expected to be much smaller than 24% (due to overestimation by the modeling).

5. GRANDUC Estimates of Additional Renourishment Volume due to SLR

Additional erosion volumes due to SLR increase the 6-year renourishment requirements. Output from GRANDUC simulations includes an estimate of the anticipated average 6-year renourishment volume. This output data was collected and analyzed to determine total renourishment material volume requirements. As mentioned in section 4, the simulations assumed a worse-case scenario of immediate full extent of SLR. Therefore the GRANDUC average renourishment volumes output are greatly overestimated if accumulated over the 50-year project life. For this analysis of total volume requirement, renourishment volumes were assumed

to vary linearly over the 50-year project life (also a more conservative assumption than the SLR projection curves). The initial renourishment volume is assumed to be from historical SLR and increases linearly until reaching the average renourishment volume for that scenario of SLR (see Figure D:2 - 5).

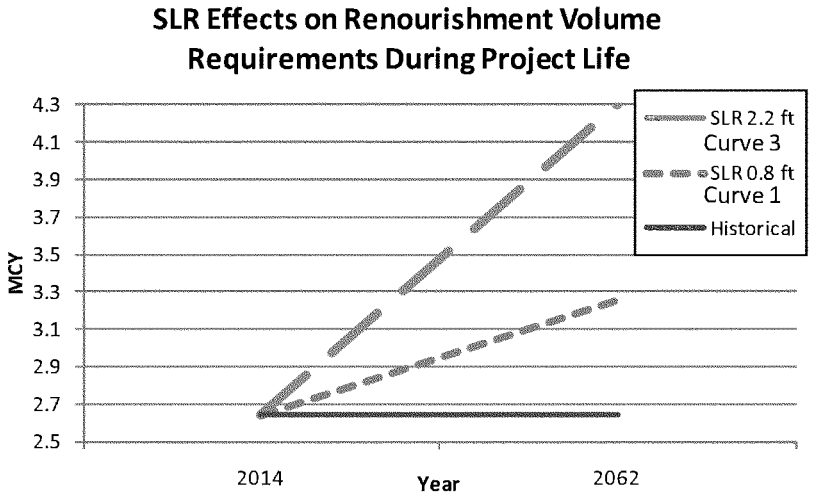


Figure D:2 – 5 – SLR Effects on 6-yr Renourishment Volume Requirements During Project Life

Estimated increase in total cumulative renourishment volume requirements range from an increase of about 2.6 MCY for SLR of 0.8 ft to an increase of about 7.2 MCY for SLR of 2.2 ft. Discussion of the effects of the increase of volume requirements can be found in the main report.

References:

Bruun 1962
Bruun, P.M (1962) Sea-Level Rise as a Cause of Shore Erosion. *Journal of Coastal Engineering*, vol. 7, no. 1, p. 77-89

National Research Council 1987
Responding to Changes in Sea Level: Engineering Implications. National Academy Press: Washington, D.C. http://www.nap.edu/catalog.php?record_id=1006

U.S. Army Corps of Engineers, Engineering Circular, EC1165-2-211
Water Resource Policies and Authorities Incorporating Sea-Level Change Considerations in Civil Works Programs – 1 July 2009

Addendum D:3
Dredging Research Program, Storm Surge Database and Recent Hurricane Modeling

1. Introduction

The tropical storm database, consisting of surge elevation and current hydrographs corresponding to selected WIS and nearshore stations along the east and Gulf coasts of the United States and Puerto Rico, was developed as part of the Dredging Research Program (Scheffner and others, 1994). The database was constructed by numerically simulating 134 historically based hurricanes that have impacted the eastern and Gulf coasts of the United States during the period 1890 to 1990. The source of data for these simulations is the National Oceanic and Atmospheric Administration's National Hurricane Centers HURDAT (HURricane DATabase), described by Jarvinen, Neumann, and Davis (1988).

Wave Information Study (WIS) stations were utilized for storm surge data. Significant tropical events were extracted from the database based on storm surge values exceeding select threshold conditions. For the 100-plus years of coverage, 37 events were identified using a minimum storm surge threshold of 1 ft. In addition to the tropical storm surge database, extratropical storm surge values were calculated for the same locations for the dates from 1976 to 1993. Instead of the storm specific time series, a continuous hourly time series was developed for the non-tropical season times of the year (September through March). Discrete event time series were extracted from the continuous time series using a combination of storm surge and wave height threshold criteria along with visual analysis to identify the start/stop times. There were 23 extratropical events identified over the 16-years of data coverage.

2. Recent Hurricane Storm Surge Modeling

The magnitude of the recent hurricanes to impact North Carolina since the mid-1990's required the storm surge database to be updated. Generation of hurricane storm surge values required two major tasks, each using a numerical model. In the first task, hurricane-induced wind and atmospheric pressure fields are generated to replicate those hurricanes (Bertha, Fran, Dennis, Floyd, Bonnie and Irene) that have impacted the study area. Using these wind and pressure fields, storm-surge events are simulated in the second task using a long-wave hydrodynamic model to obtain water-surface levels.

Wind and Atmospheric Pressure Model

The Planetary Boundary Layer (PBL) wind field model was selected for simulating hurricane-generated wind and atmospheric pressure fields. The PBL hurricane wind model requires a series of "snapshots" for input consisting of a set of meteorological storm parameters defining the storm at various stages in its development or at particular times during its life. These parameters include latitude and longitude of the storm's eye, track direction and forward speed measured at the eye, radius to maximum winds, central and peripheral atmospheric pressures, and an estimate of the geostrophic wind speed and direction. Some meteorological storm parameters were obtained from the hurricane database developed by the National Oceanic and Atmospheric Administration (NOAA)'s National Hurricane Center (NHC). This database summarizes all hurricanes and tropical storms that occurred in the North Atlantic Ocean over the 104-year period from 1886 through 1989. Information contained in this database is provided at 0000, 0600, 1200, and 1800 hr Greenwich Mean Time (GMT) and includes latitude and longitude of the storm, central pressure, and maximum wind speed. Radius to maximum winds is approximated using a function that incorporates the maximum wind speed and atmospheric pressure anomaly. Track directions and forward speeds required by the PBL model are approximated hourly, using cubic

spline interpolation technique, from the storm's 6 hr latitudinal and longitudinal positions provided in the database.

Hourly wind and atmospheric pressure fields are computed for each snapshot and interpolated using a nonlinear blending algorithm that produces a smooth transition from one snapshot to the next. Hourly wind and pressure fields are then interpolated from the PBL grid onto the hydrodynamic grid and subsequently stored for use by the hydrodynamic model.

Storm Surge Model

The ADvanced CIRCulation (ADCIRC) numerical model was chosen for simulating the long-wave hydrodynamic processes in the study area. Imposing the wind and atmospheric pressure fields computed with the PBL model, the ADCIRC model can accurately replicate hurricane-induced storm-surge levels. The ADCIRC model was developed in the USACE Dredging Research Program (DRP) as a family of two-and three-dimensional finite element-based models (Luettich, Westerink, and Scheffner 1992; Westerink et al. 1992).

ADCIRC is a finite element long-wave hydrodynamic model applied for simulating water-surface elevation and circulation over the entire model domain as a function of tidal forcing, freshwater inflow, wave stress forcing, and wind forcing. The finite element formulation has the advantage of great flexibility in resolution over the calculation domain. Coarse resolution can be specified in areas distant from the local region of interest, and fine resolution can be specified locally to meet project requirements. For instance, channels and structures can be defined for accurate calculation of flow through and around them.

The basis for the model bathymetry was an ADCIRC grid developed by the Corps of Engineers Waterways Experimental Station for the North Atlantic Ocean and the East Coast of the United States. The grid was modified to include only the areas of interest for this project. A finite element mesh was developed for the modeled area, as shown in Figure D:3 - 1.

The recent storms (Bertha, Fran, Dennis, Floyd, Bonnie and Irene) were simulated with the storm-surge model. Starting and ending times of each storm simulation corresponds to the first and last entry contained in the NHC database for that particular storm. Furthermore, each storm-surge simulation began with the hurricane residing at its initial position listed in the database and concluded at its ending position. Thus, each simulation began when the hurricane was far away from the study area. For all hurricanes, a temporal "ramp" was used to slowly increase, over a 1-day period, wind stresses and pressure gradients from zero to their measured intensity. Using this ramp eliminates spurious modes of oscillation caused by suddenly imposing full-force winds and pressure gradients on the flow field.

All storm-surge simulations were performed independently of tidal action, eliminating the task of extracting surge levels from a time-series of combined tide-and surge-induced water-surface elevations. Figure D:3 - 2 displays surge values at select output locations for the Hurricane Fran simulation. Astronomical tide conditions were generated for each event using NOS derived tidal constituents at Triple S Pier and combined with storm- surge values to produce a Total Water Level (TWL) time series. The TWL served as input into SBEACH for storm-induced beach profile response modeling.

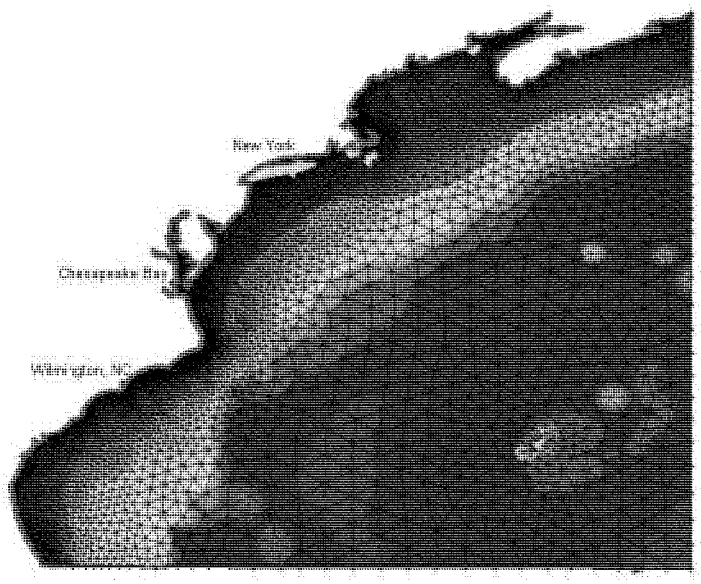


Figure D:3 – 1 - ADCIRC Model Domain

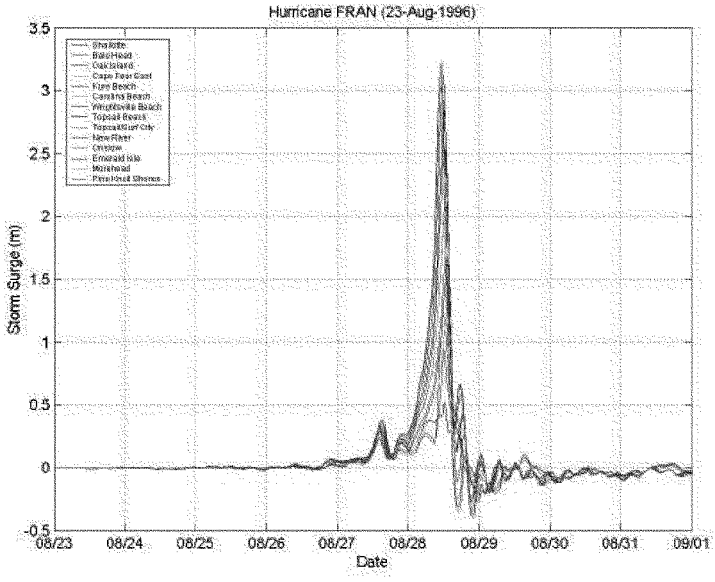


Figure D:3 – 2 - ADCIRC Model Output for Hurricane Fran Simulation

Storm-surge elevations computed in this task can be considered as approximations of the historical events. Although the frequencies associated with their maximum surge may be considered relatively accurate, the value of the peak surge may not correspond to historically observed surge elevations. The hydrographs should therefore not be considered hindcast of the historical events due to the fact that the hurricane parameters estimated from the storm database are only approximate; all information necessary to numerically simulate each event is unknown and has not been calibrated. For example, values of central pressure, radius to maximum winds, and far-field pressure are not known and were estimated from available data or observations. Because little data exist for the earlier storms, a consistent approach for selecting storm parameters was developed. This approach may not produce an accurate surge elevation for a particular event; however, it is felt that the final full population of storm data from which storm statistics are computed is representative of the range of historical events and should produce reliable and accurate hurricane stage-frequency relationships.

Addendum D:4
Overview of EST Process

This addendum provides with greater detail input and output from the Empirical Simulation Technique (EST) analysis (Scheffner and Borgman, 1992) used to develop multiple life-cycle simulations of storm activity and the effects associated with each simulated event.

SBEACH output reports contain narrative of storm input and beach response for various parameters. A Matlab routine reads and parses out the significant information from these reports and reformat to input files for EST runs. Examples of SBEACH report and reformatted EST input files are shown in Figures D:4 - 1 and D:4 - 2 below.

The output from the EST program includes frequency analysis of each of the 11 response parameters captured from SBEACH. Of these, seven were ultimately processed and used to generate the storm files for use in the GRANDUC process. A Matlab routine took each of the 11 output files from EST for each typical profile and consolidated them into a single file (for each design template) with mean values of the following parameters 1) landward most occurrence of a 0.5' vertical erosion, 2) landward most occurrence of a 2.0' vertical erosion, 3) landward most occurrence of a 4.0' vertical erosion, 4) surge, 5) setup, 6) dune elevation reduction and 7) erosion volume. These mean values represented frequencies of 1, 5, 10, 25, 50, 100, and 500-yrs. The consolidated files are then used to generate 1000, 50-yr storm simulations (see GRANDUC documentation). See Figure D:4 - 3 for example consolidated file.

```
Report for run:  Reach: NTB-7_1550_DUNE Storm: 19990916PT
                 Report
Project:  Untitled
Reach:  NTB-7_1550_DUNE
Storm:  19990916PT
                 MODEL CONFIGURATION

INPUT UNITS (SI=1, AMERICAN CUST.=2): 2
NUMBER OF CALCULATION CELLS:  672
GRID TYPE (CONSTANT=0, VARIABLE=1): 1
NUMBER OF GRID CELL REGIONS:  2
NUMBER CELLS AND CELL WIDTH IN REGION  1:  500,  5.0
NUMBER CELLS AND CELL WIDTH IN REGION  2:  172, 20.0
NUMBER OF TIME STEPS AND VALUE OF TIME STEP IN MINUTES:  2821,  1.0
 NO COMPARSION WITH MEASURED PROFILE.
PROFILE ELEVATION CONTOUR 1:  0.00
PROFILE ELEVATION CONTOUR 2:  2.10
PROFILE ELEVATION CONTOUR 3:  7.00
PROFILE EROSION DEPTH 1:  0.50
PROFILE EROSION DEPTH 2:  2.00
PROFILE EROSION DEPTH 3:  4.00
REFERENCE ELEVATION:  2.10
TRANSPORT RATE COEFFICIENT (m^4/N): 1.75E-6
COEFFICIENT FOR SLOPE DEPENDENT TERM (m^2/s): 0.0020
TRANSPORT RATE DECAY COEFFICIENT MULTIPLIER: 0.50
WATER TEMPERATURE IN DEGREES C : 20.0

WAVE TYPE (MONOCHROMATIC=1, IRREGULAR=2): 2
WAVE HEIGHT AND PERIOD INPUT (CONSTANT=0, VARIABLE=1): 1
TIME STEP OF VARIABLE WAVE HEIGHT AND PERIOD INPUT IN MINUTES:  60.0
WAVE ANGLE INPUT (CONSTANT=0, VARIABLE=1): 0
CONSTANT WAVE ANGLE:  0.0
WATER DEPTH OF INPUT WAVES (DEEP WATER = 0.0):  0.0
SEED VALUE FOR WAVE HEIGHT RANDOMIZER AND % VARIABILITY: 3626, 20.0
TOTAL WATER ELEVATION INPUT (CONSTANT=0, VARIABLE=1): 1
TIME STEP OF VARIABLE TOTAL WATER ELEVATION INPUT IN MINUTES:  60.0
WIND SPEED AND ANGLE INPUT (CONSTANT=0, VARIABLE=1): 0
CONSTANT WIND SPEED AND ANGLE:  0.0,  0.0

TYPE OF INPUT PROFILE (ARBITRARY=1, SCHEMATIZED=2): 1
DEPTH CORRESPONDING TO LANDWARD END OF SURF ZONE: 1.00
EFFECTIVE GRAIN SIZE DIAMETER IN MILLIMETERS: 0.35
MAXIMUM PROFILE SLOPE PRIOR TO AVALANCHING IN DEGREES: 45.0

 NO BEACH FILL IS PRESENT.

 NO SEAWALL IS PRESENT.

 NO HARD BOTTOM IS PRESENT.
-------------------------------------------------------------------------------

 COMPUTED RESULTS

 DIFFERENCE IN TOTAL VOLUME BETWEEN FINAL AND INITIAL PROFILES:
   -9.8 yd^3/ft

 MAXIMUM VALUE OF WATER ELEVATION + SETUP FOR SIMULATION
 16.22 ft

 TIME STEP AND POSITION ON PROFILE AT WHICH MAXIMUM VALUE
 OF WATER ELEVATION + SETUP OCCURRED
  1918,  -883.0 ft
 MAXIMUM ESTIMATED RUNUP ELEVATION: 21.92 ft
 (REFERENCED TO VERTICAL DATUM)


 POSITION OF LANDWARD MOST OCCURRENCE OF A  0.50 ft EROSION DEPTH:
   172.0 ft

  DISTANCE FROM POSITION OF REFERENCE ELEVATION ON INITIAL PROFILE
 TO POSITION OF LANDWARD MOST OCCURRENCE OF A  0.50 ft EROSION DEPTH:
   396.5 ft

 POSITION OF LANDWARD MOST OCCURRENCE OF A  2.00 ft EROSION DEPTH:
   317.0 ft

  DISTANCE FROM POSITION OF REFERENCE ELEVATION ON INITIAL PROFILE
 TO POSITION OF LANDWARD MOST OCCURRENCE OF A  2.00 ft EROSION DEPTH:
   251.5 ft

 POSITION OF LANDWARD MOST OCCURRENCE OF A  4.00 ft EROSION DEPTH:
   327.0 ft

  DISTANCE FROM POSITION OF REFERENCE ELEVATION ON INITIAL PROFILE
 TO POSITION OF LANDWARD MOST OCCURRENCE OF A  4.00 ft EROSION DEPTH:
   241.5 ft

 MAXIMUM RECESSION OF THE  0.00 ft ELEVATION CONTOUR:
 19.93 ft

 MAXIMUM RECESSION OF THE  2.10 ft ELEVATION CONTOUR:
```

Figure D:4 - 1. Example SBEACH output.

EST Input File - SURF CITY Tropical Events input and response parameters

Storm		Input Params					Response Parameters										
HIST	IH	Label	Hmo	Tp	Surge	TWL	TWL	TWL+Setup	Surge	Setup	Runup	Eros0.5	Eros2.0	Eros4.0	DuneEl	DunePos	Volume
1	1	18931003PT	27.30	12.90	3.40	5.30	5.30	7.89	3.40	2.59	12.64	97.50	0.00	0.00	15.61	-361.00	5.15 NTB-1_1550_DUNE
1	1	18931003PT	27.30	12.90	3.40	5.30	5.30	8.00	3.40	2.70	12.32	99.50	0.00	0.00	16.67	-410.00	4.39 NTB-2_1550_DUNE
1	1	18931003PT	27.30	12.90	3.40	5.30	5.30	7.98	3.40	2.68	12.71	101.50	0.00	0.00	15.00	-216.00	5.31 NTB-3_1550_DUNE
1	1	18931003PT	27.30	12.90	3.40	5.30	5.30	7.23	3.40	1.93	13.14	99.50	0.00	0.00	15.00	-118.00	5.25 NTB-3a_1550_DUNE
1	1	18931003PT	27.30	12.90	3.40	5.30	5.30	8.25	3.40	2.95	12.47	100.50	0.00	0.00	15.00	-378.00	4.90 NTB-4_1550_DUNE
1	1	18931003PT	27.30	12.90	3.40	5.30	5.30	8.04	3.40	2.74	12.49	96.50	0.00	0.00	15.00	-130.00	4.55 NTB-5_1550_DUNE
1	1	18931003PT	27.30	12.90	3.40	5.30	5.30	7.72	3.40	2.42	12.81	102.50	72.50	0.00	19.26	-238.00	5.54 NTB-6_1550_DUNE
1	1	18931003PT	27.30	12.90	3.40	5.30	5.30	7.39	3.40	2.09	14.10	161.50	86.50	0.00	15.00	-342.00	9.91 NTB-7_1550_DUNE
1	1	19101020PT	27.30	13.00	10.40	8.50	8.50	10.53	10.40	2.03	16.95	292.50	287.50	0.00	12.63	-356.00	16.20 NTB-1_1550_DUNE
1	1	19280918PT	27.30	11.80	5.50	7.00	7.00	8.65	5.50	1.65	14.71	177.50	72.50	0.00	15.61	-361.00	6.12 NTB-1_1550_DUNE
1	1	19291002PT	27.30	12.60	2.20	3.80	3.80	5.80	2.20	2.00	10.65	102.50	72.50	0.00	15.61	-361.00	5.99 NTB-1_1550_DUNE
1	1	19300912PT	16.80	8.70	1.70	4.20	4.20	5.55	1.70	1.35	8.06	97.50	72.50	0.00	15.61	-361.00	6.40 NTB-1_1550_DUNE
1	1	19350905PT	27.30	17.40	7.50	6.60	6.60	9.15	7.50	2.55	17.06	297.50	292.50	287.50	10.09	-376.00	26.02 NTB-1_1550_DUNE
1	1	19440802PT	15.40	8.40	2.40	4.20	4.20	5.70	2.40	1.50	9.68	87.50	0.00	0.00	15.61	-361.00	4.05 NTB-1_1550_DUNE
1	1	19441019PT	27.30	12.70	2.10	3.90	3.90	6.44	2.10	2.54	10.49	92.50	0.00	0.00	15.61	-361.00	4.81 NTB-1_1550_DUNE
1	1	19470924PT	27.30	12.70	2.20	3.10	3.10	6.39	2.20	3.29	10.88	92.50	0.00	0.00	15.61	-361.00	4.36 NTB-1_1550_DUNE
1	1	19530927PT	27.30	12.20	3.20	3.40	3.40	5.02	3.20	1.62	8.00	87.50	0.00	0.00	15.61	-361.00	3.34 NTB-1_1550_DUNE
1	1	19541015PT	20.50	9.70	11.30	12.00	12.00	13.26	11.30	1.26	20.21	297.50	292.50	287.50	10.68	-356.00	18.20 NTB-1_1550_DUNE
1	1	19550812PT	27.10	11.10	3.10	3.10	3.10	4.19	3.10	1.09	7.37	67.50	0.00	0.00	15.61	-361.00	3.32 NTB-1_1550_DUNE
1	1	19550817PT	11.40	7.20	4.40	6.00	6.00	7.57	4.40	1.57	10.08	92.50	0.00	0.00	15.61	-361.00	4.19 NTB-1_1550_DUNE
1	1	19550919PT	27.30	12.50	2.30	3.60	3.60	6.08	2.30	2.48	10.03	97.50	0.00	0.00	15.61	-361.00	5.40 NTB-1_1550_DUNE
1	1	19560927PT	26.60	11.00	2.70	4.20	4.20	6.42	2.70	2.22	11.82	102.50	77.50	0.00	15.61	-361.00	5.95 NTB-1_1550_DUNE
1	1	19600911PT	24.60	10.60	9.10	10.00	10.00	11.07	9.10	1.07	14.17	97.50	0.00	0.00	15.61	-361.00	4.63 NTB-1_1550_DUNE
1	1	19660611PT	21.10	9.80	1.60	3.00	3.00	5.07	1.60	2.07	8.22	82.50	0.00	0.00	15.61	-361.00	3.30 NTB-1_1550_DUNE
1	1	19680612PT	21.80	10.00	2.20	4.80	4.80	5.93	2.20	1.13	11.05	97.50	0.00	0.00	15.61	-361.00	4.94 NTB-1_1550_DUNE
1	1	19681019PT	11.00	7.10	2.30	3.40	3.40	5.02	2.30	1.62	7.97	77.50	0.00	0.00	15.61	-361.00	3.01 NTB-1_1550_DUNE
1	1	19710827PT	17.40	8.90	3.20	3.70	3.70	5.57	3.20	1.87	8.43	82.50	0.00	0.00	15.61	-361.00	3.19 NTB-1_1550_DUNE
1	1	19720621PT	27.30	12.80	3.20	3.50	3.50	6.67	3.20	3.17	10.81	92.50	0.00	0.00	15.61	-361.00	4.27 NTB-1_1550_DUNE
1	1	19790905PT	12.50	14.00	1.40	3.90	3.90	6.04	1.40	2.14	12.77	97.50	0.00	0.00	15.61	-361.00	5.46 NTB-1_1550_DUNE
1	1	19810820PT	12.80	9.00	3.80	5.90	5.90	7.79	3.80	1.89	11.37	82.50	0.00	0.00	15.61	-361.00	2.98 NTB-1_1550_DUNE

Figure D:4 - 2. Example reformatted SBEACH output.

```
NTB2_1550
Number of Simulations
1000
Simulation Period
50
Average Number of Storms Per Year
1.000000
Shoreline Adjustment Factor HF, LF
9.999999, 9.999999
Long Term Erosion
9.999999
Erosion and Volume Factors - High 4 sum
999.999999, 999.999999
First Erosion Frequency Curve
   0.00000        81.59
   0.80000       109.15
   0.90000       127.46
   0.96000       242.25
   0.98000       320.38
   0.99000       385.83
   1.00000       507.24
Second Erosion Frequency Curve
   0.00000         0.00
   0.80000         0.00
   0.90000         0.00
   0.96000        61.10
   0.98000       274.49
   0.99000       432.14
   1.00000       687.38
Third Erosion Frequency Curve
   0.00000         0.00
   0.80000         0.00
   0.90000         0.00
   0.96000        27.69
   0.98000       213.82
   0.99000       394.88
   1.00000       730.02
Surge Frequency Curve
   0.00000         3.11
   0.80000         4.55
   0.90000         5.68
   0.96000         8.05
   0.98000        10.12
   0.99000        12.16
   1.00000        16.33
Setup Frequency Curve
   0.00000         1.89
   0.80000         2.79
   0.90000         2.88
   0.96000         2.43
   0.98000         2.05
   0.99000         1.80
   1.00000         1.58
Ground Elevation Frequency Curve
   0.00000        16.70
   0.80000        16.70
   0.90000        16.70
   0.96000        15.80
   0.98000        12.96
   0.99000        10.47
   1.00000         5.23
Erosion Volume Frequency Curve
   0.00000         2.93
   0.80000         5.07
   0.90000         6.02
   0.96000         9.29
   0.98000        15.80
   0.99000        22.39
   1.00000        36.85
```

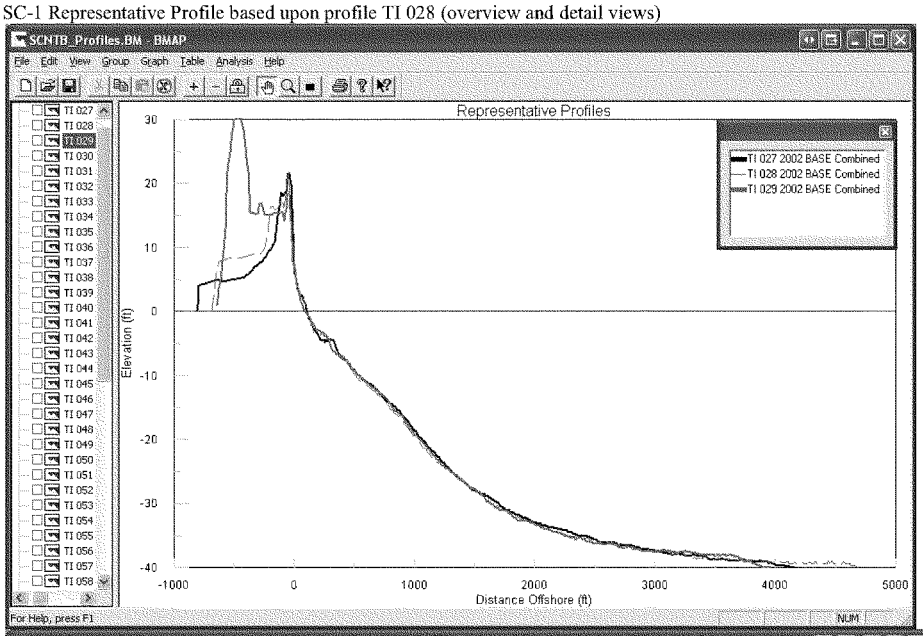
Figure D:4 - 3. Example consolidated EST output.

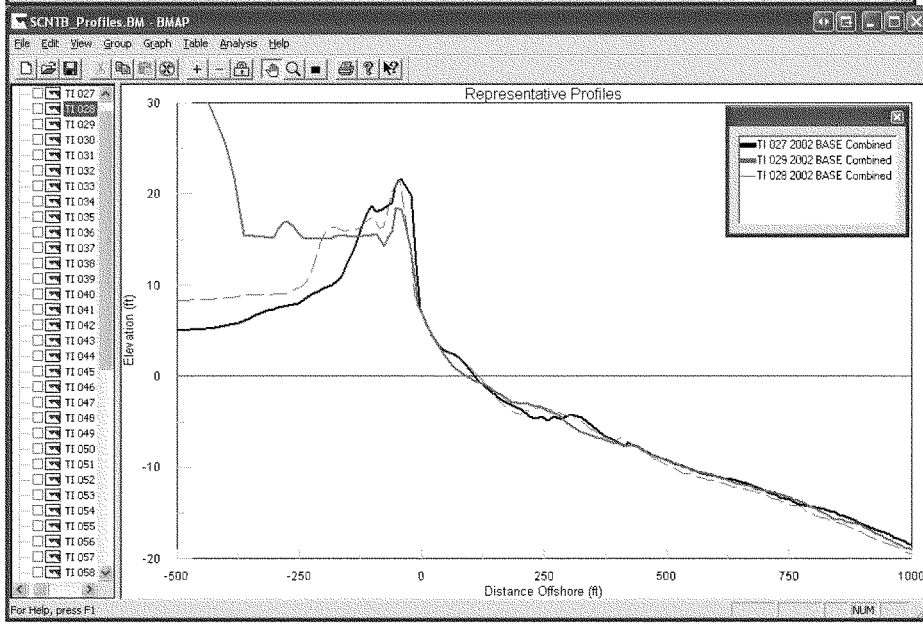
Addendum D:5
Beach Profiles

This addendum displays the surveyed beach profiles and is grouped by the representative profile. The representative profiles were selected based upon the similarity of features such as dune height, berm and nearshore profile.

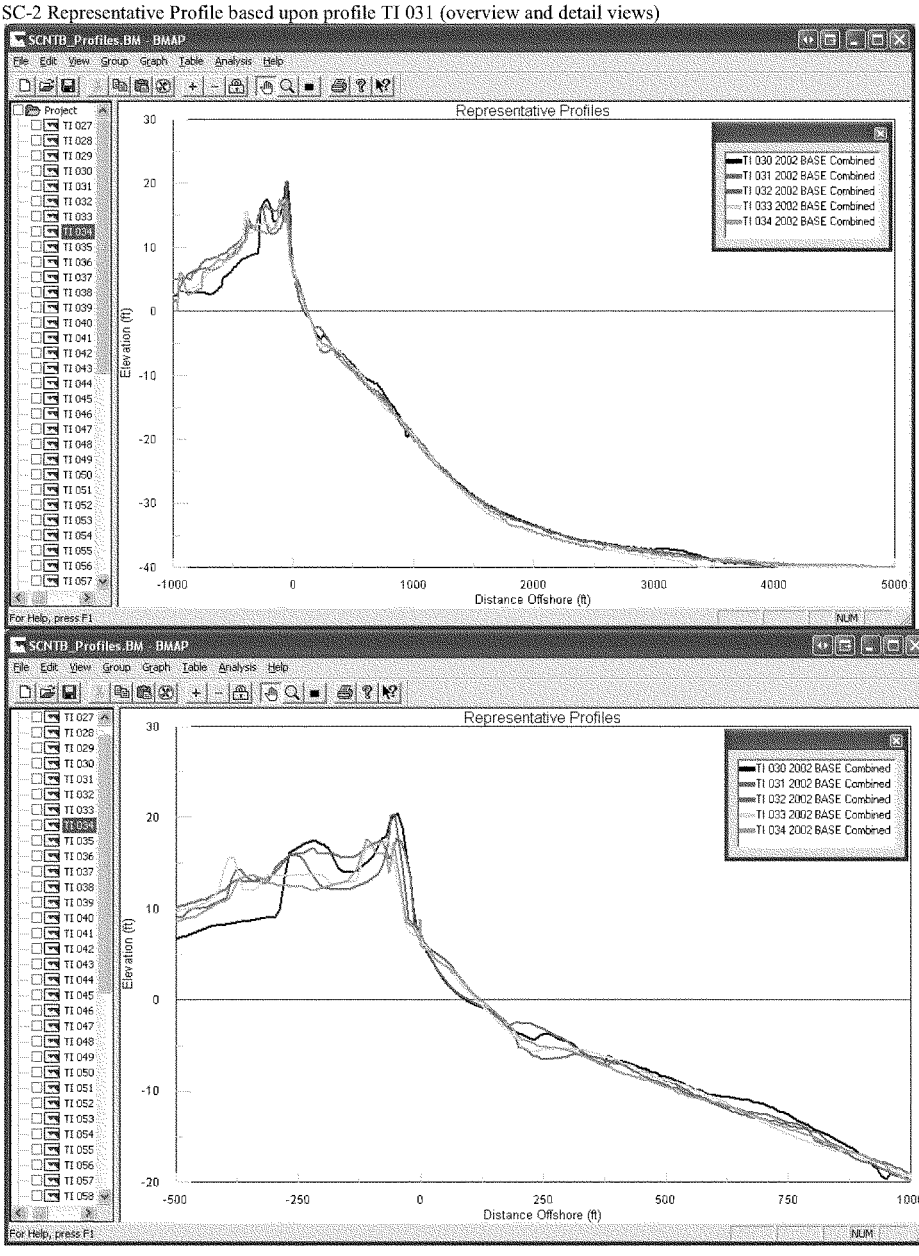
Each representative profile group is displayed in an overview and detailed view.

SC-1 Representative Profile based upon profile TI 028 (overview and detail views)

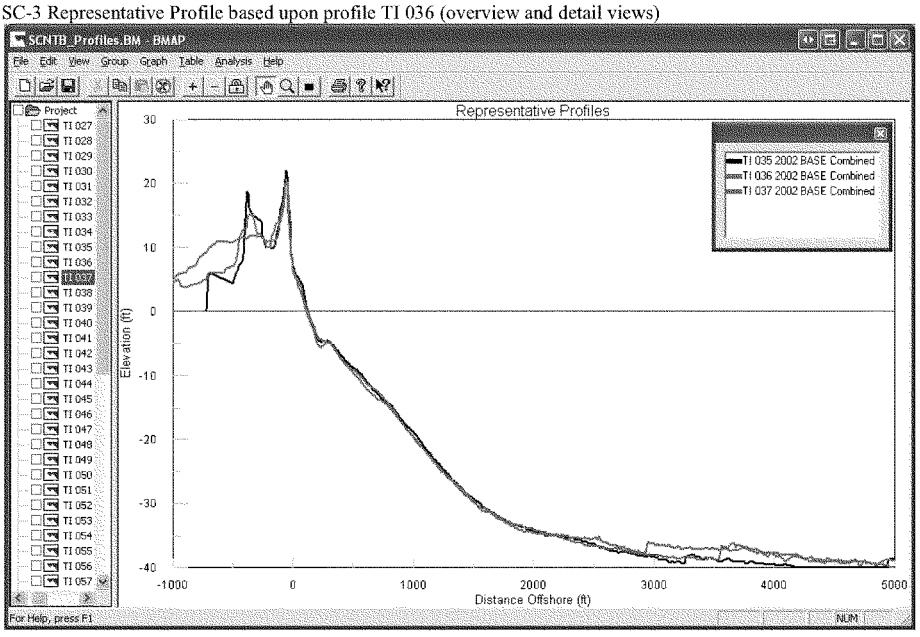


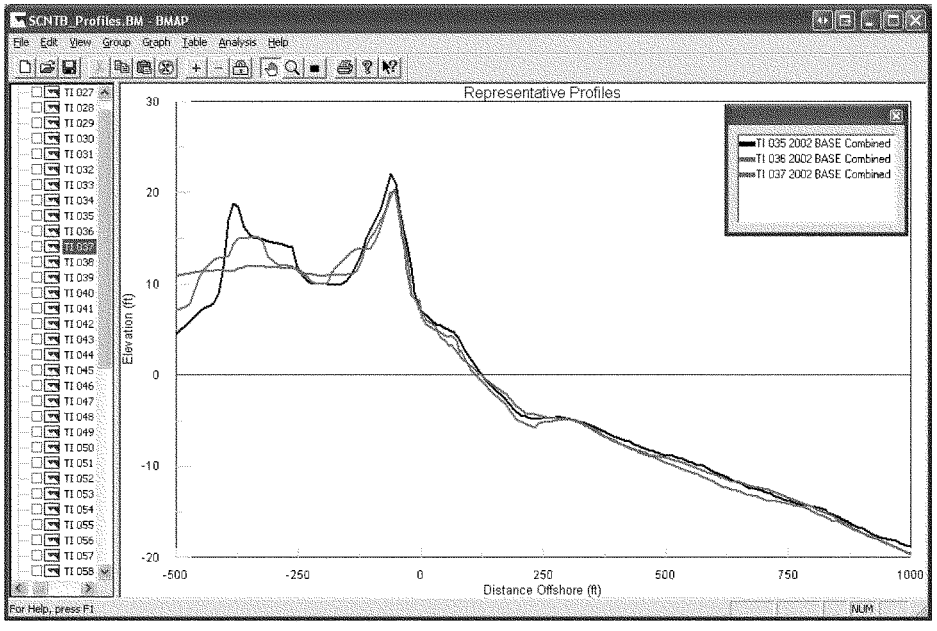


SC-2 Representative Profile based upon profile TI 031 (overview and detail views)

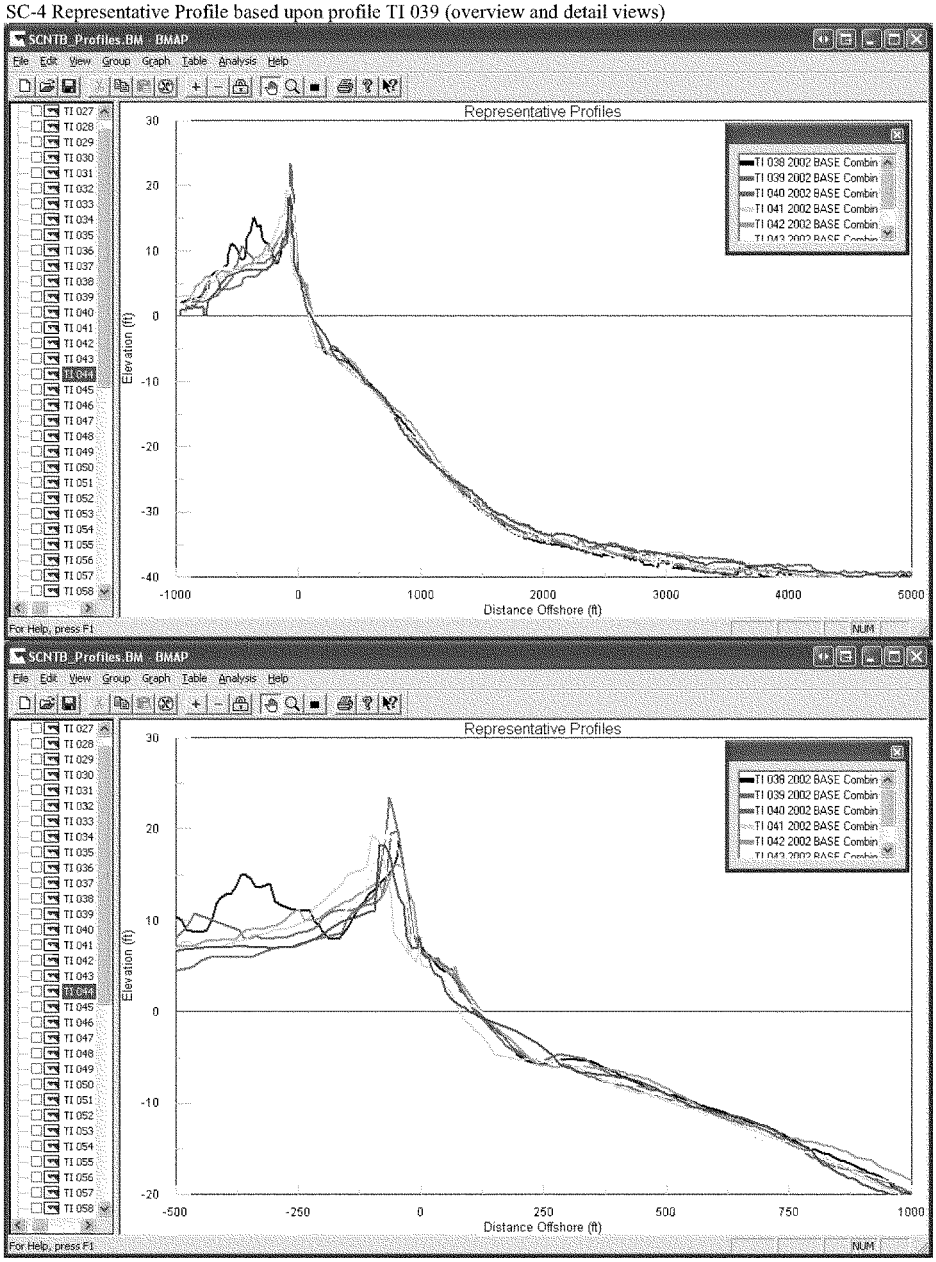


SC-3 Representative Profile based upon profile TI 036 (overview and detail views)

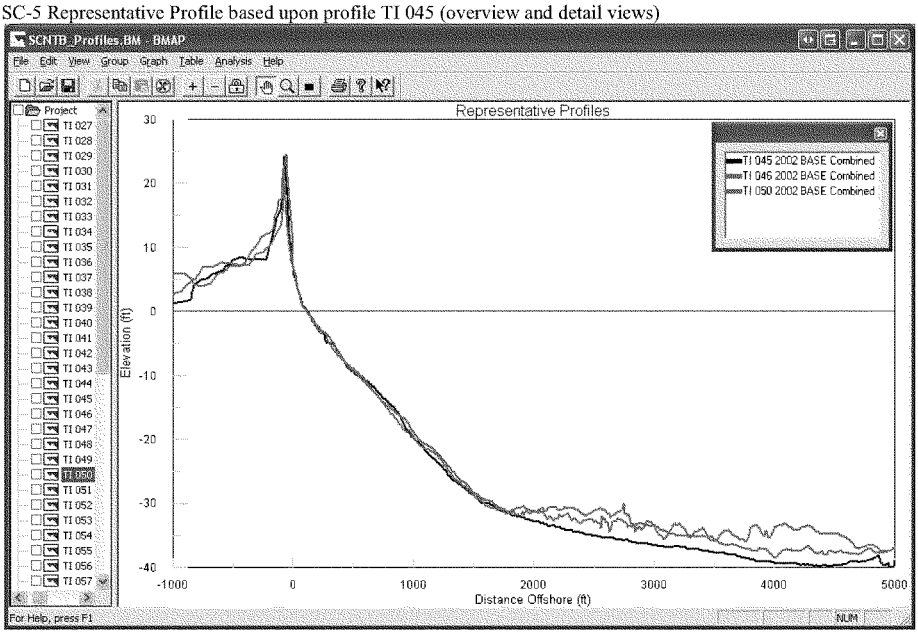


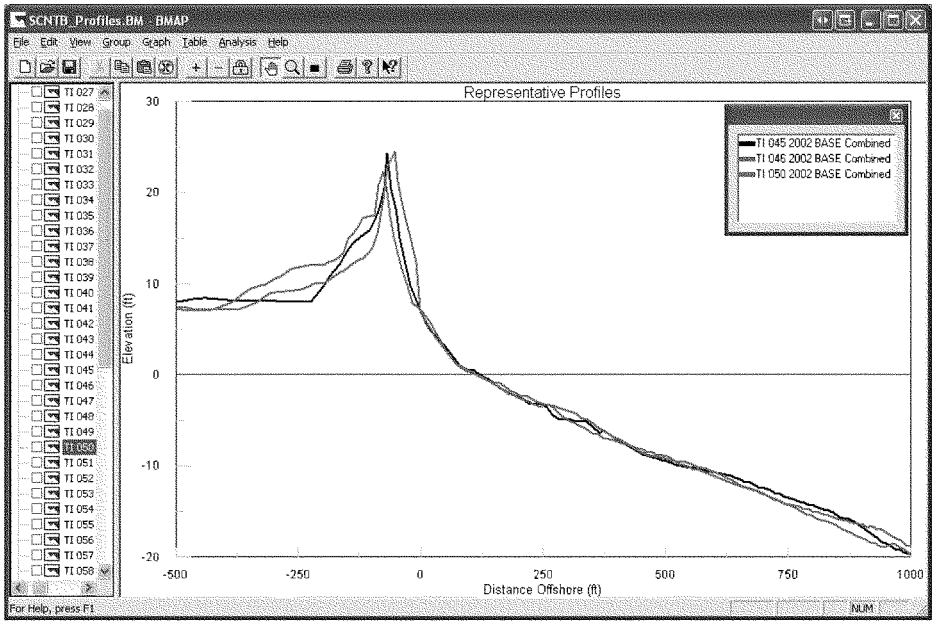


SC-4 Representative Profile based upon profile TI 039 (overview and detail views)

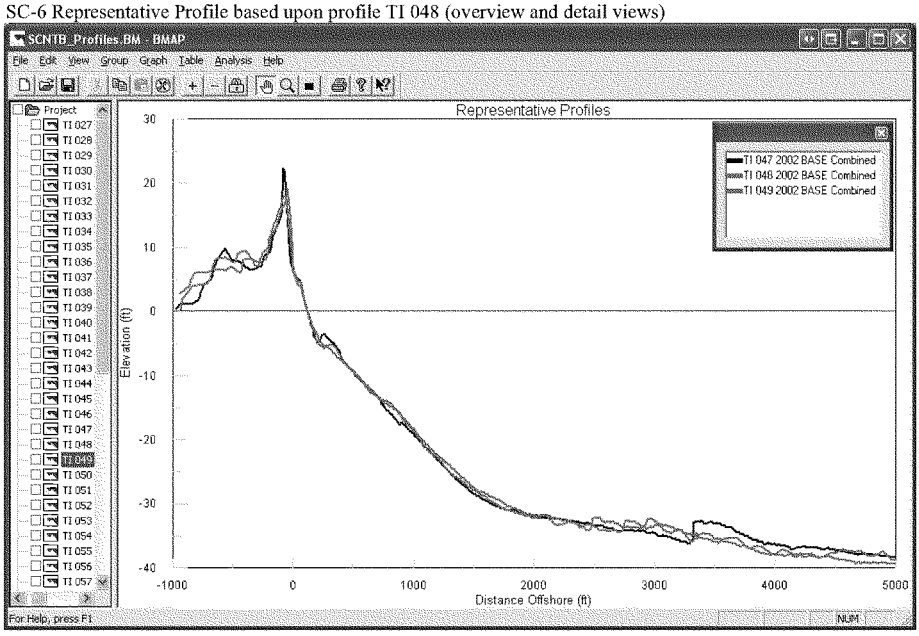


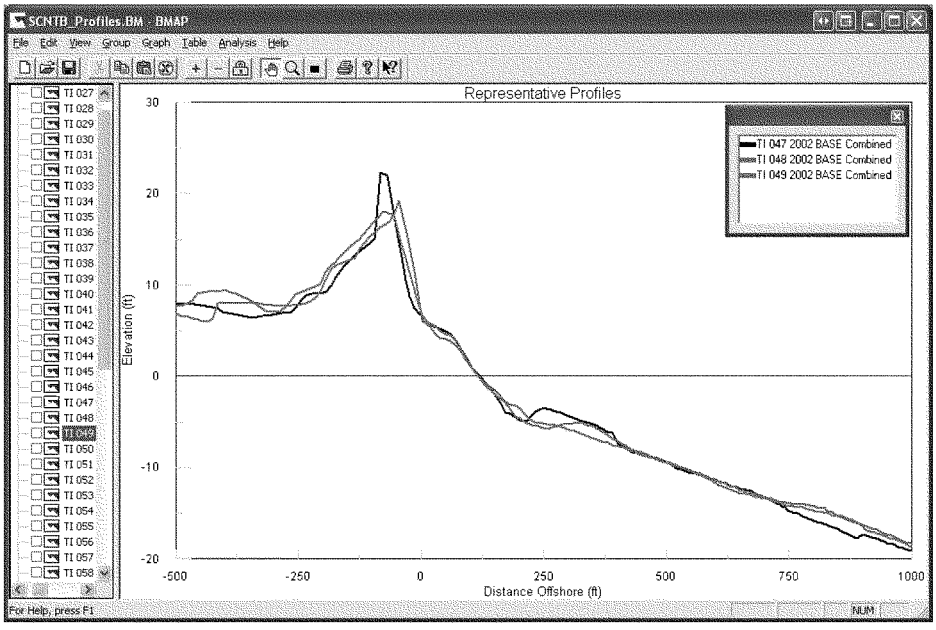
SC-5 Representative Profile based upon profile TI 045 (overview and detail views)



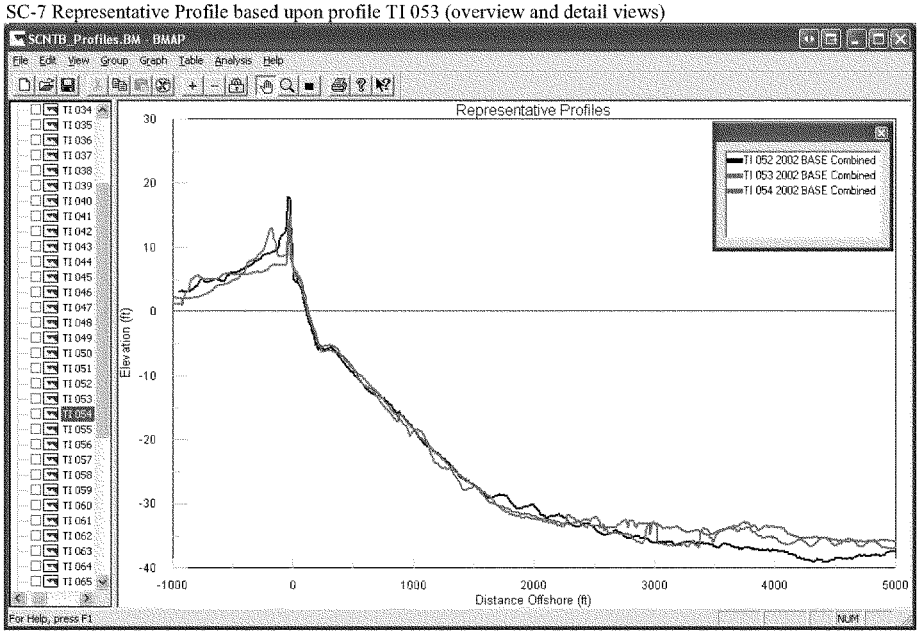


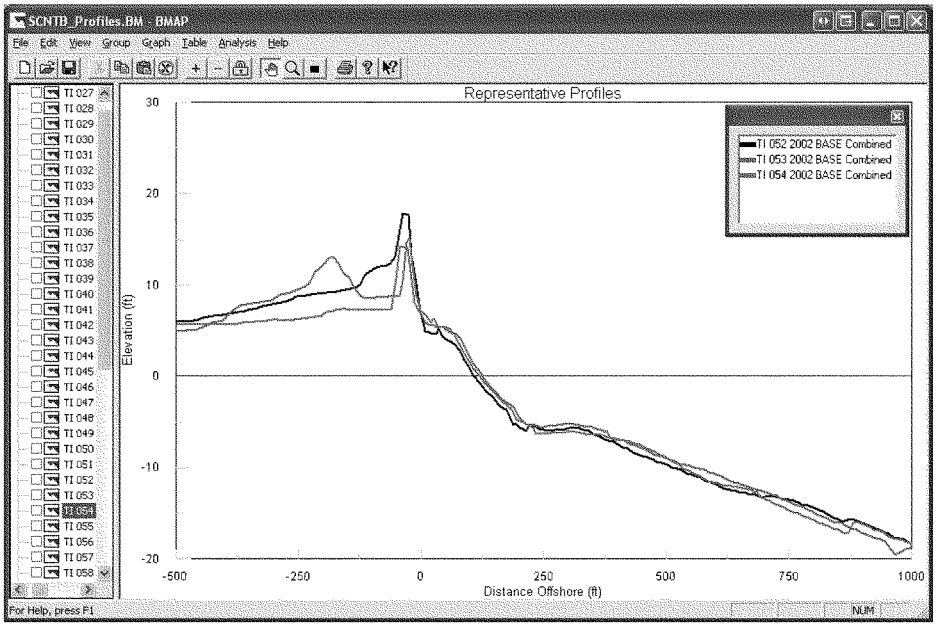
SC-6 Representative Profile based upon profile TI 048 (overview and detail views)



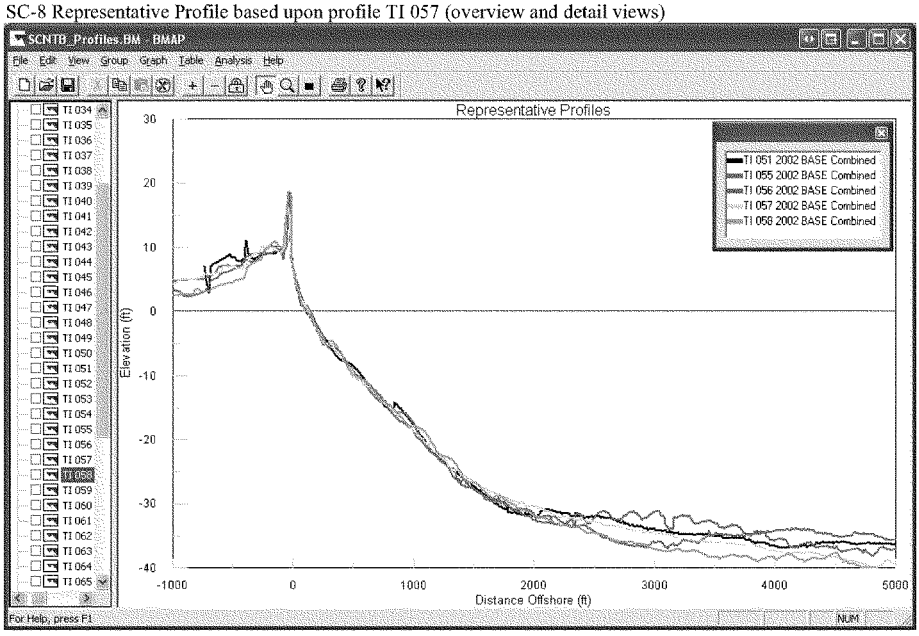


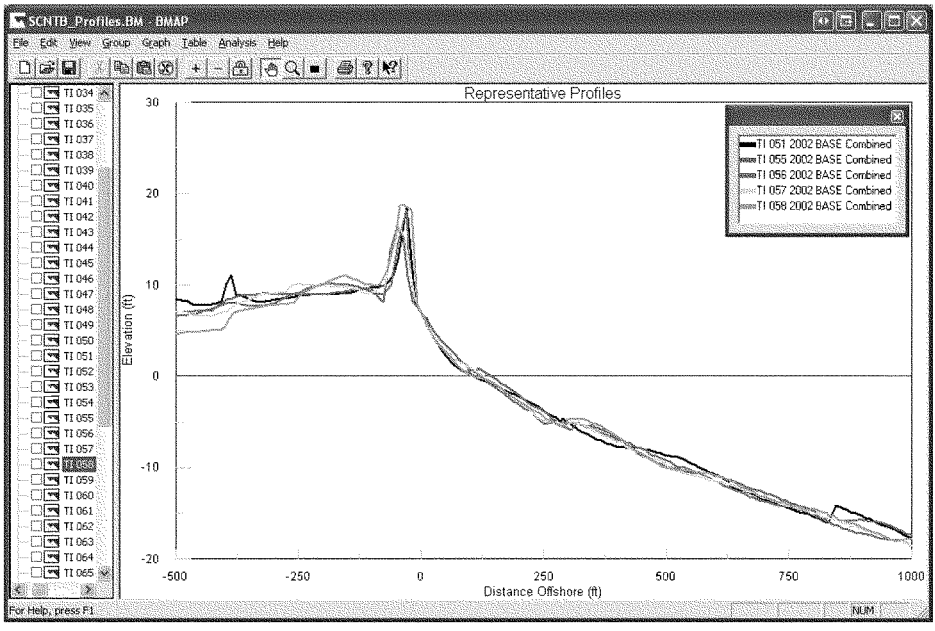
SC-7 Representative Profile based upon profile TI 053 (overview and detail views)



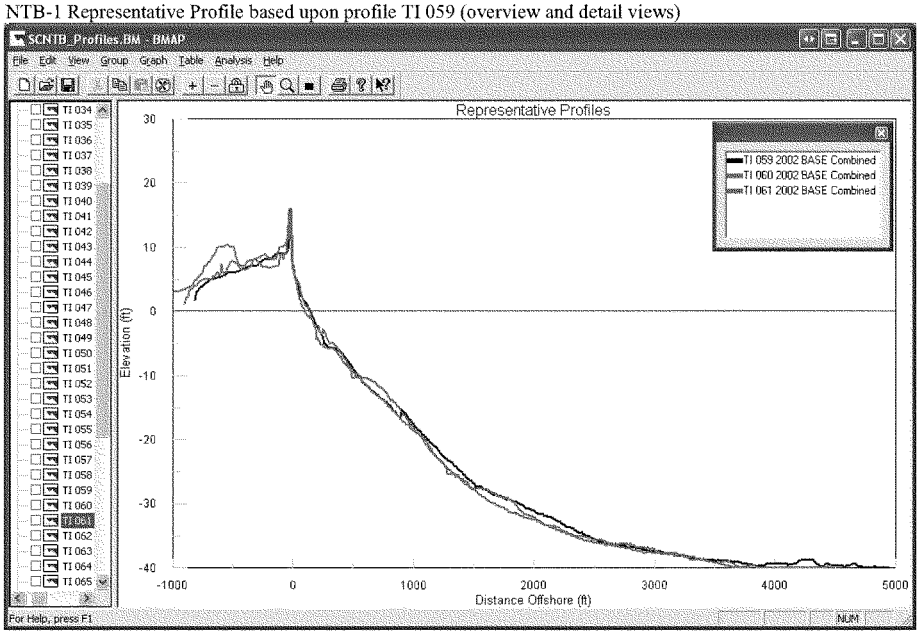


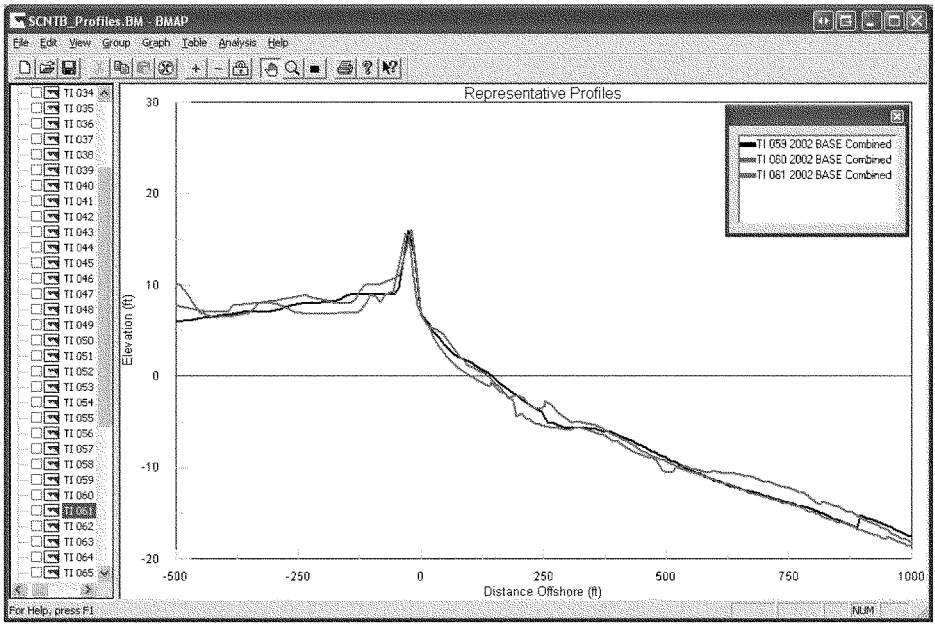
SC-8 Representative Profile based upon profile TI 057 (overview and detail views)



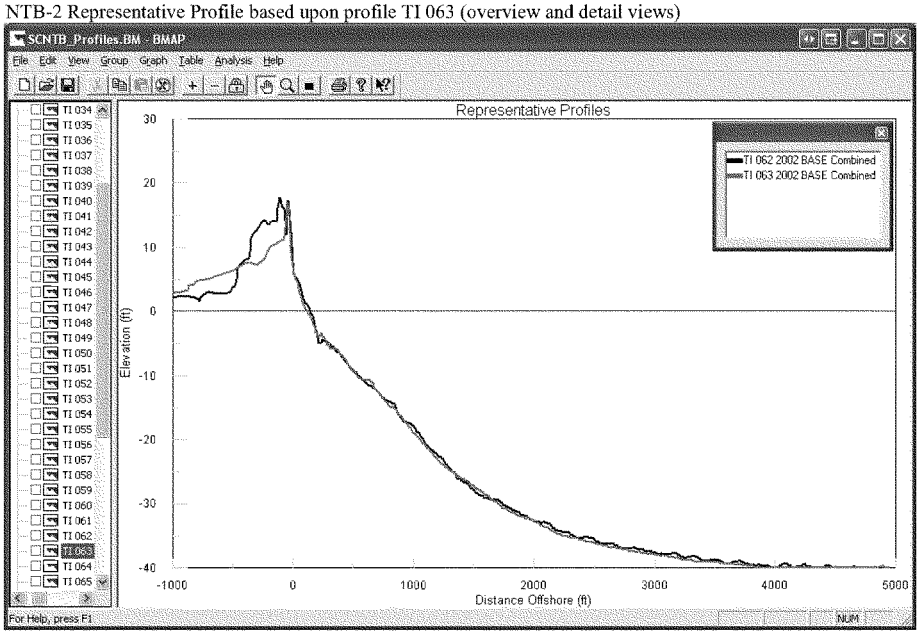


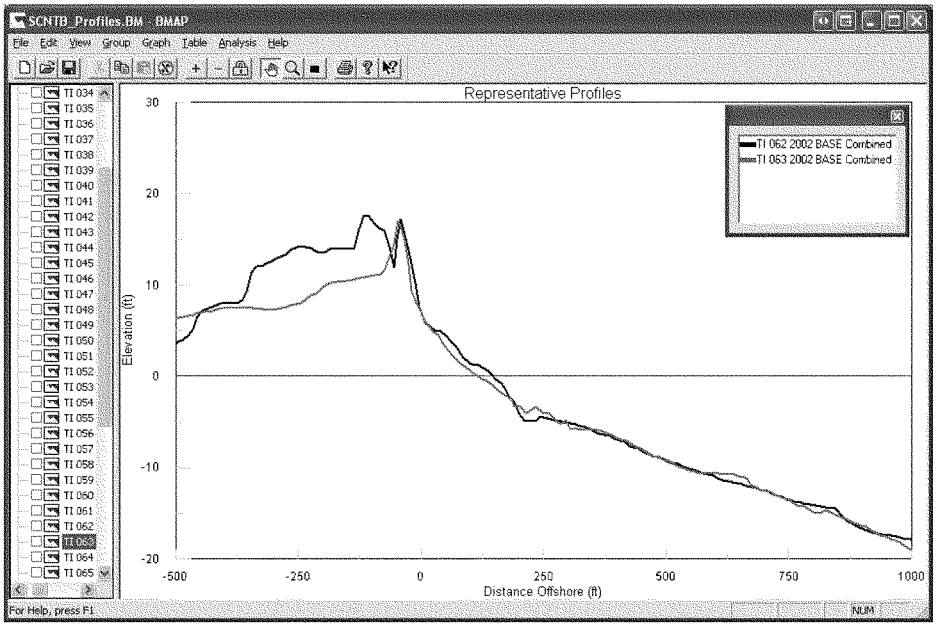
NTB-1 Representative Profile based upon profile TI 059 (overview and detail views)



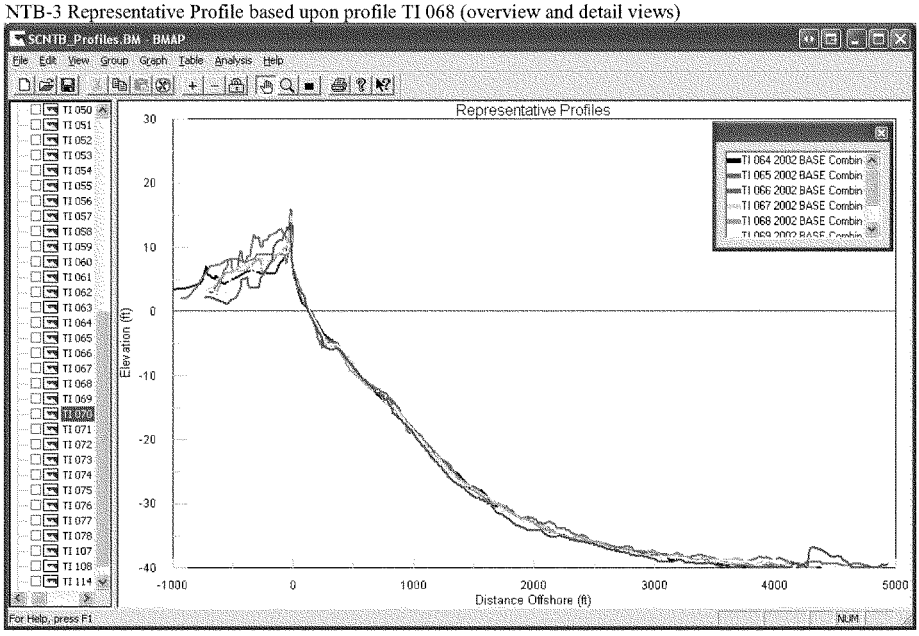


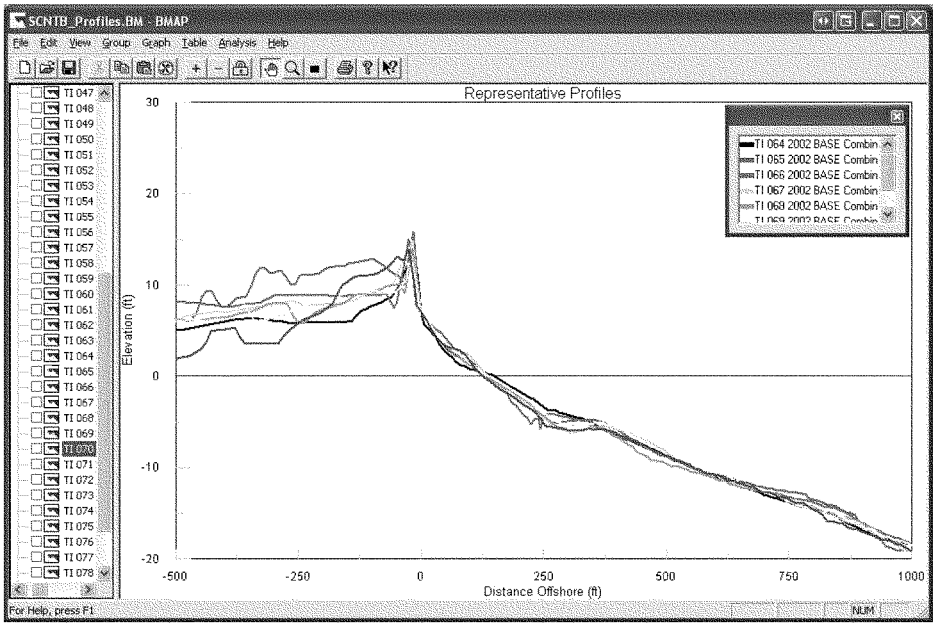
NTB-2 Representative Profile based upon profile TI 063 (overview and detail views)



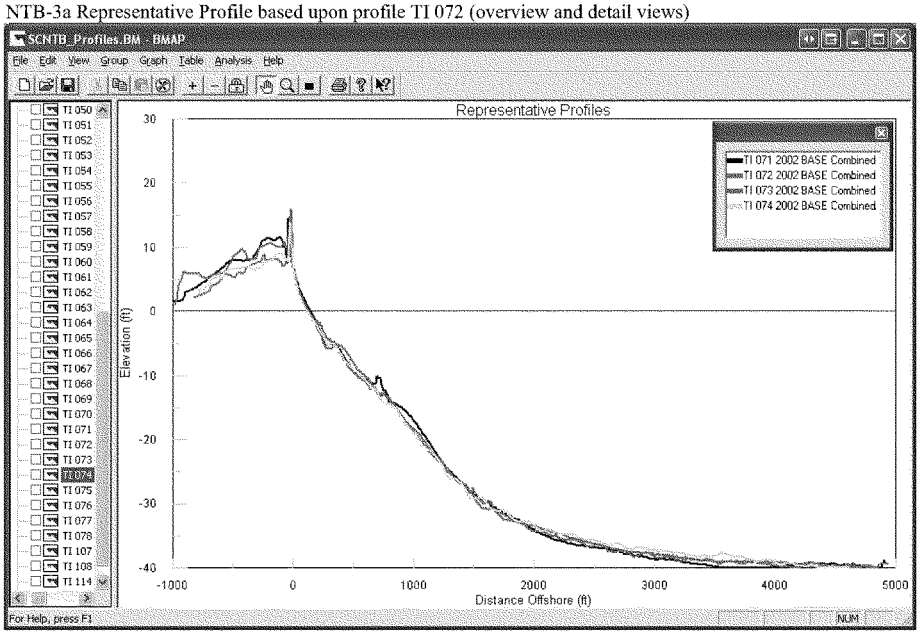


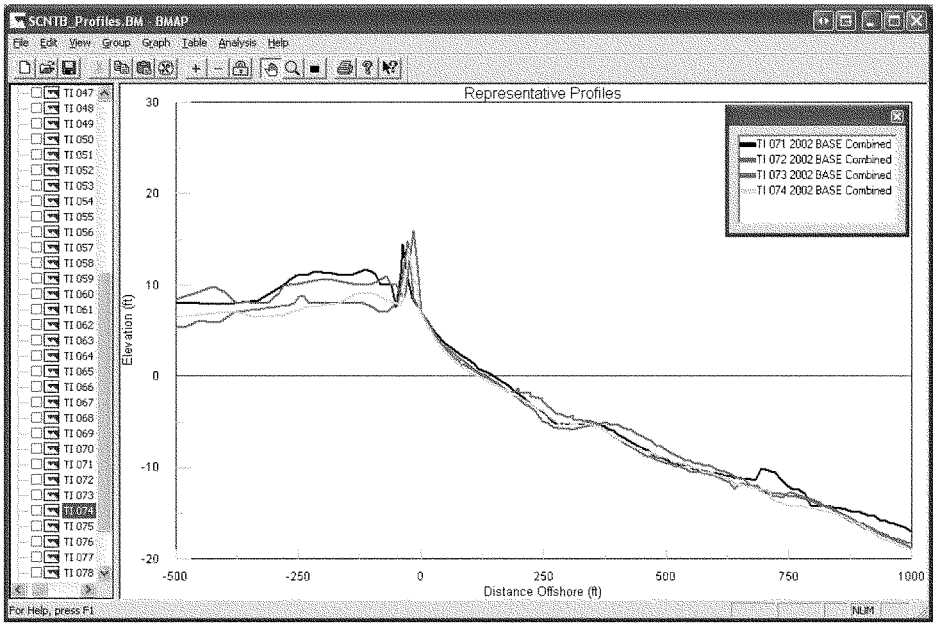
NTB-3 Representative Profile based upon profile TI 068 (overview and detail views)



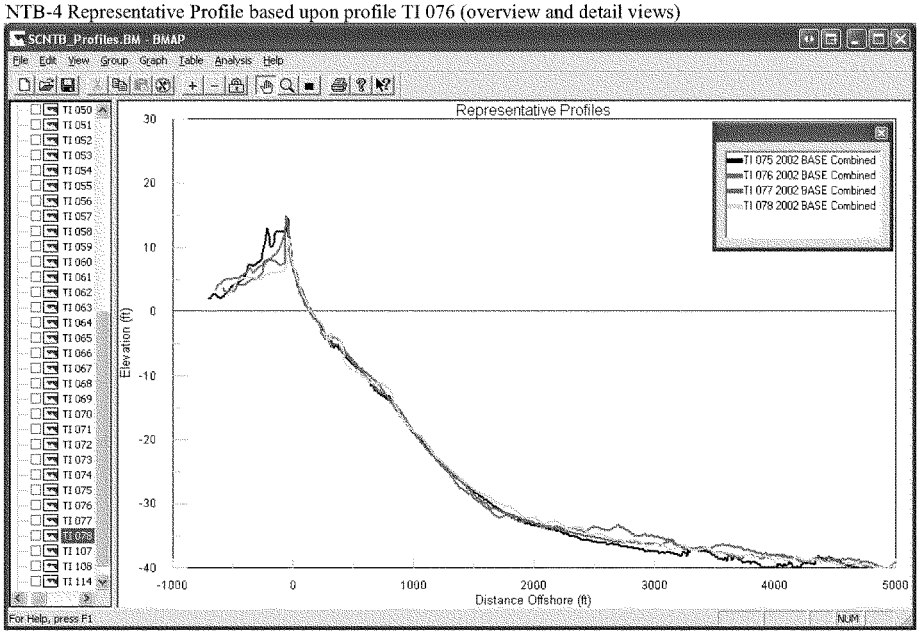


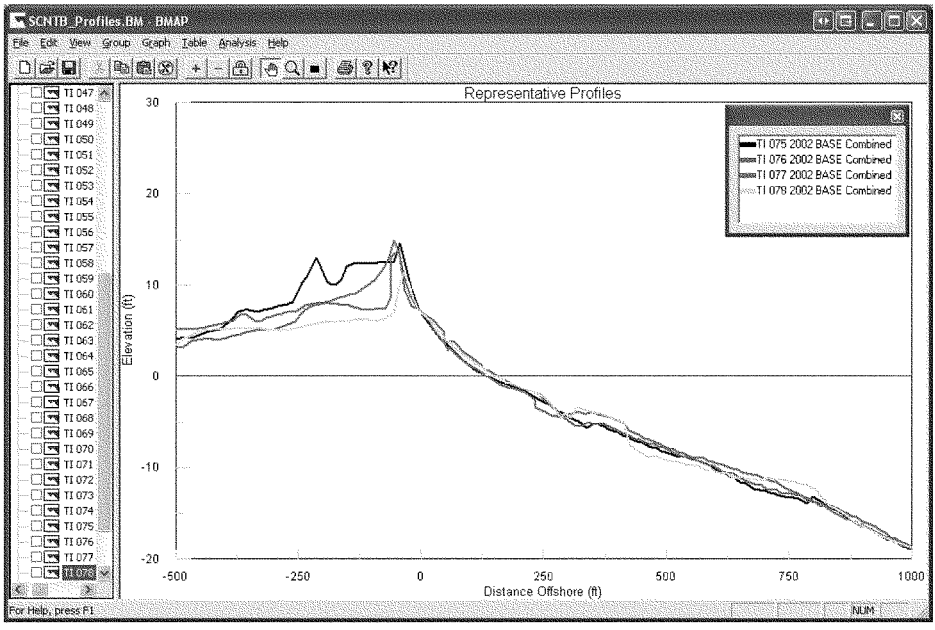
NTB-3a Representative Profile based upon profile TI 072 (overview and detail views)





NTB-4 Representative Profile based upon profile TI 076 (overview and detail views)





FEASIBILITY REPORT

AND

ENVIRONMENTAL IMPACT STATEMENT

COASTAL STORM DAMAGE REDUCTION PROJECT

SURF CITY AND NORTH TOPSAIL BEACH

NORTH CAROLINA

Appendix E

Sand Compatibility Analysis

Appendix E: Sand Compatibility Analysis

Table of Contents

Section	Page
1. Introduction	E-1
2. Definitions	E-1
3. Grain Size Nomenclature	E-3
4. Native Beach Sampling and Results	E-3
5. Borrow Material Sampling and Results	E-5
6. Overfill Ratio	E-7
7. Compatibility and Borrow Sources	E-7

List of Figures

Figure E-1 – Average Mean and Standard Deviation Versus Sample Depth
Figure E-2 - Mean Grain Size and Standard Deviation for Transect Lines

List of Tables

Table E-1 - Native Beach Samples
Table E-2 - Composite Characteristics for Native Beach
Table E-3 - Borings for Borrow Area G
Table E-4 – Borings for Borrow Area H
Table E-5 – Borings for Borrow Area J
Table E-6 – Borings for Borrow Area L
Table E-7 – Borings for Borrow Area N
Table E-8 – Borings for Borrow Area O
Table E-9 – Borings for Borrow Area P
Table E-10 – Borings for Borrow Area Q
Table E-11 – Borings for Borrow Area S
Table E-12 – Borings for Borrow Area T
Table E-13 – Borings for Borrow Area A
Table E-14 – Borings for Borrow Area B
Table E-15 – Borings for Borrow Area C
Table E-16 - Borings for Borrow Area D
Table E-17 – Borings for Borrow Area E
Table E-18 – Borings for Borrow Area F

List of Tables (cont.)

Table E-19 - Composite Characteristics for Borrow Area G
Table E-20 - Composite Characteristics for Borrow Area H
Table E-21 - Composite Characteristics for Borrow Area J
Table E-22 - Composite Characteristics for Borrow Area L
Table E-23 - Composite Characteristics for Borrow Area N
Table E-24- Composite Characteristics for Borrow Area O
Table E-25 - Composite Characteristics for Borrow Area P
Table E-26 - Composite Characteristics for Borrow Area Q
Table E-27 - Composite Characteristics for Borrow Area S
Table E-28 - Composite Characteristics for Borrow Area T
Table E-29 - Composite Characteristics for Borrow Area A
Table E-20 - Composite Characteristics for Borrow Area B
Table E-31 - Composite Characteristics for Borrow Area C
Table E-32 - Composite Characteristics for Borrow Area D
Table E-33 - Composite Characteristics for Borrow Area E
Table E-34 – Composite Characteristics for Borrow Area F
Table E-35 – Compatibility of Native and Borrow Sand

Appendix E: Sand Compatibility Analysis

1. **Introduction.** Sands making up the native beach are generally hydraulically sorted with the coarser grain sizes concentrated in the foreshore region, where wave energy is the greatest, and the finer grain sizes located in the offshore areas seaward of the surf zone. In order for the borrow material to be compatible with the native beach sand, the borrow material must contain essentially all of the same grain sizes that exist on the active beach profile of the project area. In this regard, the active beach profile is generally defined in engineering terms as the portion of the profile from the top of the beach berm seaward to depths where significant sand transport by wave energy is negligible. At Topsail Island, the active beach profile appears to end in a water depth of approximately 25 feet below National American Vertical Datum (NAVD). Note that sediment movement in water depths greater than 25 feet below NAVD is known to occur. However, the rate of sediment movement in these deeper depths is relatively small compared to rate of movement in the shallower depths and are therefore of minor importance in the day to day and year to year behavior of the beach profile.

2. **Definitions.** Definitions are included to provide better understanding of the terminology used in this appendix.

   Active zone. The zone that extends from the top of the beach berm seaward to depths where sediment transport induced by waves is negligible.

   Beach berm. A nearly horizontal part of the beach or backshore formed by the deposit of material by wave action.

   Datum. Any permanent line, plane, or surface, used as a reference datum to which reference datums are referred.

   Foreshore. The part of the shore, lying between the crest of the seaward berm (or upper limit of wave wash at high tide) and the ordinary low water mark, that is ordinarily traversed by the uprush and backrush of the waves as the tides rise and fall.

   Grain size. Refers to the mean or effective diameter of individual mineral grains or particles. Grain size analysis passes particles through a series of sieves with known

mesh sizes to determine the grain size based on the amount of particles retained or passing a sieve.

Mean high water (MHW). The average height of high waters over a 19-year period. For shorter periods of observations, corrections are applied to eliminate known variations and reduce the results to the equivalent of a mean 19-year value.

Mean low water (MLW). The average height of low waters over a 19-year period. For shorter periods of observations, corrections are applied to eliminate known variations and reduce the results to the equivalent of a mean 19-year value.

Mean sea level (MSL). The average height of the surface of the sea for all the stages of the tide over a 19-year period, usually determined from hourly height readings. Not necessarily equal to mean tide level. It is also the average water level that would exist in the absence of tides.

Offshore. The zone extending from the shoreface to the edge of the continental shelf.

Overfill ratio. Used to evaluate the compatibility of sediments and to relate the volume of borrow site sediment required for a project to perform comparably with native beach sand.

Phi scale. A common method to represent grain size distribution. The scale is a logarithmic transformation of the Wentworth grade scale for size classifications of sediment grains based on the negative logarithm to the base 2 of the particle diameter. A phi value is dimensionless and has equivalent millimeter values.

Vibracore. A drill machine driven by a vibrating head assembly to collect sediment samples. Ocean sediment samples are collected by lowering the machine from a floating vessel to the ocean floor.

3. **Grain Size Nomenclature.** Note that the mean grain sizes of the native and borrow area materials are reported in both millimeters (mm) and phi (φ) units in this report where phi is related to the grain size as follows:

$$\varphi = -\ln (d)/\ln (2)$$

where:
d = grain size in millimeters (mm)
ln = natural log

Since the distribution of the sand samples can generally be represented as log-normal distributions, the standard deviations and variances of the particle size distributions are reported in phi units.

4. **Native Beach Sampling and Results.** The characteristics of the native beach material at Topsail Island were determined through an extensive sampling program conducted by the USACE in 2003. Samples were collected from the beach along transects approximately 5,000 feet apart (see figure A-1). Only transects 7 through 16 exist within the boundaries for the Surf City/North Topsail Beach project and were evaluated to determine the native beach characteristics. Grab samples were collected by the USACE in 2003 from the along each transect at the surface at the following elevations: Toe of the Dune, Crest of the Berm, Mean High Water (MHW), Mean Sea Level (MSL), Mean Low Water (MLW), and twelve (12) samples collected seaward of MLW starting at elevation -3 feet and continuing at 2 foot depth increments from -4 to -24 feet.

The State of North Carolina implemented new rules in 2007 governing sediment compatibility for beach nourishment. The rules are titled "Technical Standards for Beach Fill Projects" and are found in 15A North Carolina Administrative Code (NCAC) 07H.0312. These rules specify that characterization of the native beach material requires a minimum of thirteen (13) samples be collected along each transect with an equal number of samples collected landward and seaward of mean low water (MLW). Because this rule was implemented after the sampling program at Topsail Island was conducted by USACE, the current data set for transects 7 through 12 contain only four landward samples of MLW. In 2007, Coastal Planning & Engineering of North Carolina, Inc. (CPE-NC) collected two (2) additional samples landward of the MLW from the dune and mid-berm (~ +3 to +5 ft NAVD) along each transect line 13 through 16 to meet this requirement for the North Topsail Beach

non-Federal Shore Protection Project. The CPE-NC data for transect lines 13 through 16 has been incorporated into this evaluation performed for the Surf City/North Topsail Beach Federal Shore Protection Project. To comply with the beach fill standard, two (2) additional samples will be required to be collected landward of MLW for each transect line 7 through 12 prior to construction of this project. To be consistent with the samples collected by CPE-NC along transect lines 13 through 16, these additional samples along transect lines 7 through 12 will be collected from the dune and mid-berm (~ +3 to +5 ft NAVD).

To comply with the beach fill standards, only 6 of the 12 samples collected seaward of MLW were combined with the MLW sample and samples landward of MLW to develop the composite characteristics of the native beach material to be used in the compatibility analysis of the borrow material. The grain size distribution of each sample was determined by standard sieve analysis, from which the mean and standard deviation of the grain size distribution of each sample were determined. The samples at each transect line were combined to develop the composite characteristics of the native beach material to be used in the compatibility analysis of the borrow material.

Active Beach Profile Zone

The vertical datum used for the collection of the native beach samples by USACE in 2003 was the National Geodetic Vertical Datum of 1929 (NGVD '29). The beach fill standards implemented by North Carolina in 2007 adopted the North American Vertical Datum of 1988 (NAVD '88) as the vertical datum. Therefore, the vertical elevation for near shore samples collected by USACE has been converted to NAVD for consistency in this appendix. The mean grain size and standard deviation of the native samples collected along the transect lines in regards to depth is illustrated on figure E-1. The mean grain size variation with depth is typical of other beaches in North Carolina where coarser material is present in the foreshore area ranging from mean high water (+1.1 NAVD) to around -4 to -5 feet NAVD. The mean grain size gradually decreases seaward from this point. The standard deviation of the particle size distribution is larger at the same depths where the coarser material is present in the foreshore to around -4 to -5 feet NAVD. The standard deviation is gradually smaller seaward of this point.

Composite Characteristics of Native Beach Material

The grain size distribution of each of the samples collected from the transect lines were combined and the average grain size distribution and standard deviation for each transect determined. The individual transect line characteristics are summarized in table E-1. The average grain size distribution and standard deviation for the 10 transect lines (7-16) were then combined to determine the composite grain size distribution and standard deviation for the Surf City/North Topsail Beach study area, which are summarized in table E-2. The composite mean grain size for the Surf City/North Topsail Beach study area is 2.15 phi (0.23 mm) with a standard deviation of 0.71 phi (0.61 mm).

The mean grain size and standard deviation of each transect line is plotted on figure E-2. The mean grain size for each transect is relatively similar with the exception of transect line 8, which is slightly coarser and the largest percentage of shell present. The standard deviation is also largest at transect line 8 indicating the material is less sorted in this area than along the other transects. Generally, the material appears to be relatively well sorted throughout the study area as illustrated by the small standard deviation with the exception of transect line 8.

5. **Borrow Material Sampling and Results.** The search for borrow material was concentrated in the ocean waters off Topsail Island beginning approximately 1 mile offshore and in water depths of 33 feet Mean Lower Low Water (MLLW) and extending seaward to approximately 6 miles offshore. Details of this offshore search for beach compatible material is described in Appendix C, Geotechnical Analyses, and consisted of a combination of seismic and sonar surveys followed by the collection of vibracores at 369 locations. Boring logs were developed for each vibracore based on visual classifications of the material in the cores. The sand layers in each vibracore were sampled for grain size analysis. The results of the grain size analysis of the vibracore material combined with the seismic bottom profile data, was used to delineate the boundaries of potential offshore borrow areas. Composite grain size characteristics of the material in each of these potential borrow areas were computed for comparison with the composite characteristics of the native beach material.

Borrow Material Vibracores

The investigation was conducted in two major phases. Phase one consisted of the collection of over 315 miles of seismic subbottom profiles performed offshore of

Topsail Island, with 173 miles of these miles for the Surf City/North Topsail Beach project. Phase 2 involved the collection of 369 vibracores offshore of Topsail Island, with 208 of these vibracores for the Surf City/North Topsail Beach project. The search area and the seismic lines surveyed in this effort for the entire Topsail Island are discussed in detail in the Geophysical Report in Attachment 1 to Appendix C, Geotechnical Analyses. The seismic survey data was analyzed to determine areas where beach quality material of sufficient depth appeared likely.

Based on the interpretation of the seismic data, a vibracore drilling plan was developed to determine the characteristics of the subbottom material. In this regard, the seismic data only provides information on the layering of material and does not provide information of the granular characteristics of the material. The vibracores consist of vibrating a 20-foot long plastic core into the ocean bottom. The plastic core is then split and the material characteristics in the core visually classified. Material collected in the core was sampled and the size distribution of that material was determined through standard sieve analysis. In general, the cores were sampled in two-foot intervals or more frequently if a significant difference in the character of the material was visually apparent. The locations of the vibracores collected for the Topsail Beach study area are shown on figure A-1. Logs of each of the vibracores are provided in Attachment 2 to Appendix C, Geotechnical Analyses. In addition, laboratory data for grain size analysis from each sample is provided in Attachment 3 to Appendix C.

Borrow Site Vibracore Analysis

An initial compatibility analysis was conducted of the vibracore logs and sample lab data in 2004. This analysis identified fourteen preliminary borrow areas (G, H, I, J, K, L, M, N, O, P, Q, R, S, and T) for the Surf City/North Topsail Beach project (See Appendix A, Figure A-1). Mid-Atlantic Technology and Environmental Research, Inc completed an archeological resources survey (magnetometer and side-scan sonar) of the preliminary borrow areas in 2005. The survey identified the presence of hard bottom in and around several of the preliminary borrow areas. Due to the presence of significant hard bottom in borrow areas I, K, and M, these borrow areas were eliminated as potential borrow sources.

The grain size characteristics of all of the samples collected from each of the cores within the remaining potential borrow areas are given in tables E-3 through E-18. The grain size characteristics of the borrow area samples were used to develop weighted average composite grain size distribution representative of all of the

material in each of the borrow areas. The weighting was based on the thickness of the core represented by a particular sample in each core from which a weighted composite distribution for each core was determined. The weighted average core distributions were used to compute the overall composite characteristics for the entire borrow area. To comply with the NC beach fill standards, tables E-3 through E-18 also identify the amount of fine-grained sediment, defined as smaller than 0.062 mm (#230 sieve), the amount of granular sediment, defined as smaller than 4.76 mm (#4 sieve) and greater than or equal to 2.0 mm (#10 sieve), and the amount of gravel, defined as greater than or equal to 4.76 mm (#4 sieve). The final weighted composite characteristics for each of the borrow areas are given in tables E-19 to E-34.

6. **Overfill Ratio.** The suitability of the borrow material for placement on the beach is based on the overfill ratio. The overfill ratio is computed by numerically comparing the size distribution characteristics of the native beach sand with that in the borrow area and includes an adjustment for the percent of fines in the borrow area. The overfill ratio is primarily based on the assumption that the borrow material will undergo sorting and winnowing once exposed to waves and currents in the littoral zone, with the resulting sorted distribution approaching that of the native sand.

   Since borrow material will rarely match the native material exactly, the amount of borrow material needed to result in a net cubic yard of beach fill material will generally be greater than one cubic yard. The excess material needed to yield one net cubic yard of material in place on the beach profile is the overfill ratio. The overfill ratio is defined as the ratio of the volume of borrow material needed to yield one net cubic yard of fill material. For example, if 1.5 cubic yards of fill material is needed to yield one net yard in place, the overfill factor would equal 1.5. The numerical procedure for computing the overfill ratio is contained in a suite of computer programs contained in the Automated Coastal Engineering System (ACES) produced by the U.S. Army Coastal Engineering Research Center. The procedure is also described in the U.S. Army Coastal Engineering Manual EM-1110-2-1100 Part V (July 2003). A summary of the native beach and borrow characteristics, as well as, the computed overfill ratios is shown in table E-35.

7. **Compatibility and Borrow Sources.** The compatibility analysis compares the grain size of the "native or reference beach" with the material in the proposed borrow material. The overfill ratio is the primary indicator of the compatibility of the borrow material to the beach material, with a value of 1.00 indicating that one cubic yard of borrow material is needed to match one cubic yard of beach material. An overfill

ratio of up to 1.5 is generally considered acceptable as a match of compatibility. Table E-35 illustrates the overfill ratios for potential borrow areas for the Surf City/North Topsail Beach project.

Prior to implementation of the NC beach fill rules in 2007, eleven (11) offshore borrow areas were identified for the Surf City/North Topsail Beach project and included G, H, J, L, N, O, P, Q, R, S, and T. After re-evaluation of the borrow areas using the new beach fill standards, borrow area R was determined to be well above the silt criteria and was not evaluated further. Excluding borrow area R, the compatibility analysis indicated the overfill ratio for the remaining 10 borrow areas were all below 1.5. Because additional characterization for all borrow areas will be conducted during the design phase, borrow area R has not been included in the volume calculations for material available for the project, but has been retained for future evaluation. With the exclusion of borrow area R, the total estimated volume in the remaining ten borrow areas (G, H, J, L, N, O, P, Q, S, and T) is approximately 27.59 million cubic yards (yd^3), which is insufficient to meet the required volume for the NED plan of 32.3 million yd^3.

To address the deficiency of available material for the Surf City/North Topsail Beach project, the six borrow areas identified for the Topsail Beach Federal shore protection project (A, B, C, D, E, and F) were considered. The estimated amount of compatible material in these borrow areas exceeds the Topsail Beach Federal and non-Federal project requirements by approximately 9.68 million yd^3. Therefore, these borrow areas have been included in the compatibility analysis conducted for the Surf City/North Topsail Beach project in this appendix. The overfill ratios for these six borrow areas are also all below 1.5 with the exception of borrow area C., which was 1.56. Because the overfill ratio for borrow area C was only slightly above 1.5, it has been retained for further evaluation when additional characterization is conducted during the design phase. The additional estimated amount of compatible material in the Topsail Beach borrow areas (A, B, C, D, E, and F) which exceeds the Topsail Beach project requirements (approximately 9.29 million yd^3) combined with the estimated volume (27.59 million yd^3) in borrow areas G, H, J, L, N, O, P, Q, S, and T meets the NED project requirements (32.3 million yd^3).

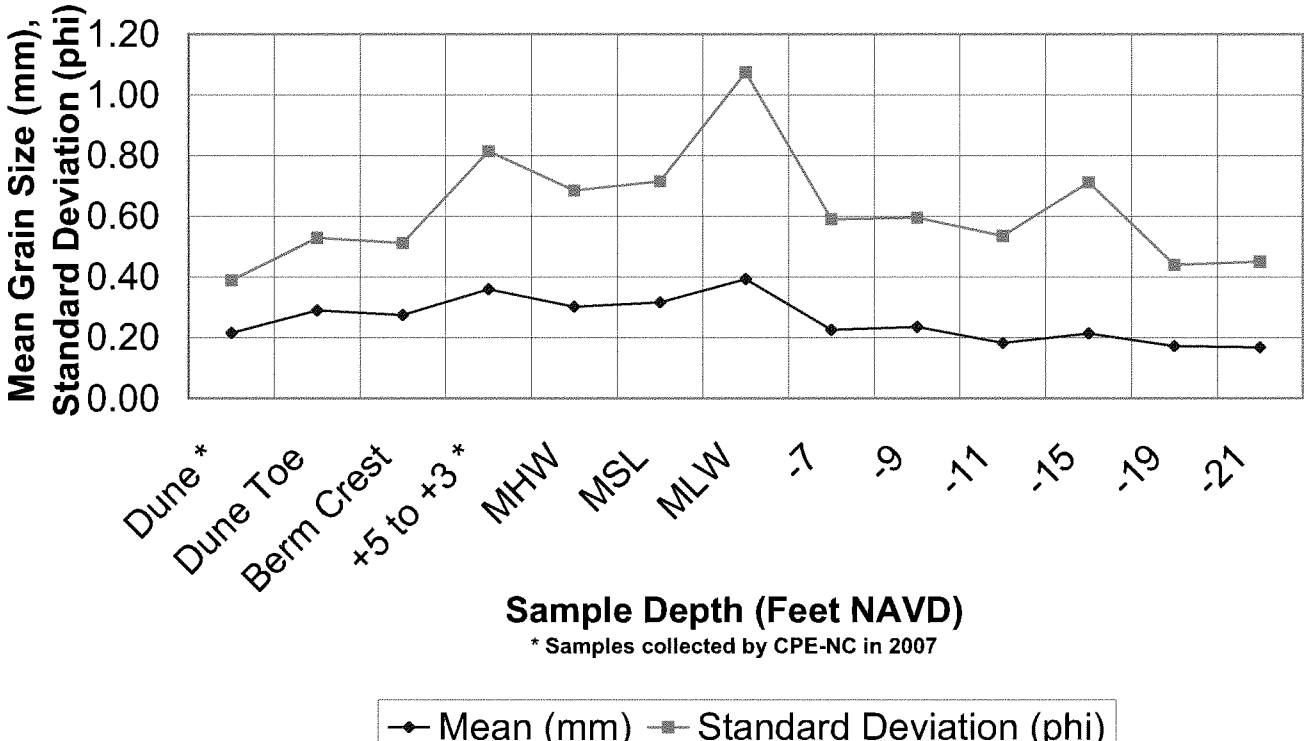
The composite mean grain size of material in the native beach material and borrow areas is illustrated in table E-35. The composite mean grain size for the borrow areas is typically within 0.03 millimeters of the native beach sand (0.23 mm), with the exceptions of borrow areas F, N, S, and T. The mean grain size for these borrow

areas is larger than the native beach material with mean grain sizes of 0.47 mm, 0.28 mm, 0.32 mm, and 0.29 mm respectively.

The NC beach fill standards require compatibility of the native beach with borrow sources in regards to the percentage of silt (< 0.062 mm), granular sediment, (< 4.76 mm and ≥ 2.0 mm), gravel (≥ 4.76 mm), and calcium carbonate. A visual estimate of shell content can be used in lieu of carbonate weight percent for samples collected prior to the effective date of beach fill rules which applies to the Surf City/North Topsail Beach project. The standards require that percent silt, granular sediment, and gravel in borrow material not exceed the amount found in the native beach plus 5% and the percent carbonate in borrow material not exceed the amount found in the native beach plus 15%. These characteristics for the native beach and borrow material are illustrated in table E-35. The analysis for the native beach material indicates the silt, granular sediment, and gravel content are 1.2%, 1.1%, and 0.5% respectively. The visual shell content for the native beach is 9%. After incorporating the tolerance permitted by the beach fill standards, the silt, granular sediment, gravel, and shell content permitted for borrow areas to be used for the Surf City/North Topsail Beach are less than 6.2%, 6.1%, 5.5%, and 24% respectively.

All of the borrow areas comply with the beach fill standards in regards to the percentage of silt with the exception of borrow areas A (6.6%) and L (6.3%). Both of these borrow areas exceed the standard slightly by 0.4 and 0.1% respectively. All of the borrow areas comply with the beach fill standards in regards to the percentage of granular sediment with the exception of borrow areas F (7.0%) and S (6.6%), which exceed the standard by 0.9 and 0.5% respectively. All of the borrow areas comply with the beach fill standards in regards to the percentage of gravel sediment with the exception of borrow areas F (8.5%) and P (6.6%), which exceed the standard by 3 and 1.1% respectively. All of the borrow areas comply with the beach fill standards in regards to the percentage of shell content (carbonate). Because all borrow areas will be further characterized during the design phase of this project, borrow areas in which the standards were exceeded for the various characteristic (A, F, L, S, and P) have been retained. Additional vibracores will be performed to comply with the beach fill standards of 1 core/acre or 1,000 foot spacing. This additional data will be incorporated into the existing borrow area data to produce the final characteristics of each borrow source, which will be evaluated using the NC beach fill standards to determine compliance.

Figure E-1: Average Mean and Standard Deviation Versus Sample Depth



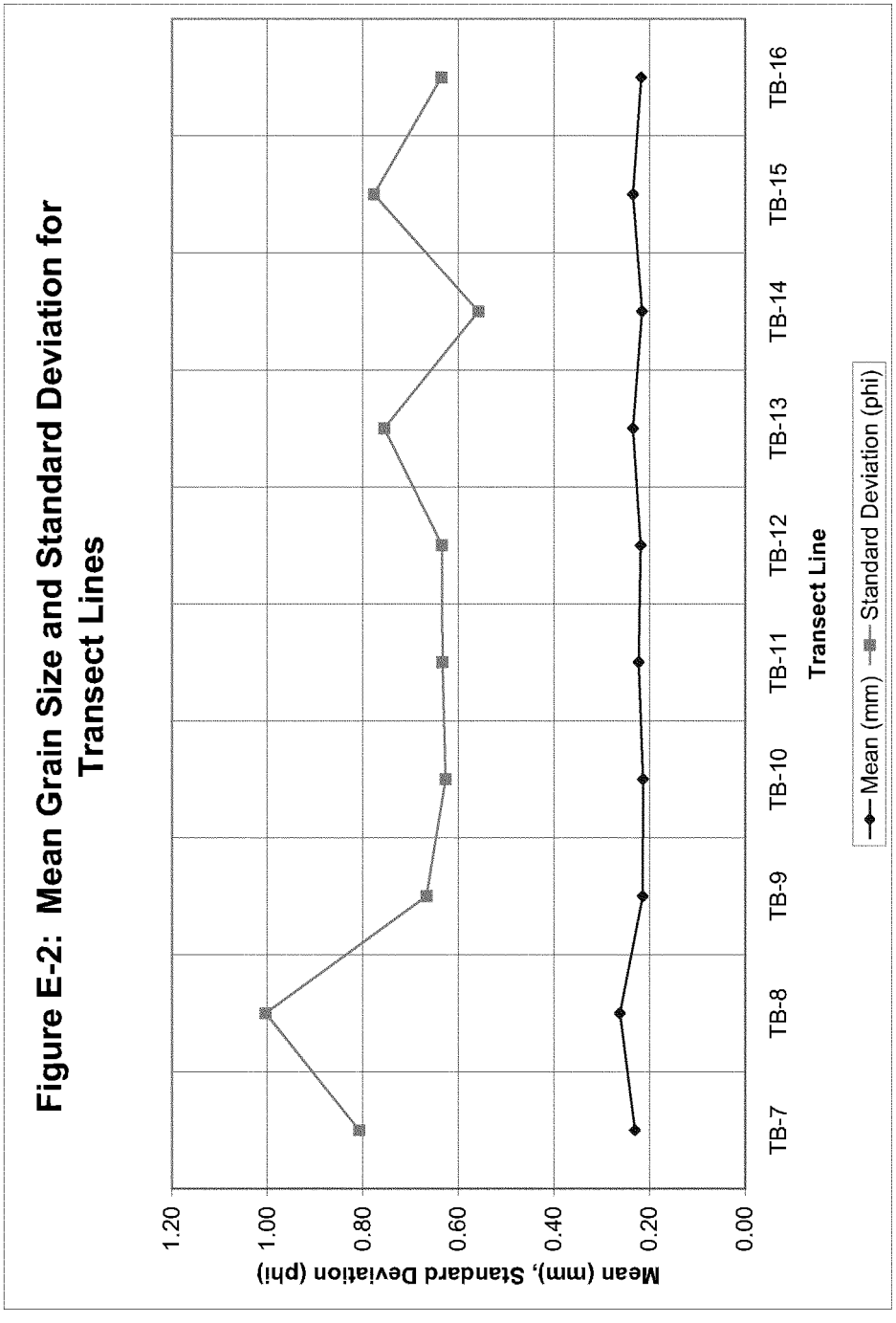


Figure E-2: Mean Grain Size and Standard Deviation for Transect Lines
Mean (mm), Standard Deviation (phi)
1.20
1.00
0.80
0.60
0.40
0.20
0.00
TB-7
TB-8
TB-9
TB-10
TB-11
TB-12
TB-13
TB-14
TB-15
TB-16
Transect Line
Mean (mm)
Standard Deviation (phi)

Table E-1
Native Beach Samples

Sample Description	Mean (phi)	Mean (mm)	Std Dev (phi)	Std Dev (mm)	% Silt (0.062 mm)	% Granular (2 - 4.76 mm)	% Gravel (4.76 mm)	% Shell
TRANSECT LINE TB-7								
TB-7-TOE	1.89	0.27	0.69	0.62	7.0	0.3	0.9	17
TB-7-CREST	1.53	0.35	0.89	0.54	0.9	0.3	0.0	24
TB-7-MHW	1.61	0.33	0.72	0.61	0.5	0.2	0.0	22
TB-7-MSL	1.47	0.36	1.00	0.50	1.1	0.1	0.0	32
TB-7-MLW	1.37	0.39	1.23	0.43	1.0	3.5	0.2	19
TB-7-6	2.52	0.17	0.41	0.76	1.3	0.1	0.0	5
TB-7-8	2.62	0.16	0.40	0.76	1.0	0.1	0.0	13
TB-7-12	2.43	0.19	0.46	0.73	1.1	0.6	0.1	8
TB-7-14	2.57	0.17	0.47	0.72	1.8	2.0	0.1	5
TB-7-18	2.52	0.17	0.42	0.75	1.3	0.0	1.0	5
TB-7-20	2.61	0.16	0.42	0.75	2.1	0.0	0.0	2
TRANSECT LINE TB-8								
TB-8-TOE	0.93	0.52	0.59	0.67	0.5	0.1	0.0	35
TB-8-CREST	1.50	0.35	0.40	0.76	1.2	4.4	1.4	20
TB-8-MHW	1.59	0.33	0.92	0.53	1.3	3.1	0.2	17
TB-8-MSL	1.53	0.35	0.81	0.57	0.6	0.2	0.0	20
TB-8-MLW	0.52	0.70	1.97	0.26	0.8	18.3	7.9	30
TB-8-6	2.01	0.25	0.65	0.64	1.0	0.3	0.0	13
TB-8-8	2.54	0.17	0.47	0.72	0.8	0.2	0.0	7
TB-8-12	2.49	0.18	0.44	0.74	1.4	0.1	0.0	6
TB-8-14	2.52	0.17	0.46	0.73	1.2	2.4	0.2	4
TB-8-18	2.57	0.17	0.41	0.75	1.7	0.0	0.0	6
TB-8-20	2.64	0.16	0.44	0.74	2.0	0.1	0.0	7
TRANSECT LINE TB-9								
TB-9-TOE	2.08	0.24	0.42	0.75	0.8	0.1	0.0	5
TB-9-CREST	2.17	0.22	0.40	0.76	0.9	0.0	0.0	6
TB-9-MHW	1.72	0.30	0.81	0.57	1.4	3.0	0.0	15
TB-9-MSL	1.44	0.37	1.19	0.44	0.7	2.3	0.0	18
TB-9-MLW	0.52	0.70	2.08	0.24	0.9	27.3	6.1	20
TB-9-6	2.43	0.19	0.44	0.74	1.3	0.1	0.0	9
TB-9-8	2.51	0.17	0.45	0.73	1.0	0.1	0.0	8
TB-9-12	2.48	0.18	0.55	0.68	1.6	2.2	0.0	9
TB-9-14	2.53	0.17	0.44	0.74	1.3	0.5	0.4	5
TB-9-18	2.57	0.17	0.43	0.74	1.9	0.1	0.0	3
TB-9-20	2.64	0.16	0.41	0.75	2.3	0.1	0.0	3
TRANSECT LINE TB-10								
TB-10-TOE	1.36	0.39	1.04	0.49	0.6	2.8	0.0	13
TB-10-CREST	1.87	0.27	0.55	0.68	0.8	0.0	0.0	12
TB-10-MHW	2.04	0.24	0.44	0.74	1.2	0.0	0.0	7
TB-10-MSL	2.04	0.24	0.47	0.72	1.1	0.1	0.0	6
TB-10-MLW	1.79	0.29	0.90	0.54	1.0	0.5	0.2	16
TB-10-6	2.59	0.17	0.39	0.76	1.4	0.0	0.0	5
TB-10-8	2.61	0.16	0.49	0.71	1.6	0.1	0.0	4
TB-10-12	2.52	0.17	0.51	0.70	1.8	0.2	0.0	5
TB-10-14	2.41	0.19	0.53	0.69	1.8	2.1	0.7	7
TB-10-18	2.45	0.18	0.42	0.75	2.2	0.5	0.3	4
TB-10-20	2.49	0.18	0.44	0.74	2.8	0.1	0.1	5

Table E-1
Native Beach Samples (continued)

Sample Description	Mean (phi)	Mean (mm)	Std Dev (phi)	Std Dev (mm)	% Silt (0.062 mm)	% Granular (2 - 4.76 mm)	% Gravel (4.76 mm)	% Shell
TRANSECT LINE TB-11								
TB-11-TOE	1.98	0.25	0.40	0.76	0.6	0.1	0.0	5
TB-11-CREST	2.10	0.23	0.39	0.76	0.3	0.0	0.0	5
TB-11-MHW	1.45	0.37	1.07	0.48	0.8	1.6	0.0	13
TB-11-MSL	1.35	0.39	1.08	0.47	0.6	0.1	0.2	30
TB-11-MLW	1.79	0.29	0.74	0.60	1.3	0.3	0.0	15
TB-11-6	2.34	0.20	0.46	0.72	1.1	0.3	0.0	6
TB-11-8	1.53	0.35	0.47	0.72	0.6	0.3	0.0	5
TB-11-12	1.62	0.32	0.53	0.69	1.3	0.4	0.1	7
TB-11-14	1.63	0.32	0.43	0.74	1.4	2.1	0.2	8
TB-11-18	1.70	0.31	0.42	0.75	1.5	0.3	0.1	4
TB-11-20	1.67	0.31	0.42	0.75	1.2	0.2	0.9	6
TRANSECT LINE TB-12								
TB-12-TOE	1.98	0.25	0.43	0.74	0.5	0.0	0.0	4
TB-12-CREST	2.10	0.23	0.43	0.74	0.1	0.0	0.0	6
TB-12-MHW	2.01	0.25	0.51	0.70	0.7	0.0	0.0	10
TB-12-MSL	1.92	0.26	0.43	0.74	0.5	0.0	0.0	7
TB-12-MLW	1.29	0.41	1.19	0.44	1.7	3.2	1.1	31
TB-12-6	2.43	0.19	0.44	0.74	0.8	0.4	0.0	5
TB-12-8	2.44	0.18	0.41	0.75	0.0	1.0	0.0	6
TB-12-12	2.47	0.18	0.48	0.72	1.6	0.6	0.8	7
TB-12-14	0.89	0.54	2.71	0.15	0.9	4.3	17.8	28
TB-12-18	2.60	0.16	0.41	0.75	2.2	0.0	0.0	4
TB-12-20	2.52	0.17	0.46	0.73	1.6	0.7	0.1	6
TRANSECT LINE TB-13								
TB-13-DUNE *	2.17	0.22	0.42	0.75	0.3	0.0	0.0	0
TB-13-TOE	1.99	0.25	0.48	0.72	0.8	0.1	0.0	10
TB-13-CREST	1.65	0.32	0.70	0.61	1.1	0.0	0.1	14
TB-13 +5 *	1.06	0.48	1.04	0.49	0.6	0.0	2.4	0
TB-13-MHW	1.71	0.31	0.68	0.63	0.5	0.0	0.1	12
TB-13-MSL	1.72	0.30	0.68	0.63	0.0	0.0	0.0	15
TB-13-MLW	1.92	0.26	0.58	0.67	1.2	0.0	0.0	12
TB-13-6	2.48	0.18	0.49	0.71	0.9	0.3	0.0	5
TB-13-8	2.43	0.19	0.56	0.68	1.0	0.3	0.0	6
TB-13-12	2.50	0.18	0.52	0.70	2.3	0.6	0.1	6
TB-13-14	2.53	0.17	0.57	0.67	2.7	0.4	0.0	6
TB-13-18	2.54	0.17	0.50	0.71	2.0	0.4	0.0	4
TB-13-20	2.60	0.17	0.50	0.70	2.6	0.1	0.0	5
TRANSECT LINE TB-14								
TB-14-DUNE *	2.35	0.20	0.36	0.78	0.21	0.0	0.0	0
TB-14-TOE	2.11	0.23	0.37	0.77	0.4	0.2	0.0	5
TB-14-CREST	1.76	0.30	0.64	0.64	0.4	0.2	0.0	9
TB-14 +3 *	2.28	0.21	0.32	0.80	0.8	0.0	0.0	0
TB-14-MHW	1.99	0.25	0.43	0.74	0.5	0.0	0.0	6
TB-14-MSL	1.94	0.26	0.44	0.74	0.4	0.0	0.0	6
TB-14-MLW	1.78	0.29	0.63	0.65	1.4	0.0	0.0	13
TB-14-6	2.40	0.19	0.51	0.70	1.0	0.2	0.0	6
TB-14-8	2.35	0.20	0.53	0.69	0.3	0.1	0.0	5
TB-14-12	2.38	0.19	0.57	0.67	1.2	0.4	0.6	5
TB-14-14	2.43	0.19	0.44	0.74	0.8	0.3	0.0	4
TB-14-18	2.50	0.18	0.44	0.74	1.7	0.3	0.0	2
TB-14-20	2.59	0.17	0.46	0.73	2.3	0.3	0.0	3

* Samples were collected by CPE-NC Inc for the North Topsail Non-Federal Shore Protection Project in 2007.

Table E-1
Native Beach Samples (continued)

Sample Description	Mean (phi)	Mean (mm)	Std Dev (phi)	Std Dev (mm)	% Silt (0.062 mm)	% Granular (2 - 4.76 mm)	% Gravel (4.76 mm)	% Shell
TRANSECT LINE TB-15								
TB-15-DUNE *	2.28	0.21	0.35	0.79	0.2	0.0	0.0	0
TB-15-TOE	2.10	0.23	0.48	0.72	0.5	0.0	0.0	6
TB-15-CREST	2.19	0.22	0.32	0.80	0.1	0.0	0.0	2
TB-15 +3 *	0.86	0.55	1.58	0.33	0.5	0.1	0.0	0
TB-15-MHW	1.87	0.27	0.56	0.68	0.4	0.0	0.0	3
TB-15-MSL	1.82	0.28	0.65	0.64	0.9	0.0	0.0	6
TB-15-MLW	1.77	0.29	0.86	0.55	0.9	0.2	0.0	10
TB-15-6	2.52	0.17	0.47	0.72	1.0	0.1	0.0	3
TB-15-8	0.58	0.67	1.23	0.43	1.1	8.5	2.7	28
TB-15-12	2.55	0.17	0.57	0.67	2.2	0.5	0.4	4
TB-15-14	2.56	0.17	0.53	0.69	1.9	1.3	0.8	3
TB-15-18	2.63	0.16	0.47	0.72	2.5	0.0	0.0	1
TB-15-20	2.65	0.16	0.46	0.73	2.3	0.0	0.0	3
TRANSECT LINE TB-16								
TB-16-DUNE *	2.08	0.24	0.43	0.74	0.2	0.0	0.0	0
TB-16-TOE	2.10	0.23	0.38	0.77	0.2	0.0	0.0	4
TB-16-CREST	2.09	0.24	0.40	0.76	0.1	0.0	0.0	4
TB-16 +4 *	2.31	0.20	0.32	0.80	0.5	0.0	0.0	0
TB-16-MHW	1.79	0.29	0.71	0.61	0.1	0.6	0.0	9
TB-16-MSL	2.00	0.25	0.42	0.75	0.6	0.0	0.0	5
TB-16-MLW	2.00	0.25	0.56	0.68	1.1	2.7	0.5	7
TB-16-6	0.84	0.56	1.63	0.32	0.4	10.5	0.4	27
TB-16-8	2.02	0.25	0.96	0.51	0.9	1.1	0.5	12
TB-16-12	2.42	0.19	0.71	0.61	1.5	1.5	0.3	7
TB-16-14	2.64	0.16	0.55	0.68	1.8	1.5	0.0	4
TB-16-18	2.67	0.16	0.48	0.72	1.1	0.0	0.0	3
TB-16-20	2.71	0.15	0.49	0.71	2.2	0.0	0.0	3

* Samples were collected by CPE-NC Inc for the North Topsail Non-Federal Shore Protection Project in 2007.

Table E-2
Composite Characteristics for Native Beach

Transect Line	Mean (phi)	Mean (mm)	Std Dev (phi)	Std Dev (mm)	% Silt (0.062 mm)	% Granular (2 - 4.76 mm)	% Gravel (4.76 mm)	% Shell
TB-7	2.12	0.23	0.81	0.57	1.7	0.7	0.2	14
TB-8	1.93	0.26	1.00	0.50	1.1	2.7	0.9	15
TB-9	2.22	0.21	0.67	0.63	1.3	3.2	0.6	9
TB-10	2.23	0.21	0.63	0.65	1.8	0.6	0.1	8
TB-11	2.17	0.22	0.63	0.64	1.0	0.5	0.1	9
TB-12	2.20	0.22	0.63	0.64	1.0	0.9	1.8	10
TB-13	2.09	0.23	0.76	0.59	1.2	0.4	1.2	7
TB-14	2.22	0.22	0.56	0.68	0.9	0.1	0.0	5
TB-15	2.09	0.23	0.78	0.58	1.1	0.8	0.3	5
TB-16	2.20	0.22	0.64	0.64	0.8	1.4	0.1	7
Native Beach Composite Data	**2.15**	**0.23**	**0.71**	**0.61**	**1.2**	**1.1**	**0.5**	**9**

Table E-3
Borings for Borrow Area G

Boring Number	Layer Number	Layer Depth (ft) Top	Bottom	Layer Thickness (ft)	Mean (phi)	Mean (mm)	Std Dev (phi)	Std Dev (mm)	% Silt (0.062 mm)	% Granular (2 - 4.76 mm)	% Gravel (4.76 mm)	% Shell
TI-03-V-254	1	-49	-51	2	2.45	0.18	0.43	0.74	1.6	0.3	0.0	3
	2	-51	-53	2	1.81	0.29	1.59	0.33	14.0	5.7	5.1	9
	3	-53	-54	1	1.33	0.40	1.62	0.33	6.8	5.4	8.8	1
		EL -49 to -54		D= 5	2.09	0.23	0.90	0.54	7.6	3.5	3.8	5
TI-03-V-256	1	-47.3	-48.8	1.5	2.09	0.23	0.62	0.65	1.0	0.8	1.6	7
	2	-48.8	-49.3	0.5	2.08	0.24	0.63	0.65	1.1	0.9	3.0	7
		EL -47.3 to -49.3		D=2	2.09	0.23	0.62	0.65	1.1	0.8	2.0	7
TI-03-V-257	1	-47.5	-50	2.5	1.92	0.26	1.09	0.47	2.4	3.2	8.4	15
	2	-50	-50.5	0.5	2.48	0.18	0.96	0.52	11.1	1.7	1.1	6
		EL -47.5 to -50.5		D= 3	2.04	0.24	0.97	0.51	3.9	2.9	7.2	14
TI-03-V-258	1	-46.5	-47.8	1.3	1.31	0.40	1.83	0.28	1.2	3.4	12.4	18
	2	-47.8	-49.3	1.5	0.75	0.60	2.70	0.15	4.2	10.0	18.5	37
		EL -46.5 to -49.3		D= 2.8	0.89	0.54	2.48	0.18	2.8	6.9	15.7	28
TI-03-V-275	1	-47.7	-50	2.3	2.65	0.16	0.60	0.66	9.3	0.9	2.9	6
	2	-50	-53.2	3.2	2.57	0.17	0.40	0.76	4.2	0.0	0.0	2
	3	-53.2	-55.5	0	2.87	0.14	0.71	0.61	14.4	0.2	0.0	2
	4	-55.5	-56	0	2.37	0.19	1.82	0.28	16.2	5.4	5.5	7
		EL -47.7 to -53.2		D=5.5	2.58	0.17	0.43	0.74	6.3	0.4	1.2	4

Table E-4
Borings for Borrow Area H

Boring Number	Layer Number	Layer Depth (ft) Top	Bottom	Layer Thickness (ft)	Mean (phi)	Mean (mm)	Std Dev (phi)	Std Dev (mm)	% Silt (0.062 mm)	% Granular (2 - 4.76 mm)	% Gravel (4.76 mm)	% Shell
TI-03-V-260	**1**	**-44.4**	**-46**	**1.6**	**1.85**	**0.28**	**0.99**	**0.50**	**1.3**	**2.7**	**5.9**	**14**
	2	**-46**	**-46.6**	**0.6**	**2.61**	**0.16**	**0.55**	**0.68**	**9.6**	**0.8**	**0.6**	**3**
		EL -44.4 to -46.6		**D= 2.2**	**2.07**	**0.24**	**0.87**	**0.55**	**3.6**	**2.2**	**4.5**	**11**
TI-03-V-273	**1**	**-45.2**	**-47.5**	**2.3**	**2.23**	**0.21**	**0.60**	**0.66**	**2.2**	**2.0**	**1.8**	**7**
	2	**-47.5**	**-50**	**2.5**	**2.30**	**0.20**	**0.52**	**0.70**	**2.0**	**0.6**	**0.0**	**4**
	3	-50	-52	0	2.56	0.17	0.39	0.76	4.4	0.6	0.1	3
	4	-52	-54	0	2.76	0.15	0.23	0.86	2.7	0.0	0.0	1
	5	-54	-55.7	0	2.58	0.17	0.36	0.78	2.1	0.0	0.0	1
	6	-55.7	-56.2	0	2.56	0.17	0.37	0.77	2.4	0.0	0.0	0
		EL -45.2 to -50		**D=4.8**	**2.27**	**0.21**	**0.55**	**0.68**	**2.1**	**1.3**	**0.9**	**5**

Table E-5
Borings for Borrow Area J

Boring Number	Layer Number	Layer Depth (ft) Top	Bottom	Layer Thickness (ft)	Mean (phi)	Mean (mm)	Std Dev (phi)	Std Dev (mm)	% Silt (0.062 mm)	% Granular (2 - 4.76 mm)	% Gravel (4.76 mm)	% Shell
TI-03-V-98	**1**	**-45.5**	**-48.3**	**2.8**	**2.13**	**0.23**	**0.73**	**0.60**	**5.2**	**1.3**	**0.5**	**11**
	2	-48.3	-51	0	4.28	0.05	3.78	0.07	22.1	5.2	1.5	15
	3	-51	-53	0	2.67	0.16	0.79	0.58	15.6	3.0	0.4	10
	4	-53	-55.5	0	3.63	0.08	2.09	0.23	18.6	1.5	0.6	6
	5	-55.5	-58	0	2.48	0.18	0.45	0.73	9.4	2.2	0.4	7
	6	-58	-61	0	2.50	0.18	0.40	0.76	6.6	0.1	0.0	3
	7	-61	-64	0	2.50	0.18	0.41	0.75	8.0	0.5	0.0	4
	8	-64	-65.5	0	2.57	0.17	0.48	0.71	12.6	0.1	0.0	2
		EL -45.5 to -48.3		**D= 2.8**	**2.13**	**0.23**	**0.73**	**0.60**	**5.2**	**1.3**	**0.5**	**11**
TI-03-V-99	**1**	**-46.7**	**-50**	**3.3**	**2.46**	**0.18**	**0.44**	**0.73**	**9.6**	**1.3**	**0.1**	**6.0**
	2	**-50**	**-53**	**3**	**2.45**	**0.18**	**0.47**	**0.72**	**11.4**	**2.1**	**0.3**	**8.0**
	3	**-53**	**-55**	**2**	**2.43**	**0.18**	**0.40**	**0.76**	**6.2**	**0.4**	**0.2**	**4.0**
	4	-55	-58.5	0	3.05	0.12	1.33	0.40	16.8	2.2	0.9	9.0
	5	-58.5	-61	0	2.48	0.18	0.40	0.76	6.4	0.3	0.0	3.0
	6	-61	-63	0	2.53	0.17	0.42	0.75	10.7	0.1	0.0	2.0
	7	-63	-66.2	0	2.49	0.18	0.40	0.76	7.6	0.0	0.0	2.0
	8	-66.2	-66.7	0	2.50	0.18	0.41	0.75	8.8	0.1	0.0	1.0
		EL -46.7 to -55		**D=8.3**	**2.45**	**0.18**	**0.44**	**0.74**	**9.5**	**1.4**	**0.2**	**6.2**
TI-03-V-102	**1**	**-45**	**-47**	**2**	**1.70**	**0.31**	**1.23**	**0.43**	**2.4**	**5.8**	**1.7**	**19**
	2	**-47**	**-48**	**1**	**2.22**	**0.21**	**0.63**	**0.65**	**2.3**	**1.9**	**0.4**	**11**
	3	-48	-51	0	2.51	0.18	0.78	0.58	14.4	3.4	0.8	12
	4	-51	-54	0	2.52	0.17	0.42	0.75	9.7	0.4	0.1	3
	5	-54	-57	0	2.52	0.17	0.42	0.75	10.1	0.0	0.0	2
	6	-57	-59.3	2.3	2.60	0.17	0.51	0.70	12.6	0.1	0.0	2
		EL -45 to -48		**D=3**	**1.86**	**0.27**	**1.05**	**0.48**	**2.3**	**4.5**	**1.3**	**16**

Table E-5
Borings for Borrow Area J (cont.)

Boring Number	Layer Number	Layer Depth (ft) Top	Bottom	Layer Thickness (ft)	Mean (phi)	Mean (mm)	Std Dev (phi)	Std Dev (mm)	% Silt (0.062 mm)	% Granular (2 - 4.76 mm)	% Gravel (4.76 mm)	% Shell
TI-03-V-103	**1**	**-47.4**	**-50**	**2.6**	**2.29**	**0.20**	**0.58**	**0.67**	**2.8**	**1.6**	**0.2**	**10**
	2	-50	-53	0	2.57	0.17	0.59	0.67	13.5	1.7	0.6	8
	3	-53	-55	0	3.17	0.11	1.40	0.38	18.0	0.4	0.0	3
	4	-55	-57	0	2.42	0.19	4.39	0.05	26.0	4.6	15.2	1
	5	-57	-59	0	3.65	0.08	1.66	0.32	32.8	3.5	1.7	2
	6	-59	-59.7	0	3.45	0.09	0.97	0.51	26.9	1.2	0.0	4
		EL -47.4 to -50		**D=2.6**	**2.29**	**0.20**	**0.58**	**0.67**	**2.8**	**1.6**	**0.2**	**10**
TI-03-V-270A	**1**	**-46.3**	**-48.3**	**2**	**2.00**	**0.25**	**0.81**	**0.57**	**1.5**	**3.0**	**1.1**	**9**
	2	-48.3	-50.5	0	3.19	0.11	0.78	0.58	17.7	0.1	0.1	1
	3	-50.5	-52.5	0	3.28	0.10	0.73	0.60	18.6	0.1	0.0	1
	4	-52.5	-54.8	0	3.21	0.11	0.72	0.61	16.9	0.5	0.0	1
		EL -46.3 to -48.3		**D=2**	**2.00**	**0.25**	**0.81**	**0.57**	**1.5**	**3.0**	**1.1**	**9**
TI-03-V-281	**1**	**-44**	**-45.5**	**1.5**	**1.73**	**0.30**	**0.99**	**0.50**	**1.5**	**4.4**	**1.9**	**15**
	2	**-45.5**	**-47.4**	**1.9**	**2.20**	**0.22**	**0.54**	**0.69**	**1.1**	**1.0**	**0.2**	**6**
	3	-47.4	-49	0	1.95	0.26	1.94	0.26	15.6	8.2	3.3	19
	4	-49	-51	0	3.29	0.10	2.55	0.17	19.1	5.9	1.8	13
	5	-51	-53	0	2.38	0.19	1.02	0.49	14.7	3.4	6.1	11
	6	-53	-55.2	0	3.27	0.10	1.69	0.31	18.4	2.8	1.7	11
	7	-55.2	-55.7	0	3.06	0.12	1.36	0.39	17.5	3.0	1.5	10
		EL -44 to -47.4		**D=3.4**	**2.02**	**0.25**	**0.72**	**0.61**	**1.2**	**2.5**	**1.0**	**10**
TI-03-V-283	**1**	**-42.4**	**-44**	**1.6**	**1.58**	**0.34**	**1.16**	**0.45**	**2.2**	**5.3**	**2.8**	**10**
	2	**-44**	**-45.6**	**1.6**	**2.15**	**0.22**	**0.57**	**0.67**	**2.0**	**2.1**	**0.8**	**7**
	3	-45.6	-48.5	0	1.87	0.27	1.82	0.28	15.3	8.4	3.1	17
	4	-48.5	-51	0	3.35	0.10	1.75	0.30	18.8	2.2	0.2	3
	5	-51	-53.5	0	2.64	0.16	0.72	0.61	14.7	2.9	2.6	8
	6	-53.5	-54.6	0	2.55	0.17	0.56	0.68	12.9	2.6	0.5	5
		EL -42.4 to -45.6		**D=3.2**	**1.87**	**0.27**	**0.88**	**0.54**	**2.1**	**3.7**	**1.8**	**9**

Table E-5
Borings for Borrow Area J (cont.)

Boring Number	Layer Number	Layer Depth (ft) Top	Bottom	Layer Thickness (ft)	Mean (phi)	Mean (mm)	Std Dev (phi)	Std Dev (mm)	% Silt (0.062 mm)	% Granular (2 - 4.76 mm)	% Gravel (4.76 mm)	% Shell
TI-03-V-286	**1**	**-42**	**-44.2**	**2.2**	**1.89**	**0.27**	**0.90**	**0.53**	**2.6**	**1.8**	**3.3**	**11**
	2	**-44.2**	**-46**	**1.8**	**1.26**	**0.42**	**2.24**	**0.21**	**12.3**	**7.0**	**11.7**	**17**
	3	-46	-49	0	2.15	0.23	2.00	0.25	16.1	5.7	7.4	12
	4	-49	-51.5	0	-0.21	1.15	4.86	0.03	15.8	9.6	33.4	1
	5	-51.5	-54	0	1.98	0.25	3.62	0.08	23.1	16.3	10.6	1
	6	-54	-55	0	-0.39	1.31	4.71	0.04	15.3	5.3	41.3	1
		EL -42 to -46		**D=4**	**1.85**	**0.28**	**1.15**	**0.45**	**7.0**	**1.8**	**3.3**	**14**

Table E-6
Borings for Borrow Area L

Boring Number	Layer Number	Layer Depth (ft) Top	Bottom	Layer Thickness (ft)	Mean (phi)	Mean (mm)	Std Dev (phi)	Std Dev (mm)	% Silt (0.062 mm)	% Granular (2 - 4.76 mm)	% Gravel (4.76 mm)	% Shell
TI-03-V-91	**1**	**-46.8**	**-48**	**1.2**	**2.00**	**0.25**	**0.78**	**0.58**	**1.4**	**1.8**	**1.1**	**7**
	2	**-48**	**-50.3**	**2.3**	**1.26**	**0.42**	**2.61**	**0.16**	**10.1**	**5.7**	**14.1**	**26**
	EL -46.8 to -50.3			**D= 3.5**	**1.61**	**0.33**	**1.69**	**0.31**	**7.1**	**4.4**	**9.6**	**19**
TI-03-V-93	**1**	**-46.7**	**-49**	**2.3**	**2.15**	**0.23**	**0.83**	**0.56**	**8.5**	**3.8**	**0.8**	**15**
	2	-49	-51	0	2.45	0.18	0.96	0.51	14.7	3.7	0.6	11
	3	-51	-53	0	2.54	0.17	0.49	0.71	11.8	0.9	0.3	4
	4	-53	-54.2	0	2.52	0.17	0.44	0.74	9.5	1.1	0.1	5
	5	-54.2	-57	0	2.62	0.16	0.56	0.68	12.7	0.4	0.0	3
	6	-57	-60	0	3.63	0.08	2.03	0.24	19.6	1.2	0.4	7
	7	-60	-63	0	3.66	0.08	2.08	0.24	20.3	1.1	0.4	2
	8	-63	-65.2	0	3.84	0.07	2.31	0.20	23.2	4.0	0.0	2
	EL -46.7 to -49			**D=2.3**	**2.15**	**0.23**	**0.83**	**0.56**	**8.5**	**3.8**	**0.8**	**15**
TI-03-V-95	**1**	**-47**	**-50**	**3**	**2.49**	**0.18**	**0.45**	**0.73**	**9.8**	**1.6**	**0.3**	**8**
	2	**-50**	**-53**	**3**	**2.49**	**0.18**	**0.45**	**0.73**	**10.2**	**1.6**	**0.5**	**9**
	3	**-53**	**-56**	**3**	**2.49**	**0.18**	**0.41**	**0.75**	**7.4**	**0.7**	**0.0**	**5**
	4	**-56**	**-58**	**2**	**2.53**	**0.17**	**0.38**	**0.77**	**4.7**	**0.1**	**0.0**	**3**
	5	**-58**	**-60.8**	**2.8**	**2.54**	**0.17**	**0.42**	**0.75**	**8.8**	**0.2**	**0.0**	**3**
	6	-60.8	-63.5	0	3.74	0.07	2.23	0.21	22.1	2.8	3.5	2
	7	-63.5	-64.3	0	2.33	0.20	4.41	0.05	23.8	9.6	15.1	1
	EL -47 to -60.8			**D=13.8**	**2.50**	**0.18**	**0.42**	**0.75**	**8.4**	**0.9**	**0.2**	**6**
TI-03-V-341	**1**	**-44.2**	**-46.5**	**2.3**	**1.97**	**0.26**	**0.96**	**0.51**	**5.1**	**3.0**	**0.5**	**7**
	2	**-46.5**	**-48.5**	**2**	**2.31**	**0.20**	**0.71**	**0.61**	**7.8**	**1.9**	**1.0**	**5**
	3	-48.5	-51	0	2.60	0.16	0.65	0.64	13.4	2.2	6.7	1
	4	-51	-53.5	0	2.54	0.17	0.45	0.73	10.5	1.2	1.4	2
	5	-53.5	-56	0	2.59	0.17	0.57	0.68	12.8	1.4	4.8	3
	6	-56	-58.2	0	0.61	0.65	3.20	0.11	10.7	5.6	26.3	5
	EL -44.2 to -48.5			**D=4.3**	**2.12**	**0.23**	**0.88**	**0.54**	**6.3**	**2.5**	**0.7**	**6**

Table E-6
Borings for Borrow Area L (cont.)

Boring Number	Layer Number	Layer Depth (ft) Top	Bottom	Layer Thickness (ft)	Mean (phi)	Mean (mm)	Std Dev (phi)	Std Dev (mm)	% Silt (0.062 mm)	% Granular (2 - 4.76 mm)	% Gravel (4.76 mm)	% Shell
TI-03-V-342	**1**	**-44.3**	**-46.3**	**2**	**1.89**	**0.27**	**1.04**	**0.49**	**3.8**	**5.6**	**2.8**	**15**
	2	-46.3	-48.5	0	1.97	0.26	1.46	0.36	12.7	6.4	1.4	14
	3	-48.5	-51.5	0	3.52	0.09	3.28	0.10	23.1	5.6	1.8	17
	4	-51.5	-54.5	0	1.92	0.26	1.81	0.28	14.5	7.8	1.6	11
	5	-54.5	-57	0	1.52	0.35	2.44	0.18	14.5	8.5	9.9	11
	6	-57	-59.1	0	2.78	0.15	1.28	0.41	16.4	4.5	3.6	4
	7	-59.1	-61	0	2.69	0.16	0.64	0.64	13.8	1.3	0.2	2
	8	-61	-63.5	0	2.63	0.16	0.49	0.71	10.5	1.5	0.1	3
	9	-63.5	-64.3	0	-1.18	2.27	3.63	0.08	7.6	6.8	48.4	2
		EL -44.3 to -46.3		**D=2**	**1.89**	**0.27**	**1.04**	**0.49**	**3.8**	**5.6**	**2.8**	**15**
TI-03-V-343	**1**	**-46**	**-48**	**1.5**	**2.37**	**0.19**	**0.48**	**0.72**	**2.3**	**0.7**	**0.0**	**2**
	2	**-48**	**-50**	**1.5**	**2.23**	**0.21**	**0.62**	**0.65**	**1.3**	**1.7**	**0.8**	**5**
	3	**-50**	**-51**	**0**	**2.53**	**0.17**	**0.43**	**0.74**	**9.2**	**0.4**	**0.4**	**1**
	4	-51	-54	0	2.65	0.16	0.55	0.68	12.7	0.2	0.0	2
	5	-54	-56.3	0	2.73	0.15	0.63	0.65	14.2	0.8	0.0	4
		EL -46 to -51		**D=5**	**2.37**	**0.19**	**0.50**	**0.71**	**3.3**	**1.0**	**0.4**	**3**
TI-03-V-344	**1**	**-45.7**	**-47.5**	**1.8**	**0.74**	**0.60**	**2.31**	**0.20**	**1.4**	**8.2**	**14.4**	**22**
	2	**-47.5**	**-48**	**0.5**	**1.36**	**0.39**	**1.44**	**0.37**	**2.3**	**2.9**	**11.5**	**23**
		EL -45.7 to -48		**D=2.3**	**0.81**	**0.57**	**2.23**	**0.21**	**1.6**	**7.0**	**13.8**	**22**
TI-03-V-345	**1**	**-42.3**	**-44.5**	**2.2**	**1.70**	**0.31**	**0.93**	**0.52**	**1.6**	**2.0**	**1.1**	**14**
	2	**-44.5**	**-45.3**	**0.8**	**1.42**	**0.37**	**1.35**	**0.39**	**2.2**	**5.0**	**4.9**	**18**
		EL -42.3 to -45.3		**D=3**	**1.65**	**0.32**	**1.01**	**0.50**	**1.8**	**2.8**	**2.1**	**15**
TI-03-V-346	**1**	**-42.5**	**-44**	**1.5**	**1.74**	**0.30**	**1.14**	**0.45**	**3.6**	**3.8**	**3.9**	**13**
	2	**-44**	**-45.5**	**1.5**	**2.25**	**0.21**	**0.79**	**0.58**	**11.7**	**2.9**	**5.9**	**13**
	3	-45.5	-47	0	2.56	0.17	0.58	0.67	13.0	1.6	2.0	1
	4	-47	-48.5	0	2.66	0.16	0.58	0.67	12.9	0.9	1.5	2
	5	-48.5	-51	0	0.77	0.59	2.92	0.13	13.7	5.8	20.0	1
	6	-51	-52	0	0.67	0.63	3.42	0.09	13.4	7.4	29.1	3
		EL -42.5 to -45.5		**D=3**	**1.93**	**0.26**	**1.09**	**0.47**	**7.6**	**3.4**	**4.9**	**13**

Table E-6
Borings for Borrow Area L (cont.)

Boring Number	Layer Number	Layer Depth (ft) Top	Bottom	Layer Thickness (ft)	Mean (phi)	Mean (mm)	Std Dev (phi)	Std Dev (mm)	% Silt (0.062 mm)	% Granular (2 - 4.76 mm)	% Gravel (4.76 mm)	% Shell
TI-03-V-351	**1**	**-44.5**	**-45.5**	**1**	**-0.43**	**1.34**	**2.67**	**0.16**	**2.2**	**14.6**	**27.9**	**28**
	2	**-45.5**	**-47.3**	**1.8**	**2.60**	**0.16**	**0.58**	**0.67**	**10.1**	**3.4**	**0.8**	**10**
	3	-47.3	-49.5	0	3.08	0.12	1.28	0.41	17.7	2.0	0.4	5
	4	-49.5	-51.5	0	2.66	0.16	1.01	0.50	15.3	1.7	8.0	1
		EL -44.5 to -47.3		**D=2.8**	**1.31**	**0.40**	**2.13**	**0.23**	**7.3**	**7.4**	**10.5**	**16**

Table E-7
Borings for Borrow Area N

Boring Number	Layer Number	Layer Depth (ft) Top	Bottom	Layer Thickness (ft)	Mean (phi)	Mean (mm)	Std Dev (phi)	Std Dev (mm)	% Silt (0.062 mm)	% Granular (2 - 4.76 mm)	% Gravel (4.76 mm)	% Shell
TI-03-V-63	1	-45.9	-47	1.1	2.18	0.22	0.52	0.70	0.7	0.5	0.3	6
	2	-47	-48.9	1.9	1.82	0.28	0.99	0.50	1.5	3.2	7.5	18
	EL -45.9 to -48.9			D= 3	2.08	0.24	0.63	0.65	1.2	2.2	4.9	14
TI-03-V-65	1	-45.7	-47	1.3	2.29	0.20	0.47	0.72	1.2	0.3	0.0	6
	2	-47	-48.5	1.5	2.38	0.19	0.46	0.73	1.3	0.9	0.3	6
	3	-48.5	-50.5	2	2.39	0.19	0.40	0.76	2.0	0.6	1.5	9
	4	-50.5	-51.2	0.7	2.41	0.19	0.42	0.75	1.3	0.2	0.0	4
	EL -45.7 to -51.2			D=5.5	2.37	0.19	0.43	0.74	1.5	0.5	0.6	7
TI-03-V-68	1	-46.7	-48.5	1.8	2.38	0.19	0.46	0.73	1.4	0.9	0.2	5
	2	-48.5	-50.5	2	1.55	0.34	1.20	0.43	7.5	4.8	4.9	3
	3	-50.5	-52	1.5	0.24	0.85	2.86	0.14	10.0	4.9	19.5	1
	4	-52	-52.7	0.7	1.73	0.30	0.85	0.55	6.0	2.7	5.7	1
	EL -46.7 to -52.7			D=6	1.71	0.31	1.20	0.44	6.1	3.4	4.8	3
TI-03-V-69	1	-43.6	-45	1.4	2.05	0.24	0.73	0.60	0.7	2.3	3.3	13
	2	-45	-46.8	1.8	0.97	0.51	1.96	0.26	1.2	8.2	10.4	30
	3	-46.8	-47.3	0.5	0.61	0.66	2.67	0.16	2.1	6.0	18.5	34
	EL -43.6 to -47.3			D=3.7	1.31	0.40	1.71	0.31	1.1	5.7	8.8	24
TI-03-V-70	1	-44.8	-47	2.2	1.27	0.42	1.36	0.39	4.6	4.2	7.1	19
	2	-47	-47.8	0.8	1.06	0.48	1.99	0.25	10.6	11.3	6.4	29
	3	-47.8	-49.3	1.5	1.74	0.30	0.98	0.51	5.0	1.3	11.4	1
	4	-49.3	-49.8	0.5	1.74	0.30	1.32	0.40	10.5	3.6	8.7	8
	EL -44.8 to -49.8			D=5	1.33	0.40	1.46	0.36	6.3	4.4	8.4	14

Table E-7
Borings for Borrow Area N (cont.)

Boring Number	Layer Number	Layer Depth (ft) Top	Bottom	Layer Thickness (ft)	Mean (phi)	Mean (mm)	Std Dev (phi)	Std Dev (mm)	% Silt (0.062 mm)	% Granular (2 - 4.76 mm)	% Gravel (4.76 mm)	% Shell
TI-03-V-72	1	-43.6	-45.5	1.9	0.71	0.61	1.29	0.41	0.9	6.5	6.7	21
	2	-45.5	-46.4	0.9	0.04	0.97	2.63	0.16	1.5	7.7	19.9	15
	EL -43.6 to -46.4			D=2.8	0.54	0.69	1.64	0.32	1.1	6.9	10.9	19
TI-03-V-74	1	-46.2	-48	1.8	2.31	0.20	0.48	0.71	1.1	1.4	0.1	5
	2	-48	-50	2	2.38	0.19	0.50	0.71	2.3	0.9	0.3	7
	3	-50	-51.7	1.7	1.08	0.47	2.17	0.22	6.9	8.3	10.8	18
	EL -46.2 to -51.7			D=5.5	2.20	0.22	0.67	0.63	3.3	3.4	3.5	10
TI-03-V-77	1	-45.7	-48	2.3	2.23	0.21	0.57	0.67	1.4	1.5	0.9	7
	2	-48	-49.2	0	-0.30	1.23	2.82	0.14	8.8	15.4	26.8	16
	EL -45.7 to -48			D=2.3	2.23	0.21	0.57	0.67	1.4	1.5	0.9	7
TI-03-V-78	1	-44.8	-46.8	2	1.41	0.38	1.82	0.28	3.3	6.9	8.1	15
	2	-46.8	-48.3	1.5	2.73	0.15	0.42	0.75	7.5	0.1	0.0	2
	3	-48.3	-48.8	0.5	2.53	0.17	0.38	0.77	2.3	0.0	0.0	2
	EL -44.8 to -48.8			D=4	2.38	0.19	0.65	0.64	4.8	3.5	4.1	9
TI-03-V-79	1	-44.1	-46.4	2.3	2.03	0.24	0.60	0.66	1.6	0.5	0.1	8
	2	-46.4	-47.5	0	-0.44	1.35	2.27	0.21	6.4	15.5	38.4	2
	EL -44.5 to -46.4			D=2.3	2.03	0.24	0.60	0.66	1.6	0.5	0.1	8
TI-03-V-86	1	-44.3	-46.5	2.2	1.75	0.30	1.03	0.49	1.0	4.9	4.2	17
	2	-46.5	-48.5	2	2.36	0.20	0.46	0.72	2.0	0.7	1.2	6
	3	-48.5	-51	2.5	2.29	0.21	0.56	0.68	2.7	1.1	1.0	5
	4	-51	-53	2	1.77	0.29	0.76	0.59	2.1	3.0	0.3	8
	5	-53	-55.5	2.5	1.80	0.29	0.73	0.60	2.6	3.2	1.0	9
	6	-55.5	-58	2.5	0.92	0.53	1.82	0.28	8.0	8.0	8.8	6
	7	-58	-59.1	1.1	1.80	0.29	0.97	0.51	6.4	3.8	3.9	0
	EL -44.3 to -59.1			D=14.8	1.88	0.27	0.91	0.53	3.4	3.6	3.0	8

Table E-7
Borings for Borrow Area N (cont.)

Boring Number	Layer Number	Layer Depth (ft) Top	Bottom	Layer Thickness (ft)	Mean (phi)	Mean (mm)	Std Dev (phi)	Std Dev (mm)	% Silt (0.062 mm)	% Granular (2 - 4.76 mm)	% Gravel (4.76 mm)	% Shell
TI-03-V-87	**1**	**-46.7**	**-49**	**2.3**	**2.06**	**0.24**	**0.84**	**0.56**	**7.9**	**1.4**	**0.0**	**3**
	2	**-49**	**-51**	**2**	**2.22**	**0.21**	**0.66**	**0.63**	**3.1**	**2.3**	**3.7**	**10**
	3	**-51**	**-52.5**	**1.5**	**0.40**	**0.76**	**3.00**	**0.12**	**6.0**	**3.9**	**24.8**	**2**
	4	-52.5	-54	0	0.52	0.70	2.25	0.21	8.2	7.9	14.9	2
	5	-54	-55.2	0	-0.33	1.25	3.22	0.11	5.6	3.8	35.8	0
	EL -46.7 to -52.5			**D=5.8**	**1.88**	**0.27**	**1.09**	**0.47**	**5.8**	**2.4**	**7.7**	**5**

Table E-8
Borings for Borrow Area O

Boring Number	Layer Number	Layer Depth (ft) Top	Bottom	Layer Thickness (ft)	Mean (phi)	Mean (mm)	Std Dev (phi)	Std Dev (mm)	% Silt (0.062 mm)	% Granular (2 - 4.76 mm)	% Gravel (4.76 mm)	% Shell
TI-03-V-83B	1	-42.9	-45	2.1	0.33	0.80	3.06	0.12	8.7	8.7	24.6	45
	2	-45	-48	3	0.36	0.78	2.89	0.13	8.0	9.0	23.2	46
	3	-48	-50	0	2.59	0.17	0.61	0.65	13.5	0.5	0.0	3
	4	-50	-51.4	0	2.57	0.17	0.59	0.66	12.8	0.6	1.4	1
	5	-51.4	-55	0	2.68	0.16	0.78	0.58	15.2	0.6	6.5	1
	6	-55	-58	0	2.49	0.18	0.44	0.74	9.1	0.5	0.1	4
	7	-58	-61	0	2.53	0.17	0.45	0.73	12.2	0.2	0.0	1
	8	-61	-62.9	0	2.56	0.17	0.54	0.69	12.8	0.5	7.4	4
		EL -42.9 to -48		D= 5.1	0.33	0.80	2.99	0.13	8.2	8.9	24.6	46
TI-03-V-85	1	-43.9	-46	2.1	2.10	0.23	0.79	0.58	7.4	3.0	1.4	5
	2	-46	-48.4	2.4	2.05	0.24	0.70	0.61	2.6	1.8	5.1	11
	3	-48.4	-51	0	1.95	0.26	1.15	0.45	9.0	1.6	10.2	1
	4	-51	-53	0	2.54	0.17	0.59	0.67	11.3	1.3	0.0	1
	5	-53	-56	0	2.67	0.16	0.70	0.62	14.5	0.4	0.2	1
	6	-56	-56.9	0	2.47	0.18	0.41	0.75	9.1	0.1	0.0	2
		EL -43.9 to -48.4		D= 4.5	2.07	0.24	0.74	0.60	4.8	2.4	3.5	8
TI-03-V-322	1	-41.9	-45	3.1	2.51	0.18	0.44	0.74	7.1	0.3	0.4	3
	2	-45	-48	0	2.70	0.15	0.48	0.72	11.2	0.6	0.0	3
	3	-48	-50	0	2.78	0.15	0.62	0.65	14.1	2.0	0.3	5
	4	-50	-52.7	0	3.03	0.12	1.12	0.46	16.9	3.4	1.6	9
	5	-52.7	-54	0	2.90	0.13	0.76	0.59	14.5	1.5	0.2	4
	6	-54	-55.4	0	0.14	0.91	4.27	0.05	9.1	3.1	25.4	3
		EL -41.9 to -45		D=3.1	2.51	0.18	0.44	0.74	7.1	0.3	0.4	3
TI-03-V-323	1	-40.6	-43.1	2.5	1.58	0.33	1.02	0.49	1.8	4.1	2.9	14
	2	-43.1	-45.5	2.4	2.46	0.18	0.43	0.74	8.0	0.4	0.5	3
	3	-45.5	-48	2.5	2.52	0.17	0.42	0.75	9.3	0.1	0.0	2
	4	-48	-50.5	2.5	2.55	0.17	0.42	0.75	8.6	0.6	0.1	2
	5	-50.5	-53	2.5	2.63	0.16	0.41	0.75	9.7	0.3	0.0	2
	6	-53	-53.7	0	2.73	0.15	0.59	0.66	13.2	1.0	0.3	4
		EL -40.6 to -53		D=12.4	2.46	0.18	0.46	0.73	7.5	1.1	0.7	5

Table E-8
Borings for Borrow Area O (cont.)

Boring Number	Layer Number	Layer Depth (ft) Top	Bottom	Layer Thickness (ft)	Mean (phi)	Mean (mm)	Std Dev (phi)	Std Dev (mm)	% Silt (0.062 mm)	% Granular (2 - 4.76 mm)	% Gravel (4.76 mm)	% Shell
TI-03-V-324	**1**	**-41.6**	**-43.4**	**1.8**	**-0.79**	**1.73**	**3.30**	**0.10**	**1.4**	**8.7**	**38.2**	**24**
	2	**-43.4**	**-45**	**1.6**	**2.27**	**0.21**	**0.58**	**0.67**	**1.6**	**1.5**	**2.2**	**7**
	3	**-45**	**-47**	**2**	**2.48**	**0.18**	**0.40**	**0.76**	**7.1**	**0.3**	**0.0**	**2**
	4	**-47**	**-48.6**	**1.6**	**2.53**	**0.17**	**0.44**	**0.74**	**11.6**	**0.3**	**0.0**	**2**
		EL -41.6 to -48.6		**D=7**	**1.85**	**0.28**	**1.22**	**0.43**	**5.4**	**2.7**	**10.3**	**9**
TI-03-V-325	**1**	**-42.7**	**-44.7**	**2**	**2.31**	**0.20**	**0.59**	**0.66**	**4.5**	**2.7**	**1.9**	**9**
	2	-44.7	-47	0	2.67	0.16	0.58	0.67	12.8	1.4	0.1	4
	3	-47	-49	0	2.64	0.16	0.57	0.67	11.8	3.2	0.0	8
	4	-49	-51.5	0	2.24	0.21	1.46	0.36	13.5	5.9	1.7	12
	5	-51.5	-53.5	0	2.78	0.15	0.60	0.66	11.4	0.1	0.1	1
	6	-53.5	-55.7	0	2.63	0.16	0.47	0.72	5.0	0.3	0.0	1
		EL -42.7 to -44.7		**D=2**	**2.31**	**0.20**	**0.59**	**0.66**	**4.5**	**2.7**	**1.9**	**9**
TI-03-V-326	**1**	**-42.3**	**-44**	**1.7**	**2.29**	**0.20**	**0.56**	**0.68**	**3.2**	**0.9**	**0.4**	**6**
	2	**-44**	**-45.3**	**1.3**	**2.55**	**0.17**	**0.47**	**0.72**	**9.7**	**0.1**	**0.0**	**0**
	3	**-45.3**	**-48**	**2.7**	**2.52**	**0.17**	**0.44**	**0.74**	**7.0**	**0.1**	**0.0**	**0**
	4	**-48**	**-50.5**	**2.5**	**2.57**	**0.17**	**0.41**	**0.75**	**4.1**	**0.0**	**0.0**	**0**
	5	**-50.5**	**-52.3**	**1.8**	**2.56**	**0.17**	**0.42**	**0.75**	**4.3**	**0.0**	**0.0**	**1**
	6	**-52.3**	**-55**	**2.7**	**2.59**	**0.17**	**0.40**	**0.76**	**4.4**	**0.1**	**0.0**	**1**
	7	-55	-57.5	0	3.05	0.12	0.54	0.69	10.6	0.0	0.0	1
	8	-57.5	-58.3	0	2.94	0.13	0.47	0.72	8.9	0.0	9.4	1
		EL -42.3 to -55		**D=12.7**	**2.54**	**0.17**	**0.43**	**0.74**	**5.3**	**0.2**	**0.1**	**1**
TI-03-V-327	**1**	**-41**	**-43**	**2**	**1.48**	**0.36**	**1.62**	**0.33**	**1.9**	**6.4**	**6.2**	**18**
	2	**-43**	**-45**	**2**	**2.56**	**0.17**	**0.52**	**0.70**	**9.8**	**0.5**	**0.2**	**4**
	3	-45	-47	0	2.81	0.14	0.77	0.58	15.0	0.6	0.2	2
	4	-47	-49.2	0	-0.79	1.72	3.20	0.11	6.6	11.6	42.7	2
	5	-49.2	-51	0	2.40	0.19	2.37	0.19	21.4	5.1	8.7	4
	6	-51	-53.5	0	3.42	0.09	1.03	0.49	25.8	0.9	0.2	2
	7	-53.5	-57	0	3.24	0.11	0.73	0.60	17.9	0.1	0.0	1
	8	-57	-57.5	0	3.21	0.11	0.75	0.59	17.2	0.3	0.0	3
		EL -41 to -45		**D=4**	**2.22**	**0.22**	**0.76**	**0.59**	**5.9**	**3.4**	**3.2**	**11**

Table E-9
Borings for Borrow Area P

Boring Number	Layer Number	Layer Depth (ft) Top	Bottom	Layer Thickness (ft)	Mean (phi)	Mean (mm)	Std Dev (phi)	Std Dev (mm)	% Silt (0.062 mm)	% Granular (2 - 4.76 mm)	% Gravel (4.76 mm)	% Shell
TI-03-V-317	**1**	**-39.5**	**-40.8**	**1.3**	**-0.83**	**1.78**	**3.30**	**0.10**	**1.8**	**9.7**	**38.7**	**25**
	2	**-40.8**	**-44**	**3.2**	**1.94**	**0.26**	**1.25**	**0.42**	**8.3**	**1.0**	**0.0**	**6**
	3	-44	-47	0	2.04	0.24	1.61	0.33	13.4	1.0	0.4	5
	4	-47	-50	0	1.99	0.25	1.67	0.31	11.7	3.7	1.3	11
	5	-50	-53	0	1.88	0.27	1.43	0.37	7.7	0.6	0.1	3
	6	-53	-55.5	0	1.88	0.27	1.42	0.37	6.5	0.1	0.0	2
		EL -39.5 to -44		**D= 4.5**	**1.52**	**0.35**	**1.75**	**0.30**	**6.4**	**3.5**	**11.2**	**11**
TI-03-V-318	**1**	**-40.5**	**-42.5**	**2**	**1.99**	**0.25**	**0.72**	**0.61**	**1.4**	**1.4**	**0.6**	**8**
	2	-42.5	-45.3	0	2.96	0.13	1.00	0.50	16.3	0.5	0.1	3
	3	-45.3	-47	0	2.45	0.18	0.52	0.70	6.2	0.1	0.0	1
	4	-47	-49.8	0	2.10	0.23	0.81	0.57	7.7	1.6	0.0	2
	5	-49.8	-50.5	0	4.18	0.06	3.09	0.12	42.8	0.5	0.0	2
	6	-50.5	-53	0	0.68	0.63	-0.17	1.12	2.2	0.5	0.0	1
	7	-53	-54.5	0	1.75	0.30	-0.84	1.80	5.9	0.1	0.0	1
		EL -40.5 to -42.5		**D= 2**	**1.99**	**0.25**	**0.72**	**0.61**	**1.4**	**1.4**	**0.6**	**8**
TI-03-V-320	**1**	**-40.5**	**-42.4**	**1.9**	**-0.56**	**1.47**	**2.84**	**0.14**	**1.3**	**13.0**	**32.0**	**21**
	2	**-42.4**	**-45**	**2.6**	**2.34**	**0.20**	**0.49**	**0.71**	**7.7**	**0.9**	**0.0**	**4**
	3	**-45**	**-48**	**3**	**2.46**	**0.18**	**0.38**	**0.77**	**5.2**	**0.1**	**0.0**	**2**
	4	**-48**	**-51**	**3**	**2.52**	**0.17**	**0.41**	**0.75**	**8.0**	**0.1**	**0.3**	**2**
	5	-51	-54	3	2.55	0.17	0.39	0.76	5.5	0.1	0.0	1
	6	-54	-54.5	0.5	2.59	0.17	0.40	0.76	8.2	0.9	0.0	3
		EL -40.5 to -51		**D=10.5**	**2.23**	**0.21**	**0.66**	**0.63**	**5.9**	**2.0**	**5.9**	**5**

Table E-10
Borings for Borrow Area Q

Boring Number	Layer Number	Layer Depth (ft) Top	Bottom	Layer Thickness (ft)	Mean (phi)	Mean (mm)	Std Dev (phi)	Std Dev (mm)	% Silt (0.062 mm)	% Granular (2 - 4.76 mm)	% Gravel (4.76 mm)	% Shell
TI-03-V-161	1	-35.4	-37.5	2.1	2.21	0.22	0.57	0.67	1.8	0.7	0.3	8
	2	-37.5	-39	1.5	2.00	0.25	1.00	0.50	6.1	3.4	6.9	11
	3	-39	-39.6	0.6	2.46	0.18	0.41	0.75	6.8	0.2	0.0	3
		EL -35.4 to -39.6		D= 4.2	2.23	0.21	0.61	0.65	4.1	1.6	2.6	8
TI-03-V-162	1	-35.2	-37.5	2.3	1.60	0.33	1.58	0.33	4.0	6.0	5.1	19
	2	-37.5	-39.7	2.2	2.76	0.15	0.57	0.67	10.6	1.5	0.3	8
	3	-39.7	-41.2	1.5	2.41	0.19	0.40	0.76	7.0	0.2	0.0	1
		EL -35.2 to -41.2		D=6	2.35	0.20	0.70	0.62	7.2	2.9	2.1	10

Table E-11
Borings for Borrow Area S

Boring Number	Layer Number	Layer Depth (ft) Top	Bottom	Layer Thickness (ft)	Mean (phi)	Mean (mm)	Std Dev (phi)	Std Dev (mm)	% Silt (0.062 mm)	% Granular (2 - 4.76 mm)	% Gravel (4.76 mm)	% Shell
TI-03-V-46	**1**	**-44.7**	**-47**	**2.3**	**0.17**	**0.89**	**2.09**	**0.23**	**3.3**	**15.6**	**12.7**	**47**
	2	-47	-48	0	2.01	**0.25**	2.22	**0.21**	16.7	6.5	0.4	8
	3	-48	-50	0	-0.13	1.10	2.42	0.19	9.2	22.1	18.1	3
	4	-50	-53	0	-1.41	2.66	2.95	0.13	6.1	21.0	39.5	1
	EL -44.7 to -47			**D= 2.3**	**0.17**	**0.89**	**2.09**	**0.23**	**3.3**	**15.6**	**12.7**	**47**
TI-03-V-47	**1**	**-44.5**	**-45.5**	**1**	**1.98**	**0.25**	**0.93**	**0.53**	**4.0**	**5.0**	**0.2**	**22**
	2	**-45.5**	**-47.3**	**1.8**	**-0.02**	**1.01**	**2.50**	**0.18**	**6.8**	**22.0**	**17.2**	**58**
	3	-47.3	-50	0	0.67	0.63	3.18	0.11	16.4	23.7	12.6	14
	4	-50	-52	0	-0.20	1.15	2.51	0.18	8.3	21.7	19.4	2
	5	-52	-54	0	0.19	0.87	2.50	0.18	12.0	19.6	16.4	1
	6	-54	-55.7	0	-0.99	1.98	2.56	0.17	5.8	22.4	34.5	1
	EL -44.5 to -47.3			**D=2.8**	**0.82**	**0.57**	**2.28**	**0.21**	**5.8**	**16.0**	**11.1**	**45**
TI-03-V-48	**1**	**-44.2**	**-46.4**	**2.2**	**1.63**	**0.32**	**1.12**	**0.46**	**3.9**	**6.2**	**2.0**	**18**
	2	-46.4	-48.2	0	1.93	0.26	2.82	0.14	17.3	10.6	5.2	27
	3	-48.2	-50	0	0.36	0.78	2.55	0.17	10.8	17.3	17.0	1
	4	-50	-52	0	-0.01	1.01	2.69	0.15	13.5	24.1	18.5	0
	5	-52	-54	0	0.15	0.90	2.39	0.19	10.3	21.9	14.7	1
	6	-54	-55.2	0	0.41	0.75	2.48	0.18	11.3	19.3	14.9	1
	EL -44.2 to -46.4			**D=2.2**	**1.63**	**0.32**	**1.12**	**0.46**	**3.9**	**6.2**	**2.0**	**18**
TI-03-V-49	**1**	**-43.8**	**-46.1**	**2.3**	**2.22**	**0.21**	**0.53**	**0.69**	**1.3**	**0.9**	**0.1**	**8**
	2	-46.1	-47.7	0	2.68	0.16	1.05	0.48	14.3	1.3	1.4	8
	3	-47.7	-49.3	0	3.52	0.09	1.26	0.42	33.1	0.1	0.0	1
	4	-49.3	-51.5	0	2.63	0.16	0.64	0.64	7.9	0.2	0.0	2
	5	-51.5	-54.1	0	1.50	0.35	1.67	0.31	11.7	5.4	7.6	2
	6	-54.1	-55	0	-0.13	1.09	2.74	0.15	7.6	14.7	23.9	1
	EL -43.8 to -46.1			**D=2.3**	**2.22**	**0.21**	**0.53**	**0.69**	**1.3**	**0.9**	**0.1**	**8**

Table E-11
Borings for Borrow Area S (cont.)

Boring Number	Layer Number	Layer Depth (ft) Top	Bottom	Layer Thickness (ft)	Mean (phi)	Mean (mm)	Std Dev (phi)	Std Dev (mm)	% Silt (0.062 mm)	% Granular (2 - 4.76 mm)	% Gravel (4.76 mm)	% Shell
TI-03-V-51	**1**	**-44.1**	**-46.7**	**2.6**	**2.01**	**0.25**	**0.67**	**0.63**	**1.8**	**2.8**	**0.5**	**16**
	2	-46.7	-50	0	3.57	0.08	2.30	0.20	27.2	3.6	3.0	12
	3	-50	-52	0	2.25	0.21	0.70	0.61	13.3	3.0	0.7	2
	4	-52	-54	0	2.28	0.21	0.69	0.62	13.1	1.2	0.2	2
	5	-54	-56	0	1.44	0.37	1.78	0.29	11.7	4.5	10.2	2
	6	-56	-57.6	0	-0.66	1.58	3.46	0.09	7.6	9.7	34.5	1
		EL -44.1 to -46.7		**D=2.6**	**2.01**	**0.25**	**0.67**	**0.63**	**1.8**	**2.8**	**0.5**	**16**
TI-03-V-52	**1**	**-44.2**	**-46**	**1.8**	**1.96**	**0.26**	**0.58**	**0.67**	**1.4**	**1.0**	**0.9**	**9**
	2	**-46**	**-47.7**	**1.7**	**2.40**	**0.19**	**0.41**	**0.75**	**2.1**	**1.0**	**1.7**	**6**
		EL -44.2 to -47.7		**D=3.5**	**2.18**	**0.22**	**0.56**	**0.68**	**1.8**	**1.0**	**1.3**	**8**
TI-03-V-53	**1**	**-44.8**	**-46.3**	**1.5**	**2.31**	**0.20**	**0.43**	**0.74**	**1.2**	**0.1**	**0.0**	**6**
	2	**-46.3**	**-47.5**	**1.2**	**1.30**	**0.41**	**1.98**	**0.25**	**11.2**	**12.4**	**1.7**	**32**
		EL -44.8 to -47.5		**D=2.7**	**1.98**	**0.25**	**0.93**	**0.52**	**5.6**	**5.6**	**1.7**	**18**

Table E-11
Borings for Borrow Area S

Boring Number	Layer Number	Layer Depth (ft) Top	Bottom	Layer Thickness (ft)	Mean (phi)	Mean (mm)	Std Dev (phi)	Std Dev (mm)	% Silt (0.062 mm)	% Granular (2 - 4.76 mm)	% Gravel (4.76 mm)	% Shell
TI-03-V-46	**1**	**-44.7**	**-47**	**2.3**	**0.17**	**0.89**	**2.09**	**0.23**	**3.3**	**15.6**	**12.7**	**47**
	2	-47	-48	0	2.01	**0.25**	2.22	**0.21**	16.7	6.5	0.4	8
	3	-48	-50	0	-0.13	1.10	2.42	0.19	9.2	22.1	18.1	3
	4	-50	-53	0	-1.41	2.66	2.95	0.13	6.1	21.0	39.5	1
	EL -44.7 to -47			**D= 2.3**	**0.17**	**0.89**	**2.09**	**0.23**	**3.3**	**15.6**	**12.7**	**47**
TI-03-V-47	**1**	**-44.5**	**-45.5**	**1**	**1.98**	**0.25**	**0.93**	**0.53**	**4.0**	**5.0**	**0.2**	**22**
	2	**-45.5**	**-47.3**	**1.8**	**-0.02**	**1.01**	**2.50**	**0.18**	**6.8**	**22.0**	**17.2**	**58**
	3	-47.3	-50	0	0.67	0.63	3.18	0.11	16.4	23.7	12.6	14
	4	-50	-52	0	-0.20	1.15	2.51	0.18	8.3	21.7	19.4	2
	5	-52	-54	0	0.19	0.87	2.50	0.18	12.0	19.6	16.4	1
	6	-54	-55.7	0	-0.99	1.98	2.56	0.17	5.8	22.4	34.5	1
	EL -44.5 to -47.3			**D=2.8**	**0.82**	**0.57**	**2.28**	**0.21**	**5.8**	**16.0**	**11.1**	**45**
TI-03-V-48	**1**	**-44.2**	**-46.4**	**2.2**	**1.63**	**0.32**	**1.12**	**0.46**	**3.9**	**6.2**	**2.0**	**18**
	2	-46.4	-48.2	0	1.93	0.26	2.82	0.14	17.3	10.6	5.2	27
	3	-48.2	-50	0	0.36	0.78	2.55	0.17	10.8	17.3	17.0	1
	4	-50	-52	0	-0.01	1.01	2.69	0.15	13.5	24.1	18.5	0
	5	-52	-54	0	0.15	0.90	2.39	0.19	10.3	21.9	14.7	1
	6	-54	-55.2	0	0.41	0.75	2.48	0.18	11.3	19.3	14.9	1
	EL -44.2 to -46.4			**D=2.2**	**1.63**	**0.32**	**1.12**	**0.46**	**3.9**	**6.2**	**2.0**	**18**
TI-03-V-49	**1**	**-43.8**	**-46.1**	**2.3**	**2.22**	**0.21**	**0.53**	**0.69**	**1.3**	**0.9**	**0.1**	**8**
	2	-46.1	-47.7	0	2.68	0.16	1.05	0.48	14.3	1.3	1.4	8
	3	-47.7	-49.3	0	3.52	0.09	1.26	0.42	33.1	0.1	0.0	1
	4	-49.3	-51.5	0	2.63	0.16	0.64	0.64	7.9	0.2	0.0	2
	5	-51.5	-54.1	0	1.50	0.35	1.67	0.31	11.7	5.4	7.6	2
	6	-54.1	-55	0	-0.13	1.09	2.74	0.15	7.6	14.7	23.9	1
	EL -43.8 to -46.1			**D=2.3**	**2.22**	**0.21**	**0.53**	**0.69**	**1.3**	**0.9**	**0.1**	**8**

Table E-11
Borings for Borrow Area S (cont.)

Boring Number	Layer Number	Layer Depth (ft) Top	Bottom	Layer Thickness (ft)	Mean (phi)	Mean (mm)	Std Dev (phi)	Std Dev (mm)	% Silt (0.062 mm)	% Granular (2 - 4.76 mm)	% Gravel (4.76 mm)	% Shell
TI-03-V-51	**1**	**-44.1**	**-46.7**	**2.6**	**2.01**	**0.25**	**0.67**	**0.63**	**1.8**	**2.8**	**0.5**	**16**
	2	-46.7	-50	0	3.57	0.08	2.30	0.20	27.2	3.6	3.0	12
	3	-50	-52	0	2.25	0.21	0.70	0.61	13.3	3.0	0.7	2
	4	-52	-54	0	2.28	0.21	0.69	0.62	13.1	1.2	0.2	2
	5	-54	-56	0	1.44	0.37	1.78	0.29	11.7	4.5	10.2	2
	6	-56	-57.6	0	-0.66	1.58	3.46	0.09	7.6	9.7	34.5	1
		EL -44.1 to -46.7		**D=2.6**	**2.01**	**0.25**	**0.67**	**0.63**	**1.8**	**2.8**	**0.5**	**16**
TI-03-V-52	**1**	**-44.2**	**-46**	**1.8**	**1.96**	**0.26**	**0.58**	**0.67**	**1.4**	**1.0**	**0.9**	**9**
	2	**-46**	**-47.7**	**1.7**	**2.40**	**0.19**	**0.41**	**0.75**	**2.1**	**1.0**	**1.7**	**6**
		EL -44.2 to -47.7		**D=3.5**	**2.18**	**0.22**	**0.56**	**0.68**	**1.8**	**1.0**	**1.3**	**8**
TI-03-V-53	**1**	**-44.8**	**-46.3**	**1.5**	**2.31**	**0.20**	**0.43**	**0.74**	**1.2**	**0.1**	**0.0**	**6**
	2	**-46.3**	**-47.5**	**1.2**	**1.30**	**0.41**	**1.98**	**0.25**	**11.2**	**12.4**	**1.7**	**32**
		EL -44.8 to -47.5		**D=2.7**	**1.98**	**0.25**	**0.93**	**0.52**	**5.6**	**5.6**	**1.7**	**18**

Table E-12
Borings for Borrow Area T

Boring Number	Layer Number	Layer Depth (ft) Top	Bottom	Layer Thickness (ft)	Mean (phi)	Mean (mm)	Std Dev (phi)	Std Dev (mm)	% Silt (0.062 mm)	% Granular (2 - 4.76 mm)	% Gravel (4.76 mm)	% Shell
TI-03-V-14	1	-37.2	-39.5	2.3	2.18	0.22	0.54	0.69	1.4	2.0	0.5	8
	2	-39.5	-40.4	0.9	1.12	0.46	1.50	0.35	1.4	4.0	10.5	24
		EL -37.2 to -40.4		D= 3.2	1.97	0.26	0.74	0.60	1.4	2.6	3.3	13
TI-03-V-17	1	-40.6	-43	2.4	1.97	0.25	0.66	0.63	1.2	1.5	0.6	14
	2	-43	-45	2	2.16	0.22	0.54	0.69	2.6	0.6	0.4	7
	3	-45	-47	2	1.40	0.38	1.46	0.36	2.9	4.6	7.5	25
	4	-47	-49.2	2.2	1.78	0.29	0.82	0.57	2.6	2.5	75.3	21
		EL -40.6 to -49.2		D=8.6	1.91	0.27	0.78	0.58	2.3	2.3	2.9	17
TI-03-V-22	1	-41.6	-42.1	0.5	1.29	0.41	1.73	0.30	4.8	9.6	5.0	9
	2	-42.1	-43.8	1.7	2.38	0.19	0.53	0.69	10.5	0.0	0.0	2
		EL -41.6 to -43.8		D=2.2	2.26	0.21	0.62	0.65	9.2	2.2	1.1	4
TI-03-V-23	1	-41.4	-43	1.6	1.80	0.29	0.65	0.64	1.6	0.5	0.0	10
	2	-43	-45	2	0.14	0.91	2.55	0.17	2.1	12.7	21.5	44
	3	-45	-45.9	0.9	2.51	0.18	0.42	0.75	4.9	0.5	0.3	4
	4	-45.9	-48.2	0	0.16	0.90	3.55	0.09	15.3	12.0	31.1	1
		EL -41.4 to -45.9		D=4.5	1.18	0.44	1.74	0.30	2.5	5.9	9.6	24
TI-03-V-27	1	-42	-43.9	1.9	1.77	0.29	0.69	0.62	1.1	0.8	0.1	19
	2	-43.9	-44.4	0.5	1.79	0.29	0.75	0.60	1.3	2.0	2.2	19
		EL -42.7 to -44.7		D=2.4	1.78	0.29	0.70	0.62	1.2	1.1	0.6	19

Table E-13
Borings for Borrow Area A

Boring Number	Layer Number	Layer Depth (ft) Top	Bottom	Layer Thickness (ft)	Mean (phi)	Mean (mm)	Std Dev (phi)	Std Dev (mm)	% Silt (0.062 mm)	% Granular (2 - 4.76 mm)	% Gravel (4.76 mm)	% Shell
TI-03-V-124	**1**	**-38.5**	**-40.5**	**2**	**1.72**	**0.30**	**1.59**	**0.33**	**9.0**	**8.5**	**2.1**	**22**
	2	-40.5	-42.5	0	2.37	0.19	0.54	0.69	18.2	3.2	1.0	11
	3	-42.5	-45	0	2.79	0.14	0.42	0.75	5.6	0.1	0.0	3
	4	-45	-48	0	2.84	0.14	0.58	0.67	12.7	0.0	0.0	1
	5	-48	-51	0	2.73	0.15	0.67	0.63	13.9	0.0	0.0	1
	6	-51	-53.5	0	2.61	0.16	0.47	0.72	11.2	0.0	0.0	1
		EL -38.5 to -40.5		**D= 2**	**1.72**	**0.30**	**1.59**	**0.33**	**9.0**	**8.5**	**2.1**	**22**
TI-03-V-125	**1**	**-38.9**	**-40.9**	**2**	**2.31**	**0.20**	**0.98**	**0.51**	**8.4**	**4.5**	**2.6**	**17**
	2	-40.9	-43	0	2.71	0.15	0.58	0.67	11.3	2.8	0.3	9
	3	-43	-46	0	2.94	0.13	0.42	0.75	11.8	0.1	0.0	1
	4	-46	-48	0	2.93	0.13	0.44	0.74	11.7	0.0	0.0	1
	5	-48	-50.5	0	2.95	0.13	0.55	0.68	13.2	0.0	0.0	1
	6	-50.5	-51	0	2.88	0.14	0.67	0.63	13.4	0.0	0.0	1
		EL -38.9 to -40.9		**D=2**	**2.31**	**0.20**	**0.98**	**0.51**	**8.4**	**4.5**	**2.6**	**17**
TI-03-V-126	**1**	**-38.7**	**-41**	**2.3**	**1.00**	**0.50**	**2.20**	**0.22**	**8.7**	**14.9**	**6.5**	**43**
	2	**-41**	**-43.5**	**2.5**	**2.77**	**0.15**	**0.38**	**0.77**	**6.0**	**0.5**	**0.1**	**3**
	3	-43.5	-45.5	0	3.06	0.12	0.64	0.64	16.4	1.1	0.0	2
	4	-45.5	-47.5	0	2.75	0.15	0.57	0.67	12.7	0.4	0.0	2
	5	-47.5	-49.2	0	3.28	0.10	1.32	0.40	21.7	1.2	0.7	1
	6	-49.2	-49.7	0	2.81	0.14	0.61	0.66	14.2	0.2	0.1	2
		EL -38.7 to -43.5		**D=4.8**	**1.76**	**0.30**	**1.79**	**0.29**	**7.3**	**7.4**	**3.2**	**22**
TI-03-V-127	**1**	**-39.8**	**-42.3**	**2.5**	**1.41**	**0.38**	**1.91**	**0.27**	**3.8**	**6.6**	**8.5**	**28**
	2	**-42.3**	**-44**	**1.7**	**2.86**	**0.14**	**0.36**	**0.78**	**6.9**	**0.1**	**0.0**	**1**
	3	**-44**	**-44.7**	**0.7**	**2.90**	**0.13**	**0.36**	**0.78**	**6.2**	**0.2**	**0.0**	**1**
		EL -39.8 to -44.7		**D=4.9**	**2.19**	**0.22**	**1.11**	**0.46**	**5.2**	**3.4**	**4.3**	**15**

Table E-13
Borings for Borrow Area A (cont.)

Boring Number	Layer Number	Layer Depth (ft) Top	Bottom	Layer Thickness (ft)	Mean (phi)	Mean (mm)	Std Dev (phi)	Std Dev (mm)	% Silt (0.062 mm)	% Granular (2 - 4.76 mm)	% Gravel (4.76 mm)	% Shell
TI-03-V-129	1	-40.9	-42.5	1.6	1.48	0.36	1.25	0.42	1.2	5.5	0.9	24
	2	-42.5	-43.4	0.9	2.41	0.19	0.54	0.69	1.8	2.1	0.3	9
	3	-43.4	-44.3	0.9	ND	ND	ND	ND	37.3	1.8	0.0	7
	4	-44.3	-47.6	3.3	1.59	0.33	1.16	0.45	7.4	2.7	0.5	6
	5	-47.6	-49.2	1.6	ND	ND	ND	ND	70.7	0.1	0.0	1
		EL -40.9 to -43.4		D=2.5	1.84	0.28	1.09	0.47	1.4	4.2	0.7	19
TI-03-V-130	1	-42.6	-45.1	2.5	2.62	0.16	0.51	0.70	8.0	2.3	0.1	7
	2	-45.1	-47	1.9	2.82	0.14	0.32	0.80	4.9	0.2	0.0	2
	3	-47	-49	2	2.82	0.14	0.29	0.82	3.6	0.1	0.0	1
	4	-49	-50.9	1.9	2.65	0.16	0.44	0.74	3.8	0.0	0.0	1
		EL -42.6 to -50.9		D=8.3	2.71	0.15	0.42	0.75	5.3	0.7	0.0	3
TI-03-V-182	1	-44.7	-46	1.3	2.30	0.20	0.63	0.65	2.5	1.8	0.5	7
	2	-46	-47	1	1.88	0.27	1.26	0.42	2.2	6.4	2.1	11
	3	-47	-49	2	2.90	0.13	0.44	0.74	11.2	0.1	0.0	1
	4	-49	-52.3	3.3	2.93	0.13	0.42	0.75	12.2	0.1	0.0	0
		EL -44.7 to -49		D=4.3	2.55	0.17	0.49	0.71	6.5	2.1	0.6	5
TI-03-V-187	1	-42.5	-44.5	2	2.40	0.19	0.65	0.64	2.9	3.5	1.3	11
	2	-44.5	-46.5	2	2.81	0.14	0.55	0.68	9.1	1.9	0.3	7
	3	-46.5	-49	2.5	2.92	0.13	0.40	0.76	8.9	0.1	0.0	1
	4	-49	-52	3	2.92	0.13	0.42	0.75	9.4	0.0	0.0	1
	5	-52	-54	2	2.81	0.14	0.56	0.68	10.6	0.0	0.0	1
	6	-54	-55.5	1.5	3.37	0.10	1.27	0.41	20.4	0.0	0.0	1
		EL -42.5 to -46.5		D=4	2.63	0.16	0.56	0.68	6.0	2.7	0.8	9

Table E-13
Borings for Borrow Area A (cont.)

Boring Number	Layer Number	Layer Depth (ft) Top	Bottom	Layer Thickness (ft)	Mean (phi)	Mean (mm)	Std Dev (phi)	Std Dev (mm)	% Silt (0.062 mm)	% Granular (2 - 4.76 mm)	% Gravel (4.76 mm)	% Shell
TI-03-V-188	**1**	**-44.2**	**-47.8**	**3.6**	**1.74**	**0.30**	**1.51**	**0.35**	**3.2**	**5.2**	**6.2**	**19**
	2	**-47.8**	**-50**	**2.2**	**2.97**	**0.13**	**0.46**	**0.73**	**12.2**	**0.2**	**0.0**	**2**
	3	**-50**	**-52**	**2**	**3.07**	**0.12**	**0.52**	**0.70**	**11.6**	**0.0**	**0.0**	**0**
	4	-52	-54.2	2.2	2.93	0.13	0.48	0.72	12.0	0.1	0.0	1
		EL -44.2 to -52		**D=7.8**	**2.69**	**0.15**	**0.65**	**0.64**	**7.9**	**2.5**	**2.9**	**9**
TI-03-V-189	**1**	**-45.5**	**-47.5**	**2**	**2.36**	**0.20**	**0.60**	**0.66**	**2.9**	**1.8**	**0.9**	**8**
	2	**-47.5**	**-51**	**3.5**	**2.06**	**0.24**	**1.16**	**0.45**	**7.6**	**5.6**	**3.8**	**16**
	3	**-51**	**-54.8**	**3.8**	**2.81**	**0.14**	**0.60**	**0.66**	**11.6**	**1.8**	**1.1**	**8**
	4	-54.8	-57	2.2	2.91	0.13	0.46	0.73	10.5	1.5	0.7	5
	5	-57	-59	2	3.04	0.12	0.55	0.68	12.1	0.1	0.0	3
	6	-59	-59.5	0.5	2.92	0.13	0.47	0.72	11.8	0.1	0.0	2
		EL -45.5 to -54.8		**D=9.3**	**2.46**	**0.18**	**0.77**	**0.59**	**8.2**	**3.3**	**2.1**	**11**
TI-03-V-197	**1**	**-45.5**	**-47**	**1.5**	**2.23**	**0.21**	**0.64**	**0.64**	**1.6**	**2.1**	**3.2**	**8**
	2	**-47**	**-49.5**	**2.5**	**2.88**	**0.14**	**0.43**	**0.74**	**10.1**	**0.5**	**0.6**	**3**
	3	-49.5	-52	2.5	3.35	0.10	0.77	0.59	26.7	0.2	0.1	1
	4	-52	-52.9	0.9	ND	ND	ND	ND	73.5	0.0	0.0	0
	5	-52.9	-55	2.1	3.61	0.08	1.03	0.49	40.5	0.0	0.0	1
	6	-55	-56.7	1.7	3.71	0.08	1.18	0.44	42.0	0.1	0.0	1
	7	-56.7	-57.5	0.8	ND	ND	ND	ND	72.4	0.1	0.0	0
		EL -45.5 to -49.5		**D=4**	**2.61**	**0.16**	**0.51**	**0.70**	**6.9**	**1.1**	**1.6**	**5**
TI-03-V-202	**1**	**-46.3**	**-48**	**1.7**	**2.24**	**0.21**	**0.75**	**0.59**	**1.8**	**3.5**	**1.5**	**9**
	2	**-48**	**-50**	**2**	**2.70**	**0.15**	**0.79**	**0.58**	**12.6**	**2.8**	**0.7**	**9**
	3	-50	-52	2	2.99	0.13	1.09	0.47	18.3	2.4	0.6	10
	4	-52	-53.9	1.9	2.92	0.13	0.69	0.62	15.3	2.3	0.8	9
		EL -46.3 to -50		**D=3.7**	**2.44**	**0.18**	**0.77**	**0.59**	**7.6**	**3.2**	**1.1**	**9**

Table E-13
Borings for Borrow Area A (cont.)

Boring Number	Layer Number	Layer Depth (ft) Top	Bottom	Layer Thickness (ft)	Mean (phi)	Mean (mm)	Std Dev (phi)	Std Dev (mm)	% Silt (0.062 mm)	% Granular (2 - 4.76 mm)	% Gravel (4.76 mm)	% Shell
TI-03-V-203	1	-43.4	-45.5	2.1	0.93	0.52	2.03	0.25	2.3	9.9	9.4	25
	2	-45.5	-46.6	1.1	2.28	0.21	0.64	0.64	1.8	2.1	3.1	10
		EL -43.4 to -46.6		D=3.2	1.34	0.39	1.78	0.29	2.1	7.2	7.2	20
TI-03-V-208	1	-49	-51	2	2.61	0.16	0.42	0.75	4.6	1.4	0.4	6
	2	-51	-52.2	1.2	2.88	0.14	0.41	0.75	9.6	0.8	0.1	3
		EL -49 to -52.2		D=3.2	2.70	0.15	0.44	0.74	6.5	1.2	0.3	5
TI-03-V-216	1	-48.2	-49	0.8	1.15	0.45	2.12	0.23	1.9	10.4	9.3	23
	2	-49	-50.3	1.3	1.75	0.30	1.94	0.26	12.3	7.9	4.6	18
		EL -48.2 to -50.3		D=2.1	1.45	0.36	1.95	0.26	8.3	8.9	6.4	20

Table E-14
Borings for Borrow Area B

Boring Number	Layer Number	Layer Depth (ft) Top	Bottom	Layer Thickness (ft)	Mean (phi)	Mean (mm)	Std Dev (phi)	Std Dev (mm)	% Silt (0.062 mm)	% Granular (2 - 4.76 mm)	% Gravel (4.76 mm)	% Shell
TI-03-V-132	**1**	**-42.2**	**-43.8**	**1.6**	**0.58**	**0.67**	**2.04**	**0.24**	**1.5**	**12.3**	**9.4**	**44**
	2	**-43.8**	**-46**	**2.2**	**2.64**	**0.16**	**0.44**	**0.74**	**5.3**	**0.9**	**0.1**	**5**
	3	**-46**	**-47.6**	**1.6**	**2.86**	**0.14**	**0.37**	**0.77**	**6.7**	**0.1**	**0.0**	**2**
		EL -42.2 to -47.6		**D= 5.4**	**2.09**	**0.23**	**1.16**	**0.45**	**4.6**	**4.0**	**2.8**	**16**
TI-03-V-205	**1**	**-43.2**	**-45.2**	**2**	**2.39**	**0.19**	**0.56**	**0.68**	**2.2**	**0.9**	**0.1**	**6**
	2	-45.2	-47.2	0	ND	ND	ND	ND	64.2	0.0	0.0	0
	3	-47.2	-50	0	3.73	0.08	1.02	0.49	36.3	0.1	0.0	1
	4	-50	-53	0	3.74	0.08	1.09	0.47	37.8	0.0	0.0	1
	5	-53	-55.2	0	3.32	0.10	0.84	0.56	21.5	0.0	0.0	1
		EL -43.2 to -45.2		**D=2**	**2.39**	**0.19**	**0.56**	**0.68**	**2.2**	**0.9**	**0.1**	**6**

Table E-15
Borings for Borrow Area C

Boring Number	Layer Number	Layer Depth (ft) Top	Bottom	Layer Thickness (ft)	Mean (phi)	Mean (mm)	Std Dev (phi)	Std Dev (mm)	% Silt (0.062 mm)	% Granular (2 - 4.76 mm)	% Gravel (4.76 mm)	% Shell
TI-03-V-174	**1**	**-45.5**	**-47.8**	**2.3**	**2.43**	**0.18**	**0.53**	**0.69**	**2.4**	**2.5**	**2.1**	**9**
	2	-47.8	-49.5	0	ND	ND	ND	ND	68.4	0.1	0.0	3
	3	-49.5	-50.5	0	ND	ND	ND	ND	80.8	0.6	0.4	3
	4	-50.5	-51.3	0	3.53	0.09	1.27	0.41	24.4	1.0	0.3	2
		EL -45.5 to -47.8		**D= 2.3**	**2.43**	**0.18**	**0.53**	**0.69**	**2.4**	**2.5**	**2.1**	**9**
TI-03-V-178	**1**	**-46.3**	**-48.5**	**2.2**	**2.58**	**0.17**	**0.53**	**0.69**	**7.0**	**0.9**	**4.9**	**9**
	2	-48.5	-50.5	0	2.95	0.13	0.43	0.74	9.5	0.2	0.3	2
	3	-50.5	-52	0	2.52	0.17	0.81	0.57	8.5	1.8	5.2	11
	4	-52	-54.5	0	2.59	0.17	0.49	0.71	7.2	0.0	0.0	2
	5	-54.5	-57	0	2.50	0.18	0.44	0.74	3.6	0.1	0.0	3
	6	-57	-60	0	2.06	0.24	0.87	0.55	3.6	0.8	0.1	9
	7	-60	-62.5	0	2.01	0.25	0.87	0.55	2.1	0.4	0.0	2
	8	-62.5	-63.3	0	2.69	0.15	0.31	0.81	3.0	0.0	0.0	1
		EL -46.3 to -48.5		**D=2.2**	**2.58**	**0.17**	**0.53**	**0.69**	**7.0**	**0.9**	**4.9**	**9**
TI-03-V-185	**1**	**-46.5**	**-48.5**	**2**	**2.38**	**0.19**	**0.53**	**0.69**	**1.2**	**1.4**	**0.5**	**5**
	2	**-48.5**	**-51**	**2.5**	**2.73**	**0.15**	**0.63**	**0.65**	**11.7**	**1.2**	**1.2**	**8**
	3	-51	-53	0	3.12	0.11	0.68	0.62	15.1	0.8	0.5	8
	4	-53	-55	0	ND	ND	ND	ND	49.9	0.3	0.2	1
	5	-55	-58	0	ND	ND	ND	ND	82.3	0.0	0.0	0
	6	-58	-61	3	ND	ND	ND	ND	84.5	0.0	0.0	0
	7	-61	-64.3	0	3.32	0.10	0.81	0.57	22.0	0.1	0.0	1
	8	-64.3	-64.8	0	3.06	0.12	0.72	0.61	14.9	0.0	0.0	1
		EL -46.5 to -51		**D=4.5**	**2.54**	**0.17**	**0.49**	**0.71**	**7.0**	**1.3**	**0.9**	**7**

Table E-15
Borings for Borrow Area C (cont.)

Boring Number	Layer Number	Layer Depth (ft) Top	Bottom	Layer Thickness (ft)	Mean (phi)	Mean (mm)	Std Dev (phi)	Std Dev (mm)	% Silt (0.062 mm)	% Granular (2 - 4.76 mm)	% Gravel (4.76 mm)	% Shell
TI-03-V-186	**1**	**-47.7**	**-49.5**	**1.8**	**2.42**	**0.19**	**0.49**	**0.71**	**2.6**	**1.5**	**1.1**	**7**
	2	**-49.5**	**-51**	**1.5**	**2.48**	**0.18**	**0.43**	**0.74**	**4.5**	**0.9**	**4.0**	**7**
	3	-51	-53.9	2.9	2.73	0.15	0.51	0.70	7.9	0.2	0.0	2
	4	-53.9	-56	2.1	ND	ND	ND	ND	54.1	0.2	0.0	2
	5	-56	-57	1	ND	ND	ND	ND	65.6	0.1	0.0	0
	6	-57	-60	3	3.28	0.10	0.84	0.56	21.8	0.2	0.1	2
	7	-60	-63	3	2.93	0.13	0.45	0.73	10.8	0.1	0.0	2
	8	-63	-65.5	2.5	3.18	0.11	0.76	0.59	16.8	0.1	0.0	1
		EL -47.7 to -51		**D=3.3**	**2.46**	**0.18**	**0.44**	**0.73**	**3.4**	**1.2**	**2.4**	**7**
TI-03-V-192	**1**	**-47**	**-49**	**2**	**2.10**	**0.23**	**0.69**	**0.62**	**1.5**	**1.2**	**0.1**	**7**
	2	-49	-50	1	ND	ND	ND	ND	35.1	1.2	0.0	1
		EL -47 to -49		**D=2**	**2.10**	**0.23**	**0.69**	**0.62**	**1.5**	**1.2**	**0.1**	**7**
TI-03-V-198	**1**	**-46.5**	**-48.5**	**2**	**1.35**	**0.39**	**1.75**	**0.30**	**1.5**	**5.3**	**9.8**	**20**
	2	**-48.5**	**-49.5**	**1**	**2.33**	**0.20**	**0.56**	**0.68**	**2.3**	**1.7**	**1.5**	**7**
	3	-49.5	-50.5	1	3.29	0.10	1.05	0.48	23.9	0.1	0.0	1
	4	-50.5	-52.5	2	2.43	0.18	0.60	0.66	6.1	0.0	0.0	0
	5	-52.5	-54.5	2	3.05	0.12	0.48	0.72	7.8	0.0	0.0	0
		EL -46.5 to -49.5		**D=3**	**1.84**	**0.28**	**1.14**	**0.45**	**1.7**	**4.1**	**7.1**	**16**
TI-03-V-199	**1**	**-46.6**	**-48.8**	**2.2**	**2.14**	**0.23**	**0.70**	**0.62**	**1.4**	**0.7**	**0.5**	**7**
	2	-48.8	-51.1	2.3	3.11	0.12	0.68	0.63	14.2	0.1	0.0	2
	3	-51.1	-51.6	0.5	2.97	0.13	0.73	0.60	13.8	0.1	0.0	2
		EL -46.6 to -48.8		**D=2.2**	**2.14**	**0.23**	**0.70**	**0.62**	**1.4**	**0.7**	**0.5**	**7**

Table E-16
Borings for Borrow Area D

Boring Number	Layer Number	Layer Depth (ft) Top	Bottom	Layer Thickness (ft)	Mean (phi)	Mean (mm)	Std Dev (phi)	Std Dev (mm)	% Silt (0.062 mm)	% Granular (2 - 4.76 mm)	% Gravel (4.76 mm)	% Shell
TI-03-V-223	1	-43.5	-45	1.5	2.12	0.23	0.63	0.65	0.9	1.3	1.1	8
	2	-45	-46.5	1.5	1.85	0.28	0.90	0.54	1.3	4.4	4.5	16
	3	-46.5	-47.2	0	3.00	0.13	1.15	0.45	19.4	3.3	1.1	8
		EL -43.5 to -46.5		D= 3	2.00	0.25	0.75	0.59	1.1	2.9	2.8	12
TI-03-V-224	1	-46.4	-48.4	2	2.23	0.21	0.54	0.69	1.5	2.1	1.4	7
	2	-48.4	-50.5	0	3.63	0.08	1.46	0.36	32.5	0.5	0.0	2
	3	-50.5	-52.6	0	3.38	0.10	0.86	0.55	28.0	0.2	0.0	1
		EL -46.4 to -48.4		D=2	2.23	0.21	0.54	0.69	1.5	2.1	1.4	7
TI-03-V-228	1	-46.9	-47.9	1	2.10	0.23	0.68	0.63	1.6	2.0	0.5	6
	2	-47.9	-50.6	2.7	1.29	0.41	2.08	0.24	7.4	12.8	5.2	18
	3	-50.6	-52.5	1.9	2.93	0.13	0.44	0.73	11.3	0.9	0.1	3
	4	-52.5	-53.6	1.1	2.92	0.13	0.46	0.73	11.0	2.2	1.7	5
		EL -46.9 to -53.6		D=6.7	2.16	0.22	1.23	0.43	8.2	6.1	2.5	10

Table E-17
Borings for Borrow Area E

Boring Number	Layer Number	Layer Depth (ft) Top	Bottom	Layer Thickness (ft)	Mean (phi)	Mean (mm)	Std Dev (phi)	Std Dev (mm)	% Silt (0.062 mm)	% Granular (2 - 4.76 mm)	% Gravel (4.76 mm)	% Shell
TI-03-V-240	**1**	**-50**	**-52**	**2**	**1.78**	**0.29**	**0.74**	**0.60**	**1.0**	**1.7**	**3.5**	**9**
	2	**-52**	**-52.8**	**0.8**	**2.56**	**0.17**	**0.42**	**0.75**	**5.7**	**0.6**	**0.2**	**3**
		EL -50 to -52.8		**D= 2.8**	**2.00**	**0.25**	**0.82**	**0.57**	**2.3**	**1.4**	**2.5**	**7**
TI-03-V-241	**1**	**-49**	**-51.2**	**2.2**	**2.01**	**0.25**	**0.50**	**0.71**	**0.8**	**0.5**	**0.5**	**4**
	2	**-51.2**	**-53**	**1.8**	**2.55**	**0.17**	**0.45**	**0.73**	**7.6**	**0.7**	**0.1**	**3**
	3	-53	-54	0	3.87	0.07	1.27	0.42	42.6	0.1	0.0	1
	4	-54	-56.1	0	3.62	0.08	1.39	0.38	36.0	0.1	0.0	1
		EL -49 to -53		**D=4**	**2.25**	**0.21**	**0.61**	**0.66**	**3.9**	**0.6**	**0.3**	**4**

Table E-18
Borings for Borrow Area F

Boring Number	Layer Number	Layer Depth (ft) Top	Bottom	Layer Thickness (ft)	Mean (phi)	Mean (mm)	Std Dev (phi)	Std Dev (mm)	% Silt (0.062 mm)	% Granular (2 - 4.76 mm)	% Gravel (4.76 mm)	% Shell
TI-03-V-245	1	-47.2	-48.5	1.3	0.50	0.71	1.47	0.36	1.8	9.6	6.6	18
	2	-48.5	-49.7	1.2	1.55	0.34	1.37	0.39	1.4	4.5	8.0	18
		EL -47.2 to -49.7		D= 2.5	0.96	0.51	1.64	0.32	1.6	7.2	7.3	18
TI-03-V-369	1	-48	-49	1	1.73	0.30	1.25	0.42	7.3	3.6	0.3	2
	2	-49	-51	2	0.82	0.56	2.34	0.20	4.7	8.4	14.1	3
	3	-51	-53	2	-0.08	1.06	2.64	0.16	6.2	13.4	20.6	1
		EL -48 to -51		D=3	1.20	0.44	1.90	0.27	5.6	6.8	9.5	2

Table E-19
Composite Characteristics for Borrow Area G

Boring Number	Depth (ft)	Mean (phi)	Mean (mm)	Std Dev (phi)	Std Dev (mm)	% Silt (0.062 mm)	% Granular (2 - 4.76 mm)	% Gravel (4.76 mm)	% Shell
TI-03-V-254	5.0	2.09	0.23	0.90	0.54	7.6	3.5	3.8	5
TI-03-V-256	2.0	2.09	0.23	0.62	0.65	1.1	0.8	2.0	7
TI-03-V-257	3.0	2.04	0.24	0.97	0.51	3.9	2.9	7.2	14
TI-03-V-258	2.8	0.89	0.54	2.48	0.18	2.8	6.9	15.7	28
TI-03-V-275	5.5	2.58	0.17	0.43	0.74	6.3	0.4	1.2	4

Borrow Area G Composite Data

Mean	**2.0**
Mean (mm)	**0.24**
Std Dev (phi)	**1.0**
Std Dev (mm)	**0.51**
% Silt	**5.2**
% Granular	**2.7**
% Gravel	**5.2**
% Shell	**10**

Table E-20
Composite Characteristics for Borrow Area H

Boring Number	Depth (ft)	Mean (phi)	Mean (mm)	Std Dev (phi)	Std Dev (mm)	% Silt (0.062 mm)	% Granular (2 - 4.76 mm)	% Gravel (4.76 mm)	% Shell
TI-03-V-260	2.2	2.07	0.24	0.87	0.55	3.6	2.2	4.5	11
TI-03-V-273	4.8	2.27	0.21	0.55	0.68	2.1	1.3	0.9	5

Borrow Area H Composite Data

Mean	**2.21**
Mean (mm)	**0.22**
Std Dev (phi)	**0.65**
Std Dev (mm)	**0.64**
% Silt	**2.6**
% Granular	**1.6**
% Gravel	**2.0**
% Shell	**7**

Table E-21
Composite Characteristics for Borrow Area J

Boring Number	Depth (ft)	Mean (phi)	Mean (mm)	Std Dev (phi)	Std Dev (mm)	% Silt (0.062 mm)	% Granular (2 - 4.76 mm)	% Gravel (4.76 mm)	% Shell
TI-03-V-98	2.8	2.13	0.23	0.73	0.60	5.2	1.3	0.5	11
TI-03-V-99	8.3	2.45	0.18	0.44	0.74	9.5	1.4	0.2	6
TI-03-V-102	3.0	1.86	0.27	1.05	0.48	2.3	4.5	1.3	16
TI-03-V-103	2.6	2.29	0.20	0.58	0.67	2.8	1.6	0.2	10
TI-03-V-270A	2.0	2.00	0.25	0.81	0.57	1.5	3.0	1.1	9
TI-03-V-281	3.4	2.02	0.25	0.72	0.61	1.2	2.5	1.0	10
TI-03-V-283	3.2	1.87	0.27	0.88	0.54	2.1	3.7	1.8	9
TI-03-V-286	4.0	1.85	0.28	1.15	0.45	2.6	1.8	3.3	14

Borrow Area J Composite Data

Mean	**2.12**
Mean (mm)	**0.23**
Std Dev (phi)	**0.75**
Std Dev (mm)	**0.60**
% Silt	**4.5**
% Granular	**2.3**
% Gravel	**1.1**
% Shell	**10**

Table E-22
Composite Characteristics for Borrow Area L

Boring Number	Depth (ft)	Mean (phi)	Mean (mm)	Std Dev (phi)	Std Dev (mm)	% Silt (0.062 mm)	% Granular (2 - 4.76 mm)	% Gravel (4.76 mm)	% Shell
TI-03-V-91	3.5	1.61	0.33	1.69	0.31	7.1	4.4	9.6	19
TI-03-V-93	2.3	2.15	0.23	0.83	0.56	8.5	3.8	0.8	15
TI-03-V-95	13.8	2.50	0.18	0.42	0.75	8.4	0.9	0.2	6
TI-03-V-341	4.3	2.12	0.23	0.88	0.54	6.3	2.5	0.7	6
TI-03-V-342	2.0	1.89	0.27	1.04	0.49	3.8	5.6	2.8	15
TI-03-V-343	5.0	2.37	0.19	0.50	0.71	3.3	1.0	0.4	3
TI-03-V-344	2.3	0.81	0.57	2.23	0.21	1.6	7.0	13.8	22
TI-03-V-345	3.0	1.65	0.32	1.01	0.50	1.8	2.8	2.1	15
TI-03-V-346	3.0	1.93	0.26	1.09	0.47	7.6	3.4	4.9	13
TI-03-V-351	2.8	1.31	0.40	2.13	0.23	7.3	7.4	10.5	16

Borrow Area L Composite Data

Mean	**2.05**
Mean (mm)	**0.24**
Std Dev (phi)	**0.94**
Std Dev (mm)	**0.52**
% Silt	**6.3**
% Granular	**2.8**
% Gravel	**3.1**
% Shell	**10**

Table E-23
Composite Characteristics for Borrow Area N

Boring Number	Depth (ft)	Mean (phi)	Mean (mm)	Std Dev (phi)	Std Dev (mm)	% Silt (0.062 mm)	% Granular (2 - 4.76 mm)	% Gravel (4.76 mm)	% Shell
TI-03-V-63	3.0	2.08	0.24	0.63	0.65	1.2	2.2	4.9	14
TI-03-V-65	5.5	2.37	0.19	0.43	0.74	1.5	0.5	0.6	7
TI-03-V-68	6.0	1.71	0.31	1.20	0.44	4.6	3.4	2.7	3
TI-03-V-69	3.7	1.31	0.40	1.71	0.31	1.1	5.7	8.8	24
TI-03-V-70	5.0	1.33	0.40	1.46	0.36	6.3	4.4	8.4	14
TI-03-V-72	2.8	0.54	0.69	1.64	0.32	1.1	6.9	10.9	19
TI-03-V-74	5.5	2.20	0.22	0.67	0.63	3.3	3.4	3.5	10
TI-03-V-77	2.3	2.23	0.21	0.57	0.67	1.4	1.5	0.9	7
TI-03-V-78	4.0	2.38	0.19	0.65	0.64	4.8	3.5	4.1	9
TI-03-V-79	2.3	2.03	0.24	0.60	0.66	1.6	0.5	0.1	8
TI-03-V-86	14.8	1.88	0.27	0.91	0.53	3.4	3.6	3.0	8
TI-03-V-87	5.8	1.88	0.27	1.09	0.47	5.8	2.4	7.7	5

Borrow Area N Composite Data

Mean	**1.86**
Mean (mm)	**0.28**
Std Dev (phi)	**0.96**
Std Dev (mm)	**0.51**
% Silt	**3.6**
% Granular	**3.2**
% Gravel	**4.8**
% Shell	**9**

Table E-24
Composite Characteristics for Borrow Area O

Boring Number	Depth (ft)	Mean (phi)	Mean (mm)	Std Dev (phi)	Std Dev (mm)	% Silt (0.062 mm)	% Granular (2 - 4.76 mm)	% Gravel (4.76 mm)	% Shell
TI-03-V-83B	5.1	0.33	0.80	2.99	0.13	8.2	8.9	24.6	46
TI-03-V-85	4.5	2.07	0.24	0.74	0.60	4.8	2.4	3.5	8
TI-03-V-322	3.1	2.51	0.18	0.44	0.74	7.1	0.3	0.4	3
TI-03-V-323	12.4	2.46	0.18	0.46	0.73	7.5	1.1	0.7	5
TI-03-V-324	7.0	1.85	0.28	1.22	0.43	5.4	2.7	10.3	9
TI-03-V-325	2.0	2.31	0.20	0.59	0.66	4.5	2.7	1.9	9
TI-03-V-326	12.7	2.54	0.17	0.43	0.74	5.3	0.2	0.1	1
TI-03-V-327	4.0	2.22	0.22	0.76	0.59	5.9	3.4	3.2	11

Borrow Area O Composite Data

Mean	**2.12**
Mean (mm)	**0.23**
Std Dev (phi)	**0.86**
Std Dev (mm)	**0.55**
% Silt	**6.2**
% Granular	**2.0**
% Gravel	**4.7**
% Shell	**9**

Table E-25
Composite Characteristics for Borrow Area P

Boring Number	Depth (ft)	Mean (phi)	Mean (mm)	Std Dev (phi)	Std Dev (mm)	% Silt (0.062 mm)	% Granular (2 - 4.76 mm)	% Gravel (4.76 mm)	% Shell
TI-03-V-317	4.5	1.52	0.35	1.75	0.30	6.4	3.5	11.2	11
TI-03-V-318	2.0	1.99	0.25	0.72	0.61	1.4	1.4	0.6	8
TI-03-V-320	10.5	2.23	0.21	0.66	0.63	5.9	2.0	5.9	5

Borrow Area P Composite Data

Mean	**2.01**
Mean (mm)	**0.25**
Std Dev (phi)	**0.96**
Std Dev (mm)	**0.52**
% Silt	**5.5**
% Granular	**2.4**
% Gravel	**6.6**
% Shell	**7**

Table E-26
Composite Characteristics for Borrow Area Q

Boring Number	Depth (ft)	Mean (phi)	Mean (mm)	Std Dev (phi)	Std Dev (mm)	% Silt (0.062 mm)	% Granular (2 - 4.76 mm)	% Gravel (4.76 mm)	% Shell
TI-03-V-161	4.2	2.23	0.21	0.61	0.65	4.1	1.6	2.6	8
TI-03-V-162	6.0	2.35	0.20	0.70	0.62	7.2	2.9	2.1	10

Borrow Area Q Composite Data

Mean	**2.30**
Mean (mm)	**0.20**
Std Dev (phi)	**0.66**
Std Dev (mm)	**0.63**
% Silt	**5.9**
% Granular	**2.4**
% Gravel	**2.3**
% Shell	**10**

Table E-27
Composite Characteristics for Borrow Area S

Boring Number	Depth (ft)	Mean (phi)	Mean (mm)	Std Dev (phi)	Std Dev (mm)	% Silt (0.062 mm)	% Granular (2 - 4.76 mm)	% Gravel (4.76 mm)	% Shell
TI-03-V-46	2.3	0.17	0.89	2.09	0.23	3.3	15.6	12.7	47
TI-03-V-47	2.8	0.82	0.57	2.28	0.21	5.8	16.0	11.1	45
TI-03-V-48	2.2	1.63	0.32	1.12	0.46	3.9	6.2	2.0	18
TI-03-V-49	2.3	2.34	0.20	0.30	0.81	1.3	0.9	0.1	8
TI-03-V-51	2.6	2.01	0.25	0.67	0.63	1.8	2.8	0.5	16
TI-03-V-52	3.5	2.18	0.22	0.56	0.68	1.8	1.0	1.3	8
TI-03-V-53	2.7	1.98	0.25	0.93	0.52	5.6	5.6	1.7	18

Borrow Area S Composite Data

Mean	**1.62**
Mean (mm)	**0.32**
Std Dev (phi)	**1.12**
Std Dev (mm)	**0.46**
% Silt	**3.3**
% Granular	**6.6**
% Gravel	**4.1**
% Shell	**21**

Table E-28
Composite Characteristics for Borrow Area T

Boring Number	Depth (ft)	Mean (phi)	Mean (mm)	Std Dev (phi)	Std Dev (mm)	% Silt (0.062 mm)	% Granular (2 - 4.76 mm)	% Gravel (4.76 mm)	% Shell
TI-03-V-14	3.2	1.97	0.26	0.74	0.60	1.4	2.6	3.3	13
TI-03-V-17	8.6	1.91	0.27	0.78	0.58	2.3	2.3	2.9	17
TI-03-V-22	2.2	2.26	0.21	0.62	0.65	9.2	2.2	1.1	4
TI-03-V-23	4.5	1.18	0.44	1.74	0.30	2.5	5.9	9.6	24
TI-03-V-27	2.4	1.78	0.29	0.70	0.62	1.2	1.1	0.6	19

Borrow Area T Composite Data

Mean	**1.78**
Mean (mm)	**0.29**
Std Dev (phi)	**0.95**
Std Dev (mm)	**0.52**
% Silt	**2.8**
% Granular	**3.0**
% Gravel	**3.9**
% Shell	**16.5**

Table E-29
Composite Characteristics for Borrow Area A

Boring Number	Depth (ft)	Mean (phi)	Mean (mm)	Std Dev (phi)	Std Dev (mm)	% Silt (0.062 mm)	% Granular (2 - 4.76 mm)	% Gravel (4.76 mm)	% Shell
TI-03-V-124	2.0	1.72	0.30	1.59	0.33	9.0	8.5	2.1	22
TI-03-V-125	2.0	2.31	0.20	0.98	0.51	8.4	4.5	2.6	17
TI-03-V-126	4.8	1.76	0.30	1.79	0.29	7.3	7.4	3.2	22
TI-03-V-127	4.9	2.19	0.22	1.11	0.46	5.2	3.4	4.3	15
TI-03-V-129	2.5	1.84	0.28	1.09	0.47	1.4	4.2	0.7	19
TI-03-V-130	8.3	2.71	0.15	0.42	0.75	5.3	0.7	0.0	3
TI-03-V-182	4.3	2.55	0.17	0.49	0.71	6.5	2.1	0.6	5
TI-03-V-187	4.0	2.63	0.16	0.56	0.68	6.0	2.7	0.8	9
TI-03-V-188	7.8	2.69	0.15	0.65	0.64	7.9	2.5	2.9	9
TI-03-V-189	9.3	2.46	0.18	0.77	0.59	8.2	3.3	2.1	11
TI-03-V-197	4.0	2.61	0.16	0.51	0.70	6.9	1.1	1.6	5
TI-03-V-202	3.7	2.44	0.18	0.77	0.59	7.6	3.2	1.1	9
TI-03-V-203	3.2	1.34	0.39	1.78	0.29	2.1	7.2	7.2	20
TI-03-V-208	3.2	2.70	0.15	0.44	0.74	6.5	1.2	0.3	5
TI-03-V-216	2.1	1.45	0.36	1.95	0.26	8.3	8.9	6.4	20

Borrow Area A Composite Data

Mean	**2.36**
Mean (mm)	**0.20**
Std Dev (phi)	**0.88**
Std Dev (mm)	**0.54**
% Silt	**6.6**
% Granular	**3.4**
% Gravel	**2.2**
% Shell	**11**

Table E-30
Composite Characteristics for Borrow Area B

Boring Number	Depth (ft)	Mean (phi)	Mean (mm)	Std Dev (phi)	Std Dev (mm)	% Silt (0.062 mm)	% Granular (2 - 4.76 mm)	% Gravel (4.76 mm)	% Shell
TI-03-V-132	5.4	2.09	0.23	1.16	0.45	4.6	4.0	2.8	16
TI-03-V-205	2.0	2.39	0.19	0.56	0.68	2.2	0.9	0.1	6

Borrow Area B Composite Data

Mean	**2.17**
Mean (mm)	**0.22**
Std Dev (phi)	**0.99**
Std Dev (mm)	**0.50**
% Silt	**4.0**
% Granular	**1.7**
% Gravel	**0.8**
% Shell	**13**

Table E-31
Composite Characteristics for Borrow Area C

Boring Number	Depth (ft)	Mean (phi)	Mean (mm)	Std Dev (phi)	Std Dev (mm)	% Silt (0.062 mm)	% Granular (2 - 4.76 mm)	% Gravel (4.76 mm)	% Shell
TI-03-V-174	2.3	2.43	0.18	0.53	0.69	2.4	2.5	2.1	9
TI-03-V-178	2.2	2.58	0.17	0.53	0.69	7.0	0.9	4.9	9
TI-03-V-185	4.5	2.54	0.17	0.49	0.71	7.0	1.3	0.9	7
TI-03-V-186	3.3	2.46	0.18	0.44	0.73	3.4	1.2	2.4	7
TI-03-V-192	2.0	2.10	0.23	0.69	0.62	1.5	1.2	0.1	7
TI-03-V-198	3.0	1.84	0.28	1.14	0.45	1.7	4.1	7.1	16
TI-03-V-199	2.2	2.14	0.23	0.70	0.62	1.4	0.7	0.5	7

Borrow Area C Composite Data

Mean	**2.32**
Mean (mm)	**0.20**
Std Dev (phi)	**0.63**
Std Dev (mm)	**0.64**
% Silt	**3.9**
% Granular	**1.7**
% Gravel	**2.6**
% Shell	**9**

Table E-32
Composite Characteristics for Borrow Area D

Boring Number	Depth (ft)	Mean (phi)	Mean (mm)	Std Dev (phi)	Std Dev (mm)	% Silt (0.062 mm)	% Granular (2 - 4.76 mm)	% Gravel (4.76 mm)	% Shell
TI-03-V-223	3.0	2.00	0.25	0.75	0.59	1.1	2.9	2.8	12
TI-03-V-224	2.0	2.23	0.21	0.54	0.69	1.4	2.1	0.6	7
TI-03-V-228	6.7	2.16	0.22	1.23	0.43	8.2	6.1	2.5	10

Borrow Area D Composite Data

Mean	**2.13**
Mean (mm)	**0.23**
Std Dev (phi)	**0.99**
Std Dev (mm)	**0.50**
% Silt	**5.2**
% Granular	**4.6**
% Gravel	**2.2**
% Shell	**10**

Table E-33
Composite Characteristics for Borrow Area E

Boring Number	Depth (ft)	Mean (phi)	Mean (mm)	Std Dev (phi)	Std Dev (mm)	% Silt (0.062 mm)	% Granular (2 - 4.76 mm)	% Gravel (4.76 mm)	% Shell
TI-03-V-240	2.8	2.00	0.25	0.82	0.57	2.3	1.4	2.5	7
TI-03-V-241	4.0	2.25	0.21	0.61	0.66	3.9	0.6	0.3	4

Borrow Area E Composite Data

Mean	**2.15**
Mean (mm)	**0.23**
Std Dev (phi)	**0.69**
Std Dev (mm)	**0.62**
% Silt	**3.2**
% Granular	**0.9**
% Gravel	**1.2**
% Shell	**5**

Table E-34
Composite Characteristics for Borrow Area F

Boring Number	Depth (ft)	Mean (phi)	Mean (mm)	Std Dev (phi)	Std Dev (mm)	% Silt (0.062 mm)	% Granular (2 - 4.76 mm)	% Gravel (4.76 mm)	% Shell
TI-03-V-245	2.5	0.96	0.51	1.64	0.32	1.6	7.2	7.3	18
TI-03-V-369	3.0	1.20	0.44	1.90	0.27	5.6	6.8	9.5	2

Borrow Area E Composite Data

Mean	**1.09**
Mean (mm)	**0.47**
Std Dev (phi)	**1.78**
Std Dev (mm)	**0.29**
% Silt	**3.8**
% Granular	**7.0**
% Gravel	**8.5**
% Shell	**10**

Table E-35
Compatibility of Native and Borrow Sand

Native Beach	Mean (phi)	Mean (mm)	Std Dev (phi)	Std Dev (mm)	% Silt (0.062 mm)	% Granular (2 - 4.76 mm)	% Gravel (4.76 mm)	% Shell
Surf City/North Topsail Beach	2.15	0.23	0.71	0.61	1.2	1.1	0.5	9

Borrow Site	Mean (phi)	Mean (mm)	Std Dev (phi)	Std Dev (mm)	% Silt (0.062 mm)	% Granular (2 - 4.76 mm)	% Gravel (4.76 mm)	% Shell	Overfill Ratio	Silt Correction Factor	Final Overfill Ratios Corrected for Silt Content
A ^	2.36	0.20	0.88	0.54	6.6	3.4	2.2	11	1.29	1.07	1.38
B ^	2.17	0.22	0.99	0.50	4.0	1.7	0.8	13	1.18	1.04	1.23
C ^	2.32	0.20	0.63	0.64	3.9	1.7	2.6	9	1.50	1.04	1.56
D ^	2.13	0.23	0.99	0.50	5.2	4.6	2.2	10	1.15	1.06	1.21
E ^	2.15	0.23	0.69	0.62	3.2	0.9	1.2	5	1.02	1.03	1.15
F ^	1.09	0.47	1.78	0.23	3.8	7.0	8.5	10	1.14	1.04	1.19
G	2.05	0.24	0.98	0.51	5.2	2.7	5.2	10	1.11	1.05	1.17
H	2.21	0.22	0.65	0.64	2.6	1.6	2.0	7	1.16	1.03	1.19
J	2.12	0.23	0.75	0.60	4.5	2.3	1.1	10	1.01	1.05	1.15
L	2.05	0.24	0.94	0.52	6.3	2.8	3.1	10	1.09	1.07	1.16
N	1.86	0.28	0.96	0.51	3.6	3.2	4.8	9	1.05	1.04	1.15
O	2.12	0.23	0.86	0.55	6.2	2.0	4.7	9	1.08	1.07	1.15
P	2.01	0.25	0.96	0.52	5.5	2.4	6.6	7	1.09	1.06	1.15
Q	2.30	0.20	0.66	0.63	5.9	2.4	2.3	10	1.37	1.06	1.46
S	1.62	0.32	1.12	0.46	3.3	6.6	4.1	21	1.06	1.03	1.15
T	1.78	0.29	0.95	0.52	2.8	3.0	3.9	17	1.03	1.03	1.15

^ These borrow areas have been identified for the Topsail Beach Federal project. The excess material not used for these projects is planned to be available for the Surf City/North Topsail Beach Federal project. This amount is approximately 9.68 million cubic yards.

Final

Integrated

Feasibility Report
and
Environmental Impact Statement

Coastal Storm Damage Reduction Project

Surf City and North Topsail Beach
NORTH CAROLINA

Appendix G

Section 404(b)(1) Guidelines Analysis

SURF CITY AND NORTH TOPSAIL BEACH, NORTH CAROLINA
Preliminary Evaluation of Section 404 (b) (1) Guidelines 40 CFR 230

This evaluation of the placement of any and all fill material into waters and wetlands of the United States required for construction and maintenance of the Surf City and North Topsail Beach, North Carolina, Coastal Storm Damage Reduction Project.

Section 404 Public Notice No. CESAW-TS-PE-XXXXXXX

		Preliminary 1/	Final 2/
1.	Review of Compliance (230.10(a)-(d)) A review of the NEPA Document indicates that:		
a.	The discharge represents the least environmentally damaging practicable alternative and if in a special aquatic site, the activity associated with the discharge must have direct access or proximity to, or be located in the aquatic ecosystem to fulfill its basic purpose	YES|_| NO|_|	YES|X| NO|_|
b.	The activity does not: 1) violate applicable State water quality standards or effluent standards prohibited under Section 307 of the CWA; 2) jeopardize the existence of federally listed endangered or threatened species or their habitat; and 3) violate requirements of any federally designated marine sanctuary (See Sections 8.01, 8.07 and Appendix I of the Final Integrated Feasibility Report and EIS (Final Report))	YES|_| NO|_|	YES|X| NO|_|
c.	The activity will not cause or contribute to significant degradation of waters of the U.S. including adverse effects on human health, life stages of organisms dependent on the aquatic ecosystem, ecosystem diversity, productivity and stability, and recreational, aesthetic, and economic values (See Section 8.0 of the Final Report)	YES|_| NO|_|	YES|X| NO|_|
d.	Appropriate and practicable steps have been taken to minimize potential adverse impacts of the discharge on the aquatic ecosystem (see Section 8.0 of the Final Report).	YES|_| NO |_|	YES|X| NO|_|

Proceed to Section 2

*, 1, 2/ See page 6.

2. Technical Evaluation Factors (Subparts C-F)	N/A	Not Signifi-cant	Signifi-cant*
a. Physical and Chemical Characteristics of the Aquatic Ecosystem (Subpart C)			
(1) Substrate impacts.		X	
(2) Suspended particulates/turbidity impacts.		X	
(3) Water column impacts.		X	
(4) Alteration of current patterns and water circulation.		X	
(5) Alteration of normal water fluctuations/hydroperiod.		X	
(6) Alteration of salinity gradients.	NA		
b. Biological Characteristics of the Aquatic Ecosystem (Subpart D)			
(1) Effect on threatened/endangered species and their habitat.		X	
(2) Effect on the aquatic food web.		X	
(3) Effect on other wildlife (mammals, birds, reptiles, and amphibians).		X	
c. Special Aquatic Sites (Subpart E)			
(1) Sanctuaries and refuges.	NA		
(2) Wetlands.		X	
(3) Mud flats.	NA		
(4) Vegetated shallows.	NA		
(5) Coral reefs.	NA		
(6) Riffle and pool complexes.	NA		
d. Human Use Characteristics (Subpart F)			
(1) Effects on municipal and private water supplies.	NA		
(2) Recreational and commercial fisheries impacts.		X	
(3) Effects on water-related recreation.		X	
(4) Aesthetic impacts.		X	
(5) Effects on parks, national and historical monuments, national seashores, wilderness areas, research sites, and similar preserves.		X	

Remarks: See Section 8.00 and Appendix I of the Final Integrated Feasibility Report and EIS (Final Report), Surf City and North Topsail Beach, North Carolina, dated November 2008 for more information on the above topics.

Proceed to Section 3
*See page 6.

3. Evaluation of Dredged or Fill Material (Subpart G) 3/

a. The following information has been considered in evaluating the biological availability of possible contaminants in dredged or fill material. (Check only those appropriate.)

(1) Physical characteristics. . . . . |X|
(2) Hydrography in relation to known or anticipated sources of contaminants . . . . . |X|
(3) Results from previous testing of the material or similar material in the vicinity of the project . . . . . | |
(4) Known, significant sources of persistent pesticides from land runoff or percolation . . . . . |_|
(5) Spill records for petroleum products or designated (Section 311 of CWA) hazardous substances . . . . . |_|
(6) Other public records of significant introduction of contaminants from industries, municipalities, or other sources. . . . . |X|
(7) Known existence of substantial material deposits of substances which could be released in harmful quantities to the aquatic environment by man-induced discharge activities. . . . . |_|

(8) Other sources (specify). . . . . |_|

Reference: See Sections 2.07.3, 8.03, and Appendices C and E of the Final Report for Surf City and North Topsail Beach, North Carolina, dated November 2008

Remark: Sediments to be dredged consist of beach quality sand. Contaminants do not bind to sand, therefore, contaminant testing of sediments was not required.

b. An evaluation of the appropriate information in 3a above indicates that there is reason to believe the proposed dredge or fill material is not a carrier of contaminants, or that levels of contaminants are substantively similar at extraction and disposal sites and not likely to result in degradation of the disposal site. YES |X| NO |_|

Proceed to Section 4
*, 3/, see page 6.

4. Disposal Site Determinations (230.11(f)).

a. The following factors as appropriate, have been considered in evaluating the disposal site.

(1) Depth of water at disposal site. . . . . |X|

(2) Current velocity, direction, and variability at disposal site . . . . . |X|

(3) Degree of turbulence. . . . . |X|

(4) Water column stratification . . . . . |X|

(5) Discharge vessel speed and direction . . . . . |X|

(6) Rate of discharge . . . . . |X|

(7) Dredged material characteristics (constituents, amount and type of material, settling velocities). . . . . |X|

(8) Number of discharges per unit of time. . . . . |X|

(9) Other factors affecting rates and patterns of mixing (specify) . . . . . |_|

Reference: See Final Integrated Feasibility Report and EIS, Surf City and North Topsail Beach, North Carolina, dated November 2008

b. An evaluation of the appropriate factors in 4a above indicates that the disposal site and/or size of mixing zone are acceptable. YES |X| NO |_|*

5. Actions to Minimize Adverse Effects (Subpart H).

All appropriate and practicable steps have been taken, through application of recommendations of 230.70-230.77, to ensure minimal adverse effects of the proposed discharge. YES |X| NO |_|*

See Section 8.01 of Final Report for Marine Environment
See Section 8.07 of Final Report for Water Resources
See Appendix I of the Final Report for threatened and endangered species

Return to section 1for final stage of compliance review.
See also note 3/, page 6.
*See page 6.

6. Factual Determinations (230.11).

A review of appropriate information as identified in items 2-5 above indicates that there is minimal potential for short- or long-term environmental effects of the proposed discharge as related to:

a. Physical substrate at the disposal site (review sections 2a, 3, 4, and 5). YES [X] NO [ ]*

b. Water circulation, fluctuation, and salinity (review sections 2a, 3, 4, and 5). YES [X] NO [ ]*

c. Suspended particulates/turbidity (review sections 2a, 3, 4, and 5). YES [X] NO [ ]*

d. Contaminant availability (review sections 2a, 3, and 4). YES [X] NO [ ]*

e. Aquatic ecosystem structure and function (review sections 2b and c, 3, and 5). YES [X] NO [ ]*

f. Disposal site (review sections 2, 4, and 5). YES [X] NO [ ]*

g. Cumulative impact on the aquatic ecosystem. YES [X] NO [ ]*

h. Secondary impacts on the aquatic ecosystem. YES [X] NO [ ]*

Remark: More detailed information on the topics above may be found in Sections 2.07.3, 8.03, and Appendices C, E, and J of the Final Report for Surf City and North Topsail Beach, North Carolina, dated June 2010..

7. Findings.

a. The proposed disposal site for discharge of dredged or fill material complies with the Section 404(b)(1) guidelines. . . . . [X]

b. The proposed disposal site for discharge of dredged or fill material complies with the Section 404(b)(1) guidelines with the inclusion of the following conditions:. . . . . [ ]

c. The proposed disposal site for discharge of dredged or fill material does not comply with the Section 404(b)(1) guidelines for the following reasons(s):

(1) There is a less damaging practicable alternative . . . . . [ ]

(2) The proposed discharge will result in significant degradation of the aquatic ecosystem . . . . . [ ]

(3) The proposed discharge does not include all practicable and appropriate measures to minimize potential harm to the aquatic ecosystem. . . . . [ ]

*See page 6.

8.

Jefferson Ryscavage
Colonel, U.S. Army
District Engineer

Date: _____

*A negative, significant, or unknown response indicates that the permit application may not be in compliance with the Section 404(b)(1) Guidelines.

1/ Negative responses to three or more of the compliance criteria at this stage indicate that the proposed projects may not be evaluated using this "short form procedure." Care should be used in assessing pertinent portions of the technical information of items 2 a-d, before completing the final review of compliance.

2/ Negative response to one of the compliance criteria at this stage indicates that the proposed project does not comply with the guidelines. If the economics of navigation and anchorage of Section 404(b)(2) are to be evaluated in the decision-making process, the "short form evaluation process is inappropriate."

3/ If the dredged or fill material cannot be excluded from individual testing, the "short-form" evaluation process is inappropriate.

Feasibility Report
and
Environmental Impact Statement

on

Coastal Storm Damage Reduction

SURF CITY AND NORTH TOPSAIL BEACH, NORTH CAROLINA

Appendix H

Correspondence

Appendix H

Correspondence

This appendix includes correspondence received from the sponsors and other agencies. Other correspondence from the NEPA scoping process is contained in Appendix K. Correspondence regarding Public Review [will be / is] contained in Appendix T.

April 27, 2001 - Letter from North Topsail Beach Mayor to District Engineer supporting Feasibility Study and confirming understanding cost sharing for the study and construction phases.

May 8, 2001 - Letter from Surf City Mayor to District Engineer supporting Feasibility Study and confirming understanding cost sharing for the study and construction phases. August 3, 2005 – Letter from NC State Historic Preservation Office concurring that no additional archaeological survey of borrow areas are recommended.

November 7, 2007 – Letter from Wilmington District to DOI Minerals Management Service requesting MMS to serve as a cooperating agency on this project.

February 7, 2008 – Letter from MMS to Wilmington District agreeing to serve as cooperating agency.

July 1, 2010 – Letter from Surf City Mayor to District Engineer supporting the proposed Project

June 9, 2010 – Self Certification of Financial Capability by Town of Surf City

June 4, 2010 - Letter from Surf City Mayor to District Engineer assuring compliance by town in obtaining required parking and access.

July 1, 2010 – Letter from North Topsail Beach Mayor to District Engineer supporting the proposed project

June 11, 2010 – Self Certification of Financial Capability by Town of North Topsail Beach

June 11, 2010 - Letter from North Topsail Beach Mayor to District Engineer assuring compliance by town in obtaining required parking and access.

Dec 13, 2010 – Letter from NCDENR to District Engineer indicating support by the State of North Carolina for the Proposed Project

Town Of North Topsail Beach

Routed: 07 May 01
Action: PM
CF: DE
DD
DP
DX

April 27, 2001

Colonel James W. DeLony
U.S. Army Corps of Engineers
Wilmington District
P.O. Box 1890
Wilmington, NC 28402-1890

Dear Colonel DeLony:

We have been participating in the Corps of Engineers' Reconnaissance Study for shore protection and related purposes for North Topsail Beach and Surf City, North Carolina.

We are concerned about the unprecedented erosion of the berm and dune along North Topsail Beach and Surf City, and the high vulnerability of our towns to the predicted increase in hurricanes, and appreciate your work on our behalf. We believe that further study of possible shore protection and related purposes can be a valuable contribution toward protecting our citizens. We support your continuing work on the Reconnaissance Study and seeking funding for the cost shared Feasibility Study.

North Topsail Beach is prepared to participate in development of the Project Study Plan (PSP), and to be a co-sponsor with the Town of Surf City of a Feasibility Study for this shore protection and related purposes at North Topsail Beach and Surf City. We understand that the preliminary estimated cost of the Feasibility Study indicates the total non-federal funding obligation for fifty percent of the cost would be approximately $1,500,000. The Town of North Topsail Beach is prepared to negotiate a Feasibility Cost Sharing Agreement (FCSA), along with the Town of Surf City, with the Wilmington District at the proper time. We understand that the amount of non-federal funds required from North Topsail Beach and Surf City is initially estimated to be $750,000 from each Town. We also are prepared to negotiate the terms of the non-federal funding for thirty-five percent of the cost for initial construction and 50 percent for future nourishment of any agreed upon project.

2008 LOGGERHEAD COURT NORTH TOPSAIL BEACH, NC 28460 PHONE (910) 328-1349 FAX (910) 328-4508

The Town of North Topsail Beach expects to obtain fifty percent of the funds it must provide for these activities from the State of North Carolina, Division of Water Resources. The remaining funds are to be provided by the Town of North Topsail Beach from property tax revenues, proceeds from passage of bond referendum, flood control assessments or other Town or Onslow County action.

Mr. John J. Flynn will serve as representative from the North Topsail Beach Board of Aldermen and Mr. Tony Hammond is designated as the North Topsail Beach Town staff point-of-contact for shore protection and related programs for North Topsail Beach and Surf City. Other staff members may be designated to participate in the Feasibility Study.

We look forward to working with you further on this effort to improve shore protection along North Topsail Beach and Surf City, North Carolina.

Sincerely,

Marlow F. Bostic, Jr.
Mayor

MFB/lmc

SURF CITY
NORTH CAROLINA 28445

A.D. (Sandy) GUY, JR., MAYOR
NELVA B. ALBURY, COUNCIL MEMBER
DEXTER BLIZZARD, COUNCIL MEMBER
DONALD R. HELMS, COUNCIL MEMBER
DONALD H. LUTHER, COUNCIL MEMBER
DOUGLAS C. MEDLIN, COUNCIL MEMBER

Routed: 14 May 01
Action: PM
CF: DE
DD
DX
DP
TS
OC

May 8, 2001

Colonel James W. DeLony
U.S. Army Corps of Engineers
Wilmington District
Post Office Box 1890
Wilmington, North Carolina 28402-1890

Dear Colonel DeLony:

We have been participating in the Corps of Engineers' Reconnaissance Study for shore protection and related purposes for North Topsail Beach and Surf City, North Carolina.

We are concerned about the unprecedented erosion of the berm and dune along North Topsail Beach and Surf City, and the high vulnerability of our towns to the predicted increase in hurricanes, and appreciate your work on our behalf. We believe that further study of possible shore protection and related purposes can be a valuable contribution toward protecting our citizens. We support your continuing work on the Reconnaissance Study and seeking funding for the cost shared Feasibility Study.

Surf City is prepared to participate in development of the Project Study Plan (PSP), and to be a co-sponsor with the Town of North Topsail Beach of a Feasibility Study for this shore protection and related purposes at North Topsail Beach and Surf City. We understand that the preliminary estimated cost of the Feasibility Study indicates the total non-federal funding obligation for fifty percent of the cost would be approximately $1,500,000. The Town of Surf City is prepared to negotiate a Feasibility Cost Sharing Agreement (FCSA), along with the Town of North Topsail Beach, with the Wilmington District at the proper time. We understand that the amount of non-federal funds required from North Topsail Beach and Surf City is initially estimated to be $750,000 from each town. We also are prepared to negotiate the terms of the non-federal funding for thirty-five percent of the cost for initial construction and 50 percent of future nourishment of any agreed upon project.

The Town of Surf City expects to obtain fifty percent of the funds it must provide for these activities from the State of North Carolina, Division of Water Resources. The remaining funds are to be provided by the Town of Surf City from property tax revenues, proceeds from passage of bond referendum, flood control assessments or other Town action.

EXECUTIVE OFFICE
RECEIVED

P.O. Box 2475 • 214 N. New River Drive • Telephone (910) 328-4131 • FAX: (910) 328-4132

Patrick Thomas, Surf City town manager, will be Surf City's lead representative for the study of shore protection and related purposes for North Topsail Beach and Surf City. He may designate other staff members to participate in the Study in various ways.

We look forward to working with you further on this effort to improve shore protection along North Topsail Beach and Surf City, North Carolina.

Sincerely,

A. D. (Zander) Guy, Jr.
Mayor

North Carolina Department of Cultural Resources
State Historic Preservation Office
Peter B. Sandbeck, Administrator

Michael F. Easley, Governor
Lisbeth C. Evans, Secretary
Jeffrey J. Crow, Deputy Secretary

Office of Archives and History
Division of Historical Resources
David Brook, Director

August 3, 2005

Richard H. Kimmel
Environmental Resources Section
Department of the Army
Wilmington District, Corps of Engineers
P.O. Box 1890
Wilmington, NC 28402-1890

RE: Draft Report: *An Archaeological Remote Sensing Survey of Surf City-North Topsail Beaches Borrow Areas*, Bib #5524, Pender and Onslow Counties, CH 01-0497

Dear Mr. Kimmel:

We have received the draft report summarizing the remote sensing surveys conducted by Mid-Atlantic Technology and Environmental Research, Inc. (M-AT/ER) in proposed offshore sand borrow areas near Surf City and North Topsail Beaches.

No previously recorded archaeological sites occur within the seven proposed sand borrow areas. M-AT/ER conducted marine magnetometer and side-scan sonar surveys of the proposed borrow areas for the purpose of identifying any potential archaeological resources that might be impacted by the offshore dredging activities. The survey identified no single source magnetic anomalies or acoustic targets with characteristics suggesting significant cultural resources within the proposed sand borrow areas. Because of these findings, we concur with the recommendation for no additional archaeological investigations related to sand mining activities in the seven proposed borrow areas.

Thank you for your cooperation and consideration. If you have questions concerning the above comment, please contact Renee Gledhill-Earley, environmental review coordinator, at 919/733-4763. In all future communication concerning this project, please cite the above-referenced tracking number.

Sincerely,

Peter Sandbeck

	Location	Mailing Address	Telephone/Fax
ADMINISTRATION	507 N. Blount Street, Raleigh NC	4617 Mail Service Center, Raleigh NC 27699-4617	(919)733-4763/733-8653
RESTORATION	515 N. Blount Street, Raleigh NC	4617 Mail Service Center, Raleigh NC 27699-4617	(919)733-6547/715-4801
SURVEY & PLANNING	515 N. Blount Street, Raleigh, NC	4617 Mail Service Center, Raleigh NC 27699-4617	(919)733-6545/715-4801

DEPARTMENT OF THE ARMY
WILMINGTON DISTRICT, CORPS OF ENGINEERS
P. O. BOX 1890
WILMINGTON, NORTH CAROLINA28402-1890

IN REPLY REFER TO

November 7, 2007

Environmental Resources Section

Ms. Renee Orr, Chief
Sand and Gravel Program
Minerals Management Service
Mail Stop 4010381 Elden Street
Herndon, Virginia 22071

Dear Ms. Orr:

The U. S. Army Corps of Engineers, Wilmington District is conducting a study to evaluate a shore protection project for the towns of Surf City and North Topsail Beach, North Carolina (Figure 1). As indicated in detail below, the purpose of this letter is to request that Minerals Management Service be a cooperating agency for this project.

Topsail Island is on the southeastern North Carolina coast. From south to north the three towns on the island are Topsail Beach, Surf City and North Topsail Beach. The primary study area for this report includes the Towns of Surf City and North Topsail Beach and the associated offshore borrow sites. The Towns of Surf City and North Topsail Beach are the project sponsors and the results of the study will be documented in a forthcoming integrated Feasibility Report and Draft Environmental Impact Statement.

Ten borrow areas, identified as G, H, J, L, N, 0 , P, 0, Sand T (Figures 2 and 3) have been identified for the 50-year period of analysis for the Surf City/North Topsail Beach Shore Protection Project. As shown in Table 1, borrow areas F, I, M and R have been tentatively omitted from the plan based on the existing, limited subsurface analysis that indicates that these sites may not meet the current Coastal Resource Commission (CRC) regulations for beach compatibility. However, additional subsurface analysis is planned prior to project construction which could determine that these sites meet the CRC compatibility criteria and thus may be used for the project. Site K has been permanently deleted due to its close proximity to hardbottom. With the exception of borrow sites I, 0 , and R, which are less than 3 miles offshore, all other sites (G, H, J, L, N, 0, P, Sand T) are typically between 3 and 6 miles offshore. All borrow areas have bottom depths of less than 66 feet, contain material that has approximately 10% passing the #200 sieve or less, and contain material that is compatible with the native material on the beaches. Borrow areas were identified based on

material characteristics and depth of suitable material. Magnetometer and side-scan sonar (acoustic) surveys were used to identify and thus avoid cultural resources as well as hardbottom areas. Borrow area characteristics are summarized below in Table 1.

Location (see Fig 1)	Mean Grain Size (phi)	Standard Deviation (phi)	% Silt (#230 sieve)	% Shell	Final Overfill Ratio	Available Volume MCY
A	2.35	0.86	6.6	11	1.34	*
B	2.17	0.99	6.4	13	1.19	*
C	2.32	0.63	3.9	9	1.59	*
D	2.13	0.99	5.2	6	1.18	*
E	2.15	0.69	3.2	5	1.07	*
F	site omitted					
G	.2.05	0.98	5.2	10	1.14	2.73
H	2.2]	0.65	2.6	7	1.21	0.72
I	site omitted					
J	2.12	0.75	4.5	10	1.06	3.44
L	1.99	0.97	6.4	10	1.13	6.68
M	site omitted					
N	1.78	103	34	10	1.07	6.00
0	2.28	0.71	6.6	5.3	1.32	3.61
P	2.18	0.76	5.2	7	1.07	3.34
Q	2.33	0.6	5.9	8	1.79	0.81
R	Site omitted					
S	146	1.29	3.3	22	1.10	1.82
T	1.60	1.10	2.8	18	1.06	0.50
Surf City/No Topsail Bch	2.16	0.77	149	12	Native material	
NTB	2.18	0.75	1.32	8	Native material	
SC&NTB	2.17	0.76	1.42	10	Native material	

* Material planned to be used on Topsail Beach project. All of the available material will not be needed for Topsail Beach and may be used for Surf City and North Topsail Beach).

Table 1. Surf City (SC) and North Topsail Beach (NTB) Borrow Area Characteristics.

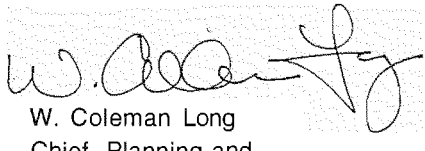
Although a detailed borrow area use plan has not yet been developed, the project would entail removing sand from the borrow areas listed above. It is anticipated that approximately 31 million cubic yards of material would be needed

to construct the Surf City and North Topsail Beach shore protection project. Please be advised that we intend to seek all required approvals from the Minerals Management Service for such sand removal.

Pursuant to 40 CFR 1501, the U.S. Army Corps of Engineers Wilmington District requests that the Minerals Management Service serve as a cooperating agency during the required National Environmental Policy Act process for the Surf City and North Topsail Beach Shore Protection Project. The U.S. Army Corps of Engineers further requests that MMS serve as a cooperating agency on environmental requirements related to the Endangered Species Act, National Historic Preservation Act, Coastal Zone Management Act, and Magnusson-Stevens Fishery Management and Conservation Act. This letter serves as the coordinating request prescribed for ESA Section 7 (50 CFR 402), NHPA Section 106 (36 CFR 800), Subpart C Consistency (15 CFR 930), and Magnusson-Stevens Section 305 (50 CFR 600). pursuant to 50 CFR 402, the U.S. Army Corps of Engineers will notify the U.S. Fish and Wildlife Service and NOAA National Marine Fisheries Service of its lead role and MMS' cooperating role provided your agreement to serve as a cooperating agency.

Please advise us, at your earliest convenience, as to your agency's willingness to serve as a cooperating agency in the NEPA process for this project. Jenny Owens, Environmental Resources Section, will serve as the major point of contact for any MMS involvement in this project, and she can be reached at 910-251-4757 in the event that you would like additional information regarding this matter. We look forward to an efficient and productive relationship with MMS regarding this important shore protection project.

Sincerely,



W. Coleman Long
Chief, Planning and
Environmental Branch

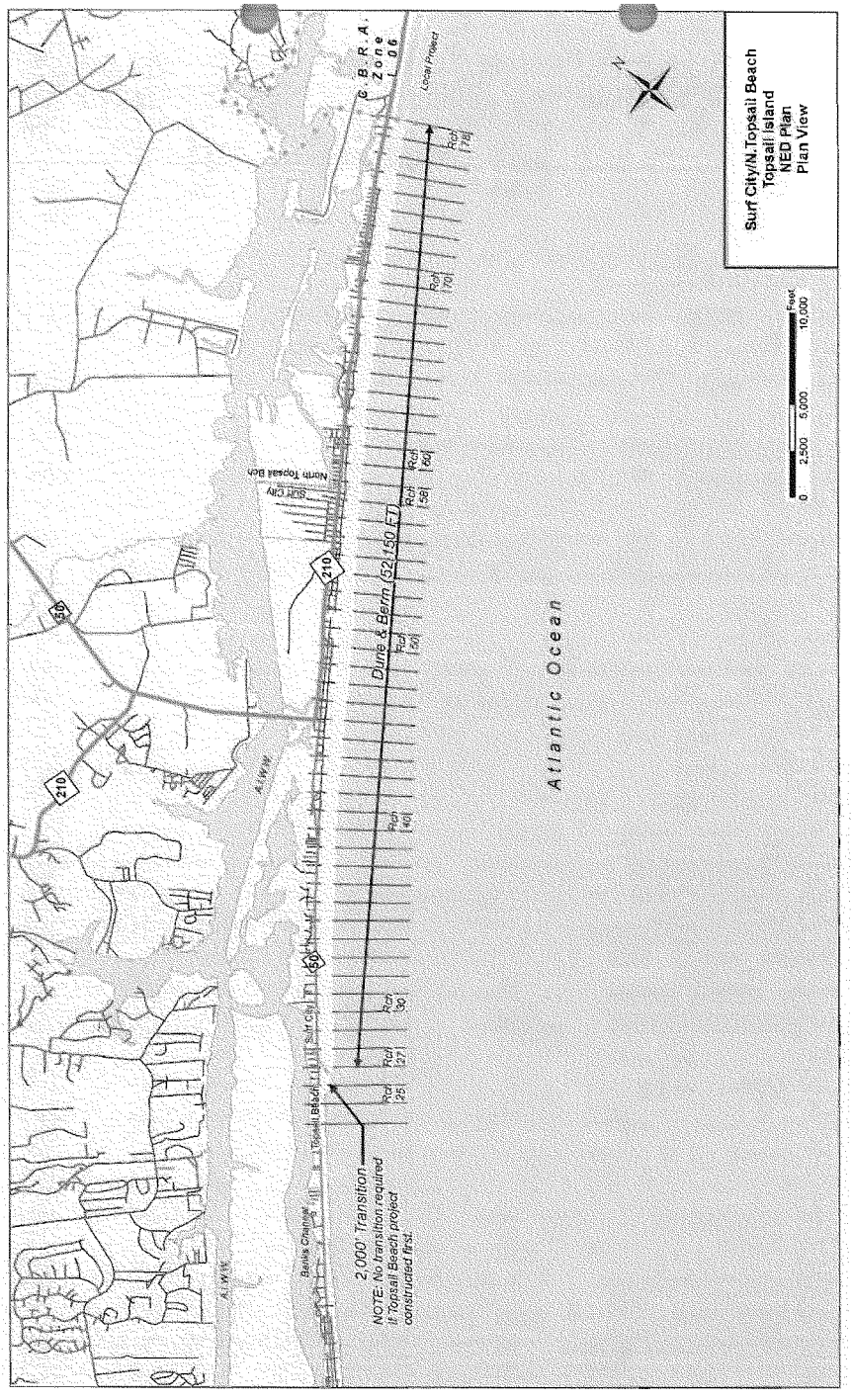


Figure 1. Surf City, North Topsail Beach Project Study Area

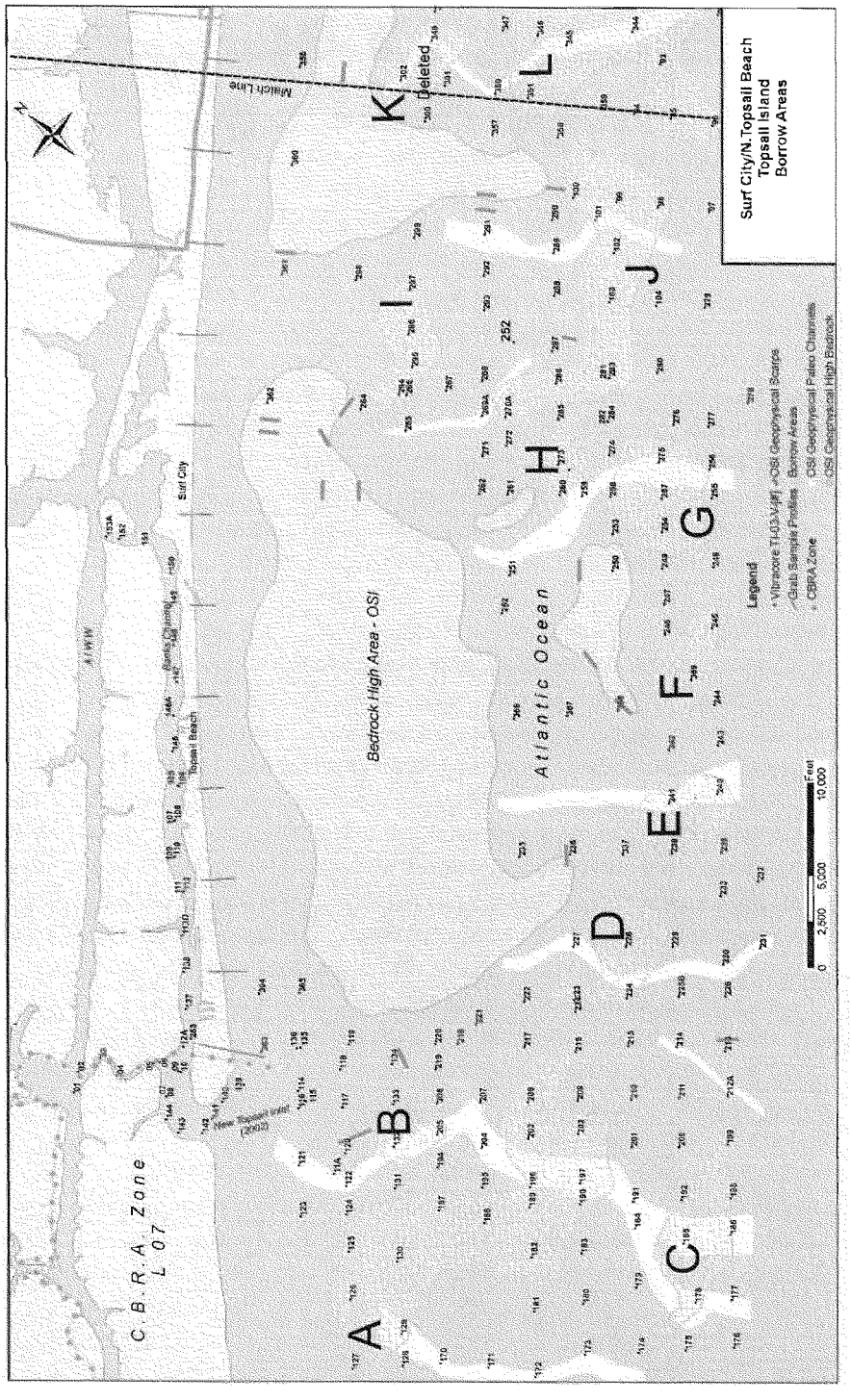


Figure 2. Borrow Areas (1 of 2)

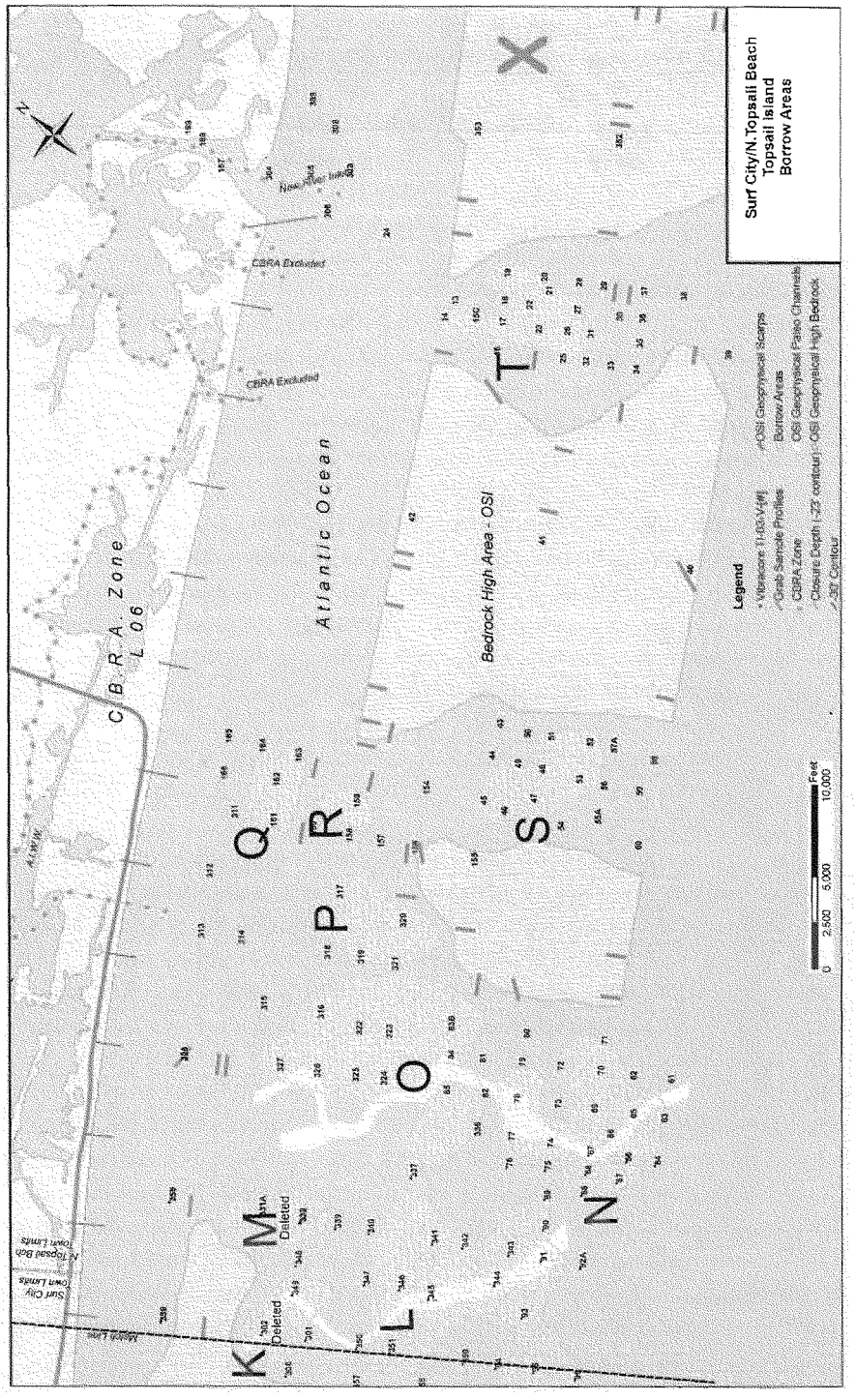


Figure 3. Borrow Areas (2 of 2)

United States Department of the Interior

MINERALS MANAGEMENT SERVICE
Washington, DC 20240

Mr. W. Coleman Long
Chief, Planning and Environmental Branch
Environmental Resources Branch
Department of the Army
Corps of Engineers, Wilmington District
P.O. Box 1890
Wilmington, North Carolina 28402

FEB 07 2008

Dear Mr. Long:

Thank you for your November 7,2007, letter requesting Outer Continental Shelf (OCS) sand for the Surf City / North Topsail Beach Shore Protection Project, and that the Minerals Management Service (MMS) become a cooperating agency during the required National Environment Act (NEPA) process. The MMS welcomes the opportunity to participate in the NEPA effort and agrees to serve as a cooperating agency. As a cooperating agency we expect to: participate *in* the NEPA process at the earliest possible time; participate *in* the seeping process; assume, on the request of U.S. Army Corps of Engineers (USACE), responsibility for developing information and preparing environmental analyses for which the MMS has special expertise; make available staff support at the lead agency's request to enhance the interdisciplinary capability of the USACE; and use our own funds to accomplish these responsibilities.

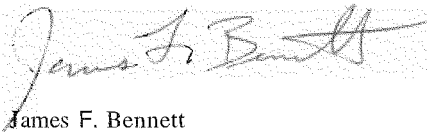
The MMS also agrees to participate in: the required Endangered Species Act (ESA) Section 7 consultation; the Magnuson-Stevens Fishery and Conservation Management Act Essential Fish Habitat consultation (Section 305); the National Historic Preservation Act Section 106 process: and the Coastal Zone Management Act Section 307 consistency determination. As the lead federal agency for ESA Section 7 and the Essential Fish Habitat consultations, the USACE must notify U.S. Fish and Wildlife Service (FWS) and National Marine Fisheries Service (NMFS) of its lead role and MMS' cooperating role. We would expect to jointly submit with the USACE the ESA Section 7 and Essential Fish Habitat assessments to FWS and NMFS.

The USACE recommended plan requires about 11.5 million cubic yards of borrow material during initial construction. Thereafter, the project maintenance requirements for the 4-year renourishment cycle are about 1.6 million cubic yards of borrow material over the 50-year project. It is MMS policy to negotiate a new agreement for each use of OCS material (or per nourishment event); therefore, this agreement only applies to the NEPA and environmental requirements for initial construction. The final NEPA document, as well as the outcome of the other environmental requirements, may be used to establish stipulations or conditions in the final negotiated agreement.

TAKE PRIDE IN AMERICA

The MMS looks forward to working with you during this process. We ask that the following staff be included on all communication regarding this project, Geoffrey Wikel, Leasing Division, (703) 787-1283 and Sally Valdes, Environmental Division, (703) 787-1707. If you would like to discuss any of these items further, please contact Sally Valdes at (703) 787-1707.

Sincerely,



James F. Bennett
Chief, Branch of Environmental Assessment
Environmental Division

TOWN OF SURF CITY

P. O. BOX 2475 214 N. NEW RIVER DRIVE SURF CITY, NC 28445
Telephone: (910) 328-4131 Fax: (910) 328-4132
www.townofsurfcity.com

A. D. (Zander) Guy, Jr., Mayor
Douglas C. Medlin, Mayor Pro-tem
Nelva R. Alhury, Council Member
Michael H. Curley, Council Member
Donald R. Helms, Council Member
William J. (Buddy) Fowler, Council Member

July 1, 2010

Colonel Jefferson M. Ryscavage, District Commander
Department of the Army
Wilmington District, Corps of Engineers
69 Darlington Avenue
Wilmington, NC 28403-1343

Dear Colonel Ryscavage:

On behalf of Surf City I would like to express and confirm our continued support of the proposed Surf City and North Topsail Beach Coastal Storm Damage Reduction Project. The feasibility study was authorized by two Transportation and Infrastructure Committee resolutions dated February 16, 2000 and April 11, 2000.

Surf City supports the selected National Economic Development Plan (NED) consisting of a sand dune constructed to an elevation of 15 feet above the National Geodetic Vertical Datum (NGVD), fronted by a 50-foot wide beach berm constructed to an elevation of 7 feet above NGVD with a six-year re-nourishment cycle. The berm and dune project extends along a reach of 52,150 feet.

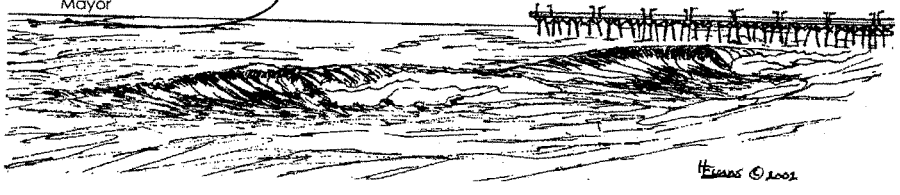
Further, we have been advised that the Initial Construction is $123,135,000, the first renourishment is $20,872,000, and each re-nourishment event from the 2nd to 8th cycle on a 6-year interval is $29,242,000. The estimated costs are based on October 2008 price levels and interest rate of 4.375 percent. The estimated operating and maintenance cost is approximately at $52,000 per year.

We understand the obligation of the local sponsors to cost share the initial construction at a rate of 65% Federal and 35% non-Federal and the obligation to cost share in the post construction re-nourishment costs at a rate of 50% federal and 50% non-Federal. We have been informed by the U.S. Army Corps of Engineers that the sponsors will be required to provide public beach access at a minimum of one access point and associated parking every half mile of the proposed project or the Federal cost sharing percentages will be reduced.

With Warm Personal Regards I am

Sincerely yours,

A.D. (Zander) Guy, Jr.
Mayor



NON-FEDERAL SPONSOR'S
SELF-CERTIFICATION OF FINANCIAL CAPABILITY
FOR DECISION DOCUMENTS

I, J. Michael Moore, do hereby certify that I am the Chief Financial Officer for the Town of Surf City, North Carolina; that I am aware of the financial obligations of the Non-Federal Sponsor for the Surf City and North Topsail Beach Coastal Storm Damage Reduction Project; and that the Non-Federal Sponsor will have the financial capability to satisfy the Non-Federal Sponsor's obligations for the project. I understand that the Government's acceptance of this self-certification shall not be construed as obligating either the Government or the Non-Federal Sponsor to implement a project.

IN WITMESS WHEREOF, I have made and executed this certification this 9th day of June, 2010.

BY: J Michael Moore

TITLE: Town Manager

DATE: June 9, 2010

TOWN OF SURF CITY

P. O. BOX 2475 214 N. NEW RIVER DRIVE SURF CITY, NC 28445
Telephone: (910) 328-4131 Fax: (910) 328-4132
www.townofsurfcity.com

A. D. (Zander) Guy, Jr., Mayor
Douglas C. Medlin, Mayor Pro-tem
Nelva R. Albury, Council Member
Michael H. Curley, Council Member
Donald R. Helms, Council Member
William J. (Buddy) Fowler, Council Member

June 4, 2010

Colonel Jefferson M. Ryscavage, District Commander
Department of the Army
Wilmington District, Corps of Engineers
69 Darlington Avenue
Wilmington, NC 28403-1343

Re: Assurance of Compliance to the Required Public Access and Parking Requirement for Surf City and North Topsail Beach Coastal Reduction Project.

Dear Colonel Ryscavage:

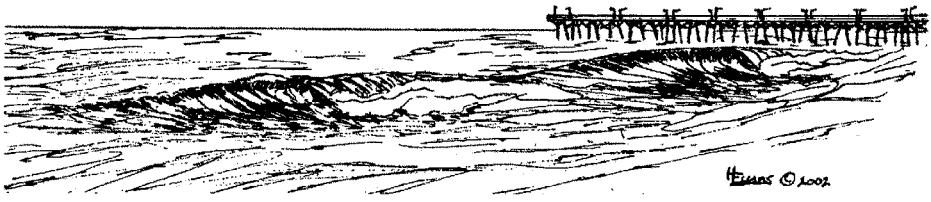
The Surf City Town Council recognizes the parking and public access requirements that are required under Sections 3.04 and 9.02 from the revised Feasibility Report and Environmental Impact Statement. Further this is to verify our Board is committed to provide the required public parking and access as outlined in both sections. The Council further assures that the Town will acquire the property that will provide the required accesses and parking. The one area identified in the Feasibility Report (map attached), shown in red at approximately 1600 South Shore Drive is being worked on by the Town Attorney and will be designated as a Public Beach Access. The Attorney has actually identified 7 accesses between 1600 down to 2500 block of South Shore Drive that will be identified as public beach accesses. The Town is in the process of purchasing a lot at 2303 South Shore Drive and will be designated for public parking. We have identified other lots in the yellow area on the map and are negotiating with property owners in order to purchase and designate for public parking. We understand that the feasibility report states we need 37 additional public parking spots to meet the requirements and will continue to pursue until we can meet the requirements.

The Town understands that the Federal cost share of the project would be decreased if the Town does not comply with the parking and access requirements. The share would decrease from 65% to 51.3% for the initial construction and from 50% to 39% for subsequent maintenance renourishment.

Town Council would like to thank you for all the assistance you and your staff have provided with this most important project and should you have any additional request, please advise.

With Warm Personal Regards I am,
Sincerely yours,

A.D. (Zander) Guy, Jr.
Mayor



Town of North Topsail Beach

Daniel Tuman, Mayor
Michael Yawn, Mayor Pro Tem
Aldermen:
Richard Farley
Deborah Lanci
Richard Macartney
Robert Swantek



Steven H. Foster
Town Manager

Carin Z. Faulkner, MPA
Town Clerk

July 1, 2010

Colonel Jefferson M. Ryscavage, District Commander
Department of the Army
Wilmington District, Corps of Engineers
69 Darlington Ave.
Wilmington, NC 28403-1343

Regarding: Surf City and North Topsail Beach Coastal Storm Damage Reduction Project Letter of Support

Dear Colonel Ryscavage,

The purpose of this correspondence is to express and confirm our continued support of the proposed Surf City and North Topsail Beach Coastal Storm Damage Reduction Project. The feasibility study was authorized by two Transportation and Infrastructure Committee resolutions dated February 16, 2000 and April 11, 2000.

We support the selected National Economic Development Plan (NED) consisting of a sand dune constructed to an elevation of 15 feet above the National Geodetic Vertical Datum (NGVD), fronted by a 50-foot wide beach berm constructed to an elevation of 7 feet above NGVD with a six-year re-nourishment cycle. The berm and dune project extends along a reach of 52,150 feet.

Further, we have been advised that the Initial Construction is $123,135,000, the first renourishment is $20,872,000, and each re-nourishment event from the 2nd to 8th cycle on a 6-year interval is $29,242,000. The estimated costs are based on October 2008 price levels and interest rate of 4.375 percent. The estimated operating and maintenance cost is approximately at $52,000 per year.

We understand the obligation of the local sponsors to cost share the initial construction at a rate of 65% Federal and 35% non-Federal and the obligation to cost share in the post construction re-nourishment costs at a rate of 50% Federal and 50% non-Federal. We have been informed by the U.S. Army Corps of Engineers that the sponsors will be required to provide public beach access at a minimum of one access point and associated parking every half mile of the proposed project or the Federal cost sharing percentages will be reduced.

Sincerely,

p.p. Carin Faulkner
Dan Tuman
Mayor

2008 LOGGERHEAD COURT NORTH TOPSAIL BEACH, NC 28460 PHONE (910) 328-1349 FAX (910) 328-4508
www.north-topsail-beach.org

Town of North Topsail Beach

Daniel Tuman, Mayor
Michael Yawn, Mayor Pro Tem
Aldermen:
Richard Farley
Deborah Lanci
Richard Macartney
Robert Swantek



Steven H. Foster
Town Manager

Carin Z. Faulkner, MPA
Town Clerk

NON-FEDERAL SPONSOR'S SELF-CERTIFICATION OF FINANCIAL CAPABILITY

I, Steven H. Foster, do hereby certify that I am the Town Manager of the Town of North Topsail Beach; that I am aware of the financial obligations of the Non-Federal Sponsor for the Town of North Topsail Beach renourishment project and that the Non-Federal Sponsor has the financial capability to satisfy the Non-Federal Sponsor's obligations under the Surf City and North Topsail Beach Storm Damage Reduction Project.

IN WITNESS WHEREOF, I have made the executed this certification this 11th day of June, 2010.

BY: Steven H. Foster

TITLE: Town Manager

DATE: June 11, 2010

Town of North Topsail Beach

Daniel Tuman, Mayor
Michael Yawn, Mayor Pro Tem
Aldermen:
Richard Farley
Deborah Lanci
Richard Macartney
Robert Swantek

Steven H. Foster
Town Manager

Carin Z. Faulkner, MPA
Town Clerk

June 11, 2010

Colonel Jefferson M. Ryscavage
Department of the Army
Wilmington District, Corps of Engineers
69 Darlington Ave.
Wilmington, NC 28403

Regarding: Surf City and North Topsail Beach Coastal Reduction Project- North Topsail Beach Board of Aldermen Assurance of Compliance to the Required Public Access and Parking Requirement

Dear Colonel Ryscavage,

The purpose of this letter is to state that the Board of Aldermen recognizes the parking and public access requirement that is required under Sections 3.04 and 9.02 from the revised Feasibility Report and Environmental Impact Statement. Further this is to verify the Board is committed to provide the required parking and access as outlined in those sections. The Board further assures that the Town will acquire the property that will provide an additional 20 parking spaces, and an additional access way. (Please find attached a map that will indicate those areas)

The Town understands that the Federal cost share of the project would be decreased if the Town does not comply with the parking and access requirements. That share would decrease from 65% to 51.3% for initial construction and from 50% to 39% for subsequent maintenance renourishment.

Thank you for all of the assistance that you and your staff have provided in this project, and should you have any additional request, please advise.

Sincerely,

Mayor Dan Tuman

Enclosure

North Carolina Department of Environment and Natural Resources
Division of Water Resources

Beverly Eaves Perdue
Governor

Thomas A. Reeder
Director

Dee Freeman
Secretary

December 13, 2010

Colonel Jefferson M. Ryscavage, District Commander
Department of the Army
Wilmington District, Corps of Engineers
PO Box 1890
Wilmington, NC 28402-1890

Dear Colonel Ryscavage:

The purpose of this correspondence is to express our continued support of the proposed Surf City and North Topsail Beach Coastal Storm Damage Reduction Project.

The North Carolina General Assembly has previously authorized the Division of Water Resources to use water resource capital improvement funds for the project study to the extent state funds became available. The Division of Water Resources understands that the selected National Economic Development Plan (NED) consists of a sand dune constructed to an elevation of 15 feet above the National Geodetic Vertical Datum (NGVD), fronted by a 50-foot wide beach berm constructed to an elevation of 7 feet above NGVD with a six-year re-nourishment cycle. The berm and dune project extends along a reach of 52,150 feet.

We have been advised that the Initial Construction cost is $127,973,000, and the total cost for the 7 planned renourishments is $215,525,000. The estimated costs are based on October 2010 price levels and an interest rate of 4.375 percent. The estimated operating and maintenance cost is approximately at $52,000 per year.

We understand the obligation of the local sponsors to cost share the initial construction at a rate of 65% Federal and 35% non-Federal and the obligation to cost share in the post construction re-nourishment costs at a rate of 50% Federal and 50% non-Federal. The State will assist in the financial support of this Project based on availability of state funds and continued authorization by the North Carolina General Assembly. Furthermore, this expression of potential financial support should not be construed as any form of regulatory approval of this project. The execution of this project is still subject to all State regulations and applicable permitting decisions and requirements.

Sincerely,

Thomas A. Reeder

1611 Mail Service Center, Raleigh, North Carolina 27699-1611
Phone: 919-733-4064 \ FAX: 919-733-3558 Internet: www.ncwater.org

An Equal Opportunity \ Affirmative Action Employer – 50% Recycled \ 10% Post Consumer Paper

One NorthCarolina Naturally

Final Feasibility Report
and
Environmental Impact Statement

SURF CITY AND NORTH TOPSAIL BEACH, NORTH CAROLINA

Coastal Storm Damage Reduction Project

Appendix I

Biological Assessment

FINAL
BIOLOGICAL ASSESSMENT

Surf City and North Topsail Beach
Pender and Onslow Counties, North Carolina
Coastal Storm Damage Reduction Project

1.00 PROPOSED PROJECT

The tentatively selected National Economic Development (NED) Plan, consists of a sand dune constructed to an elevation of 15 feet above the National Geodetic Vertical Datum (NGVD), fronted by a 50-foot wide beach berm constructed to an elevation of 7 feet above NGVD. This plan is identified among the other alternatives as "Plan 1550". The berm and dune project extends along a reach of 52,150 feet. On the north end, the project will adjoin an adjacent non-Federal beachfill project for North Topsail Beach. At the south end, a 2,000-foot long, berm-only transition section would extend from the town boundary along the Topsail Beach shoreline. If the Federal project for Topsail Beach is constructed first, then the transition is not needed. All the proposed dredging will occur within the Atlantic Ocean in offshore borrow areas located approximately 1-6 miles offshore.

2.00 NATIONAL MARINE FISHERIES SERVICE (NMFS): SECTION 7 CONSULTATION HISTORY

Prior to 1991, in accordance with Section 7 requirements under the Endangered Species Act (ESA), each US Army Corps of Engineers (USACE) district within the Corps' South Atlantic Division (SAD) prepared individual project specific biological assessments for dredging activities in the South Atlantic and received subsequent individual biological opinions from the National Marine Fisheries Service (NMFS). Beginning in 1991, NMFS moved away from individual consultations for Corps dredging activities with the development of the 1991 South Atlantic Regional Biological Opinion (SARBO) for dredging of channels in the Southeastern United States from North Carolina through Cape Canaveral, Florida. In order to assess the regional implications of USACE dredging actions, the NMFS extended the use of a Regional Biological Opinion (RBO) in subsequent 1995 and 1997 SARBO consultations. To date, SAD has been implementing its dredging program under the 1997 SARBO. However, since the 1997 consultation, several re-initiation triggers have been met, such as: (1) modification of the proposed activity, (2) listing of a new species and/or critical habitat, (3) the inclusion of Puerto Rico and the U.S. Virgin Islands which had been excluded from previous opinions and (4) the current status of Section 10(a)(1)(A) scientific research permits. Therefore, on April 30, 2007 SAD sent a letter to NMFS formally requesting re-initiation of consultation for dredging activities and other associated actions in the South Atlantic under Section 7 of the ESA.

On 12 September 2008, SAD provided NMFS with the Corps' South Atlantic Regional Biological Assessment (SARBA) for federal, federally permitted, or federally sponsored (funded or partially funded) dredging activities (i.e. hopper, cutterhead, mechanical, bed leveling, and side cast) in the coastal waters, navigation channels (including designated Ocean Dredged Material Disposal Sites (ODMDS)), and sand mining areas in the South Atlantic Ocean (including OCS sand resources under Minerals Management Service (MMS) jurisdiction) from the North Carolina/Virginia Border

through and including Key West, Florida and the Islands of Puerto Rico and the US Virgin Islands (USVI). Dredging methods and other associated actions considered under this assessment include hydraulic dredges (i.e. pipeline and hopper), mechanical dredges, bed leveling, transportation methodology (i.e. hopper, tugs/scows, and barges), and relocation trawling. Federally threatened, endangered, or candidate species considered under this assessment include: six species of marine turtles (leatherback, loggerhead, Kemp's ridley, hawksbill, green, and olive ridley sea turtles), Acroporid corals (staghorn and elkhorn), three large whale species (North Atlantic right whale (NARW), humpback whale, and sperm whale), Johnson's seagrass, and three anadromous or marine fish species (shortnose sturgeon, Atlantic sturgeon, and smalltooth sawfish). Of the species covered under the SARBA, the following are found within the Surf City and North Topsail Beach proposed project area: five species of sea turtles (loggerhead, green, Kemp's ridley, hawksbill, and leatherback), three large whale species (NARW, humpback whale, and sperm whale), and shortnose sturgeon.

In May 2007, during a SARBA scoping meeting at the NMFS Southeast Regional Office in St. Pete, Fl, Corps and NMFS representatives agreed that all dredging activities in the South Atlantic would continue to work under the 1997 SARBO until the new SARBO was developed and finalized. For the purposes of this assessment, all dredging actions will work under the Reasonable and Prudent Measures (RPM's), Terms and Conditions (T&C's), and Incidental Take Statement (ITS) of the 1997 SARBO until a superseding SARBO is completed. Upon completion of the new SARBO by NMFS, all new RPM's, T&C's, and ITS will be adhered to as a component of this project. For those species present within the proposed project vicinity of the Surf City and North Topsail Beach (SCNTB) coastal storm damage reduction project that have already been addressed in the Corps' 12 September 2008 SARBA, an additional species life history analysis and project impact evaluation will not be provided in the ensuing text, but rather reference to the existing NMFS consultation will be made.

In summary, based on a detailed evaluation provided in the 12 September 2008 SARBA of the effects of the proposed action on sea turtle, large whale, and sturgeon species found within the SCNTB project area, Table 1 provides the effect determinations for hopper dredging and associated activities.

Table 1. Effect determination for hopper dredging and associated activities for sea turtle, large whale, and sturgeon species found within the proposed SCNTB project area (No Effect (NE – green); May Affect Not Likely to Adversely Affect (MANLA – orange); May Affect Likely to Adversely Affect (MALAA – red); and Not Likely to Adversely Modify (NLAM – yellow/orange)). (Reference: *USACE. September 2008. Regional Biological Assessment for Dredging Activities in the Coastal Waters, Navigation Channels (including designated Ocean Dredged Material Disposal Sites (ODMDS)), and Sand Mining Areas in the South Atlantic Ocean. USACE, Wilmington District. Submitted to NMFS on 12 September 2008.)*

Proposed Activity	Effect Determination									
	Sea Turtle					Large Whales			Shortnose Sturgeon	Smalltooth Sawfish
	Leatherback	Loggerhead	Green	Kemp's Ridley	Hawksbill	NARW	Humpback	Sperm		
Hydraulic Hopper	NE	MALAA	MALAA	MALAA	MALAA	NE	NE	NE	MALAA	NE
Bed Leveling	NE	MANLAA	MANLAA	MANLAA	MANLAA	NE	NE	NE	NE	NE
Transport - Hopper, Tug/Scow, Barge	NE	NE	NE	NE	NE	MANLAA	MANLAA	MANLAA	NE	NE
Trawling	MANLAA	MANLAA	MANLAA	MANLAA	MANLAA				MALAA	NE
Tissue Sampling	MANLAA	MANLAA	MANLAA	MANLAA	MANLAA					
Tagging	MANLAA	MANLAA	MANLAA	MANLAA	MANLAA					
Dredge Lighting	MANLAA	MANLAA	MANLAA	MANLAA	MANLAA					
Critical Habitat	NLAM		NLAM		NLAM	NLAM				

718

2.00 SPECIES CONSIDERED UNDER THIS ASSESSMENT

Updated lists of endangered and threatened (T&E) species for the project area (Pender and Onslow Counties, NC) were obtained from the NMFS (Southeast Regional Office, St. Petersburg, FL) (http://sero.nmfs.noaa.gov/pr/pdf/North%20Carolina.pdf) and the USFWS (Field Office, Raleigh, NC) (http://www.fws.gov/raleigh/es_tes.html) websites. These lists were combined to develop the following composite list of T&E species that could be present in the area based upon their geographic range. However, the actual occurrence of a species in the area would depend upon the availability of suitable habitat, the season of the year relative to a species' temperature tolerance and migratory habits, and other factors.

Table 2. Threatened and Endangered Species Potentially Present in Pender and Onslow Counties, NC.

Species Common Names	Scientific Name	Federal Status
Mammals		
West Indian Manatee	*Trichechus manatus*	Endangered
North Atlantic Right whale	*Eubaleana glacialis*	Endangered
Sei whale	*Balaenoptera borealis*	Endangered
Sperm whale	*Physeter macrocephalus*	Endangered
Finback whale	*Balaenoptera physalus*	Endangered
Humpback whale	*Megaptera novaeangliae*	Endangered
Blue Whale	*Balaenoptera musculus*	Endangered
Birds		
Piping Plover	*Charadrius melodus*	Threatened
Red-cockaded woodpecker	*Picoides borealis*	Endangered
Reptiles		
American alligator	*Alligator mississippiensis*	T(S/A)
Green sea turtle	*Chelonia mydas*	Threatened[1]
Hawksbill turtle	*Eretmochelys imbricata*	Endangered
Kemp's ridley sea turtle	*Lepidochelys kempii*	Endangered
Leatherback sea turtle	*Dermochelys coriacea*	Endangered
Loggerhead sea turtle	*Caretta caretta*	Threatened
Fish		
Shortnose sturgeon	*Acipenser brevirostrum*	Endangered
Smalltooth sawfish	*Pristis pectinata*	Endangered
Vascular Plant		
Golden sedge	*Carex lutea*	Endangered
Chaffseed	*Schwalbea Americana*	Endangered
Cooley's meadowrue	*Thalictrum cooleyi*	Endangered
Rough-leaved loosestrife	*Lysimachia asperulaefolia*	Endangered
Seabeach amaranth	*Amaranthus pumilus*	Threatened

Status	Definition
Endangered	A taxon "in danger of extinction throughout all or a significant portion of its range."
Threatened	A taxon "likely to become endangered within the foreseeable future throughout all or a significant portion of its range."

T(S/A)	Threatened due to similarity of appearance (e.g., American alligator)--a species that is threatened due to similarity of appearance with other rare species and is listed for its protection. These species are not biologically endangered or threatened and are not subject to Section 7 consultation.

[1]Green turtles are listed as threatened, except for breeding populations in Florida and on the Pacific Coast of Mexico, which are listed as endangered.

3.00 ASSESSMENT OF IMPACTS TO LISTED THREATENED AND ENDANGERED SPECIES

3.01 General Impacts

Dredging and placement of beach quality sand have the potential to affect animals and plants in a variety of ways. The potential for adverse impacts may result from actions of the dredging equipment (i.e. suction, sediment removal, hydraulic pumping of water and sediment); physical contact with dredging equipment and vessels; physical barriers imposed by the presence of dredging equipment (i.e. pipelines); and placement of dredged material on the beach within the proposed construction template (i.e. covering, suffocation). Although beach placement of material, and associated construction operations (i.e. operation of heavy equipment, pipeline route, etc.), may adversely affect some species and their habitat, the resultant constructed beach profile also promotes restoration of important habitat that has been lost or degraded as a result of erosion. Potential impacts vary according to the type of equipment used, the nature and location of sediment discharged, the time period in relation to life cycles of organisms that could be affected, and the nature of the interaction of a particular species with the dredging activities.

Any potential impacts on federally listed threatened and endangered species would be limited to those species that occur in habitats provided by the project area. Therefore, the proposed work will not affect any listed species, which generally reside in freshwater, forested habitats, or savannas, including the American alligator, red-cockaded woodpecker, golden sedge, chaffseed, Cooley's meadowrue, and rough-leafed loosestrife. Federally listed species which could be present in the project area during the proposed action are the blue whale, finback whale, humpback whale, NARW, sei whale, sperm whale, West Indian manatee, green sea turtle, hawksbill sea turtle, Kemp's ridley sea turtle, leatherback sea turtle, loggerhead sea turtle, shortnose sturgeon, seabeach amaranth, and piping plover.

Dredging methods and placement of beach quality sand associated with the proposed action are similar to current maintenance dredging methods and existing beach nourishment projects. These methods have been addressed in a number of previous environmental documents, including biological assessments and biological opinions rendered regarding endangered and threatened species. The accounts, which follow, will summarize this information as it applies to the proposed action.

3.02 Species Accounts

3.02.1 American Alligator, Red-cockaded Woodpecker, Golden Sedge, Chaffseed, Cooley's Meadowrue, and Rough-leaved Loosestrife.

These are all terrestrial, freshwater, woodland, or savanna species. Since this habitat type is not present in the areas to be affected by the proposed action, these species are unlikely to occur.

Effect Determination. It has been determined that the proposed action is not likely to adversely affect any of these species or their habitat.

3.02.2 Blue Whale, Finback Whale, Humpback Whale, North Atlantic Right Whale (NARW), Sei Whale, and Sperm Whale

a. Status. Endangered

b. Occurrence in Immediate Project Vicinity. These whale species all occur infrequently in the ocean off the coast of North Carolina. Of these, only the NARW and the humpback whale routinely come close enough inshore to encounter the project area. Humpback whales were listed as "endangered" throughout their range on June 2, 1970 under the Endangered Species Act and are considered "depleted" under the Marine Mammal Protection Act. Humpbacks are often found in protected waters over shallow banks and shelf waters for breeding and feeding. They migrate toward the poles in summer and toward the tropics in winter and are in the vicinity of the North Carolina coast during seasonal migrations, especially between December and April. Since 1991, humpback whales have been seen in nearshore waters of North Carolina with peak abundance in January through March (NMFS, 2003). In the Western North Atlantic, humpback feeding grounds encompass the eastern coast of the United States, the Gulf of St. Lawrence, Newfoundland/Labrador, and western Greenland. Major prey species include small schooling fishes (herring, sand lance, capelin, mackerel, small Pollock, and haddock) and large zooplankton, mainly krill (up to 1.5 tons per day) (http://www.nmfs.noaa.gov). Based on an increased number of sightings and stranding data, the Chesapeake and Delaware Bays and the U.S. mid-Atlantic and southeastern states, particularly along Virginia and North Carolina coasts, have become increasingly important habitat for juvenile humpback whales (Wiley *et al.*, 1995).

There are 6 major habitats or congregation areas for the western NARW; these are the coastal waters of the southeastern United States, the Great South Channel, Georges Bank/Gulf of Maine, Cape Cod and Massachusetts Bays, the Bay of Fundy, and the Scotian Shelf. However, the frequency with which NARWs occur in offshore waters in the southeastern U.S. remains unclear (NMFS, 2003). While it usually winters in the waters between Georgia and Florida, the NARW can, on occasion, be found in the waters off North Carolina. NARWs swim very close to the shoreline and are often noted only a few hundred meters offshore (Schmidly, 1981). NARWs have been documented along the North Carolina coast, as close as 250 meters from the beach, between December and April with sightings being most common from mid to late March (Dr. Frank J. Schwartz, personal communication). Sighting data provided by the NARW Program of the New England Aquarium indicates that 93 percent of all North Carolina sightings between 1976 and 1992 occurred between mid-October and mid-April (Slay, 1993). The occurrence of NARWs in the State's waters is usually associated with spring or fall migrations. Due to their occurrence in the

nearshore waters, the transport of hopper dredges to and from the offshore borrow areas could result in an encounter with humpback and NARW species.

c. Project Impacts.

(1) Habitat. No critical habitat has been designated for NARWs and humpback whales within the proposed project area.

(2) Food Supply. North Atlantic right whales feed primarily on copepods (*Calanus* sp.) and euphausids (krill) (NMFS, 1991) and humpback whales feed on small fish and krill. The proposed dredging will not diminish productivity of the nearshore ocean; therefore, the food supply of these species should be unaffected.

(3) Relationship to Critical Periods in Life Cycle.

North Atlantic Right Whale (NARW).

Detailed life history information for NARWs and potential effects from dredging activities area provided within the following Section 7 consultation documents:

National Marine Fisheries Service. 1997. Regional Biological Opinion for the Continued Hopper Dredging of Channels and Borrow Areas in the Southeastern United States. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, Silver Spring, Maryland

USACE. September 2008. Regional Biological Assessment for Dredging Activities in the Coastal Waters, Navigation Channels (including designated Ocean Dredged Material Disposal Sites (ODMDS)), and Sand Mining Areas in the South Atlantic Ocean. USACE, Wilmington District. Submitted to NMFS on 12 September 2008.

The referenced September 2008 Section 7 consultation document discusses in detail the 26 June, 2006 proposed regulations by NMFS to implement mandatory vessel speed restrictions of 10 knots or less on vessels 65 ft. or greater in overall length in certain locations and at certain times of the year along the east coast of the U.S. Atlantic seaboard. Following the release of the referenced USACE consultation document, NMFS announced the release of the Final Rule and subsequent OMB approval of the collection-of-information requirements. Specifically, on October 10, 2008 NMFS published a final rule implementing speed restrictions to reduce the incidence and severity of ship collisions with North Atlantic right whales (73 FR 60173) with an effective date of December 9, 2008 through December 9, 2013. That final rule contained a collection-of-information requirement subject to the Paperwork reduction Act (PRA) that had not yet been approved by OMB. Specifically, 50 CFR 224.105(c) requires a logbook entry to document that a deviation from the 10-knot speed limit was necessary for safe maneuverability under certain conditions. On October 30, 2008, OMB approved the collection-of-information requirements contained in the October 10, 2008, final rule. On 5 December 2008, NMFS announced that the collection-of-information requirements were approved under Control Number 0648–0580, with an expiration date of April 30, 2009 (15 CFR Part 902).

Humpback Whales.

The overall North Atlantic population of humpback whales is estimated at 10,600 individuals and is increasing (Waring *et al.*, 1999); however the minimum population estimates for the Gulf of Maine stock is 647 individuals with a steadily increasing trend (NMFS, 2003). For the period 1993-1997, the total estimated human-caused mortality and serious injury from fishery interactions and vessel collisions is estimated at 4.4 per year (NMFS, 2003). According to Jensen and Silber's (2003) large whale ship strike database, of the 292 records of confirmed or possible ship strikes to large whales, 44 records (15%) were of humpback whales, the second most often reported species next to finback whales (75 records) (26%). Of the 5 documented ship strikes resulting in serious injury or mortality for North Atlantic humpback whales from January 1997-December 2001, 3 where located in North Carolina and South Carolina waters. Though the total level of human-caused mortality and serious injury is unknown, current data indicate that it is significant; furthermore, mortality off the U.S. Mid-Atlantic States continues to increase (NMFS, 2003).

(4) Effect Determination. Of the six species of whales being considered, only the NARW and humpback whale would normally be expected to occur within the project area during the project construction period. Therefore, the proposed project is not likely to adversely affect the blue whale, finback whale, sei whale, and sperm whale. Conditions outlined in previous consultations in order to reduce the potential for accidental collision (i.e. contractor pre-project briefings, large whale observers, slow down and course alteration procedures, etc.) will be implemented as a component of this project. Based on the implementation of these conditions, dredging activities associated with the proposed project may affect but are not likely to adversely affect the NARW and humpback whale species.

3.02.3 West Indian Manatee

a. Status. Endangered.

b. Occurrence in Immediate Project Vicinity. The manatee is an occasional summer resident off the North Carolina coast with presumably low population numbers (Clark, 1987). The species can be found in shallow (5 ft to usually <20 ft), slow-moving rivers, estuaries, saltwater bays, canals, and coastal areas (USFWS, 1991). The West Indian manatee is herbivorous and eats aquatic plants such as hydrilla, eelgrass, and water lettuce (USFWS, 1999a). Manatees are thermally stressed at water temperatures below 18°C (64.4°F) (Garrot *et al.*, 1995); therefore, during winter months, when ambient water temperatures approach 20°C (68°F), the U.S. manatee population confines itself to the coastal waters of the southern half of peninsular Florida and to springs and warm water outfalls as far north as southeast Georgia. During the summer months, sightings drop off rapidly north of Georgia (Lefebvre *et al., 2001*) and are rare north of Cape Hatteras (Rathbun *et al., 1982*; Schwartz, 1995). However, they are sighted infrequently in southeastern North Carolina with most records occurring in July, August, and September, as they migrate up and down the coast (Clark, 1993). The Species is considered a seasonal inhabitant of North Carolina with most occurrences reported from June through October (USFWS, 2001). According to Schwartz (1995), manatees have been reported in the state during nine months, with most sightings in the August-September period. Manatee population trends are poorly understood, but deaths have increased steadily. A large percent of mortality is due to collisions with watercrafts, especially of calves. Another closely related factor in their decline has been the loss of

suitable habitat through incompatible coastal development, particularly destruction of sea grass beds by boating facilities (USFWS, 2001).

Manatees are rare visitors to the SCNTB Region. According to Schwartz (1995), a total of 68 manatee sightings have been recorded in 11 coastal counties of North Carolina during the years 1919-1994. Therefore, it is likely that manatees transit through the SCNTB region during the warm water months. Manatees are known to infrequently occur within nearly all North Carolina ocean and inland waters (Schwartz, 1995) with four North Carolina records having been from inlet-ocean sites and six from the open ocean (Rathbun, 1982). According to the existing literature, specific numbers of manatees using the region are not known but are presumed to be very low. More research is needed to determine the status of the species in North Carolina and identify areas (containing food and freshwater supplies), which support summer populations.

c. Current Threats to Continued Use of the Area. Current threats to this species in the SCNTB area cannot be clearly assessed due to our lack of knowledge regarding its population, seasonality, distribution, and the habitat components in the project area that may be needed for its use. However, considering that manatees become thermally stressed at water temperatures below 18°C (64°F) (Garrot *et al.*, 1995), cold winter temperatures keep the species from over wintering in the project area.

d. Project Impacts.

(1) Habitat. Impacts to estuarine and nearshore ocean habitat of the area associated with the placement of sediment on the beach should be minor. With the current state of knowledge on the habitat requirements for the manatee in North Carolina, it is difficult to determine the magnitude of such impacts. Studies currently underway by the USFWS using animals fitted with satellite transmitters will hopefully provide data on the nature of these seasonal movements and habitat requirements during migrational periods.

(2) Food Supply. Foods, which are used by the manatee in North Carolina, are unknown. In Florida, their diet consists primarily of vascular plants. The proposed action will involve minimal change to the physical habitat of the estuary with no known impacts to vascular plants and overall estuarine and nearshore productivity should remain high throughout the project area. Therefore, potential food sources for the manatee should be unaffected.

(3) Relationship to Critical Periods in Life Cycle. Since the manatee is considered to be an infrequent summer resident of the North Carolina coast, the proposed action should have little effect on the manatee since its habitat and food supply will not be significantly impacted. In regards to vessel collisions, the proposed borrow sites are located between 1-6 miles offshore and the hopper dredge pumpout stations will be located within a mile offshore; thus, hopper dredging activities will not occur in the estuarine or inlet habitat area and direct impacts from collision will not occur. Nonetheless, the Corps will implement precautionary measures for avoiding impacts to manatees from associated transiting vessels during construction activities, as detailed in the "Guidelines for Avoiding Impacts to the West Indian Manatee" established by the USFWS.

(4) Effect Determination. Since the habitat and food supply of the manatee will not be significantly impacted, overall occurrence of manatees in the project vicinity is infrequent, all hopper dredging will occur in the offshore environment, and precautionary measures for avoiding impacts to manatees, as established by USFWS, will be implemented for transiting vessels associated with the project, the proposed action may affect by is not likely to adversely affect the manatee.

3.02.4 Sea Turtles.

a. Status.

Loggerhead	*Caretta caretta*	Threatened
Hawksbill	*Eretmochelys imbricata*	Endangered
Kemp's Ridley	*Lepidochelys kempii*	Endangered
Green	*Chelonia mydas*	Threatened[1]
Leatherback	*Dermochelys coriacea*	Endangered

[1]Green turtles are listed as threatened, except for breeding populations in Florida and on the Pacific Coast of Mexico, which are listed as endangered.

b. Critical Habitat. Critical habitat has not been designated in the continental U.S. for the five species of sea turtles identified to occur within the proposed project vicinity. Therefore, the proposed actions would not result in an adverse modification to identified critical habitat.

c. Background. Detailed life history information associated with the in-water life cycle requirements for sea turtles and a subsequent analysis of impacts from the proposed dredging activities is provided within the following NMFS Section 7 consultation documents:

National Marine Fisheries Service. 1997. Regional Biological Opinion for the Continued Hopper Dredging of Channels and Borrow Areas in the Southeastern United States. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, Silver Spring, Maryland

USACE. September 2008. Regional Biological Assessment for Dredging Activities in the Coastal Waters, Navigation Channels (including designated Ocean Dredged Material Disposal Sites (ODMDS)), and Sand Mining Areas in the South Atlantic Ocean. USACE, Wilmington District. Submitted to NMFS on 12 September 2008

A summary of project specific information associated with beach and in-water habitat use is provided in the ensuing text.

1.) Occurrence in Immediate Project Vicinity. All five species of sea turtles identified above are known to occur in both the estuarine and oceanic waters of North Carolina. According to Epperly *et al.* (1994), inshore waters, such as Pamlico and Core Sounds, are important developmental and foraging habitats for loggerheads, greens, and Kemp's ridleys. Nearly all sea turtles found within these sounds are immature individuals immigrating into the sounds in the spring and emigrating from the sounds in the late fall and early winter (Epperly et. al, 1995).

Loggerhead, green, and Kemp's ridley sea turtles are known to frequently use coastal waters offshore of North Carolina as migratory travel corridors (Wynne, 1999) and commonly occur at the edge of the continental shelf when they forage around coral reefs, artificial reefs, and boat wrecks.

Hawksbill and leatherback sea turtles infrequently enter inshore waters (Epperly *et al.*, 1995) and are normally associated solely with oceanic waters (Schwartz, 1977). However, Lee and Palmer (1981) document that leatherbacks normally frequent the shallow shelf waters rather than those of the open sea, with the exception of long-range migrants.

Of the five species of sea turtles considered for this project, only the loggerhead sea turtle (*Caretta caretta*), the green sea turtle (*Chelonia mydas*), and the leatherback sea turtle (*Dermochelys coriacea*) nest regularly on North Carolina beaches and have the potential to nest within the project area. There are no documented nesting attempts of hawksbill and Kemp's ridley sea turtles on the project beaches; however, Kemp's ridley nests have been documented twice in North Carolina, once on Oak Island in 1992 and once on Cape Lookout in 2003 ((Matthew Godfrey, pers. comm.). With a few exceptions, the entire Kemp's ridley population nests on the approximately 15 miles of beach in Mexico between the months of April and June (USFWS, 1991). The hawksbill sea turtle nests primarily in tropical waters in south Florida and the Caribbean. Considering the infrequency of Kemp's ridley nesting occurrence throughout North Carolina and the lack of historical nesting of Kemp's ridley and hawksbill sea turtles on Topsail Island, these species are not anticipated to nest within the project area. The loggerhead is considered to be a regular nester in the state, while green sea turtle nesting is infrequent and primarily limited to Florida's east coast (300 to 1,000 nests reported annually). According to Rabon *et al.* (2003), seven leatherback nests have been confirmed in North Carolina since 1998 constituting the northernmost nesting records for leatherbacks along the East Coast of the United States. Though almost all confirmed nesting activity in North Carolina has been between Cape Lookout and Cape Hatteras, the potential for leatherback nesting within the project area is likely.

Topsail Island is considered to be one of the more heavily nested areas along the North Carolina coast. Table 3, shows the total number of recorded loggerhead and green sea turtle nests on SCNTB beaches from 1990 to 2008. Though records were kept as early as 1984, consistent turtle nesting data has been recorded on Topsail Island only since 1990. Furthermore, Standardized nest patrols were not enacted statewide until the mid 1990s; therefore, values from the first part of the 1990's may not represent a full season of monitoring. Of the 1483 nests laid within the project areas since 1990, loggerhead sea turtles laid 1471 nests and 12 nests were laid by greens (Matthew Godfrey, pers. comm.). As shown in Table 3, sea turtle nesting numbers declined following hurricanes in the 1990's - Hurricane Emily, 1993, Hurricanes Bertha and Fran, 1996, and Hurricane Floyd, 1999. As part of the terms of local cooperation for this project, the project area will be monitored for sea turtle nesting and hatchling activity on an annual basis by the towns of Surf City and North Topsail Beach.

Table 3. Total sea turtle nest numbers for Surf City and North Topsail Beaches from 1990-2008. Loggerhead and green sea turtles are the only species with recorded nesting activity on Surf City and North Topsail beaches.

Year	Loggerhead (*Caretta caretta*)	Green (*Chelonia mydas*)
1990	68	0
1991	116	0
1992	91	0
1993	53	0
1994	80	0
1995	71	0
1996	102	1
1997	61	1
1998	89	3
1999	152	6
2000	87	0
2001	62	0
2002	77	0
2003	52	0
2004	49	0
2005	59	1
2006	77	0
2007	46	0
2008	79	0
TOTAL	1471	12

2.) Current Threats to Continued Use of the Area. In addition to affecting the coastal human population, coastal sediment loss also poses a threat to nesting sea turtles. A large percentage of sea turtles in the United States nest on nourished beaches (Nelson and Dickerson, 1988a), therefore, nourishment has become an important technique for nesting beach restoration (Crain *et al.*, 1995). Most of the project area has experienced severe erosion because of frequent hurricanes passing over or near the area since 1996. Since consistent turtle nesting surveys began on Topsail Island in 1990, there has been a gradual decline in the average numbers of nests laid per year (Table I-2). Coupled with this decline is the increase in nest relocations for those that are laid. One potential cause for decreased nest numbers and increased relocation numbers is loss of nesting habitat (Jean Beasley, pers. comm.). In areas were erosion is most severe, the tide is so high there is not acceptable beach to nest and without relocation efforts in these highly erosive areas, nests will be inundated and lost. Though concerns about beach nourishment, as it relates to relocation and nest success, are evident, with overall loss of habitat over time due to erosion, there will be complete loss of nesting on Topsail Island (Jean Beasley, pers. comm.).

Topsail Island is considered to be one of the major rookeries for the declining Northern loggerhead population; thus restoration of this important nesting habitat on Topsail Island is critical. Historically,

the north and south ends of Topsail Island have experienced beach disposal operations from the maintenance of navigation channels. These small-scale disposal events have re-established lost nesting habitat and have allowed for some turtles to continue nesting in areas that would have otherwise been lost. In regards to suitability for nesting, turtles continue to nest on disposal beaches with hatch rate successes similar to non-disposal beaches (Jean Beasley, pers. comm.).

The primary threats facing these species worldwide are the same ones facing them in the project area. Of these threats, the most serious seem to be loss of breeding females through accidental drowning by shrimpers (Crouse, *et al.*, 1987) and human encroachment on traditional nesting beaches. Research has shown that the turtle populations have greatly declined in the last 20 years due to a loss of nesting habitat along the beachfront and by incidental drowning in shrimp trawl nets. It appears that the combination of poorly placed nests coupled with unrestrained human use of the beach by auto and foot traffic has impacted this species greatly. Other threats to these sea turtles include excessive natural predation in some areas and potential interactions with hopper dredges during the excavation of dredged material. With the exception of hopper dredges, none of the dredge plants (i.e., pipeline dredges) proposed for use in the construction of this project are known to take sea turtles.

d. Project Impacts.

In order to avoid periods of peak sea turtle abundance during warm water months and minimize impacts to sea turtles in the offshore environment, the proposed hopper dredging window for this project is 1 December through 31 March. By adhering to this dredging window to the maximum extent practicable, all subsequent beach placement of sediment will occur outside of the North Carolina sea turtle nesting season of 1 May through 15 November. The limits of the nesting season window are based on the known nesting sea turtle species within the state and the earliest and latest documented nesting events for those species.

In the unanticipated event that construction activities extend into the nesting season (i.e. weather, equipment breakdown, etc.), all available data associated with the nesting activities within the project area will be utilized to consider risks of working within the nesting season. Variables to consider will include the number of days construction will extend into the nesting season, existing conditions of the pre-project nesting habitat such as: erosion rates, existing protective measures (i.e. sandbags, beach bulldozing, etc.), development, recreational use, the historic nesting density within the project area, etc. In coordination with the USFWS and NCWRC, an evaluation of these variables will be used to potentially incorporate project modifications (i.e. modified pipeline routes, staging areas, etc.) during the nesting season that may avoid or minimize potential impacts.

Upon evaluation of site-specific conditions, if nourishment beach activities extend into a portion of the nesting season, monitoring for sea turtle nesting activity will be considered throughout the construction area including the disposal area and beachfront pipeline routes, in accordance with guidelines provided by the NCWRC and USFWS, so that nests laid in a potential construction zone can be bypassed and/or relocated outside of the construction zone prior to project commencement. However, relocation measures should be considered as a last alternative. The location and operation of heavy equipment on the beach within the project area will be limited to daylight hours to the maximum extent practicable in order to minimize impacts to nesting sea turtles.

Considering that the proposed 1 December to 31 March construction window for initial construction and each nourishment interval will avoid the nesting season, direct impacts associated with construction activities during the nesting season are not anticipated and will be avoided to the maximum extent practicable. However, if construction extends into the nesting season do to unforeseen circumstances, the following direct impacts may occur:

(1) Both stockpiled pipe on the beach and the pipeline route running parallel to the shoreline may impede nesting sea turtles from accessing more suitable nesting sites.
(2) The operation of heavy equipment on the beach may impact incubating nests.
(3) During nighttime operations, the nourishment construction process, including heavy equipment use and associated lighting, may deter nesting females from coming ashore and disorient emerging hatchlings down the beach.
(4) Burial of existing nests may occur if missed by monitoring efforts.
(5) Escarpment formations and resulting impediment to nesting females.
(6) Reduced nest success as a result of relocation efforts.

Indirect impacts associated with changes to the nesting and incubating environment, from the placement of sediment from alternate sources on the beach, are expected. The following section discusses both potential direct and indirect impacts to nesting sea turtles associated with the proposed project:

(1) Beach Placement of Sediment Impacts.

Post-nourishment monitoring efforts have documented potential impacts on nesting loggerhead sea turtles for many years (Fletemeyer, 1984; Raymond, 1984; Nelson and Dickerson, 1989; Ryder, 1993; Bagley *et al.*, 1994; Crain *et al.*, 1995; Milton *et al.*, 1997; Steinitz *et al.*, 1998; Trindell *et al.*, 1998; Davis *et al.*, 1999; Ecological Associates, Inc., 1999; Herren, 1999; Rumbold *et al.*, 2001; Brock, 2005). Results from these studies indicate that, in most cases, nesting success decreases during the year following nourishment as a result of escarpments obstructing beach accessibility, altered beach profiles, and increased compaction. A comprehensive post-nourishment study conducted by Ernest and Martin (1999) documented an increase in abandoned nest attempts on nourished beaches compared to control or pre-nourished beaches as well as a change in nest placement with subsequent increase in wash-out of nests during the beach equilibration process. Contrary to previous studies, this study suggests that a post-nourishment decline in nest success is more likely a result from changes in beach profile than an increase in beach compaction and escarpment formation. According to Brock (2005), the sediment used for the nourishment of Brevard County beaches in Florida offered little or no impediment to sea turtles attempting to excavate an egg chamber. Furthermore, the physical attributes of the nourished sediment did not facilitate excessive scarp formation and; therefore, turtles were not limited in their ability to nest across the full width of beach. However, a decrease in nest success was still documented in the year following nourishment with an increase in loggerhead nesting success rates during the second season post-nourishment. This was attributed to increased habitat availability following the equilibration process of the seaward crest of the berm. This study suggests that, if compatible sediment and innovative design methods are utilized to minimize post-nourishment impacts documented in previous studies, than the post-nourishment decrease in nest

success without the presence of scarp formations, compaction, etc. may indicate an absence of abiotic and or biotic factors that cue the female to initiate nesting.

As suggested by the historical literature, there are inherent changes in beach characteristics as a result of mechanically placing sediment on a beach from alternate sources. The change in beach characteristics often results in short-term decreases in nest success and/or alterations in nesting processes. Based on the available literature, it appears that these impacts are, in many cases, site specific. Careful consideration must be placed on pre- and post-project site conditions and resultant beach characteristics after beach-fill episode at a given site in order to thoroughly understand identified post-project changes in nesting processes. By better understanding potential project specific impacts, modifications to project templates and design can be implemented to improve habitat suitability. The following sections review, more specifically, documented direct or indirect impacts to nesting females and hatchlings.

a. Pipe Placement.

In the event unanticipated circumstances arise and construction operations extend into the sea turtle nesting season pipeline routes and pipe staging areas may act as an impediment to nesting females approaching available nesting habitat or to hatchlings orienting to the waters edge. If the pipeline route or staging areas extend along the beach face, including the frontal dune, beach berm, mean high water line, etc., some portion of the available nesting habitat will be blocked. Nesting females may either encounter the pipe and false crawl, or nest in front of the pipeline in a potentially vulnerable area to heavy equipment operation, erosion, and washover. If nests are laid prior to placement of pipe and are landward of the pipeline, hatchlings may be blocked or mis-oriented during their approach to the water.

Though pipeline alignments and staging areas may pose impacts to nesting females and hatchlings during the nesting season, several measures can be implemented to minimize these impacts. If construction activities extend into the nesting season, monitoring should be done in advance to document all nests within the beach placement template. Construction operations and pipeline placement could be modified to bypass existing nests. If bypassing is not a practical alternative for a given project, the relocation of nests outside of construction areas could be implemented as a last resort. Throughout the period of sea turtle nesting and hatching, construction pipe that is placed on the beach parallel to the shoreline could be placed as far landward as possible so that a significant portion of available nesting habitat can be utilized and nest placement is not subject to inundation or wash out. Furthermore, temporary storage of pipes and equipment can be located off the beach to the maximum extent practicable. If placement on the beach is necessary, it will be done in a manner so as to impact the least amount of nesting habitat by placing pipes perpendicular to shore and as far landward as possible without compromising the integrity of the existing or constructed dune system.

b. Slope and Escarpments.

Beach nourishment projects are designed and constructed to equilibrate to a more natural profile over time relative to the wave climate of a given area. Changes in beach slope as well as the development of steep escarpments may develop along the mean high water line as the constructed beach adjusts from a construction profile to a natural beach profile (Nelson *et al.*, 1987). For the

purposes of this assessment, escarpments are defined as a continuous line of cliffs or steep slopes facing in one general direction, which is caused by erosion or faulting. Depending on shoreline response to the wave climate and subsequent equilibration process for a given project, the slope both above and below mean high water may vary outside of the natural beach profile; thus resulting in potential escarpment formation. Though escarpment formation is a natural response to shoreline erosion, the escarpment formation as a result of the equilibration process during a short period following a nourishment event may have a steeper and higher vertical face than natural escarpment formation and may slough off more rapidly landward.

Adult female turtles survey a nesting beach from the water before emerging to nest (Carr and Ogren, 1960; Hendrickson, 1982). Parameters considered important to beach selection include the geomorphology and dimensions of the beach (Mortimer, 1982; Johannes and Rimmer, 1984) and bathymetric features of the offshore approach (Hughes, 1974; Mortimer, 1982). Beach profile changes and subsequent escarpment formations may act as an impediment to a nesting female resulting in a false crawl or nesting females may choose marginal or unsuitable nesting areas either within the escarpment face or in front of the escarpment. Often times these nests are vulnerable to tidal inundation or collapse of the receding escarpment. If a female is capable of nesting landward of the escarpment prior to its formation, as the material continues to slough off and the beach profile approaches a more natural profile, there is a potential for an incubating nest to collapse or fallout during the equilibration process. Loggerheads preferentially nest on the part of the beach where the equilibration process takes place (Brock, 2005; Ecological Associates, Inc., 1999) and are more vulnerable to fallout during equilibration. However, according to Brock (2005), the majority of green turtle nests are placed on the foredune and; therefore, the equilibration process of the nourished substrate may not affect green turtles as severely.

A study conducted by Ernest and Martin (1999) documented increased abundance of nests located further from the toe of the dune on nourished vs. control beaches. Thus, post-nourishment nests may be laid in high-risk areas where vulnerability to sloughing and equilibration are greatest. Though nest relocation is not encouraged, considering that immediately following nourishment projects the likelihood of beach profile equilibration and subsequent sloughing of escarpments as profile adjustment occurs, nest relocation may be used as a last alternative to move nests that are laid in locations along the beach that are vulnerable to fallout (i.e. near the mean high water line). As a nourished beach is re-worked by natural processes and the construction profile approaches a more natural profile, the frequency of escarpment formation declines and the risk of nest loss due to sloughing of escarpments is reduced. According to Brock (2005), the return of loggerhead nesting success to equivalent rates similar to those on the adjacent non-nourished beach and historical rates two seasons post-nourishment were observed and are attributed to the equilibration process of the seaward crest of the berm.

Though the equilibration process and subsequent escarpment formation are features of most beach projects, management techniques can be implemented to reduce the impact of escarpment formations. For completed sections of beach during beach construction operations, and for subsequent years following as the construction profile approaches a more natural profile, visual surveys for escarpments could be performed. Escarpments that are identified prior to or during the nesting season that interfere with sea turtle nesting (exceed 18 inches in height for a distance of 100 ft.) can be leveled to the natural beach for a given area. If it is determined that escarpment

leveling is required during the nesting or hatching season, leveling actions will be directed by the NCWRC and USFWS.

The Corps' Jacksonville, FL District Headquarters is currently working with the Florida DEP to identify aspects of beach nourishment construction templates that negatively impact sea turtles and develop alternative design criteria that may minimize these impacts. Project design modifications to develop a more "turtle friendly" beach profile could potentially increase post-nourishment nest density and success. A draft final report for phase one of this study, "Assessment of Alternative Construction Template for Beach Nourishment Projects," has been developed and reviewed. Based on the final results and feasibility of recommendations, the Corps may incorporate, to the maximum extent practicable, 'turtle friendly' beach profile criteria in future project designs in order to enhance sea turtle nesting habitat requirements; however, at this point in time no formal recommendations have been identified.

c. Incubation Environment.

Physical changes in sediment properties that result from the placement of sediment, from alternate sources, on the beach pose concerns for nesting sea turtles and subsequent nest success. Constructed beaches have had positive effects (Broadwell, 1991; Ehrhart and Holloway-Adkins, 2000; Ehrhart and Roberts, 2001), negative effects (Ehrhart, 1995; Ecological Associates, Inc., 1998), or no apparent effect (Raymond, 1984.; Nelson *et al.*, 1987; Broadwell, 1991; Ryder, 1993; Steinitz *et. al.*, 1998; Herren, 1999) on the hatching success of marine turtle eggs. Differences in these findings are related to the differences in the physical attributes of each project, the extent of erosion on the pre-existing beach, and application technique (Brock, 2005).

If nesting occurs in new sediment following beach construction activities, embryonic development within the nest cavity can be affected by insufficient oxygen diffusion and variability in moisture content levels within the egg clutch (Ackerman, 1980; Mortimer, 1990; Ackerman *et al.*, 1992); thus, potentially resulting in decreased hatchling success. Ambient nest temperature and incubation time are affected by changes in sediment color, sediment grain size, and sediment shape as a result of beach nourishment (Milton *et al.*, 1997) and; thus, affect incubation duration (Nelson and Dickerson, 1988a). Sexual differentiation in chelonians depends on the temperature prevailing during the critical incubation period of the eggs (Pieau, 1971; Yntema, 1976; Yntema and Mrosovsky, 1979; Bull and Vogt, 1979), which occurs during the middle third of the incubation period (Yntema, 1979; Bull and Vogt, 1981; Pieau and Dorizzi, 1981; Yntema and Mrosovsky, 1982; Ferguson and Joanen, 1983; Bull, 1987; Webb *et al.* 1987; Deeming and Ferguson, 1989; Wibbels *et al.*, 1991), and possibly during a relatively short period of time in the second half of the middle trimester (Webster and Gouviea, 1988). Eggs incubated at constant temperatures of 28°C or below develop into males. Those kept at 32°C or above develop into females. Therefore, the pivotal temperature, those giving approximately equal numbers of males and females, is approximately 30°C (Yntema and Mrosovsky, 1982). Estimated pivotal temperatures for loggerhead sea turtles nesting in North Carolina, Georgia, and southern Florida are close to 29.2°C (Mrosovsky and Provancha, 1989). Therefore, fluctuation in ambient nest temperature on constructed beaches could directly impact sex determination if nourished sediment differs significantly from that found on the natural beach. Since, the pivotal temperatures for the northern and southern geographic nesting ranges of loggerheads in the United States are similar, a higher

percentage of males are produced on North Carolina beaches and a higher percentage of females on Florida beaches. Hatchling sex ratios are of conservational significance (Mrosovsky and Yntema, 1980; Morreale *et al.*, 1982) since they may affect the population sex ratio and thus could alter reproductive success in a population (Hanson *et al.*, 1998).

This assessment assumes sediment being placed on the beach meets the new state Sediment Criteria Rule Language (15A NCAC 07H .0312) (http://dcm2.enr.state.nc.us/Rules/rules.htm) for borrow material and subsequent beach placement adopted by North Carolina Coastal Resources Commission (CRC). Therefore, sediment characteristics will be compatible with native beaches.

d. Nest Relocation.

Relocation of sea turtle nests to less vulnerable sites was once common practice throughout the southeastern U.S. to mitigate the effects of natural or human induced factors. However, the movement of eggs creates opportunities for adverse impacts. Therefore, more recent USFWS guidelines are to be far less manipulative with nests and hatchlings to the maximum extent practicable. Though not encouraged, nest relocation is still used as a management technique of last resort where issues that prompt nest relocation cannot be resolved. Potential adverse impacts associated with nest relocation include: survey error (Shroeder, 1994), handling mortality (Limpus *et al.* 1979; Parmenter 1980), incubation environment impacts (Limpus *et al.*, 1979; Ackerman, 1980; Parmenter, 1980; Spotila *et al.*, 1983; McGehee, 1990), hatching and emergence success, and nest concentration.

Construction efforts associated with this project are scheduled, to the maximum extent practicable, to work outside of the sea turtle nesting season in order to avoid impacts to nesting females and the nest incubation environment. However, in some instances where an extension into the nesting season cannot be avoided, nest relocation may be used as a management tool to re-locate nests laid in the impact area to areas that are not susceptible to disturbance. For the identified project area, if the earliest documented nest attempt precludes the project completion date, nest relocation may be used as a last resort mitigation effort. If relocation is implemented, the proper protocol established by the NCWRC and USFWS will be adhered to in order to avoid the potential adverse impacts outlined above.

e. Beach Compaction and Hardness.

Sediment placed on the beach, as a component of coastal storm damage reduction projects, beach disposal, sand-bypassing, etc. is often obtained from three main sources: inlets, channels, or offshore borrow sites (Crain *et al.*, 1995) with occasional use of upland sources. Significant alterations in beach substrate properties may occur with the input of sediment types from other sources. Sediment density (compaction), shear resistance (hardness), sediment moisture content, beach slope, sediment color, sediment grain size, sediment grain shape, and sediment grain mineral content can be changed by beach nourishment.

Current sea turtle literature has attributed post-nourishment beach hardness to sand compaction but it should be more appropriately attributed to sediment shear resistance. Increased shear resistance can be due to increased sand compaction (density), but it can also be due to other

factors such as sand particle characteristics (size, shape) and interactions between the particles (Spangler and Handy, 1982; Nelson *et al.*, 1987; Nelson and Dickerson, 1989; Ackerman, 1996). Shear resistance describes the ability of the beach sand to resist sliding along internal surfaces. A measure of shear resistance can be described as a measure of beach hardening or strength. The sand particle surface characteristics contribute to the sliding friction ability of the sand particles. Various parameters (chemical composition, cohesion, moisture content, sediment layering and mixing) contribute to the interlocking ability of the sand particles. Sliding friction, interlocking, and compaction of the sand particles all contribute to a measure of shear resistance. Thus, a measurement of increased shear resistance does not necessarily mean that the beach is also compacted (Ackerman, 1996).

Factors which may contribute to increased beach hardness (shear resistance) on nourished beaches include a high silt component, angular fine-grained sand, higher moisture content, equipment and vehicular traffic, and hydraulic slurry deposition of sediments (Nelson, 1985; Nelson *et al.*, 1987; Nelson and Dickerson, 1988a; 1989; Ackerman, 1996). Beach fill can vary in amount of carbonate sand, quartz sand, shell, coral, silt, and clay content (National Research Council 1995). Sediments used for beach fill with clay or silt contents higher than 5-10% may cause high beach hardness once the sediment dries (Nelson, 1985; Dean, 1988). Harder nourished beaches typically result from angular, finer grain sand dredged from stable offshore borrow sites; whereas, less hard or "softer" beaches result from smoother, coarse sand dredged from high energy locations (e.g. inlets) (Spangler and Handy 1982; Nelson *et al.,* 1987; Nelson and Dickerson 1988a; 1989). Nourished beaches may result in sediment moisture content more than 4% higher than adjacent, natural beaches (Ackerman 1996, Ackerman *et al.,* 1992). Placement of fill material with heavy equipment imparts a component of "compactness" that should not occur on natural beaches. The natural process of beach formation, over an extended period of time, results in extensive sorting of the sand both by layers and within layers. Layer orientation is determined by the wave wash which is not the same for nourished beaches (National Research Council, 1995).

Hard sediment can prevent a female from digging a nest or result in a poorly constructed nest cavity. Females may respond to harder physical properties of the beach by spending more time on the beach nesting, which may result in physiological stress and increased exposure to disturbances and predation; thus, in some cases leading to a false dig (Nelson and Dickerson, 1989). Although increased shear resistance does not occur with every nourishment project, higher shear resistance measurement values have been more frequently reported over the past 30 years from nourished beaches than on natural beaches of the same area (e.g. Mann 1977; Fletemeyer 1983; Raymond 1984; Nelson *et al.,* 1987; Moulding and Nelson 1988; Nelson and Dickerson 1988a; Ryder 1995; Bagley *et al.*, 1994; Crain *et al.,* 1995; Ernest *et al.*, 1995; Foote and Truitt 1997; Milton *et al.,* 1997; Steinitz *et al.*, 1998; Trindell *et al.*, 1998; Davis *et al.,* 1999; Herren 1999; Allman *et al.*, 2001; Rumbold *et al.,* 2001; Piatkowski, 2002; Scianna *et al.,* 2001; Brock, 2005). Results have varied tremendously on the nesting success reported in these studies when comparing nourished and natural beaches of different shear resistance values. The natural variance in shear resistance values and the nesting success related to these values is still poorly understood. Due to the many variables involved from natural and non-natural causes, it is extremely difficult to identify impacts from nourishment projects by only evaluating nesting success data. Analyses of shear resistance values and nesting success have yet to determine a consistent relationship (Trindell *et al.*, 1998). It is difficult to define absolute or optimal shear resistance values until these relationships are better understood throughout the sea turtle nesting range in the

United States (Gulf and South Atlantic states). Crain *et al.* (1995) also recommended this as a research priority for beach nourishment impact studies.

Measuring shear resistance has become a common procedure of most beach nourishment projects and is usually done with a hand-held cone-penetrometer (Crain et al 1995). While holding the instrument in a vertical orientation, measurements are obtained by manually pushing it into the beach sediment. Based on data collected during the 1980's from nourished and non-nourished projects on the Atlantic coast of Florida, the U.S. Army Corps of Engineers provided initial guidelines on maximum cone-penetrometer values (600) below which might be more compatible with natural nesting beaches (Nelson *et al.*., 1987; Moulding and Nelson 1988; Nelson *et al.*, 1987; Nelson and Dickerson 1988a; 1989). The USFWS later adopted these guidelines into permitting regulations for all nourished projects along the U.S. Atlantic and Gulf of Mexico coasts with potential sea turtle nesting habitat. These requirements are still in effect to date and are outlined in state construction permit requirements and Biological Opinions issued by USFWS. According to the general USFWS compaction measurement guidelines for NC outlined below, compaction measurements of 500 PSI establishes the level of beach hardness when post-nourishment beach tilling should be done to reduce the shear resistance measurements.

General USFWS Compaction Guidelines

1. Compaction sampling stations will be located at 500-foot intervals along the project area. One station will be at the seaward edge of the dune line (when material is placed in this area); and one station must be midway between the dune line and the high water line (normal wrack line).

At each station, the cone penetrometer will be pushed to a depth of 6, 12, and 18 inches three times (three replicates). Material may be removed from the hole if necessary to ensure accurate readings of successive levels of sediment. Layers of highly compact material may lie over less compact layers. Replicates will be located as close to each other as possible, without interacting with the previous hole and/or disturbed sediments. The three replicate compaction values for each depth will be averaged to produce final values for each depth at each station. Reports will include 18 values for each transect line, and the final 6 averaged compaction values.

2. If the average value for any depth exceeds 500 pounds per square inch (psi) for any two or more adjacent stations, then that area must be tilled prior to May 1. If values exceeding 500 psi are distributed throughout the project area, but in no case do those values exist at two adjacent stations at the same depth, then consultation with the Fish and Wildlife Service will be required to determine if tilling is required. If a few values exceeding 500 psi are randomly present within the project area, tilling will not be required. For all circumstances where tilling is implemented, the designated area shall be tilled to a depth of 36 inches. Tilling will be performed (i.e. overlapping rows, parallel and perpendicular rows, etc.) so that all portions of the beach are tilled and no furrows are left behind All tilling activities must be completed prior to May 1 in accordance with the following protocol..

Readings of cone index values can be roughly equated to pounds per square inch (psi). However, this is a relative value and caution should be used when attempting to compare cone index values in pounds per square inch to other sources of data (Moulding and Nelson 1988). Ferrel *et al.* (2002) and Piatkowski (2002) used a Lang penetrometer, as opposed to the cone-penetrometer, because readings are not influenced by the mass of the user. This is an issue when multiple people of varying mass and strength are conducting the measurements. Much of the variation in the compaction data could be due to variability inherent in the use of the cone-penetrometer itself. Ferrell *et al.* (2002) investigated the strengths and weaknesses of several different types of instruments that measure sediment compaction and shear resistance suggesting that other instruments may be more suitable for measuring beach compaction relative to sea turtle nesting behavior. Because of instrument error and given that turtles do not dig vertically in the same fashion as a penetrometer moves through the sediment layers, some have concluded that penetrometers are not appropriate for assessing turtle nesting limitations (Davis *et al.*, 1999). However, even with this limitation, the hand-held cone-penetrometer remains the accepted method for assessing post-nourishment beach hardness.

According to Davis *et al.* (1999), on the Gulf Coast of Florida (1) there was no relationship between turtle nesting and sediment compactness, (2) the compactness ranges and varies widely in both space and time with little rationale, (3) tilling has a temporary influence on compactness and no apparent influence on nesting frequency, (4) and current compactness thresholds of 500 psi are artificial. According to Brock (2005), the physical attributes of the fill sand for Brevard County beaches did not result in severe compaction and therefore did not physically impede turtles in their attempts to nest. Therefore, additional studies should be considered to evaluate the validity of this threshold (500 PSI) and its general application across all beaches as a means to assess beach-tilling requirements. If sediment characteristics are similar to the native beach and sediment grain sizes are homogenous, the resultant compaction levels will likely be similar to the native beach and tilling should not be encouraged. A study by Nelson and Dickerson (1988b) documented that a tilled nourished beach will remain un-compacted for up to one year; however, this was a site-specific study and for some beaches it may not be necessary to till beaches in the subsequent years following nourishment.

Beach hardness impacts can be minimized by using compatible sand in accordance with the new NC state Sediment Criteria Rule Language (15A NCAC 07H .0312) (http://dcm2.enr.state.nc.us/Rules/rules.htm). In some cases, though sediment placed on the beach is compatible with the native sediment characteristics and the resultant compaction is similar to the native beach, tilling is still encouraged regardless of compaction levels. It has been suggested that, in some cases, the process of tilling a beach, with compaction levels similar to native beach, may have an effect on sea turtle nesting behavior and nest incubation environment. Research on evaluating tilling impacts to nesting turtles is limited. Therefore, the idea of not tilling beaches (immediately following and/or during consecutive years after construction operations) where compatible sediments are used and compaction levels are similar to the native beach should be taken into consideration on a case-by-case basis in order to account for potential impacts of tilling activities on nest success.

Recognizing the recent literature on beach compaction measurements and associated tilling, as well as and the current concerns with the existing compaction evaluation and subsequent tilling process outlined in the USFWS general compaction guidelines, the Corps, in coordination with

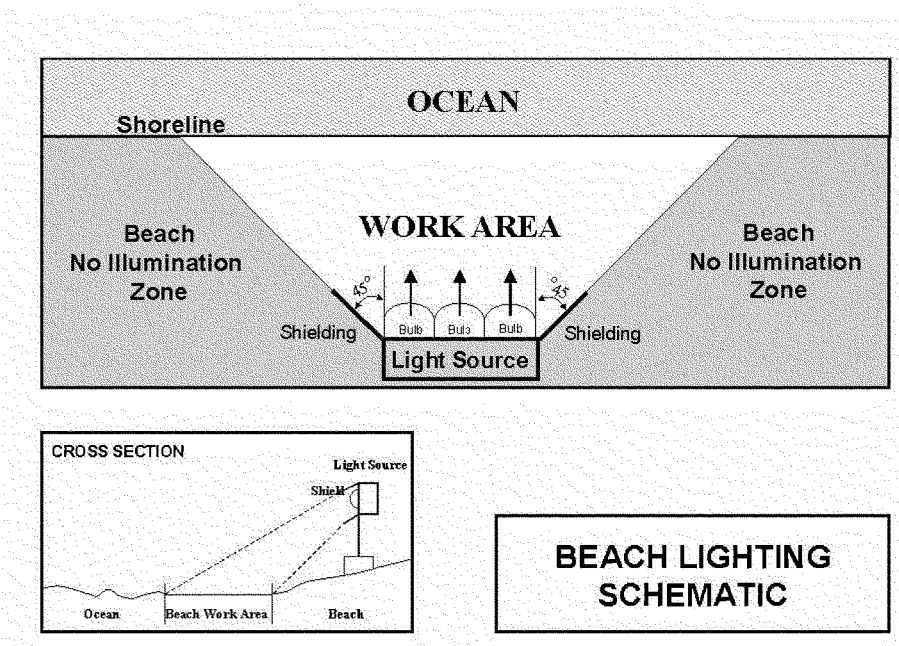
NCWRC and USFWS, has initiated a more qualitative approach for post construction compaction evaluations on North Carolina beaches where sediment meets the state compatibility standard. Results from this effort have recognized a reduction in the need for post construction tilling for many disposal and nourishment projects. Considering that only beach compatible sediment (i.e. in accordance with NC Sediment Criteria Rule Language) will be placed on the beach as a component of this project, the Corps will continue to work with NCWRC and USFWS in this qualitative post construction compaction and tilling evaluation in order to assure that impacts to nesting and incubating sea turtles are minimized.

f. Lighting.

The presence of artificial lighting on or within the vicinity of nesting beaches is detrimental to critical behavioral aspects of the nesting process including nesting female emergence, nest site selection, and the nocturnal sea-finding behavior of both hatchlings and nesting females. Artificial lighting on beaches tends to deter sea turtles from emerging from the sea to nest; thus, evidence of lighting impacts on nesting females is not likely to be revealed by nest to false crawl ratios considering that no emergence may occur (Mattison *et al.*, 1993; Witherington, 1992; Raymond, 1984). Though nesting females prefer darker beaches (Salmon *et al.*, 1995), considering the increased development and associated lighting on most beaches, many do nest on lighted shorelines. Although the effects of lighting may prevent female emergence, if emergence, nest site selection, and oviposition does occur, lighting does not affect nesting behavior (Witherington and Martin, 2003). However, sea turtles rely on vision to find the sea upon completion of the nesting process and use a balance of light intensity within their eyes to orient towards the brightest direction (Ehrenfeld, 1968); thus, misdirection by lighting may occur resulting in more time being spend to find the ocean. Furthermore, successful nesting episodes on lighted shorelines will directly effect the orientation and sea-finding process of hatchlings during the nest emergence and frenzy process to reach the ocean. Hatchlings rely almost exclusively on vision to orient to the ocean and brightness is a significant cue used during this immediate orientation process after hatch out (Mrosovsky and Kingsmill, 1985; Verheijen and Wilschut, 1973; Mrosovsky and Shettleworth, 1974; Mrosovsky *et al.*, 1979). Hatchlings that are mis-oriented (oriented away from the most direct path to the ocean) or disoriented (lacking directed orientation or frequently changing direction or circling) from the sea by artificial lighting may die from exhaustion, dehydration, predation, and other causes. Though hatchlings use directional brightness of a natural light field (celestial sources) to orient to the sea, light from artificial sources interferes with the natural light cues resulting in misdirection (Witherington and Martin, 2003).

The impact of light on nesting females and hatchlings can be minimized by reducing the number and wattage of light sources or by modifying the direction of light sources through shielding, redirection, elevation modifications, etc. (Figure 1). If shielding of light sources is not effective, it is important that any light reaching the beach has spectral properties that are minimally disruptive to sea turtles like long wavelength light. The spectral properties of low-pressure sodium vapor lighting are the least disruptive to sea turtles among other commercially available light sources.

Figure 1. Schematic for recommended shielding of lighting associated with beach construction activities.



During beach placement construction operations associated with the proposed project, lighting is required during nighttime activities at both the pumpout site and the location on the beach where sediment is being placed. In compliance with the US Army Corps of Engineers Safety and Health Requirements Manual (2003), a minimum luminance of 30 lm/ft^2 is required for dredge operations and a minimum of 3 lm/ft^2 is required for construction activities on the beach. For dredging vessels, appropriate lighting is necessary to provide a safe working environment during nighttime activities on deck (i.e. general maintenance work deck, endangered species observers, etc.). During beach construction operations, lighting is generally associated with the active construction zone around outflow pipe and the use of heavy equipment in the construction zone (i.e. bulldozers) in order to maintain safe construction operations at night. Furthermore, on newly nourished beaches where the elevation of the beach berm is raised for coastal storm damage reduction purposes, it is possible that lighting impacts to nesting females and emerging hatchlings from adjacent lighting sources (streets, parking lots, hotels, etc) may become more problematic as shading from dunes, vegetation, etc. is not longer evident (Brock, 2005; Ehrhart and Roberts, 2001). In a study on Brevard county beaches, Brock (2005) found that loggerhead hatchling disorientations increased significantly post-nourishment. This was attributed to the increase in light sources not previously visible to be seen by hatchlings as a result of the increase in profile elevation combined with an easterly expansion of the beach. However, a dune feature will be constructed as a component of this project and is, therefore, expected to reduce lighting impacts to nesting and hatchling sea turtles that are associated with raising the beach elevation.

If beach construction activities extend into the sea turtle nesting and hatching season, all lighting associated with project construction will be minimized to the maximum extent practicable while maintaining compliance with all Corps, U.S. Coast Guard, and OSHA safety requirements. Direct lighting of the beach and near shore waters will be limited the immediate construction area(s). Lighting aboard dredges and associated vessels, barges, etc. operating near the sea turtle nesting beach shall be limited to the minimal lighting necessary to comply with the Corps, U.S. Coast Guard, and OSHA requirements. Lighting on offshore or onshore equipment will be minimized through reduced wattage, shielding, lowering, and/or use of low pressure sodium lights, in order to reduce illumination of adjacent beach and nearshore waters will be used to the extent practicable.

The use of sea turtle friendly lighting has been shown to significantly improve beaches for sea turtle nesting. Therefore, in conjunction with the proposed beach project, local lighting ordinances will be encouraged to the maximum extent practicable in order to reduce lighting impacts to nesting females and hatchlings. The local sponsors will be encouraged to work with the USFWS, local monitoring groups, and other concerned organizations to develop the best plan for the Towns of Surf City and North Topsail Beach.

(2) Dredging Impacts.

a. Food Supply.

After leaving the nesting beach, hatchling green and loggerhead turtles head towards the open ocean pelagic habitats (Carr, 1987) where their diet is mostly omnivorous with a strong carnivorous tendency in green turtles (Bjorndal, 1985). At about 20-25 cm carapace length Atlantic green turtles enter benthic foraging areas and shift to an herbivorous diet, feeding predominantly on sea grasses and algae but may also feed over coral reefs and rocky bottoms (Mortimer, 1982). At about 40 to 50 cm carapace length, loggerheads move into shallow water where they forage over benthic hard and soft bottom habitats (Carr, 1986). Loggerhead sea turtles feed on benthic invertebrates including mollusks, crustaceans, and sponges (Mortimer, 1982) but have also been found to eat fish, clams, oysters, sponges, jellyfish, shrimp, and crabs when near shore. Hawksbill and Kemp's ridley sea turtles are carnivorous (Mortimer, 1995) with a principal food source of crustaceans, mollusks, other invertebrates, and fish (Schwartz, 1977). Hawksbills feed on encrusting organisms such as sponges, tunicates, bryozoans, mollusks, and algae; whereas Kemp's ridleys feed predominantly on portunid crabs (Bjorndal, 1985). Leatherback sea turtles are carnivorous (Mortimer, 1995) and feed primarily on cnidarians and tunicates (salps, pyrosomas) throughout the water column but are commonly observed feeding at the surface (Bjorndal, 1985).

Dredging will be performed within offshore borrow areas located approximately 1 to 6 miles offshore and will not affect these resources in the inshore environment. Impacts on benthic habitat at the offshore borrow sites will be minor as dredging will only affect a limited portion of the offshore benthic habitat. Hardbottom surveys and subsequent mapping were performed within all proposed borrow sites and diver ground truth surveys were performed to characterize select sites. Dredging buffers of 400 ft for low relief and 500 m for moderate and high relief hard bottom systems will be adhered to in order to avoid impacts to hard bottom associated foraging habitat. Impacts to sandy bottom foraging habitat are expected to be isolated and short term in duration. Therefore, the project should not significantly affect the food supply of benthic foraging sea turtles

in the offshore borrow sites. Considering that leatherbacks feed primarily within the water column on non-benthic organisms, the project should not significantly affect the food supply of this species

b. Relationship to Critical Periods in Life Cycle.

Sea turtles migrate within North Carolina waters throughout the year, mostly between April and December. The dredging of sediment from designated borrow sites during initial construction and each nourishment interval will be performed using a hopper dredge. Hopper dredges potentially pose the greatest risk to benthic oriented sea turtles through physical injury or death by entrainment as the hopper dredge dragheads remove sediment from sea bottom.

In order to minimize potential impacts, hopper dredges will be used from 1 December to 31 March of any year when water temperatures are cooler and sea turtle abundance is low, generally <14°C (57.2°F). However, because some sea turtle species may be found year-round in the offshore area, hopper-dredging activities may occur during low levels of sea turtle migration. Therefore, the proposed hopper dredging activities may adversely effect loggerhead, green, hawksbill, and Kemp's ridley sea turtles. Based on historic hopper dredging take data, leatherback sea turtles are not known to be impacted by hopper dredging operations. The Corps will abide by the provisions of the September 25, 1997 Regional Biological Opinion for The Continued Hopper Dredging Of Channels And Borrow Areas In The Southeastern United States or any superseding RBO provided by NMFS. To reduce impacts, the Corps anticipates taking certain precautions as prescribed by NMFS and USACE under standard hopper dredging protocol and will maintain observers on hopper dredges for the periods prescribed by NMFS to document any takes of turtle species and to ensure that turtle deflector dragheads are used properly.

(3) Summary Effect Determination.

All five species are known to occur within oceanic waters of the proposed project borrow areas; however, only the loggerhead, green, and leatherback sea turtles are known to nest within the limits of the project beach placement area. Therefore, species specific impacts may occur from both the beach placement and dredging operations. Considering the proposed dredging window to avoid the sea turtle nesting season to the maximum extent practicable, the proposed project may affect but is not likely to adversely affect nesting loggerhead, green, and leatherback sea turtles by altering nesting habitat. Though significant alterations in beach substrate properties may occur with the input of sediment types from other sources, re-establishment of a berm and dune system with a gradual slope can enhance nesting success of sea turtles by expanding the available nesting habitat beyond erosion and inundation prone areas. As previously stated, in regards to suitability for nesting, turtles continue to nest on disposal beaches of Topsail Island with hatch rate successes similar to non-disposal beaches (Jean Beasley, pers. comm.).

The proposed hopper dredging activities for initial construction, as well as each nourishment interval, may occur in areas used by migrating turtles. Hopper dredges pose risk to benthic oriented sea turtles through physical injury or death by entrainment. Though the 1 December to 31 March dredging window will avoid periods of peak turtle abundance during the warm water months, the risk of lethal impacts still exist as some sea turtle species may be found year-round in the offshore area. Therefore, the proposed hopper dredging activities may adversely affect loggerhead, green, hawksbill, and Kemp's ridley sea turtles. Based on historic hopper dredging

take data, leatherback sea turtles are not known to be impacted by hopper dredging operations.

3.02.6 Shortnose Sturgeon

Detailed life history information associated with the the life cycle requirements for shortnose sturgeon and a subsequent analysis of impacts from the proposed dredging activities are provided within the following Section 7 consultation documents:

National Marine Fisheries Service. 1997. Regional Biological Opinion for the Continued Hopper Dredging of Channels and Borrow Areas in the Southeastern United States. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, Silver Spring, Maryland

USACE. September 2008. Regional Biological Assessment for Dredging Activities in the Coastal Waters, Navigation Channels (including designated Ocean Dredged Material Disposal Sites (ODMDS)), and Sand Mining Areas in the South Atlantic Ocean. USACE, Wilmington District. Submitted to NMFS on 12 September 2008

A summary of project specific information and associated impacts is provided in the ensuing text.

a. Status. Endangered

b. Occurrence in Immediate Project Vicinity. Populations of shortnose sturgeon range along the Atlantic seaboard from the Saint John River in New Brunswick, Canada to the Saint Johns River, Florida (USFWS, 1999b). It is apparent from historical accounts that this species may have once been fairly abundant throughout North Carolina's waters; however, many of these early records are unreliable due to confusion between this species and the Atlantic sturgeon (*Acipenser oxyrhynchus*). There are historical records of the shortnose sturgeon both in Albemarle Sound and the nearshore ocean (Dadswell, *et al.*, 1984). However, in the recent past, this species was thought to be extirpated from North Carolina (Schwartz, *et al.*, 1977). During the winter of 1986-87, the shortnose sturgeon was taken from the Brunswick River, a component of the Cape Fear River basin. With this discovery, the species is once again considered to be a part of the state's fauna; however, there are still no recent records of the species within the New River inlet vicinity of the project area (F. Rhode 2008, pers. comm.). Because of the lack of suitable freshwater spawning areas in the project area and the requirement of low salinity waters by juveniles, any shortnose sturgeons present would most likely be non-spawning adults (NMFS, 1998).

c. Current Threats to Continued Use of the Area. Pollution, blockage of traditional spawning grounds, and over fishing are generally considered to be the principal causes of the decline of this species. The prohibition by North Carolina Division of Marine Fisheries (NCDMF) on taking any sturgeon in North Carolina should help to protect the species from commercial and recreational fishing pressure.

d. Project Impacts.

(1) Habitat.

The shortnose sturgeon is principally a riverine species and is known to use three distinct portions of river systems: (1) non-tidal freshwater areas for spawning and occasional over wintering; (2) tidal areas in the vicinity of the fresh/saltwater mixing zone, year-round as juveniles and during the summer months as adults; and (3) high salinity estuarine areas (15 parts per thousand (ppt.) salinity or greater) as adults during the winter. Habitat conditions suitable for juvenile and adult shortnose sturgeon could occur within the project area; however, spawning habitat should lie well outside of the project area and should not be affected by this project. The presence of juvenile shortnose sturgeon is not likely due to high salinity. Adults are found in shallow to deep water (6 to 30 feet) and, if present, would be expected to occupy the deeper channels during the day and the shallower areas adjacent to the channel during the night (Dadswell *et al.*, 1984).

(2) Food Supply.

The shortnose sturgeon is a bottom feeder, consuming various invertebrates and stems and leaves of macrophytes. Adult foraging activities normally occur at night in shallow water areas adjacent to the deep-water areas occupied during the day. Juveniles are not known to leave deep-water areas and are expected to feed there.

Dredging for this project will occur at borrow sites located between 1-6 miles offshore; therefore, shallow water feeding areas will not be affected by the project.

(3) Effect Determination.

Although hopper dredges have been known to impact shortnose sturgeons, dredging for this project will occur in offshore environments, outside of its habitat range. Therefore, impacts from dredges are not anticipated to occur. Because of the unlikelihood of shortnose sturgeon being present in the project area (Fritz Rhode 2008, pers.comm.) and since dredging will occur in the offshore environment, it has been determined that the actions of the proposed project are not likely to adversely affect the shortnose sturgeon.

3.02.7 Seabeach Amaranth

a. Status. Threatened

b. Occurrence in Immediate Project Vicinity. Seabeach amaranth is an annual or sometimes perennial plant that usually grows between the seaward toe of the dune and the limit of the wave uprush zone occupying elevations ranging from 0.2 to 1.5 m above mean high tide (Weakly and Bucher, 1992). Greatest concentrations of seabeach amaranth occur near inlet areas of barrier islands, but in favorable years many plants may occur away from inlet areas. It is considered a pioneer species of accreting shorelines, stable foredune areas, and overwash fans (Weakly and Bucher, 1992; Hancock and Hosier, 2003). Seed dispersal of seabeach amaranth is achieved in a number of ways, including water and wind dispersal (USFWS, 1995).

Historically, seabeach amaranth was found from Massachusetts to South Carolina, but according to recent surveys (USACE 1992-2004), its distribution is now restricted to North and South Carolina with several populations on Long Island, New York. The decline of this species is caused

mainly by development of its habitat, such as inlet areas and barrier islands, and increased ORV and human traffic, which tramples individual plants (Fussell, 1996).

Seabeach amaranth surveys have been performed on the northern 3.8 miles of North Topsail Beach since 1992; however, surveys were not conducted along the southern limits of North Topsail Beach (~8.0 miles) or Surf City (~5.5) miles) until 2006. Based on the available data, a total of 24,369 plants have been recorded throughout the towns of North Topsail Beach and Surf City for all years surveyed (Table 4). Hurricanes, long term shoreline erosion, and subsequent habitat loss, have likely played a role in the reduction in plant numbers on North Topsail Beach from 2001-2008.

Table 4. Annual seabeach amaranth survey results (1992-2008) at North Topsail Beach and Surf City, NC.

County	Beach Name	Sub-Part (Reach)	TOTAL AMARANTHUS PLANT COUNT BY YEAR																Total All Yrs
			1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	
Onslow	North Topsail Beach	A	247	231	925	819	578	1	548	32	117	1,344	433	493	248	381	1	18	68	6,484
Onslow	" "	B	237	72	375	96	142	0	1,300	57	^ ^ ^	590	188	117	12	5	3	5	18	3,217
Onslow	" "	C	939	821	293	10,214	1,068	21	758	29	^ ^ ^	173	2	33	4	0	0	0	3	14,358
Onslow	" "	D	1	0	0	0	0	0	36	5	^ ^ ^	0	0	0	0	0	1	0	0	43
Onslow	" "	A1															0	63	66	129
Onslow	" "	A2															5	8	66	79
Onslow	" "	A3															3	37	11	51
Pender	Surf City	A															0	0	4	4
Pender		B															0	0	4	4
Pender		C															0	0	0	0
NOTES:			1,424	1,124	1,593	11,129	1,788	22	2,642	123	117	2,107	623	643	264	386	13	131	240	24,369

= Not surveyed

^ ^ ^ = Count combined in reach above

= Year of hurricane impact

= Count exceeding 1,000 Amaranthus

= New Reach 2006

744

Since sea beach amaranth seeds are fairly resilient and germination is dependent on critical physical conditions, populations of seabeach amaranth are very dynamic with numbers of plants fluctuating dramatically from year to year. Germination begins in April as temperatures reach about 25ºC (77ºF) and continues at least through July with greatest germination occurring at 35ºC (95ºF) (USFWS, 1996b; Hancock and Hosier, 2003). Seed production begins in July or August, peaks in September, and continues until the plant dies (USFWS, 1996b). According to Hancock and Hosier (2003) sea beach amaranth is physically controlled (salt water inundation, temperature, emergence at depth, etc.) rather than biologically controlled (web worm). Furthermore, seedlings are unable to emerge from depths greater than 1cm; however, seabeach amaranth seeds are resilient, and century–old seeds of some species of amaranth are capable of successful germination and growth (USFWS, 1996b).

c. Current Threats to Continued Occurrence in the Project Area.

Seabeach amaranth has been eliminated from approximately two-thirds of its historic range. Habitat loss and degradation are the greatest threats to the continued existence of seabeach amaranth with localized herbivory by webworms also contributing to mortality in North Carolina. Though beach stabilization efforts are thought to be a leading contributor to the decrease in the population (USFWS, 1996b), new populations have been observed to follow sand placement on beaches where sand has been disposed by the Corps of Engineers (ex. Wrightsville Beach and Bogue Banks) (USFWS, 1996b; CSE, 2004). Seabeach amaranth is dependent on terrestrial, upper beach habitat that is not flooded during the growing season from May in to the fall. Therefore, beach erosion is probably the primary threat to the continued presence in the area. Furthermore, beach bulldozing is common practice on Topsail Beach and in many cases may add to the existing erosion problem and loss of seabeach amaranth habitat.

d. Project Impacts.

(1) Habitat.

The berm and dune project extends along a reach of 52,150 feet. On the north end, the project will adjoin an adjacent non-Federal beachfill project for North Topsail Beach. The proposed project limits avoids the northern portion of North Topsail Beach where historic survey data indicate amaranth most commonly occurs. The beachfront within the project limits is currently conducive to the growth of seabeach amaranth; however, due to high erosion rates and inundation from storm events its available habitat is deteriorating. Beach nourishment would have initial impacts through burial of existing plants and seeds; however, much of the habitat requirements for seabeach amaranth lost to erosion will be restored.

(2) Relationship to Critical Periods in Life Cycle.

Beach nourishment will be conducted outside of the germination and growing period. Initial construction and each nourishment event will be performed using a hopper dredge from 1 December through 31 March. If dredging takes place in the winter when only seabeach amaranth seeds are present, the direct impacts on individual plants will be avoided; however, burying seeds during any season could effect the population. While such construction is not an ideal management practice for the species, the restoration of the habitat is of prime importance. Beach

nourishment rebuilds habitat for seabeach amaranth and can have long-term benefits (USFWS, 1996b). The project area would be included in the USACE seabeach amaranth monitoring program during the summertime growing season for the life of the beachfill.

(3) Effect Determination. Beach nourishment will restore much of the existing habitat lost to erosion and is expected to provide long-term benefits to seabeach amaranth; however, construction and deep burial of seeds on a portion of the beaches during project construction may slow germination and population recovery over the short-term. Therefore, the project may affect, but is not likely to adversely affect seabeach amaranth.

3.02.8 Piping Plover

a. Status. Threatened

b. Occurrence in Immediate Project Vicinity: The Atlantic Coast piping plover population breeds on coastal beaches from Newfoundland to North Carolina (and occasionally in South Carolina) and winters along the Atlantic Coast (from North Carolina south), the Gulf Coast, and in the Caribbean where they spend a majority of their time foraging. Since being listed as threatened in 1986, only 800 pairs were known to exist in the three major populations combined and by 1995 the number of detected breeding pairs increased to 1,350. This population increase can most likely be attributed to increased survey efforts and implementation of recovery plans (Mitchell *et. al.*, 2000).

Piping plovers are known to nest in low numbers in widely scattered localities on North Carolina's beaches. The species typically nests in sand depressions on unvegetated portions of the beach above the high tide line on sand flats at the ends of sand spits and barrier islands, gently sloping foredunes, blowout areas behind primary dunes, sparsely vegetated dunes, and washover areas cut into or between dunes. Piping plovers head to their breeding grounds in late March or early April (http://pipingplover.fws.gov/overview.html) and nesting usually begins in late April; however, nests have been found as late as July (Potter, *et al.*, 1980; Golder, 1985). During a statewide survey conducted in 1988, 40 breeding pairs of piping plovers were located in North Carolina. LeGrand (1984a) states that "all of the pipings in the state nest on natural beachfronts, both completely away from human habitation and [yet] in moderate proximity to man". The largest reported nesting concentration of the species in the State appears to be on Portsmouth Island where 19 nests were discovered in 1983 by John Fussell (LeGrand, 1983). The southernmost nesting record for the state was one nest located in Sunset Beach by Phillip Crutchfield in 1983 (LeGrand, 1984b). Feeding areas include intertidal portions of ocean beaches, washover areas, mud flats, sand flats, wrack lines, and shorelines of coastal ponds, lagoons, or salt marshes (USFWS, 1996a). Prey consist of worms, fly larvae, beetles, crustaceans, mollusks, and other invertebrates (Bent, 1928).

The piping plover is a fairly common winter resident along the beaches of North Carolina (Potter *et al.*, 1980). On 10 July 2001, the USFWS designated 137 areas along the coasts of North Carolina, South Carolina, Georgia, Florida, Alabama, Mississippi, Louisiana, and Texas as critical habitat for the wintering population of the piping plover where they spend up to 10 months of each year on the wintering grounds. Constituent elements for the piping plover wintering habitat are those habitat

components that are essential for the primary biological needs of foraging, sheltering, and roosting, and only those areas containing these primary constituent elements within the designated boundaries are considered critical habitat. The USFWS has defined textual unit descriptions to designate areas within the critical habitat boundary. These units describe the geography of the area using reference points, include the areas from the landward boundaries to the MLLW, and may describe other areas within the unit that are utilized by the piping plover and contain the primary constituent elements. Though no units are designated within the immediate project area, unit NC-11 is designated at the southern end of Topsail Beach on Topsail Island. Unit NC-11 encompasses approximately 1114 acres in Pender and New Hanover counties extending southwest from 1.0 km northeast of MLLW of New Topsail Inlet on Topsail Island to 0.53 km southwest of MLLW of Rich Inlet on Figure Eight Island. This unit includes Topsail Inlet and associated lands including emergent sandbars, from MLLW on Atlantic Ocean and sound side to where densely vegetated habitat, not used by the piping plover, begins and where the constituent elements no longer occur. In Topsail Sound, the unit stops as the entrance to tidal creeks become narrow and channelized (Federal Register/Vol. 66, No 132, July 10, 2001).

Most piping plovers on Topsail Island have been observed as predominantly migratory and winter residents utilizing intertidal flats exposed at low tide for feeding and roosting; however, two breeding pairs have been observed on North Topsail Beach (Table 5). Based on survey data conducted since 1989 (annual nesting habitat surveys, coast-wide wintering surveys, and opportunistic surveys) a total of 11 piping plovers have been identified within the project vicinity.

Table 5. Piping plover observations based on nesting habitat annual surveys conducted since 1989, coast-wide wintering surveys conducted on select years (most recently in 1996, 2001, and 2006), and opportunistic surveys.

Location	Survey Date	Season	Number of Birds	Number of Breeding Pairs
North Topsail Beach - New River Inlet	7/1/1992	Breeding	2	1
North Topsail Beach	7/1/1993	Breeding	2	1
North Topsail Beach - New River Inlet	4/30/2000	Spring Migration	2	NA
North Topsail Beach	10/18/2000	Fall Migration	1	0
North Topsail Beach - New River Inlet	9/8/2001	Fall Migration	1	0
North Topsail Beach	9/2/2004	Fall Migration	2	NA
North Topsail Beach - New River Inlet	8/26/2008	Fall Migration	1	NA

c. Current Threats to Continued Use of the Area. Loss and degradation of habitat due to development and shoreline stabilization have been major contributors to the decline of piping plovers. The current commercial, residential, and recreational development has decreased the amount of coastal habitat available for piping plovers to nest, roost, and feed. Specifically on

North Topsail Beach, nesting habitat continues to be degraded. Washover habitat that was created after Hurricane Fran in 1996 has since been developed with residential homes resulting in a continued decrease in nesting habitat availability. Additionally, nesting habitat along the northern end of North Topsail beach, adjacent to New River Inlet, continues to be eroded away as result of the recent southwesterly shift of New River Inlet and the subsequent erosion towards the residential structures. Furthermore, long and short-term coastal erosion and the abundance of predators, including wild and domestic animals as well as feral cats, have further diminished the potential for successful nesting of this species. Since project beaches are wintering area for the piping plover, the major threat to its occupation of the area during the winter months would be continued degradation of beach foraging habitat. Similar degradation of beaches elsewhere could be a contributing element to declines in the state's nesting population.

d. Project Impacts.

(1) Habitat. The existing shorelines of Surf City and North Topsail Beaches are heavily developed and are experiencing significant shoreline erosion. Piping plover breeding territories on the Atlantic Coast typically include a feeding area along expansive sand or mudflats in close proximity to a sandy beach that is slightly elevated and sparsely vegetated for roosting and nesting (http://nc-es.fws.gov/birds/pipiplov.html). As erosion and development persist, piping plover breeding, nesting, roosting, and foraging habitat loss continues. Habitat loss from development and shoreline erosion and heavy public use has led to the degradation of piping plover habitat in the project area. The enhancement of beach habitat through the addition of beach fill may potentially restore lost roosting and nesting habitat; however, short-term impacts to foraging and roosting habitat may occur during project construction.

Initial construction and each periodic nourishment cycle will be performed using a hopper dredge and will adhere to a 1 December to 31 March dredging window. Since piping plovers head to their breeding grounds in late March and nesting occurs in late April, project initial construction and nourishment events will avoid impacts to breeding and nesting piping plovers to the maximum extent practicable. Additionally, the project construction limits do not extend into the high valued habitat located adjacent to New River Inlet at the North end of North Topsail Beach and will therefore avoid this documented nesting habitat. However, wintering habitat for roosting and foraging may be impacted. Direct short-term foraging habitat losses will occur during construction of the project fill. Since only a small portion of the foraging habitat is directly affected at any point in time during pumpout and adjacent habitat is still available, overall direct loss of foraging habitat will be minimal and short-term. Additionally, complete initial project construction template will be completed in four sections; therefore, un-impacted or recovered foraging habitat will be available throughout the duration of the initial construction period.

The selected plan consists of a sand dune constructed to an elevation of 15 feet above NGVD fronted by a 50-foot wide beach berm constructed to an elevation of 7 feet above NGVD. Piping plover nesting habitat includes blowout areas behind primary dunes as well as washover areas cut into or between dunes. The size and shape of the constructed dune may minimize the frequency of sand washover areas and subsequent nesting habitat availability. However, the project area is heavily developed already and based on the post-storm development response evidenced by Hurricane Fran, the washover fans created by large storm events are quickly re-developed by land

owners. Due to the current development practices within the project area, the formation of these washover features will not be sustained in a similar fashion to undeveloped barrier islands; rather, it is anticipated that, without the proposed project, these washover features would be located on private (private residences) or state (NC Department of Transportation) owned property and would be cleared or built upon in order to re-establish the community to the pre-storm condition. Existing undeveloped habitat located adjacent to New River Inlet will not be impacted by the project.

(2) Food Supply. Piping plovers feed along beaches and intertidal mud and sand flats. Primary prey includes polychaete worms, crustaceans, insects, and bivalves. According to Section 8.01.6 of the EIS, the benthic invertebrate community will suffer short-term impacts from the placement of sediment on the beach; thus, a diminished prey base will subsequently impact piping plovers over the short term. However, only a portion of the beach is affected at any point in time (approximately 4-5,000 feet per month). Once construction passes that point, recruitment from adjacent beaches can begin. Therefore, un-impacted or recovering foraging habitat on Surf City and North Topsail beaches will be available throughout the duration of the project.

(3) Relationship to Critical Periods in Life Cycle. Beach placement of sand derived from identified borrow sites is expected to occur from 1 December to 31 March during initial construction and each periodic nourishment interval. Therefore, the breeding and nesting season will be avoided. However, foraging, sheltering, and roosting habitat may be temporarily impacted.

(4) Effect Determination. The long-term effects of the project may restore lost roosting and nesting habitat through the addition of beach fill; however, short-term impacts to foraging, sheltering, roosting habitat may occur during project construction. Therefore, it has been determined that the project may affect, but is not likely to adversely affect the piping plover.

3.02.9 Smalltooth Sawfish

Detailed life history information associated with the life cycle requirements for smalltooth sawfish and a subsequent analysis of impacts from the proposed dredging activities are provided within the following Section 7 consultation document:

USACE. September 2008. Regional Biological Assessment for Dredging Activities in the Coastal Waters, Navigation Channels (including designated Ocean Dredged Material Disposal Sites (ODMDS)), and Sand Mining Areas in the South Atlantic Ocean. USACE,Wilmington District. Submitted to NMFS on 12 September 2008

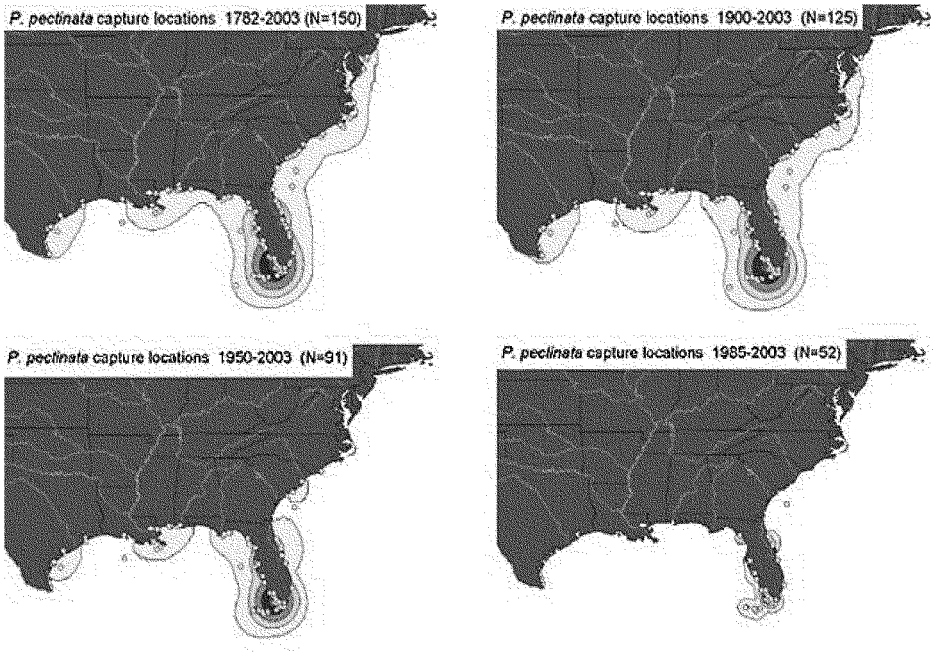
A summary of project specific information and associated impacts is provided in the ensuing text.

a. Status. Endangered. The U.S. smalltooth sawfish distinct population segment (DPS) was listed as endangered under the ESA on April 1, 2003 (68 FR 15674) and is the first marine fish to be listed in the United States.

b. Occurrence in Immediate Project Vicinity. Historic records suggest that during the 19th century the smalltooth sawfish was a common resident of the Atlantic and Gulf coastal waters of the southeastern United States. Throughout the 20th century it was recorded with declining

frequency and today it can be no longer considered a functional member of the nearshore coastal community of the northwest Atlantic. Historic records indicate that the smalltooth sawfish abundantly occurred in the mid-Atlantic region only during the summer months (Adams and Wilson, 1995). The smalltooth sawfish range has subsequently contracted to peninsular Florida and, within that area, can only be found with any regularity off the extreme southern portion of the state between the Caloosahatchee River and the Florida Keys (Figure 2). Smalltooth sawfish are most common within the boundaries of the National Everglades National Park and the Florida Keys, and become less common with increasing distance from this area (Simpfendorfer, 2002).

Figure 2. Historic and Current Distribution of Smalltooth Sawfish in the U.S. (Burgess *et al.,* 2003).



c. Current Threats to Continued Use of the Area. The principal habitats for smalltooth sawfish in the southeast U.S. are the shallow coastal areas and estuaries, with some specimens moving upriver in freshwater (Bigelow and Schroeder, 1953). The continued urbanization of the southeastern coastal states has resulted in substantial loss of coastal habitat through such activities as agricultural and urban development; commercial activities; dredge and fill operations; boating; erosion and diversions of freshwater run-off (SAFMC, 1998). Smalltooth sawfish may be especially vulnerable to coastal habitat degradation due to their affinity to shallow, estuarine systems. Smalltooth sawfish have historically been caught as by-catch in various fishing gears throughout their historic range, including gillnet, otter trawl, trammel net, seine, and to a lesser degree, hand line. Today, they are occasionally incidentally caught in commercial shrimp

trawls, bottom longlines, and by recreational rod-and-reel gear. With the K-selected life history strategy of smalltooth sawfish, including slow growth, late maturation, and low fecundity, long-term commitments to habitat protection are necessary for the eventual recovery of the species. A complete review of the factors contributing to the decline of the smalltooth sawfish can be found in the "Status Review of Smalltooth Sawfish (*Pristis pectinata*)", (NMFS, 2000). The Draft Recovery plan for smalltooth sawfish (NMFS, 2006) also presents a detailed threats assessment with four major categories of threats: 1) Pollution; 2) Habitat degradation or loss; 3) Direct injury and 4) Fisheries Interactions. Neither of these discussions will be repeated in detail in this assessment, but are incorporated herein by reference.

d. Project Impacts. As identified in the August 2006 Draft Smalltooth Sawfish Recovery Plan, "habitat effects of dredging include the loss of submerged habitats by disposal of excavated materials, turbidity and siltation effects, contaminant release, alteration of hydrodynamic regimes, and fragmentation of physical habitats (SAFMC, 1998). Cumulatively, these effects have degraded habitat areas for smalltooth sawfish." The current range of sawfish has contracted to peninsular Florida and can only be found with any regularity off the extreme southern portion of the state. Smalltooth sawfish occur in shallow estuarine environments and juvenile sawfish are particularly dependent on mangrove habitat.

In the GRBO issued by NMFS on November 19, 2003 (as amended in 2005 and 2007), in the section entitled "Species Not Likely to Be Affected," NMFS concludes the following: "Smalltooth sawfish (*Pristis pectinata*) are tropical marine and estuarine fish that have the northwestern terminus of their Atlantic range in the waters of the eastern U.S. Currently, their distribution has contracted to peninsular Florida and, within that area, they can only be found with any regularity off the extreme southern portion of the state. The current distribution is centered in the Everglades National Park, including Florida Bay. They have been historically caught as by-catch in commercial and recreational fisheries throughout their historic range; however, such by-catch is now rare due to population declines and population extirpations. Between 1990 and 1999, only four documented takes of smalltooth sawfish occurred in shrimp trawls in Florida (Simpfendorfer, 2000). After consultation with individuals with many years in the business of providing qualified observers to the hopper dredge industry to monitor incoming dredged material for endangered species remains (C. Slay, Coastwise Consulting, pers. comm. August 18, 2003) and a review of the available scientific literature, NOAA Fisheries determined that there has never been a reported take of a smalltooth sawfish by a hopper dredge, and such take is unlikely to occur because of smalltooth sawfishes affinity for shallow, estuarine systems."

(e) Effect Determination. Based on the current South Atlantic distribution of smalltooth sawfish and only one sighting in North Carolina since 1999, hopper dredge impacts to smalltooth sawfish within the project area are unlikely. Additionally, the take of a smalltooth sawfish by a hopper dredge is unlikely considering the smalltooth sawfishes affinity for shallow, estuarine systems as well as the fact that there has never been a reported take of a smalltooth sawfish by a hopper dredge. Therefore, hopper dredge activities associated with this project are not likely to adversely affect smalltooth sawfish.

4.00 COMMITMENTS TO REDUCE IMPACTS TO LISTED SPECIES

The following is a summary of environmental commitments to protect listed species related to the construction and maintenance of the proposed project. These commitments address agreements with resource agencies, mitigation measures, and construction practices:

1. The Corps will strictly adhere to all conditions outlined in the most current National Marine Fisheries Service RBO for dredging of channels and borrow areas in the southeastern United States. Furthermore, as a component of this project, hopper dredging activities for both initial construction and each nourishment interval will adhere, to the maximum extent practicable, to a dredging window of 1 December to 31 March in order to avoid periods of peak sea turtle abundance. The use of turtle deflecting dragheads, inflow and/or overflow screening, and NMFS certified turtle and whale observers will also be implemented.

2. In order to determine the potential taking of whales, turtles and other species by hopper dredges, NMFS certified observers will be on board during all hopper dredging activities. Recording and reporting procedures will be in accordance with the conditions of the current NMFS RBO.

3. Endangered species observers (ESOs) will be on board all hopper dredges and will record all large whale sightings and note any potential behavioral impacts. The Corps and the Contractor will keep the date, time, and approximate location of all marine mammal sightings. Care will be taken not to closely approach (within 300 feet) any whales, manatees, or other marine mammals during dredging operations or transportation of dredged material. An observer will serve as a lookout to alert the dredge operator and/or vessel pilot of the occurrence of these animals. If any marine mammals are observed during other dredging operations, including vessel movements and transit to the dredged material disposal site, collisions shall be avoided either through reduced vessel speed, course alteration, or both.

4. The Corps will avoid the sea turtle nesting season during initial construction and each nourishment interval. If, due to unforeseen circumstances, construction extends into the nesting season, the Corps will implement a sea turtle nest monitoring and avoidance/relocation plan through coordination with USFWS and NCWRC.

5. Monitoring of sea turtle nesting activities in beach nourishment areas will be required to assess post nourishment nesting activity. This will include daily surveys beginning at sunrise from May 1 until September 15. Information on false crawl location, nest location, and hatching success of all nests will be recorded and provided to NCWRC.

6. The beach will be monitored for escarpment formation by the Contractor prior to completion of beach construction activities associated with initial construction and each nourishment interval. Additionally, the beach will be monitored by the local sponsor for escarpment formation prior to each turtle nesting season every year between nourishment events. Escarpments which exceed 18 inches in height for a distance of 100 ft. will be leveled by the Contractor or local sponsor accordingly. If it is determined that escarpment leveling is required during the nesting or hatching season, leveling actions should be directed by the USFWS

7. Only beach compatible sediment will be placed on the beach as a component of this project. Post nourishment beach compaction (hardness) will be evaluated by the Corps, in coordination with the NCWRC and USFWS, using qualitative assessment techniques to assure that impacts to nesting and incubating sea turtles are minimized and, if necessary, identify appropriate mitigation responses.

8. Local lighting ordinances will be encouraged to the maximum extent practicable in order to reduce lighting impacts to nesting females and hatchlings. The local sponsors will be encouraged to work with the USFWS, local monitoring groups, and other concerned organizations to develop the best plan for the Towns of Surf City and North Topsail Beach.

9. Throughout the duration of each nourishment event, both initial construction and periodic nourishment, the Contractor will be required to monitor for the presence of stranded sea turtles, live or dead. If a stranded sea turtle is identified, the Contractor will immediately notify the NCWRC of the stranding and implement the appropriate measures, as directed by the NCWRC. Construction activities will be modified appropriately as not to interfere with stranded animals, live or dead.

10. In order to better understand the threshold of sediment color change and resultant heat conduction from nourishment on temperature dependent sex determination of sea turtles, the Corps will monitor nest temperatures in the project area during the nesting season following initial construction. This data will be compared to non-nourished native sediment temperatures in order to support development of management criteria for sediment color guidelines.

11. In order to assess the abundance of sea turtles, and potential risk of hopper dredge take, within the proposed borrow areas for this project, the Corps will participate in the NCWRC's current satellite telemetry efforts to track the distribution and habitat usage of sea turtles in NC offshore waters.

12. Monitoring for seabeach amaranth on Surf City and North Topsail Beaches will be implemented in the growing season following initial construction to assess the post nourishment presence of plants. This survey will broken down into survey reaches for each town in accordance with the designated USACE sea beach amaranth survey reaches from 1991-2008 in order to maintain consistent data and survey techniques over time and results will be provided to USFWS

13. The Corps will implement precautionary measures for avoiding impacts to manatees during construction activities as detailed in the "Guidelines for Avoiding Impacts to the West Indian Manatee in North Carolina Waters" established by the USFWS.

14. The Corps will adhere to appropriate environmental windows for piping plovers and other shorebirds to the maximum extent practicable.

15. All staging areas, pipeline routes, and associated construction activities will avoid high value piping plover and shorebird habitat, located within the vicinity of New River Inlet, to the maximum extent practicable.

5.00 SUMMARY EFFECT DETERMINATION

Threatened and endangered species summary effect determination for beach placement and dredging activities associated with the proposed project area (No Effect (NE – green); May Affect Not Likely to Adversely Affect (MANLAA – orange); and May Affect Likely to Adversely Affect (MALAA – red).

Listed Species w/in the Project Area		Effect Determination	
		Beach Placement Activities (USFWS)	In-Water Dredging Activities (NMFS)
Sea Turtles	*Leatherback*	MANLAA	MANLAA
	Loggerhead	MANLAA	MALAA
	Green	MANLAA	MALAA
	Kemp's Ridley	NE	MALAA
	Hawksbill	NE	MALAA
Large Whales	*Blue, Finback, Sei, and Sperm*	NE	NE
	NARW	NE	MANLAA
	Humpback	NE	MANLAA
West Indian Manatee		NE	MANLAA
American Alligator		NE	NE
Piping Plover		MANLAA	NE
Red-cockaded Woodpecker		NE	NE
Shortnose Sturgeon		NE	NE
Smalltooth Sawfish		NE	NE
Seabeach Amaranth		MANLAA	NE
Golden Sedge		NE	NE
Chaffseed		NE	NE
Cooley's Meadowrue		NE	NE
Rough-leaved Loosestrife		NE	NE

6.00 LITERATURE CITED

Ackerman, R.A., 1980. Physiological and ecological aspects of gas exchange by sea turtle eggs. *American Zoology*, 20, 575-583.

Ackerman, R.A.; Rimkus, R., and Horton, R., 1992. Hydric structure and climate of natural and renourished sea turtle nesting beaches along the coast of Florida. Florida Department of Natural Resources, Tallahassee, Florida.

Ackerman, R.A. 1996. The nest environment and the embryonic development of sea turtles. Pp. 83-106 in The Biology of Sea Turtles (Lutz, P.L. and J.A. Musick, eds.) Boca Raton, FL, CRC Press.

Adams, W. F. and C.W. Wilson. 1995. The Status of the Smalltooth Sawfish, *Pristis pectinata* Latham 1974 (*Pristiformes: Pristidae*) in the United States. Chondros; 6 (4).

Allman, P., Seitz, J., and Kraus, M. (2001). An analysis of sand characteristics in Collier County, Florida. *In* Proceedings of the 21st Annual Symposium on Sea Turtle Biology and Conservation, 24-28 February 2001. 86-88 pp.

Bagley, D., T. Cascio, R. Owens, S. Johnson, and L. Ehrhart. 1994. Marine turtle nesting at Patrick Air Force Base, Florida; 1987-1993; trends and issues. Pages 180-181 *in* K.

Bent, Arthur C. 1928. Life histories of North American shorebirds. Vol. 2 . Dover Publications, Inc., N.Y. 412 pp .

Bigelow, H.B. and W.C. Schroeder. 1953. Sawfishes, guitarfishes, skates and rays, pp. 1 -514. In: Tee-Van, J., C.M. Breder, A.E. Parr, W.C. Schroeder and L.P. Schultz (eds). Fishes of the Western North Atlantic, Part Two. Mem. Sears Found. Mar. Res. I.

Bjorndal, K.A. 1985. Nutritional ecology of sea turtles. *Copeia* 736.

Broadwell, A.L., 1991. Effects of beach nourishment on the survival of loggerhead sea turtles. Boca Raton, Florida: Florida Atlantic University, Master's thesis, 42p.

Brock, K. 2005. Effects of a shore protection project on loggerheads and green turtle nesting activity and reproduction in Brevard County, Florida. M.S. Thesis, University of Central Florida, Orlando, Florida. 66 p.

Bull, J. J. and Vogt, R.C., 1979. Temperature dependent sex determination in turtles. *Science*, 206, 1186-1188.

Bull, J. J. and Vogt, R.C., 1981. Temperature-sensitive periods of sex determination in emybid turtles. *Journal of Experimental Zoology*, 218, 435-440.

Bull, J. J. 1987. Temperature-sensitive periods of sex determination in a lizard: comparisons with turtles and crocodiles. *Journal of Experimental Zoology*, 241, 143-148.

Burgess, G.H., and T.H. Curtis. Temporal Reductions in the Distribution and Abundance of the U.S. Atlantic Sawfishes (*Pristis spp.*). Oral presentation at AES 2003. Manaus, Brazil.

Cameron, Sue. North Carolina Wildlife Resources Commission. 2004. Personal Communication.

Carr, A. and Ogren, L., 1960. The ecology and migrations of sea turtles. 4. *Bulletin of American Museum of Natural History*, 121, 1-48.

Carr, A. 1986. Rips, FADS, and little loggerheads. *BioScience* 36:92.

Carr, A. 1987. New Perspectives on the pelagic stage of sea turtle development. *Conservation Biology* 1:103.

Caswell, H., S. Brault, and M. Fujiwara. 1999. Declining survival probability threatens the North Atlantic right whale. *Proc. Natl. Acad. Sci.* USA 96: 3308-3313.

Clark, M. K. 1987. West Indian Manatee. Pages 18-21 in: Endangered, threatened and rare fauna of North Carolina Part I. A re-evaluation of the mammals (M. K. Clark, editor). Occasional Papers of the North Carolina Biological Survey 1987-3.

Clark, M.K. 1993. Curator of Mammals, North Carolina State Museum of Natural Sciences. Personal communication regarding seasonal distribution of manatees in the Cape Fear region; p.6, In: Biological Assessment: Channel Realignment Masonboro Inlet, New Hanover County, NC. August 1995. USACOE.

Crain, D.A., A.B. Bolten, and K.A. Bjorndal. 1995. Effects of beach nourishment on sea turtles: Review and research initiatives. *Restoration Ecology* 3(2): 95-104.

Crouse, Deborah T., L. B. Crowder, and H. Caswell. 1987. A staged-based population model for loggerhead sea turtles and implications for conservation. Ecology 68(5):1412-1423.

CSE. 2004. Bogue Banks beach restoration Project – Seabeach Amaranth Survey (Federal Permit 200000362). Prepared for US Army Corps of Engineers and NC Division of Coastal Management; submitted by Carteret County, Town of Pine Knoll Shores, Town of Indian Beach, Town of Emerald Isle, NC; prepared by Coastal Science & Engineering, Columbia, SC.

Dadswell, M.J., B .D. Taubeert, T.S. Squiers, D. Marchette, and J. Buckley. 1984. Synopsis of biological data on shortnose sturgeon, Acipenser brevirostrum LeSeur 1818. FEIS 10 –1 National Oceanic and Atmospheric Administration Technical Report NMFS 14, Washington, DC.

Davis, Jr., D.A., FitzGerald, M.V. and Terry, J. 1999. Turtle nesting on adjacent beaches with different construction styles: Pinellas County, Florida. *Journal of Coastal Research*, Vol 15:1, 111-120 pp.

Dean, R.G. 1988. Review of dredging effects on adjacent park system. UFL/COEL-88/015, Coastal and Oceanographic Engineering Department, University of Florida, Gainesville, Florida.

Deeming, D.C. and Ferguson, M.W.J., 1989. The mechanism of temperature dependent sex determination in crocodilians: A hypothesis. *American Zoology*, 29: 973-985.

Ecological Associates, Inc., 1998. Beach Nourishment Project: results of the 1998 sea turtle monitoring, Jupiter Island, Florida. Vero Beach, Florida: Ecological Associates, Inc., *Report to Coastal Technology Corp*, 26p.

Ecological Associates, INC., 1999. Martin County Beach Nourishment Project, Sea Turtle Monitoring and Studies, 1997 Annual Report and Final Assessment. Jensen Beach, Florida: Ecological Associates, Inc., 115p.

Ehrenfeld, D.W. 1968. The role of vision in the sea-finding orientation of the green turtle (*Chelonia mydas*). II. Orientation mechanism and range of spectral sensitivity. *Animal Behaviour.* 16:281-287.

Ehrhart, L.M., 1995. The relationship between marine turtle nesting and reproductive success and the beach nourishment project at Sebastian Inlet, Florida, in 1994. Melbourne, Florida: University of Central Florida, *Technical Report to the Florida Institute of Technology*, 55p

Ehrhart, L.M. and Holloway-Adkins, K.G., 2000. Marine Turtle Nesting and Reproductive Success at Patrick Air Force Base; Summer, 2000. Orlando, Florida: University of Central Florida, *Final Report to US Air Force Eastern Space and Missile Center; Patrick Air Force Base, Florida*, 45p.

Ehrhart, L.M. and Roberts, K.A., 2001. Marine Turtle Nesting and Reproductive Success at Patrick Air Force Base; Summer, 2001. Orlando, Florida: University of Central Florida, *Final Report to US Air Force Eastern Space and Missile Center; Patrick Air Force Base, Florida*, 58p.

Epperly, S.P., J. Braun, and A.J. Chester. 1994. Aerial surveys for sea turtles in North Carolina inshore waters. *Fishery Bulletin* 93:254-261.

Epperly, S.P., J. Braun, & A. Veishlow. 1995. Sea turtles in North Carolina waters. *Conservation Biology* 9(2): 384-394.

Ernest, R.G., Martin, R.E., Howard, B., and Black, A.M. 1995. The effect of beach nourishment on sea turtle nesting: A case study on Hutchinson Island, Florida. *In* Proceedings of the Coastal Ecosystems and Federal Activities Technical Training Symposium, August 20-22, 2001. 93-108 pp.

Ernest, R.G. and R.E. Martin. 1999. Martin County beach nourishment project: sea turtle monitoring and studies. 1997 annual report and final assessment. Unpublished report prepared for the Florida Department of Environmental Protection.

Federal Register/Vol. 66. No. 132, July 10, 2001.

Federal Register/Vol. 69., No. 105

Ferguson, M.W.J. and Joanen, T., 1983. Temperature-dependent sex determination in the *Alligator mississippiensis*. *Journal of Zoology*, 200, 143-177.

Ferrell, C., Webster, D., and D. Piatkowski. 2002. Comparison of five soil compaction measurement devices. *Proceedings Twenty-Second International Sea Turtle Symposium.* Miami, Fl., USA.

Fletemeyer, J.R. 1983. The impact of beach renourishment on sea turtle nesting. Pages168-177 *in* L.S. Tait, compiler. 1983 Joint Annual Meeting of the American Shore and Beach Preservation Association and Florida Shore and Beach Preservation Association: the new threat to beach preservation. Boca Raton, Florida.

Fletemeyer, J., 1984. The impact of beach renourishment on sea turtle nesting. *In*: TAIT, L.S. (compiler), *Proceedings of the 1983 Joint Annual Meeting of the American Shore and Beach Preservation Association and Florida Shore and Beach Preservation Association,* Tallahassee, Florida, pp. 168-177.

Foote, J.J. and Truitt, C. 1997. Evaluation of beach compactness following maintenance renourishment. Town of Longboat Key Project #105-525. Mote Marine laboratory Technical Report No. 520. 8 pp.

Fussell, J. 1996. Comments about Piping Plover, Beach Amaranth, and Other Declining Species on South Spit of Figure Eight Island. December, 1996.

Garrott, R.A., B.B. Ackerman, J.R. Cary, D.M. Heisey, J.E. Reynolds, III, and J.R. Wilcox. 1995. Assessment of trends in sizes of manatee populations at several Florida aggregation sites. Pages 34-35 *in* T.J. O'Shea, B.B. Ackerman, and H.F. Percival (eds.). Population Biology of the Florida Manatee. National Biological Service, Information and Technology Report No. 1. Washington, D.C.

Godfrey, Matthew H., Sea Turtle Program Coordinator, North Carolina Wildlife Resources Commission, 307 Live Oak Street, Beaufort, North Carolina 28516 USA. Personal Communication. 2006.

Golder, W. Walker. 1985. Piping plovers (Charadrius melodus) nesting at the Cape Hatteras National Seashore . Unpublished manuscript.

Hancock, TE and PE Hosier. 2003. Ecology of the Threatened Species *Amaranthus pumilus* Rafinesque. Castanea 68(3): 236-244.

Hendrickson, J.R. 1982. Nesting behaviour of sea turtles with emphasis on physical and behavioural determinants of nesting success or failure. *In*: K.A. Bjorndal (ed.), *Biology and Conservation of Sea Turtles*. Washington, D.C.: Smithsonian Institution Press, pp. 53-57.

Herren, R.M. 1999. The effect of beach nourishment on loggerhead (*Caretta caretta*) nesting and reproductive success a Sebastian Inlet, Florida. MS Thesis. University of Central Florida, Orlando, Florida. 138 pages.

Hughes, G.R. 1974. The sea turtles of southeast Africa. 1. Status, morphology, and distribution. *Oceanographic Research Institution Investigative Republic of Durban*, 35, 1-144.

Jean Beasley. 2004. Karen Beasley sea turtle rescue and rehabilitation center. Topsail Island,North Carolina. Personal Communication.

Jensen, A., and G. Silber. 2003. Large Whale Ship Strike Database. U.S. Dep. Commerce, NOAA Technical Memorandum NFMS-F/OPR-25, 37 p.

Johannes, R.E. and Rimmer, D.W., 1984. Some distinguishing characteristics of nesting beaches of the green turtle *Chelonia mydas* on North West Cape Peninsula, Western Australia. *Marine Biology*, 83, 149-154.

Lefebvre, L.W., M. Marmontel, J.P. Reid, G.B. Rathbun, and D.P. Domning. 2001. Status and biogeography of the West Indian manatee. Pp. 425-474 *in* C.A. Woods and F.E. Sergile, eds. Biogeography of the West Indies: Patterns and Perspectives. CRC Press, Boca Raton, FL. 582pp.

LeGrand, Harry E . 1983 . Southern Atlantic Coast Region . American Birds 37 :978-980.

Lee, D. S. and W. M. Palmer. 1981. Records of leatherback turtles, *Dermochelys coriacea* (Linnaeus), and other marine turtles in North Carolina waters. Brimleyana 5:95-106.

Limpus, C.J., V.Baker, and J.D. Miller. 1979. Movement induced mortality of loggerhead eggs. *Herpetologica*. 35(4):335-338.

Mann, T.M. 1977. Impact of developed coastline on nesting and hatchling sea turtles in southeastern Florida. M.S. thesis. Florida Atlantic University, Boca Raton, Florida. 100 pp.

Mattison, C., C. Burney, and L. Fisher. 1993. Trends in the spatial distribution of sea turtle activity on an urban beach (1981-1992). Pp. 102-104 *in* B. Schroeder and B. Witherington, eds. Proceedings of the Thirteenth Annual Symposium on Sea Turtle Biology and Conservation. NOAA Technical Memorandum NMFS-SEFC-341.

McGehee, M.A. 1990. Effects of moisture on eggs and hatchlings of loggerhead sea turtles (*Caretta caretta*). *Herpetologica*. 46(3):251-258.

Milton, S.L.; Shulman, A.A., and Lutz, P.L., 1997. The effect of beach renourishment with aragonite versus silicate sand on beach temperature and loggerhead sea turtle nesting success. *Journal of Coastal Research*, 13, 904-915.

Mitchell, W. A., Guilfoyle, M. P., and Wolters, M. S. (2000). "Riparian shorebirds potentially impacted by USACE reservoir operations," EMRRP Technical Notes Collection (ERDC TN-EMRRP-SI-17), U.S. Army Engineer Research and Development Center, Vicksburg, MS. WWW.Wes.Army.mil/el/emrrp.

Morreale, S.J.; Ruiz, G.J.; Spotila, J.R., and Standora, E.A., 1982. Temperature dependent sex determination: Current practices threaten conservation of sea turtles. *Science*, 216, 1245-1247.

Mortimer, J.A. 1982. Feeding ecology of sea turtles, in *Biology and Conservation of Sea Turtles*,

Mortimer, J.A., 1990. The influence of beach sand characteristics on the nesting behavior and clutch survival of green turtles (*Chelonia mydas*). *Copeia*, 1990, 802-817.

Mortimer, J.A. 1995. Feeding Ecology of Sea Turtles, p. 103-109. *In*: K.A. Bjorndal (Editor). Biology and Conservation of Sea turtles, Smithsonian Institution Press, Washington, D.C.

Moulding, J.D. and D.A. Nelson. 1988. Beach nourishment issues related to sea turtle nesting. *In* W.L. Lyke and T.J. Hoban (editors). Symposium on Coastal Water Resources, American Water Resources Association, May 1988, p.87-93

Mrosovsky, N. and S.J. Shettleworth. 1974. Further studies on the sea-finding mechanism in green turtle hatchlings. *Behaviour*. 51:195-208.

Mrosovsky, N., A.M. Granda, and T. Hay. 1979. Seaward orientation of hatchling turtles: turning systems in the optic tectum. *Brain Behavior and Evolution*. 16:203-221.

Mrosovsky, N. and Yntema, C.L., 1980. Temperature dependence of sexual differentiation in sea turtles: Implications for conservation practices. *Biological Conservation*, 18, 271-280.

Mrosovsky, N. and S.F. Kingsmill. 1985. How turtles find the sea. *Zeitschrift fur Tierpsychologie*. 67:237-256.

Mrosovsky, N. and Provancha, J. 1989. Sex ratio of hatchling loggerhead sea turtles hatching on a Florida beach. *Canadian Journal of Zoology*, 67, 2533-2539.

National Marine Fisheries Service. 1991. Final Recovery Plan for the Northern Right Whale (Eubalaena glacialis). Office of Protected Resources National Marine Fisheries Service National Oceanic and Atmospheric Administration Silver Spring, MD.

National Marine Fisheries Service. 1997. Regional Biological Opinion for the Continued Hopper Dredging of Channels and Borrow Areas in the Southeastern United States. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, Silver Spring, Maryland.

National Marine Fisheries Service. 1998. Final Recovery Plan for the Shortnose Sturgeon *Acipenser brevirostrum*. U.S. Department of Commerce, National Oceanic and Atmospheric Administration.

National Marine Fisheries Service. 2000. Smalltooth Sawfish Status Review. NMFS, SERO. December. 73pp.

National Marine Fisheries Service. 2003. Humpback Whale Stock Assessment. html.

National Marine Fisheries Service. 2003 (as amended in 2005 and 2007). Biological Opinion to the U.S. Army Corps of Engineers on Dredging of Gulf of Mexico Navigation Channels and Sand Mining ("Borrow") Areas Using Hopper Dredges by USACE Galveston, New Orleans, Mobile, and Jacksonville Districts (Consultation Number F/SER/2000/01287). NOAA National Marine Fisheries Service, Southeast Regional Office. November 19, 2003.

National Marine Fisheries Service. 2006. Recovery Plan for Smalltooth Sawfish (*Pristis pectinata*). Prepared by the Smalltooth Sawfish Recovery Team for the National Marine Fisheries Service, Silver Spring, Maryland

National Research Council. 1995. Beach Nourishment and Protection. National Academy Press, Washington, D.C. 334 pages.

Nelson, D.A. 1985. Beach nourishment sand compatibility with loggerhead sea turtle nesting. Page 60 *in* J. Richardson, compiler. Proceedings of the Fifth Annual Workshop on Sea Turtle Biology and Conservation, Waverly, Georgia.

Nelson, D.A., and D.D. Dickerson. 1987. Correlation of loggerhead turtle nest digging times with beach sand consistency. Paper presented at the Seventh Annual Workshop on Sea Turtle Biology and Conservation. Wekiwa Springs State Park, Florida, February 25-27, 1987.

Nelson, D.A. and D.D. Dickerson. 1988a. Hardness of nourished and natural sea turtle nesting beaches on the east coast of Florida. U.S. Army Corps of Engineers Waterways Experiment Station, Vicksburg, Mississippi.

Nelson, D.A. and D.D. Dickerson. 1988b. Response of nesting sea turtles to tilling of compacted beaches, Jupiter Island, Florida. Unpubl. Report. U.S. Army Corps of Engineers Waterways Experiment Station, Vicksburg, MS. 26pp.

Nelson, D.A. and D.D Dickerson. 1989. Comparison of loggerhead sea turtles nesting times on nourished and natural beaches. U.S. Army Corps of Engineers Waterways Experimental Station, Vicksburg, Mississippi.

Parmenter, C.J. 1980. Incubation of the eggs of the green sea turtle, *Chelonia mydas*, in Torres Strait, Australia: the effect of movement on hatchability. *Aust. Wildl. Res.* 7:487-491.

Piatkowski, D. 2002. Effects of beach nourishment on the nesting environment of loggerhead sea turtles (*Caretta caretta*). M.S. Thesis, University of North Carolina at Wilmington, 33 p.

Pieau, C., 1971. Sur la proportion sexuelle chez les embryons de deux cheloniens (*Testudo graeca L. et Emys orbicularis L.*) issus DD'oeufs incubes artificiellement. *C. R. Hebd. Seanc. Acad. Sci.*, Paris, 272: 3071-4.

Pieau, C. and Dorizzi, M., 1981. Determination of temperature sensitive stages for sexual differentiation of gonads in the embryos of turtles, *Emys orbicularis*. *Journal of Experimental Zoology*, 170, 373-382.

Potter, Eloise F., J . F. Parnell, and R. P. Teulings. 1980. Birds of the Carolinas. University of North Carolina Press, Chapel Hill. 408pp.

Rabon, D.R. Jr., S.A. Johnson, R. Boettcher, M. Dodd, M. Lyons, S. Murphy, S. Ramsey, S. Roff, and K. Stewart. 2003. *Marine Turtle Newsletter No.* 101, 2003, page. 4.

Rathbun, G.B., R.K. Bonde, and D. Clay. 1982. The status of the West Indian manatee on the Atlantic coast north of Florida. Pages 152-165. *in* R.R. Odum and J.W. Guthrie (eds.). Proceedings of the Symposium for Nongame and Endangered Wildlife. Technical Bulletin WL 5. Georgia Department of Natural Resources. Social Circle, Georgia.

Raymond, P.W. 1984. Effects of beach restoration on marine turtles nesting in south Brevard County, Florida. M.S. Thesis. University of Central Florida, Orlando, Florida.

Rohde, Fritz. 2004. North Carolina Division of Marine Fisheries. Personal Communication.

Rumbold, D.G., Davis, P.W. and Perretta, C. 2001. Estimating the effect of beach nourishment on *Caretta caretta* (loggerhead sea turtle) nesting. *Restoration Ecology* 9(3): 304-310.

Ryder, C.E., 1993. The effect of beach renourishment on sea turtle nesting and hatching success at Sebastian Inlet State Recreation Area. Blacksburg, Virginia: Virginia Polytechnic Institute and State University, Master's thesis,109p.

Ryder, C.E. 1995. The effects of beach renourishment on sea turtle nesting and hatchling success at Sebastian Inlet State Recreation Area, East-Central, Florida. *In* Proceeding of the Twelfth Annual Workshop of Sea Turtle Biology and Conservation, 25-29 February 1992. NOAA Technical Memorandum NMFS-SEFSC-361. 230-234 pp.

SAFMC. 1998. Final Habitat Plan for the South Atlantic Region; Essential Fish Habitat Requirements for the Fishery Management Plans of the South Atlantic Fishery Management Council. Prepared by the South Atlantic Fishery Managmenet Council, October 1998. Available from: SAFMC, 1 Southpark Circle, Suite 306, Charleston, SC 29407

Salmon, M., R. Reiners, C. Lavin, and J. Wyneken. 1995. Behavior of loggerhead sea turtles on an urban beach. I. Correlates of nest placement. *Journal of Herpetology*. 29:560-567.

Schmidly, DJ. 1981. Marine mammals of the southeastern United States coast and the Gulf of Mexico. USFWS-Office of Biological Services Report No. 80/41, 165 pp.

Schroeder, B.A. 1994. Florida index nesting beach surveys: Are we on the right track? Pages 132-133 *in* Bjorndal, K.A., A.B. Bolten, D.A. Johnson, and P.J. Eliazar (compilers). Proceedings of the 14th Annual Symposium on Sea Turtle Biology and Conservation. NOAA Technical Memorandum NMFS-SEFSC-351.

Schwartz, F.J. 1977. Modern sea turtles, in Endangered and Threatened Plants and Animals of North Carolina. Editors J.E. Cooper et. al. North Carolina State Museum of Natural History, Raleigh, North Carolina. pp 303-308.

Schwartz, F.J. 1995. Florida Manatees, *Trichechus manatus* (Sirenia: Trichechidae), in North Carolina 1919-1994. Brimleyana No. 22:53-60. June 1995.

Schwartz, F.J. 1996. Personal Communication. January 19,1996.

Scianna, M.A., Shirley, A. and Sisson, P. 2001. Preliminary results of the effects of beach renourishment preferences in loggerhead sea turtles (*Caretta caretta*) on South Carolina's beaches. In Proceedings of the 22nd Annual Symposium on Sea Turtle Biology and Conservation. 160-161 pp.

Simpfendorfer, C.A. 2002. Smalltooth sawfish: The USA's first endangered elasmobranch? Endangered Species Update 19: 53-57.

Simpfendorfer, C.A. 2000. Predicting population recovery rates for endangered western Atlantic sawfishes using demographic analyses. Environmental Biology of Fishes 58:371-377.

Slay, C. 1993. Right Whale Research Project, New England Aquarium. Personal communication regarding seasonal occurrence of right whales of the Cape Fear region; p.5, In: Biological Assessment: Channel Realignment Masonboro Inlet, New Hanover County, NC. August 1995. USACOE.

Slay, C. Coastwise Consulting, pers. comm. August 18, 2003

Spanger, M.G. and Handy, R.L. 1982. Soil Engineerig, 4th ed., Harper & Row, New York.

Spotilla, J.R., E.A. Standora, S.J. Morreale, G.J. Ruiz, and C. Puccia. 1983. Methodology for the

study of temperature related phenomena affecting sea turtle eggs. U.S. Fish and Wildlife Service Endangered Species Report 11. 51 pp.

Steinitz, M. J., Salmon, M. and Wyneken, J. 1998. Beach renourishment and loggerhead turtle reproduction: a seven year study at Jupiter Island, Florida. *Journal of Coastal Research* 14(3):1000-1013.

Trindell, R., D. Arnold, K. Moody, and B. Morford. 1998. Post-construction marine turtle nesting monitoring results on nourished beaches. Pages 77-92 *in* Tait, L.S. (compiler). Proceedings of the 1998 Annual National Conference on Beach Preservation Technology. Florida Shore & Beach Preservation Association, Tallahassee, Florida.

USACE, 1976. FONSI – Maintenance of Atlantic Intracoastal Waterway Side Channels, North Carolina. U.S. Army Engineer District, Wilmington, North Carolina. July 1976.

USACE. 1992-2004. Wilmington District seabeach amaranth surveys. Unpublished data.

USACE. 1997. FONSI – Advanced Maintenance Dredging AIWW Side Channels Topsail Creek, Banks Channel, and Cedar Bush Cut. Pender and Onslow Counties, North Carolina. January 1997.

USACE. 2003. Safety and Health Requirements Manual. EM 385-1-1.

USACE. 2008. Regional Biological Assessment for Dredging Activities in the Coastal Waters, Navigation Channels (including designated Ocean Dredged Material Disposal Sites (ODMDS)), and Sand Mining Areas in the South Atlantic Ocean. USACE, Wilmington District. Submitted to NMFS on 12 September 2008.

USFWS. 1991. *Endangered and Threatened Species of the Southeast United States.* U.S. Fish and Wildlife Service.

USFWS. 1995. Seabeach amaranth technical/agency draft recovery plan, September 1995. U.S. Fish and Wildlife Service, Atlanta, GA, 75 pp.

USFWS. 1996a. Revised Recovery Plan for Piping Plover (*Charadrius melodus*), Atlantic Coast Population, Region Five, Haley, Massachusetts.

USFWS. 1996b. Recovery Plan for Seabeach Amaranth (*Amaranthus pumilus*), Southeast Region, Atlanta, Georgia.

USFWS. 1999a. West Indian manatees in North Carolina. http://web.ral.r4.fws.gov/mammal/manatee.html.

USFWS. 1999b. Shortnose sturgeon in North Carolina. http://web.ral.r4.fws.gov/fish/shortst.html.

USFWS. 2001. Florida Manatee Recovery Plan, (*Trichechus manatus latirostris*), Third Revision. U.S. Fish and Wildlife Service. Atlanta, Georgia. 144 pp. + appendices.

Verheijen, F.J. and J.T. Wildschut. 1973. The photic orientation of sea turtles during water finding behaviour. *Netherlands Journal of Sea Research*. 7:53-67.

Waring G.T., D.L. Palka, P.J. Clapham, S. Swartz, M.C. Rossman, T.V.N. Cole, L.J. Hansen, K.D. Bisack, K.D. Mullin, R.S. Wells, D.K. Odell, and N.B. Barros. 1999. U.S. Atlantic and Gulf of Mexico Marine Mammal Stock Assessments (1999). *NOAA Technical Memorandum NMFS-NE-153*. U.S. Dept. of Commerce, Woods Hole, Massachusetts.

Weakley , AS, and MA Bucher. 1992. Status survey of seabeach amaranth (*Amaranthus pumilus* Rafinesque) in North and South Carolina. Report to the North Carolina Plant Conservation Program, and Endangered Species Field Office. 178p.

Webb, G.J.W., Beal, A.M., Manolis, S.C., and Dempsey, K.E., 1987. The effects of incubation temperature on sex determination and embryonic development rate in *Crocodylus johnstoni* and *C. porosus*. *In:* G.J.W. Webb, S.C. Manolis, and P.J. Whitehead (eds.), *Wildlife management: Crocodiles and alligators*. Winnellie, Australia: Surrey Beatty and Sons, pp. 507-531

Webster, W.D. and Gouviea, J.F., 1988. Predicting hatchling sex ratios in loggerhead sea turtles (*Caretta caretta*) by incubation duration. *Proceedings Eighth Annual Workshop Sea Turtle Conservation and Biology*. NOAA Technical Memorandum NMFS-SEFC-214. 127-128.

Wibbels, T., Martin, R.E., Owens, D.W., and Amoss, M.S., 1991. Female-biased sex ratio of immature loggerhead sea turtles inhabiting the Atlantic coastal waters of Florida. *Canadian Journal. of Zoology*, 69, 2973-2977.

Wiley, D.N., R.A. Asmutis, T.D. Pitchford, and D.P. Gannon. 1995 Stranding and mortality of humpback whales, *Megaptera novaengliae*, in the mid_Atlantic and southeast United States, 1985-1992. *Fish. Bull.*, U.S. 93: 196-205.

Witherington, B.E. 1992. Behavioral responses of nesting sea turtles to artificial lighting. h*erpetologica*. 48, 31.

Witherington, B.E. and R. E. Martin. 2003. Understanding, Assessing, and Resolving Light-Pollution Problems on Sea Turtle Nesting Beachs. 3rd ed. rev. Florida Marine Research Institute Technical Report. Technical Report TR-2.

Wynne, B. 1999. Scoping information to be used in preparing an environmental document for the dredging of Mason Inlet, New Hanover County. North Carolina Wildlife Resources Commission, Raleigh.

Yntema, C.L., 1976. Effects of incubation temperatures on sexual differentiation in the turtle, *Chelydra serpentina*. *Journal of Morphology*, 150, 453-461.

Yntema, C.L., 1979. Temperature levels and periods of sex determination during incubation of eggs of *Chelydra serpentina*. *Journal of Morphology*, 159, 17-27.Yntema, C.L. and Mrosovsky, N., 1979. Incubation temperature and sex ratio in hatchling loggerhead turtles, a preliminary report. *Marine Turtle Newsletter*, 11, 9-10.

Yntema, C.L. and Mrosovsky, N., 1982. Critical periods and pivotal temperatures for sexual differentiation in loggerhead sea turtles. *Canadian Journal of Zoology*, 60, 1012-1016.

Http://nc-es.fws.gov/birds/pipiplov.html.

http://pipingplover.fws.gov/overview.html

http://www.fws.gov/raleigh/es_tes.html)

(http://sero.nmfs.noaa.gov/pr/pdf/North%20Carolina.pdf)

(http://www.nmfs.noaa.gov)

North Carolina Sediment Criteria Rule Language (15ANCAC 07H .0312)
(http://dcm2.enr.state.nc.us/Rules/rules.htm)

Feasibility Report
and
Environmental Impact Statement

on

Coastal Storm Damage Reduction

SURF CITY AND NORTH TOPSAIL BEACH
NORTH CAROLINA

Appendix J

Cumulative Impact Assessment

APPENDIX J
Cumulative Impact Assessment
Surf City and North Topsail Beach, NC
Coastal Storm Damage Reduction Project

The Council on Environmental Quality (CEQ) defines cumulative impact as:

The impact on the environment which results from the incremental impact of the action when added to other past, present, and reasonably foreseeable actions regardless of what agency (Federal or non-Federal) or person undertakes such other actions. Cumulative impacts can result from individually minor but collectively significant actions taking place over a period of time (40 CFR 1508.7). This analysis follows the 11-step process outlined by the CEQ in their 1997 publication Considering Cumulative Effects Under the National Environmental Policy Ac (Table J-1).

Table J-1. Steps in the Cumulative Effects Analysis (as adapted from CEQ 1997)

Environmental Impact Assessment Components	CEA Steps
I. Scoping	a. Identify the significant cumulative effects issues associated with the proposed action and define the assessment goals. b. Establish the geographic scope for the analysis. c. Establish the time frame for the analysis. d. Identify other actions affecting the resources, ecosystems, and human communities of concern.
II. Describing the Affected Environment	a. Characterize the resources, ecosystems, and human communities identified in scoping in terms of their response to change and capacity to withstand stresses. b. Characterize the stresses affecting these resources, ecosystems, and human communities and their relation to regulatory thresholds. c. Define a baseline condition for the resources, ecosystems, and human communities.
III. Determining the Environmental Consequences	a. Identify the important cause-and-effect relationships between human activities and resources, ecosystems, and human communities. b. Determine the magnitude and significance of the cumulative effects. c. Modify or add alternatives to avoid, minimize, or mitigate significant cumulative effects. d. Monitor the cumulative effects of the selected alternative and adapt management.

1. Significant Cumulative Effects Issues

This assessment of cumulative impacts will focus on impacts of dredging from the proposed ocean borrow sites and impacts of placement of sand material on the beach (whether for beach nourishment or disposal of dredge maintenance material) on significant coastal shoreline resources. In making this assessment, we have reviewed the following reports:

- U.S. Department of the Interior, Minerals Management Service (MMS) report entitled "Use of Federal Offshore Sand Resources for Beach and Coastal Restoration in New Jersey, Maryland, Delaware, and Virginia," dated November 1999 (DOI 1999)
- MMS report entitled "Collection of Environmental Data Within Sand Resource Areas Offshore North Carolina and the Environmental Implications of Sand Removal for Coastal and Beach Restoration, dated 2003 (Byrnes et al. 2003)
- U.S. Army Corps of Engineers Dare County Beaches (Bodie Island Portion) Final Feasibility Report and EIS on Hurricane Protection, dated September 2000
- U.S. Army Corps of Engineers Draft Evaluation Report and Environmental Assessment, Morehead City Harbor Section 933, dated May 2003.
- U.S. Army Corps of Engineers Final Integrated General Reevaluation Report and Environmental Impact Statement, Shore Protection, West Onslow Beach and New River Inlet (Topsail Beach), North Carolina, dated March 2009.

The last three reports listed above included comprehensive assessments of state-wide cumulative impacts. In discussing the potential cumulative impacts of offshore borrow area dredging and beach nourishment, we consider time crowded perturbations, and space crowded perturbations, as defined below, to be pertinent to this action.

> ***Time crowded perturbations*** *– repeated occurrence of one type of impact in the same area.*
> ***Space crowded perturbations*** *– a concentration of a number of different impacts in the same area.*

2. Geographic Scope

This analysis will focus on cumulative impacts within the project area since portions of affected beaches under the current proposal have received fill in the past and the proposed action represents an approximately 3.1% increase in the area of North Carolina beaches affected by sand placement as described in the Dare County Beaches EIS (USACE, 2000), Morehead City Harbor Section 933 (USACE, 2003) and Topsail Beach (USACE, 2009) documents referenced. Additionally, this analysis will study the cumulative impacts within the project area associated with increased offshore borrow area use. The proposed project represents a new impact to the offshore benthic resources in the Topsail Island area. However, cumulative impacts of beach nourishment/disposal and offshore borrow area use on a statewide scale will also be assessed herein.

3. Time Frame

This analysis considers known past, present and the reasonably foreseeable future sand placement and offshore borrow on a statewide scale and project vicinity scale over a 50-year period of analysis from 1965 to 2015. This time period was selected to include the first U.S. Army Corps of Engineers Wilmington District, beach nourishment projects in 1965 and includes the first Wilmington District placement of dredged material within the project area (in the vicinity of Topsail Beach) in about 1969. While historic accounts of local coastal storm damage reduction efforts including sand placement on Wrightsville Beach dating back to the mid-1930s were considered in this assessment, no attempt was made to quantify these actions since detailed data were not available. Projections were extended to 2015, as that date represents a reasonably foreseeable future and the majority of remaining ocean beach that could reasonably be expected to have federal and non-federal projects implemented or studies initiated.

At the project vicinity scale the cumulative assessment considers past periodic beach disposal of AIWW maintenance material either annually or on a six-year basis along portions of Topsail Island. This assessment assumes continued periodic beach disposal of maintenance material along Topsail Island and construction of the West Onslow Beach and New River Inlet (Topsail Beach) and proposed beach nourishment projects. The cumulative analysis also considers the potential that future federal (i.e. Brunswick County Beaches, Bogue Banks, etc.) and non-federal (i.e. Topsail Beach, Bald Head Island, Figure Eight Island, etc.) beach nourishment projects under study could be constructed.

4. Actions Affecting Resources of Concern

This analysis of cumulative effects of the proposed action will focus on the impacts of dredging from the proposed ocean borrow sites and placement of sand material on the beach. In making this assessment, we have reviewed an Environmental Report prepared for and published by the U.S. Department of Interior, Minerals Management Service, entitled "Use of Federal Offshore Sand Resources for Beach and Coastal Restoration in New Jersey, Maryland, Delaware, and Virginia," dated November 1999 (DOI 1999) and the report titled "Collection of Environmental Data Within Sand Resource Areas Offshore North Carolina and the Environmental Implications of Sand Removal for Coastal and Beach Restoration," dated 2003 (Byrnes et al. 2003). Additionally, a detailed review of the current pier reviewed scientific literature on the effects of dredging and beach placement of sediment was conducted and cited in sections 2.0 and 8.0 of the main report.

4a. Actions Affecting Benthic Resources

Dredging: Benthic organisms within the defined borrow areas dredged for construction and periodic nourishment will be impacted. However, re-colonization by

opportunistic species is expected to begin soon after the dredging activity stops. Due to the opportunistic nature of the species that inhabit these soft bottom benthic habitats, recovery is expected to occur within 1-2 years. Rapid recovery is expected from re-colonization from the migration of benthic organisms from adjacent areas and by larval transport. Monitoring studies of post dredging effects and recovery rates of borrow areas indicates that most borrow areas usually show significant recovery by benthic organisms approximately 1 to 2 years after dredging (Naqvi and Pullen, 1982; Bowen and Marsh, 1988; Johnson and Nelson, 1985; Saloman *et al.*, 1982; Van Dolah *et al.*, 1984; and Van Dolah *et al.* 1992). According to Posey and Alphin (2000), benthic fauna associated with sediment removal from borrow areas off of Carolina Beach recovered quickly with greater inter-annual variability than differences from the effects of direct sediment removal. However, a potential change in species composition, population, and community structure may occur from the initial sediment removal impact as well as the change in surficial sediment characteristics, resulting in the potential for longer recovery times (2-3 years) (Johnson and Nelson, 1985; Van Dolah *et al.*, 1984). Differences in community structure may occur that may last 2-3 years after initial density and diversity levels recover (Wilber and Stern, 1992). Specifically, large, deeper-burrowing infauna can require as much as 3 years to reach pre-disturbance abundance. According to Turbeville and Marsh (1982), long term effects of a borrow site at Hillsboro Beach, FL, indicated that species diversity was higher at the borrow site than at the control site. Jutte *et al.* (1999 and 2001) evaluated recovery rates of post-hopper dredged borrow areas and found that hopper dredging creates a series of ridges and furrows, with the ridges representing areas missed by the hopper dredge. Rapid recolonization rates were documented due to the dredge's inability to completely remove all of the sediment. Furthermore, Jutte *et al.* (2002) documented that dredging to shallower depths is less likely to modify wave energy and currents at a borrow site; thus, reducing the likelihood of infilling of fine grained sediment.

As a result of dredging borrow areas for beach nourishment sand, there is concern for potential cumulative impacts due to repeated dredging in a borrow area within short periods of time such that the benthic community may not have time to recover. Dredging in subsequent areas close to one another may result in impacts to potential adult organism recruitment to the dredged areas, further lengthening the time for recovery in an area (DOI 1999). However, as noted in Section 8.01.7 of the main report, considering the distance offshore and the shallow volumes of sediment within the borrow areas, it is anticipated that all dredging activities associated with initial construction and each re-nourishment interval will be conducted using a hopper dredge. Recognizing the thin volumes of sediment within each borrow area, it is anticipated that all available sediment within each dredged portion of a borrow site will be fully utilized. Therefore, re-occurring impacts to an individual portion of a borrow area are not anticipated and full recovery of each dredged site is expected prior to the next dredging event.

Other factors affecting Benthic Resources: Many factors unrelated to dredging of sand from borrow areas may affect benthic resources including, beach resources and ocean fish stocks. The factors can be a result of natural events such as natural population

cycles or as a result of favorable or negative weather conditions including La Niña, El Niño, and major storms or hurricanes to name a few. These global events have far greater impacts on these resources at the population level than relatively local activities such as removal of sand from a given area of ocean bottom. Primary man-induced factors affecting fish stocks are over fishing and degradation of water quality due to pollution. When examining the cumulative effect of space crowded perturbations, these other factors may outweigh the potential incremental effects of borrow dredging of sand on benthic or fish populations.

4b. Actions Affecting Beach Resources

The major sources of beach impacts are local beach maintenance activities (which include local beach nourishment), disposal of dredged material from maintenance of navigation channels, and beach nourishment (berm and dune construction with long-term periodic maintenance). Of particular concern are macroinvertebrate (section 8.01.6 of the Feasibility Report/EIS), fisheries (section 8.01.3 of the Feasibility Report/EIS), shorebird (section 8.02.3 of the Feasibility Report/EIS), and sea turtle species (appendix I of the Feasibility Report/EIS) that utilize or occur on or adjacent to ocean beaches. These resources are also impacted by natural events and anthropogenic activities that are unrelated to disposal of sand on the beach as discussed below.

Local Maintenance Activity: Under the existing condition the project area is subjected to repeated and frequent maintenance disturbance by individual homeowners and local communities following major storm events. These efforts are primarily made to protect adjacent shoreline property. Such repairs consist of dune rebuilding using sand from beach scraping and/or upland fill. Limited fill and sandbags are generally used to the extent allowable by CAMA permit. Such frequent maintenance efforts could keep the natural resources of the barrier island ecosystems from re-establishing a natural equilibrium with the dynamic coastal forces of the area.

Non-Federal Beach Nourishment: Local efforts can also include beach nourishment such as that conducted along Pine Knoll Shores, Salter Path, Indian Beach, and Emerald Isle by local interests in 2001-2004. The number of locally funded beach nourishment activities has increased significantly since 2004 along other developed North Carolina beaches. Though non-federal beach nourishment efforts continue to increase, many of these projects are being pursued as one-time interim efforts until the federal beach nourishment projects can be implemented. Therefore, this increase permitted non-federal projects does not necessarily reflect a subsequent increase in resource acreage impacts. Many of the non-federal projects occur within the limits of federal projects which are already authorized but un-funded (i.e. Dare County Beaches) or projects which are under study (i.e. Bogue Banks). Beaches that have been nourished under permit, or may be permitted to be nourished, include, but are not limited to: Nags Head, Bogue Banks, North Topsail Beach, Topsail Beach, Figure Eight Island, Bald Head Island, and Holden Beach (Table J-2). Individually, these projects total approximately 75 miles of beach or 23% of North Carolina beaches. These frequent maintenance efforts could keep

the natural resources of the barrier island ecosystems from reestablishing a natural equilibrium with the dynamic coastal forces of the area.

Federal (USACE) Beach Nourishment: Federal beach nourishment activities typically include the construction and long-term (50-year) maintenance of a berm and dune. The degree of cumulative impact would increase proportionally with the total length of beach nourishment project constructed. The first federal North Carolina beach nourishment projects were constructed at Carolina and Wrightsville Beaches in 1965, and totaled approximately 6.4 miles. An additional 3.8 miles of federal beach nourishment project was constructed in 1975 at Kure Beach. In 2004, coastal storm damage reduction along 14 miles of Dare County Beaches was authorized, but has not yet been constructed. Most of the remaining developed North Carolina beaches (including the proposed project area) are currently under study by the Wilmington District for potential future beach nourishment projects (Table J-2). Individually, these existing or proposed federal projects total approximately 122 miles of beach or 38% of North Carolina beaches. Considering all existing and proposed federal and non-federal nourishment projects, and recognizing that some of the projects are overlapping or represent the same project area, approximately 112 miles or 35 % of the North Carolina coast could have private or federal beach nourishment projects by 2015.

Table J-2. Summary of federal and non-federal beach nourishment projects in North Carolina that have recently occurred, are currently underway, or will occur in the reasonably foreseeable future. (This list is not entirely comprehensive and does not include all small scale beach fill activities (i.e. dune restoration, beach scraping, etc.). (* - federal or non-federal projects which may utilize the same borrow sources and/or overlap beach placement locations).

Federal / Non-Federal	Project	Source of Sand for Nourishment	Beachfront Nourished	Approximate Length of Shoreline (miles)	Approximate Distance From the SCNTB Project Area (miles)
Federal	*Dare County Beaches, NC Bodie Island (Coastal Storm Damage Reduction)	Offshore Borrow Areas	Kitty Hawk and Nags Head Beaches	14	150
	Dare County Beaches, NC Hatteras to Ocracoke Portion	NA	Hatteras and Ocracoke Island (Hot Spots)	10	130
	Cape Lookout National Seashore -East Side of Cape Lookout Lighthouse	Channel	East Side of Cape Lookout Lighthouse	1	50
	*Beaufort Inlet Dredging - Section 933 Project (Outer Harbor)	Beaufort Inlet Outer Harbor	Indian Beach, Salter Path, and Portions of Pine Knoll Shores	7	35
	*Beaufort Inlet and Brandt Island Pumpout - Section 933 (Dredge Disposal to Eastern Bogue Banks)	Beaufort Inlet Inner Harbor and Brandt Island Pumpout	Fort Macon and Atlantic Beach	4	40
	*Bogue Banks, NC (Coastal Storm Damage Reduction)	Offshore Borrow Areas	Communities of Bogue Banks	24	35
	Surf City and North Topsail Beach - (Coastal Storm Damage Reduction)	Offshore Borrow Areas	Surf City and North Topsail Beach	10	0
	*West Onslow Beach New River Inlet (Topsail Beach) (Coastal Storm Damage Reduction)	Offshore Borrow Areas	Topsail Beach	6	10
	Wrightsville Beach (Coastal Storm Damage Reduction)	Masonboro Inlet and Banks Channel	Wrightsville Beach	3	30
	Carolina Beach and Vicinity, NC Carolina Beach Portion (Coastal Storm Damage Reduction)	Carolina Beach Inlet	Carolina Beach	2	40
	Carolina Beach and Vicinity, NC Kure Beach Portion (Coastal Storm Damage Reduction)	Wilmington Harbor Confined Disposal Area 4 and an Offshore Borrow Area	Kure Beach	2	45
	*Brunswick County Beaches, NC - Oak Island, Caswell, and Holden Beaches (Coastal Storm Damage Reduction)	Offshore Borrow Areas - Jay Bird Shoals and Frying Pan Shoals	Caswell Baach, Yaupon Beach, Long Beach, Holden Beach	30	65
	*Wilmington Harbor Deepening (Section 933 Project) - Sand Management Plan	Wilmington Harbor Ocean Entrance Channels	Bald Head Island, Caswall Beach, Oak Island	4	65
	*Holden Beach (Section 933 Project)	Wilmington Harbor Ocean Entrance Channels	Holden Beach	2	65
	*Oak Island Section 1135 - Sea Turtle Habitat Restoration	Upland Borrow Area - Yellow Banks	Oak Island	2	65
	Ocean Isle Beach, NC (Coastal Storm Damage Reduction)	Shallotte Inlet	Ocean Isle Beach	2	70

Non-Federal	*Town of Nags Head - Beach Nourishment Project	Offshore Borrow Areas	Nags Head	10	150
	*Emerald Isle FEMA Project	Offshore Borrow Areas - Morehead City Port Shipping Channel (ODMDS)	Emerald Isle	4	30
	*Bogue Banks FEMA Project	Offshore Borrow Areas – Morehead City Port Shipping Channel (ODMDS)	Emerald Isle (2 segments), Indian Beach, Salter Path, Pine Knoll Shores	13	35
	*Bogue Banks Restoration Project – Phase I – Pine Knoll Shores and Indian Beach Joint Restoration	Offshore Borrow Areas	Pine Knoll Shores and Indian Beach	7	35
	*Bogue Banks Restoration Project – Phase II – Eastern Emerald Isle	Offshore Borrow Areas	Indian Beach and Emerald Isle	6	30
	*Bogue Banks Restoration Project – Phase III– Bogue Inlet Channel Realignment Project	Bogue Inlet Channel	Western Emerald Isle	5	30
	*North Topsail Dune Restoration (Town of North Topsail Beach)	Upland borrow source near Town of Wallace, NC	North Topsail Beach	NA	0
	*North Topsail Beach Shoreline Protection Project	New River Inlet Realignment and Offshore Borrow Area	North Topsail Beach	11	0
	*Topsail Beach - Beach Nourishment Project	New Topsail Inlet Ebb Shoal and Offshore Borrow areas	Topsail Beach	6	10
	Figure Eight Island	Banks Channel and Nixon Channel	North & South Sections of Figure Eight Island	3	30
	Rich Inlet Management Project	Relocation of Rich Inlet	Figure Eight Island	NA	30
	Mason Inlet Relocation Project	Mason Inlet (new channel) and Mason Creek	North end of Wrightsville Beach and south end of Figure Eight Island	2	30
	Bald Head Island Creek Project	Bald Head Creek	South Beach	0.34	55
	Bald Head Island - Beach Nourishment	Offshore Borrow Area - Jay Bird Shoals	West and South Beach of Bald Head Island	4	55
	*Holden Beach East & West	Upland Borrow Source (Truck Haul)	Extension of 933 Project	3	65
	*Holden Beach East & West	Upland Borrow Source (Truck Haul)	Extension of 933 Project	3	65

Federal (USACE) Navigation Beach Disposal: Maintenance material from dredging in the vicinity of Topsail Island has historically been disposed within authorized disposal limits along 1.5 miles of beach at North Topsail Beach and 1.6 miles of beach at Topsail Beach (Table J-3). Throughout North Carolina, a total of approximately 41 miles of beach (~13% of North Carolina beaches) are authorized for disposal of beach quality dredged material from maintenance dredging of navigation channels. However, not all of these projects are routinely dredged and a majority of the authorized disposal limits are not actually disposed on to the full extent. Additionally, many of the authorized disposal limits overlap with existing federal or non-federal beach projects. Therefore, without double counting for overlapping beach projects, navigation dredged material is placed along approximately 19 miles, or 6% of North Carolina beaches. The Wilmington District currently uses about 50 percent of the length of beach in North Carolina that is approved for this purpose and does not anticipate significant increases in beach disposal in the foreseeable future.

Beach quality sand is a valuable resource that is highly sought by beach communities to provide wide beaches for recreation and tourism, as well as to provide hurricane and wave protection for public and private property in these communities. When beach quality sand is dredged from navigation projects, it has become common practice of the Corps to make this resource available to beach communities, to the maximum extent practicable. Placement of this sand on beaches represents return of material, which eroded from these beaches, and is, therefore, replenishment with native material. The design of beach placement sites generally extends the elevation of the natural berm seaward.

Table J-3 Summary of dredged material disposal activities on North Carolina ocean front beaches associated with navigation dredging. Projects listed and associated disposal locations and quantities may not be all encompassing and represent an estimate of navigation disposal activities for the purposes of this cumulative impacts assessment. (* - Navigation disposal sites which may overlap with existing Federal or Non-Federal beach nourishment projects).

	PROJECT	DISPOSAL LOCATION	APPROVED DISPOSAL LIMITS	ESTIMATED ACTUAL DISPOSAL LIMITS	ESTIMATED QUANTITY (CY)	COMMENTS
Outer Banks	**Avon**	Begins at a point 1.15 miles south of Avon Harbor and extends north 3.1 miles	3.1 miles (16,368 lf)	0.4 miles or 2,000 linear feet	<50,000 every 6 yrs	Special Use Permit Required From NPS/CHNS
	Rodanthe	Extends from rd to Rodanthe Harbor south 700' to south end of beach disposal area (straight out from existing dirt road). North end at Wildlife Refuge Boundary (PINWR)	.91 miles (4,800 lf)	0.4 miles or 2,000 linear feet	<100,000 every 6 yrs	Special Use Permit Required From NPS/CHNS
	Ocracoke Island	Begins at a point 5,000 linear feet south of Hatteras Inlet and extends southward about 3,000 linear feet.	0.6 mile (3,000 lf)	0.4 mile or 2,000 linear feet	<100,000 every 2 to 3 years	Special Use Permit Required From NPS/CHNS
	Rollinson (Hatteras)	Begins at a point 0.85 miles south of Hatteras Harbor and extends north 5.85 miles to a point north of Frisco, NC	5.85 miles (30,888 lf)	0.4 miles or 2,000 linear feet	<60,000 every 2 years	Special Use Permit Required From NPS/CHNS
	Silver Lake (Teaches Hole/Ocracoke)	From a point 2,000' NE of inlet and extending approximately 2,000 linear feet (0.4 miles) to the NE (Ocracoke Island)	0.4 miles (2,000 lf)	0.4 miles or 2,000 linear feet	<50,000 every 2 yrs	Special Use Permit Required From NPS/CHNS
	Oregon Inlet		3 miles(15,840 lf)	1.5 miles or 7,920 linear feet	300,000 Annually	Special Use Permit Required From USFWS/PINWR
	Drum Inlet	Core Banks. From a point 2,000 feet on either side of inlet extending for 1 mile in either direction	2 miles (10,560 lf)	1 mile or 5,280 linear feet	298,000 initial, 100,000 maint. (Assume 8 year cycle)	SUP from NPS/CLNS (Included in analysis; however, no determination of site being reused can be made at this time)
Beaufort	***Morehead City (Brandt Island)**	2,000 ft west of inlet, Fort Macon and Atlantic Beach to Coral Bay Club, Pine Knoll Shores	7.3 miles (38,300 lf)	5.2 miles or 27,800 linear feet	3.5 million every 8 yrs	Material from Ocean Bar routinely placed in nearshore berm or ODMDS on annual basis

	***AIWW Section I, Tangent B**	Pine Knoll Shores, vicinity of Coral Bay	2 miles (10,500 lf)	0.4 miles or 2,000 linear feet	<50,000 every 5 yrs	This area is included every 8 years as part of the pumpout fo Brandt Island. Also included in the area under investigation for beach nourishment at Bogue Banks.
Swansboro	***AIWW Bogue Inlet Crossing Section I, Tangent-H through F**	Approx. 2,000 feet from inlet going east to Emerald Point Villas, Emerald Isle (Bogue Banks)	1mile (5,280 lf)	0.4 miles or 2,000 linear feet	<100,000 annually	
Browns Inlet	**AIWW Section II, Tangents-F,G,H**	Camp Lejeune, 3,000 feet west of Browns Inlet extending westward	1.58 miles (6,000 lf)	1 mile or 5,280 linear feet	<200,000 every 2 yrs	
New River Inlet	***AIWW, New River Inlet Crossing Section II, Tangents I & J, Channel to Jax. Section III, tangents 1&2**	N. Topsail Beach, 3,000 feet west of inlet extending westward to Maritime Way (Galleon Bay area)	1.5 miles (8,000 lf)	0.8 miles or 4,000 linear feet	<200,000 annually	Two areas 2,000 linear feet on either side of disposal area are routinely used.
Hampstead	***AIWW, Sect. III**	Topsail Island, Queens Grant	0.6 miles (2,500 lf)	0.6 miles or 2,500 lf	<50,000 every 6 yrs	
	***AIWW, Topsail Inlet Crossing & Topsail Creek**	Topsail Beach, from a point 2,000 feet north of Topsail Inlet	1 mile (5,280 lf)	0.4 mi or 2,000 ft	<75,000 annually	
Wrightsville Beach	**AIWW Sect. III,Tang 11&12 Mason Inlet Crossing**	Shell Island (north end of Wrightsville Beach from a point 2,000 feet from Mason Inlet	0.4 miles (2,000 lf)	0.4 mi. or 2,000 lf	<100,000	Not recently required since the inlet crossing closed up. If reopened will be rescheduled if needed
	***Masonboro Sand Bypassing**	At a point 9,000 feet from jetty extending southward midway of island	1.2 miles (6,000 lf)	1 mile 5,280 lf	500,000 every 4 years	Same time as Wrightsville Beach Nourishment
Carolina Beach	**AIWW, Section IV, Tangent 1**	Southern end of Masonboro Island at a point 2,000 linear feet from Carolina Beach Inlet extending northward to Johns Bay area	1.3 miles (7,000 lf)	0.4 miles (2,000 linear feet)	<50,000 annually	This site is used alternately with Carolina Beach Disposal Site on North end of Island
Caswell Beach	***Caswell Beach**	Beachfront on eastern end of island	4.7 miles (25,000 lf)	4.7 miles or (25,000 linear feet)	1.1 million every 6 years	Disposal Material from Wilmington Harbor Ocean Bar Project
Bald Head	***Bald Head**	Beach front on eastern and western shoreline	3.0 miles (16,000 lf)	3.0 miles or 16,000 lf	1.1 million every 2 years (except every 6th when it goes to Caswell)	Least Costly Disposal Option From Wilmington Harbor Ocean Bar Project.

Table J-3 (Continued)

Other factors affecting Beach Resources: Many factors unrelated to placement of sand on the beach may affect beach resources including: benthic invertebrate resources, shorebird populations, and ocean fish stocks. The factors can be a result of natural events such as natural population cycles or as a result of favorable or negative weather conditions including droughts, floods, La Niña, El Niño, and major storms or hurricanes to name a few. A primary anthropogenic factor affecting shorebird populations is beach development resulting in a loss or disturbance of nesting habitat and invasion of domestic predators. Primary man-induced factors affecting fish stocks are over fishing and degradation of water quality due to pollution.

5. Significant Resources

Based on scoping comments from resource agencies and others, the primary concerns with the proposed dredging and beach disposal are direct and indirect impacts to hard bottom communities, macro-invertebrates, fish, shorebirds, and sea turtles. Federally listed threatened or endangered species which could be present along the North Carolina coast are the blue whale, finback whale, humpback whale, North Atlantic right whale, sei whale, sperm whale, West Indian manatee, green sea turtle, hawksbill sea turtle, Kemp's ridley sea turtle, leatherback sea turtle, loggerhead sea turtle, shortnose sturgeon, seabeach amaranth, and piping plover. Impacts to all listed species are provided in Appendix I and summarized below and include, but are not limited to, mortality, reduction in prey species, habitat change, and disturbance during construction activities. Also discussed are the benefits of periodic renourishments, which are expected to enhance nesting habitat of sea turtles and to provide additional habitat for sea beach amaranth. In relation to dredging of offshore sites for material, the primary concerns are the potential impacts to benthic organisms, fish species, and hard bottom habitat areas. Detailed discussions of all significant resources and associated impacts considered in this assessment are included in Sections 2.0 and 8.0 of the Feasibility Report/EIS.

Beach and Dune. Terrestrial habitat types within these areas include sandy or sparsely vegetated beaches and vegetated dune communities. Mammals occurring within this environment are opossums, cottontails, gray foxes, raccoons, feral house cats, shrews, moles, voles, and house mice. Common vegetation of the upper beach includes beach spurge, sea rocket and pennywort. The dunes are more heavily vegetated, and common species include American beach grass, panic grass, sea oats, broom straw, seashore elder, and salt meadow hay. Seabeach amaranth, a Federally listed threatened species, is present throughout most of North Carolina. Ghost crabs are important invertebrates of the beach/dune community. The beach and dune also provide important nesting habitat for loggerhead and green sea turtles as well as habitat for a number of shorebirds and many other birds, including resident and migratory songbirds. Placement of material along the ocean beach enhances and improves important habitat for a variety of plants and animals, and restores lost habitat in the areas of most severe erosion. This is especially important for nesting loggerhead sea turtles and seabeach amaranth. Historic nesting data from Topsail Island indicate that sea turtles continue to nest on

disposal beaches with hatch rate successes similar to non-disposal beaches (Jean Beasley, pers. comm.). Furthermore, new populations of seabeach amaranth have been observed to follow sand placement on beaches where sand has been disposed by the Corps of Engineers (ex. Wrightsville Beach and Bogue Banks) (USFWS, 1996b; CSE, 2004). Individually and cumulatively, in addition to providing important habitat, beach nourishment projects protect public infrastructure, public and private property, and human lives.

Marine Waters. Along the coast of North Carolina, marine waters provide habitat for a variety of ocean fish and are important commercial and recreational fishing grounds. Kingfish, spot, bluefish, weakfish, spotted seatrout, flounder, red drum, king mackerel, and Spanish mackerel are actively fished from boats, the beach, and local piers. Offshore marine waters serve as habitat for the spawning of many estuarine dependent species. Oceanic large nekton located offshore of North Carolina are composed of a wide variety of bony fishes, sharks, and rays, as well as fewer numbers of marine mammals and reptiles. Marine mammals and sea turtles that may be present in the offshore borrow sites are addressed in Appendix I. Dredging and placement of beach fill may create impacts in the marine water column in the immediate vicinity of the activity, potentially affecting the surf zone and nearshore ocean. These impacts may include minor and short-term suspended sediment plumes and related turbidity, as well as the release of soluble trace constituents from the sediment. Overall water quality impacts for any given project are expected to be short-term and minor. Cumulative effects of multiple simultaneous beach nourishment operations could potentially impact fishes of the surf zone. However, the high quality of the sediment selected for beach fill and the small amount of beach affected at any point in time would not suggest that this activity poses a significant threat.

Intertidal and Nearshore Zones. The intertidal zone within the proposed beach nourishment areas serves as habitat for invertebrates including mole crabs, coquina clams, amphipods, isopods, and polychaetes, which are adapted to the high energy, sandy beach environment. These species are not commercially important; however, they provide an important food source for surf-feeding fish and shore birds. The surf zone is suggested to be an important migratory area for larval/juvenile fish moving in and out of inlets and estuarine nurseries (Hackney *et al.*, 1996). Disposal operations along the beach can result in increased turbidity and mortality of intertidal macrofauna, which serves as food sources for various fish and bird species. Therefore, feeding activities of these species may be interrupted in the immediate area of beach sand placement. These mobile species are expected to temporarily relocate to other areas as the project proceeds along the beach. Though a short-term reduction in prey availability may occur in the immediate disposal area, only a small area is impacted at any given time, and once complete, organisms can recruit into the nourished area. The anticipated construction timeframes for beach projects are typically from 15 November to 30 April and would avoid a majority of the peak recruitment and abundance time period of surf zone fishes and their benthic invertebrate prey source. To summarize, the impacts of beach renourishment projects on the intertidal and nearshore zones are considered temporary, minor and reversible. Cumulative effects of multiple simultaneous beach nourishment

operations could be potentially harmful to benthic invertebrates in the surf zone; however, the high quality of the sediment selected for beach fill and the small amount of beach affected at any point in time would suggest that this activity would not pose a significant threat.

Hardbottoms. Hardbottoms are also called "live-bottoms" because they support a rich diversity of invertebrates such as corals, anemones, and sponges, which are refuges and food sources for fish and other marine life. They provide valuable habitat for reef fish such as black sea bass, red porgy, and groupers. Hardbottoms are also attractive to pelagic species such as king mackerel, amberjack, and cobia. While hardbottoms are most abundant in southern portions of North Carolina, they are located along the entire coast (USFWS, 1990). As identified in Figure J-1, there are dispersed hardbottom areas present in offshore environment and borrow areas off of Surf City and North Topsail Beach. Hardbottoms in the Surf City North Topsail Beach area and potential project related impacts are discussed in detail in Sections 2.01.10 and 8.01.8.2 of the Feasibility Report/EIS. In order to assess the potential impact of the proposed project on: (1) nearshore hard bottom habitat as a result of burial or sedimentation from the beach fill equilibration process and (2) offshore habitat from hopper dredging activities, the Corps contracted side scan sonar, multi-beam, and diver ground truth data collection. Diver ground truth verification was used to confirm the presence or absence of hard bottom within high backscatter areas identified as "potential hard bottom" from the remote sensing efforts. Diver ground truth confirmation of 8 selected areas previously identified as "potential" hard bottom, in conjunction with the sidescan interpretation, supported the conclusion that no hard bottom was identified landward of the calculated -7 m (-23 ft.) depth of closure. Additional refined analyses of the remote sensing data coupled with the (1) diver ground truth transects, (2) collected sediment samples, and (3) digital video, identified the previously defined "high backscatter anomalies" to be regions of coarse gravel and shell hash. These features identified in the nearshore environment off Surf City and North Topsail Beach are consistent with previously identified "rippled scour depressions (RSD)" (Cacchione *et al.*, 1984; Thieler *et al.*, 1999; Thieler *et al.*, 2001), "ripple channel depressions (RCD)" (McQuarrie, 1998), or "sorted bedform"(Murray and Thieler, 2004) features identified throughout the coast of NC (Wrightsville Beach, Figure Eight Island, Topsail Island, etc.). Hard bottom of varying low (<0.5 m (1.6 ft.)) to moderate (0.5 m (1.6 ft.) to 2.0 m (6.6 ft.)) relief (i.e. large contiguous hard bottom, patchy outcroppings, and/or distinct ledges) and total area were confirmed and characterized within multiple borrow areas in the offshore (>-23 ft NGVD) environment. Sections 2.01.10 and 8.01.8.2 of the main report and Appendix R discuss the identified hard bottom resources and potential impacts in more detail. Additionally, specific project measures in order to avoid impacts to hard bottoms are provided. Recognizing the detailed hard bottom resource inventory completed for this project and the avoidance measures identified impacts to hard bottom communities are not anticipated from this project. Though hard bottom communities are located throughout North Carolina, recognizing the current resource inventories in place to identify and avoid hard bottom communities for dredging and beach nourishment projects, the cumulative effects are not significant.

Figure J-1. Hard bottom resources identified within 16 borrow areas (A-T) located offshore of Topsail Island.

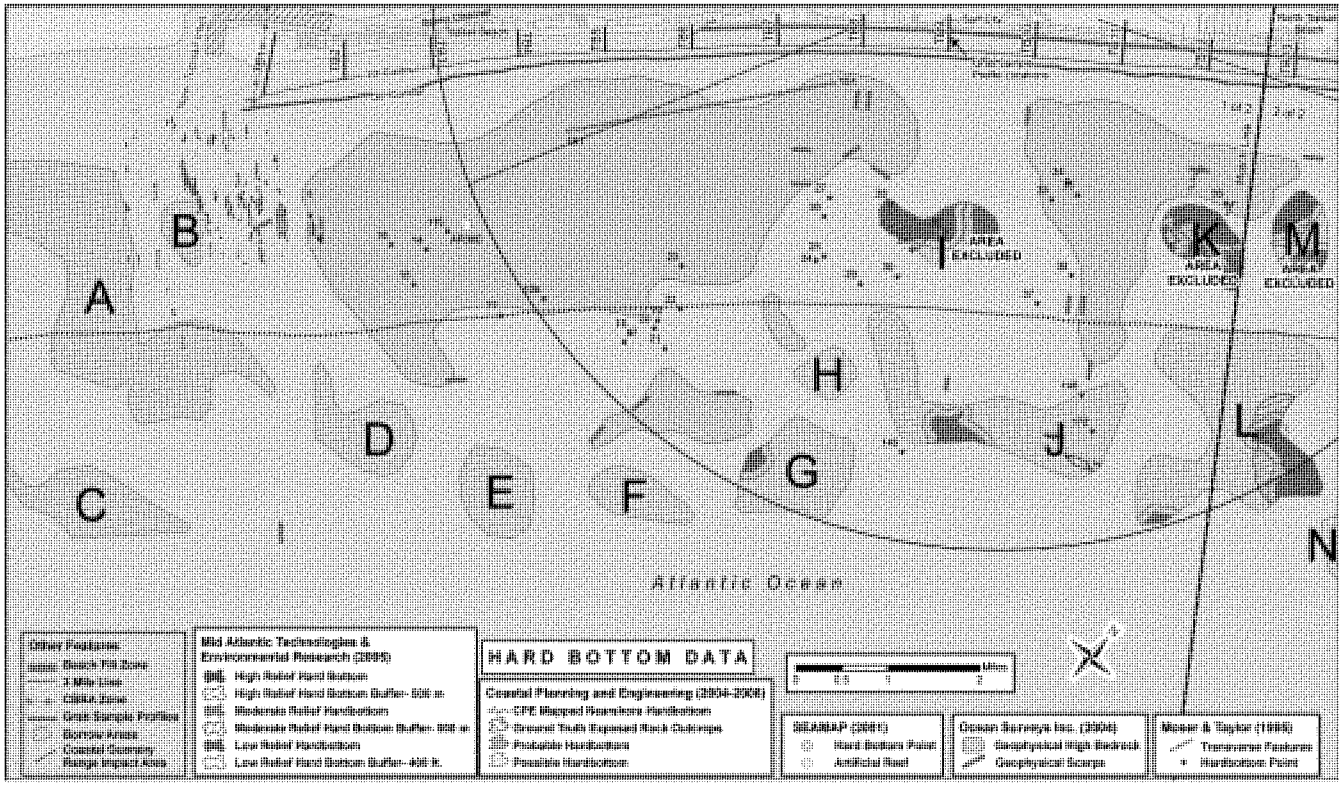
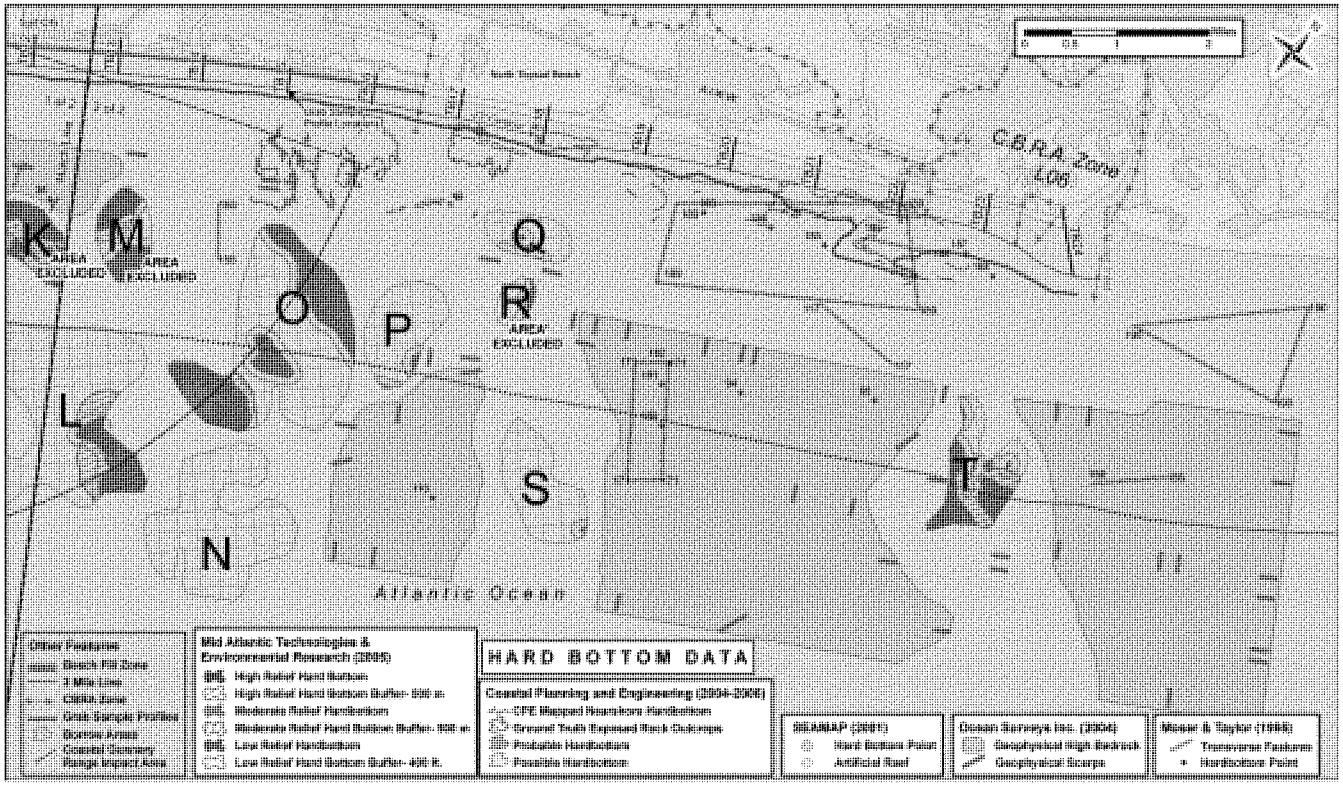


Figure J-1. (continued)



Nearshore Zone. Beach nourishment projects introduce fill into nearshore waters out to a specified depth of closure, usually from about –20 to –25 feet NGVD Benthic organisms, phytoplankton, and seaweeds are the major primary producers in this community with species of *Ulva* (sea lettuce), *Fucus*, and *Cladocera* (water fleas) being fairly common where suitable habitat occurs. Many species of fish-eating birds are typically found in this area including gulls, terns, cormorants, loons, and grebes (Sections 2.02.3 and 8.02.3). Marine mammals and sea turtles also are frequently seen in this area and are discussed in detail in Sections 2.01.7, 2.02.4, and Appendix I. Fishes and benthic resources of this area are discussed in Sections 2.01.4, 2.01.5, 2.01.8, and 2.01.9 respectively.

5a. Other Resources

Air Quality. The ambient air quality for all of coastal North Carolina has been determined to be in compliance with the National Ambient Air Quality Standards. All coastal counties in North Carolina are designated as attainment areas and do not require conformity determinations.

Additionally, although ozone is not a significant problem in the coastal counties, ozone is North Carolina's most widespread air quality problem, particularly during the warmer months. High ozone levels generally occur on hot sunny days with little wind, when pollutants such as nitrogen oxides and hydrocarbons react in the air. The ozone season is April through October. Dredging with beach disposal or renourishment typically takes place during the cooler months of the year, during times of low biological activity and outside of the ozone season. Section 8.08.1 provides detailed emissions analysis of the proposed project. Based on this analysis, this project is not anticipated to create any adverse effect on the air quality of this attainment area or cumulative effect on the ambient air quality for all of coastal North Carolina.

Social and Economic. The coastal areas of North Carolina will continue to grow and expand both with and without beach nourishment projects. Therefore, the economic benefit analysis for the proposed project claims no increase in benefits or hurricane and storm damage due to induced development. Development of vacant lots is limited to lots buildable under the regulations set forth by CAMA, flood plain regulations, State and local ordinances, and applicable requirements of the Federal Flood Insurance Program.

IWR Report 96-PS-1, FINAL REPORT: An Analysis of the U.S. Army Corps of Engineers Shore Protection Program, June 1996 states: "Corps projects have been found to have no measurable effect on development, and it appears that Corps activity has little effect on the relocation and/or construction decisions of developers, homeowners, or housing investors."

Wave Conditions. Localized deepening of offshore borrow areas is the only potential source of impacts on wave conditions, however, these changes are not expected to be significant considering the shallow nature of the proposed borrow sites. For the proposed Surf City North Topsail Beach project, the borrow area use plan identifies sixteen detached, relatively small borrow areas scattered offshore of Topsail Island.

These borrow areas include 10 identified for the Surf City/North Topsail Beach project and the excess amount from 6 borrow areas identified for the Topsail Beach Federal project (USACE, 2009). These areas are typically between 1 and 6 miles offshore and have pre-dredge bottom depths between 35 and 50 feet. This identified borrow area use plan should have less impact on wave conditions than dredging of a large, contiguous area.

Shoreline and Sand Transport. Existing water depths in offshore borrow areas are substantially deeper than the estimated active profile depths. Therefore no impacts to the active profile are expected due to borrow area dredging for this project or any other projects in the State.

Net movement of material placed on Surf City North Topsail Beach will be predominantly to the north based on transport analysis, with northerly sediment transport being roughly twice that of southerly transport on average. On a regional basis, renourishment projects add material to the longshore transport system, thus providing positive impacts. Although a regional sediment budget analysis has not been completed, it is expected that the proposed action and the combined effects of all other existing and proposed beach projects will have a minimal effect on shoreline and sand transport.

6. Resource Capacity to Withstand Stress and Regulatory Thresholds

There are no known thresholds relating to the extent of ocean bottom that can be disturbed without significant population level impacts to fisheries and benthic species. Therefore, a comparison of cumulative impacts to established thresholds is not made. However, the potential impact area of the proposed project is small relative to the area of available similar habitat on a local, vicinity, and statewide basis and the quick recovery rate of opportunistic species. It is expected that there is a low risk that the direct and cumulative impacts of the proposed action and other known similar activities would reach a threshold with potential for population level impacts on important commercial fish stocks. In regard to physical habitat alterations it is expected that alterations in depths and bottom sediment may occur and be persistent. However, site modifications would be within the range of tolerance by these species and, although man-altered, consistent with natural variations in depth and sediment within the geographic range of EFH for local commercial fish species. The Final Report, Collection of Environmental Data Within Sand Resource Areas Offshore North Carolina and The Environmental Implications of Sand Removal for Coastal and Beach Restoration (Byrnes et al. 2003) provided the following assessment of potential impacts to benthic organisms from dredging:

Because the sedimentary regime of North Carolina sand source areas is vertically uniform, recolonization of surficial sediments by later successional stages likely will proceed even if dredged shoals are not completely reestablished. Furthermore, dredging of only a small portion of the area within each of the resource areas will ensure that a supply of non-transitional, motile taxa will be available for rapid migration into dredged sites. While community composition may differ for a period of time after the last

dredging, the infaunal assemblage type that exists in mined areas will be similar to naturally occurring assemblages in the study area, particularly those assemblages inhabiting inter-ridge troughs. Based on previous observations of infaunal reestablishment in dredged sites, the infaunal community in dredged sites most likely will become reestablished within 2 years, and will exhibit levels of infaunal abundance, diversity, and composition comparable to nearby non-dredged sites.

In a 1999 Environmental Report on the use of federal offshore sand resources for beach and coastal restoration, the U.S. Department of Interior, Minerals Management Service (DOI 1999) provided the following assessment of potential impacts to beach fauna from beach disposal:

Because benthic organisms living in beach habitats are adapted to living in high energy environments, they are able to quickly recover to original levels following beach nourishment events; sometimes in as little as three months (Van Dolah et al. 1994; Levison and Van Dolah 1996). This is again attributed to the fact that intertidal organisms are living in high energy habitats where disturbances are common. Because of a lower diversity of species compared to other intertidal and shallow subtidal habitats (Hackney et al. 1996), the vast majority of beach habitats are recolonized by the same species that existed before nourishment (Van Dolah et al. 1992; Nelson 1985; Levison and Van Dolah 1996; Hackney et al. 1996).

While the proposed beach disposal may adversely impact benthic macrofauna, these organisms are highly resilient and any effects will be localized, short-term, and reversible.

7. Baseline Conditions

The following Feasibility Report/EIS section describes the status of significant resources that may be affected by this and other similar projects that are pertinent to this analysis.

Section 2.0, Affected Environment.

8. Cause and Effect Relationships

The following Feasibility Report/EIS section describes impacts of the proposed action on significant resources. Cause and effect relationships described in the report are consistent with those that would be expected for other similar projects that are pertinent to this analysis.

Section 8.0, Environmental Effects.

9. Magnitude and Significance of Resource Impacts

9a. Offshore Borrow Areas

Site Specific Impacts: Sixteen borrow areas have been identified for the Surf City/North Topsail Beach Coastal Storm Damage Reduction Project. These borrow areas include 10 identified for the Surf City/North Topsail Beach project and the excess amount from 6 borrow areas identified for the Topsail Beach Federal project (Figure J-1 and Table J-4).

Table J-4. Topsail Island Borrow Area Characteristics.

Borrow Area	Total Acreage (**excluding hard bottom and buffers)	Estimated Volume (Million yd^3)	Distance Offshore (miles)	Surface Elevation (ft. MLLW)
A	2,272	*	1 to 3	-38.5 to –49.0
B	158	*	1.5 to 2.5	-42.2 to –43.2
C	598	*	4 to 5.5	-45.5 to -47.7
D	471	*	3.5 to 4.5	-43.5 to –46.9
E	406	*	4.5 to 5.5	-49 to –50
F	282	*	4.5 to 5.5	-47.2 to -48
G	574	2.41	4 to 5.5	-46.5 to -49
H	158	0.72	3.5 to 4.5	-44.4 to -45.2
J	912	3.67	3 to 4.5	-42 to -47.4
L	1298	6.13	3 to 5.5	-42.3 to -47
N	1001	5.64	4 to 6	-43.6 to -46.7
O	807	3.85	1.5 to 4	-40.6 to -43.9
P	409	2.73	2 to 3.5	-39.5 to -40.5
Q	144	0.73	1 to 1.5	-35.2 to -35.4
S	472	1.46	3.5 to 4.5	-43.8 to -44.8
T	86	0.25	2 to 4	-37.2 to -42

* - These borrow areas are planned to be used for the Topsail Beach Federal and non-Federal projects (USACE, 2009). The excess material not used for these projects is expected to be available for the Surf City/North Topsail Beach project. This amount is approximately 9.68 million cubic yards.

** - Acreage calculations represent available area to be dredged for sediment taking into account the avoidance of hard bottom habitat and associated buffers.

There are many possible sequences and methods for dredging and placing available material on the beach for the project and a site specific borrow area use plan has

yet to be defined. The economic optimization of the use of the borrow areas for the life of the project will be further evaluated when the final borrow area data has been collected and fully analyzed during the Plans and Specifications (P&S) phase. However, for a majority of the identified borrow sites to be utilized for this project, the depths of available sediment are relatively shallow with an average range of 2.6 to 6.4 ft for borrow areas G-T located offshore of Surf City and North Topsail Beach. Under the proposed plan, initial construction would require about 11.8 mcy and each nourishment interval would require about 2.6 mcy. Both initial construction and each nourishment interval will likely utilize multiple borrow areas with a sequence of temporary impacts to benthic resources over the life of the project. Considering the shallow average thickness of the borrow areas and the associated dredging operations and production capabilities to effectively dredge the sediment, it is anticipated that individual dredged areas within each borrow area will be fully utilized and will not be dredged again at consecutive dredging events. Therefore, once the dredged site recovers from the initial dredging impact, it will likely not be impacted again as all of the available sediment would be exhausted from the dredged area. Considering that the identified borrow areas are all consistently shallow, the size of the impact area can be correlated to the volume of sediment needed. For example, initial construction will require about 11.8 mcy and will therefore have the largest acreage impact among multiple borrow areas during that one time event. Each subsequent nourishment interval will require about 2.6 mcy and will impact a reduced amount of acres at six year intervals for the duration of the project. Once all of the sand is dredged from the identified borrow areas to meet the demand for the 50 year duration of the project, a total of about 10,047 acres (SCNTB (G-T) – 5,861 acres; Topsail Beach (A-F) – 4,186 acres) could be impacted among all 16 identified borrow sites offshore of Topsail Island (Table J-4).

Subsequent intervals of dredging within an individual borrow area will likely occur in portions of the borrow area that have not previously been dredged. Upon each dredging interval, recovery in adjacent areas will have already occurred; therefore, re-occurring impacts to any sub-component of a borrow area are not anticipated. Therefore, the total acreage of impact that could occur during any given dredging event is the one time impact of the surface area required to dredge the volume of sediment for initial construction or nourishment. This cyclic use of borrow areas would result in cumulative effects from space crowded perturbations on a local scale. Assuming that the borrow areas are not impacted by repeatedly dredging recently used areas, unusually high sedimentation rates, or some other disturbance, a natural succession of species should occur, potentially restoring the area to its original levels of abundance and biomass within 1-5 years (Naqvi and Pullen, 1982; Bowen and Marsh, 1988; Johnson and Nelson, 1985; Saloman *et al.*, 1982; Van Dolah *et al.*, 1984; Van Dolah *et al.* 1992; Johnson and Nelson, 1985; Van Dolah *et al.*, 1984; and Wilber and Stern, 1992). Considering that un-impacted or recovered portions of the borrow area will likely be available during any particular dredging event, more rapid recruitment from adjacent areas is expected to expedite recovery. The impacts of this activity on benthic invertebrates are discussed in more detail in Section 8.01 Feasibility/EIS titled "Marine Environment."

Cumulative impacts from space crowded perturbations could occur at the local scale resulting from the use of borrow sites A-F for initial project construction and periodic maintenance of the Topsail Beach federal and non-federal projects as well as borrow areas G-T for the Surf City and North Topsail Beach federal and non-federal projects.

Statewide Impacts:

Existing and Potential Sites: Beach compatible sediment identified for all federal and non-federal nourishment projects throughout North Carolina is most often identified from: upland sites, maintenance or deepening of navigation channels, and/or offshore borrow areas (Table J-2). For the purposes of this impact assessment, only offshore borrow areas are evaluated for cumulative marine resource impacts considering that upland sources are outside of the marine environment and navigation channels are repeatedly dredged already in order to maintain navigation servitude. Of all the projects listed with offshore borrow areas in Table J-2, there is currently only one federal (Carolina Beach and Vicinity, NC Kure Beach portion) and three non-federal (Bogue banks FEMA, Bogue Banks Restoration Project – Phases 1&2, and Bald Head Island Beach Nourishment) offshore borrow sites that have received permits and/or authorizations and funding, and are currently in use. Other offshore borrow areas identified for projects are either under study and have not been permitted and/or authorized yet or have received permits and/or authorizations but have not been funded or constructed yet. Considering only the projects that are currently in use, significant cumulative impacts associated with time and space crowded perturbations are not expected considering that these borrow areas are spread out throughout the state and the acreage of impact for these borrow areas relative to the available un-impacted sites throughout the state is not significant. However, recognizing the potential for all of the federal and non-federal projects identified in North Carolina to occur within the reasonably foreseeable future (Table J-2), there is a potential for cumulative impacts for time and space crowded perturbations associated with the cyclic use of the offshore borrow areas throughout the state.

9b. Beach Areas

The impacts of beach disposal on North Carolina beaches are evaluated in Section 8.0 of the Feasibility Report/EIS. The degree of cumulative impact would increase proportionally with the total length of beach impacted. The most likely projects to increase the length of North Carolina beach disposal are beach nourishment projects.

As shown in Table J-5 below, the North Carolina ocean beaches (320 miles) can be divided up based on the potential that a beach nourishment project will be proposed for them. The Coastal Area Management Act (CAMA) applies to all 20 North Carolina Coastal Counties. Proper beach nourishment , navigation disposal, and/or local maintenance within these counties is generally regulated under CAMA or USACE permitting authorities alone, and for this analysis, are labeled CAMA regulated. Approximately 37 percent of North Carolina beaches are in this category. Other North

Carolina ocean beach areas which are less likely to be considered for beach disposal include those identified under the Coastal Barrier Resources Act (CBRA) of 1982 (PL 9-348), the Coastal Barrier Improvement Act of 1990 (PL 101-591), and National and State park lands. CBRA restricts federal expenditures in those areas comprising the Coastal Barrier Resources System (CBRS); thus, long term federal beach nourishment projects will not occur in defined CBRA zones. However, though long term federal beach nourishment projects are restricted from CBRA zones, non-federal permitted projects may still occur (i.e. North Topsail Beach) on a short term basis. National or state park lands are the least likely to have beach nourishment projects considering that their mission is often to manage lands in their natural state and protection of infrastructure is less common. National and state parks allow highly restricted disposal under special use permits and conduct disposal only as required to protect resources, such as at Pea Island. Only about 10 percent (on National/Federal and State Parks) of all existing or projected disposal/nourishment in North Carolina are on beaches within this category.

Table J-5. North Carolina beach classifications and associated potential for beach disposal/nourishment activities.

Beach Classification	Percentage of NC Beaches	Potential for Beach Disposal/Nourishment Activities
Coastal Barrier Resource System	19	Medium
Developed and/or CAMA Regulated	37	High
National Park Lands	40	Low
State Park Lands	4	Low

Statewide Impacts

The following quantitative analyses of statewide impacts were determined based on data provided in Tables J-2 and J-3. These data represent an estimate of the percent of North Carolina beach affected by sand disposal for maintenance of federal navigation channels, and existing, proposed, or potential federal and non-federal beach nourishment projects. Table J-6 represents the total project miles for all existing and proposed federal and non-federal beach nourishment projects and the full authorized limits for beach disposal of navigation dredged material. However, assuming all of these activities were constructed to the full extent (which is very unlikely considering funding constraints, dredging needs from navigation channels, etc.) these estimates would not represent the actual extent of North Carolina ocean beach impacted because of overlapping project areas.

Table J-6. Summary of total project miles for existing and/or proposed federal and non-federal nourishment activities and federal navigation disposal.

Project Type	Total Project Miles	% NC Beach
Federal Beach Nourishment	122	38
Non-Federal Beach Nourishment	75	23
Federal Authorized Beach Disposal	41	13
TOTAL	**238**	**75**

Recognizing that many of the existing or proposed federal and non-federal beach nourishment project limits overlap and that some portions of the federal authorized beach disposal limits are within these project areas as well, Table J-7 provides an estimate of total mileage of North Carolina Ocean beach that could cumulatively be impacted by beach nourishment or navigation disposal activities without double counting the overlapping projects.

Table J-7. Summary of cumulative mileage of North Carolina Ocean beach that could be impacted by beach nourishment and/or navigation disposal activities.

Project Type	Total Miles Impacted (*w/o double counting for overlapping projects)	% NC Beach
Federal and Non-Federal Beach Nourishment	112	35
Federal Authorized Beach Disposal	19	6
TOTAL	**131**	**41**

a. Existing Beach Nourishment:

- Of the total 197 potential federal and non-federal beach nourishment project miles proposed for NC ocean beaches (Table J-6), a total of 74 (23%) have actually been constructed. However, this estimate represents actual project miles nourished and does not reflect circumstances where the projects overlap. Therefore, the total number of actual miles of beach nourished is less.

b. Proposed Beach Renourishment:

- 123 miles or 38 percent of the North Carolina ocean beaches are proposed for beach nourishment (federal and non-federal).

c. Cumulative Impacts:

- Considering all proposed and existing disposal and nourishment impacts throughout the ocean beaches of North Carolina, a significant portion of the shoreline will have beach placement activities in the foreseeable future, likely resulting in time and space crowded perturbations. However, recognizing the funding constraints to complete all authorized and/or permitted activities, the availability of dredging equipment, etc.; it is very unlikely that all of these proposed projects would ever be constructed all at once. Therefore, though time and space crowded perturbations are expected in the reasonably foreseeable future, assuming each project adheres to project related impact avoidance measures, it is likely that adjacent un-impacted and/or recovered portions of beach will be available to support dependent species (i.e. surf zone fish, shore birds, etc.) and facilitate recovery of individual project sites to pre-project conditions.

Project Level Impacts
(10-mile study area)

The Surf City and North Topsail Beach study area is a berm and dune project extending along approximately 10 miles of the oceanfront. The southern limit of the project is the boundary between Topsail Beach and Surf City. The northern limit is within North Topsail Beach at the southern edge of the Coastal Barrier Resources System (Topsail Unit, L06).

a. Existing Local Maintenance:

- Under existing conditions, the entire study area (10 miles) is expected to experience frequent local maintenance, including beach scraping, bulldozing, dune restoration, beach restoration, etc.

b. Existing Disposal Activities:

- Annual disposal activities (<200,000 cy) occur within a 1.5 mile area on the north end of N. Topsail Beach, approximately 3,000 feet west of inlet extending westward to Maritime Way (Galleon Bay area).
- The placement of nourishment material along the 10-mile study area is not expected to affect the current disposal schedule.

c. Existing Beach Nourishment:

- None.

d. Proposed Beach Nourishment:

- The entire 10-mile federal study area is proposed for beach nourishment. Additionally, a non-federal study is proposed to nourish the remaining portions of North Topsail beach, including the CBRA units.

e. Cumulative Impacts:

- The currently approved navigation disposal limits are located outside of the proposed project area study area; therefore, none of the area proposed for sand deposition within the 10-mile study area has had previous beach disposal, other then small scale emergency fill events.

- For areas that have had local disturbances (i.e. beach bulldozing), it is possible that the proposed action will impact beach invertebrates in areas that have not fully recovered from past sand deposition, extending recovery time.

Conclusion

Historically, the extent of beach nourishment activities on North Carolina beaches was limited to a few authorized federal projects including: Wrightsville Beach, Carolina and Kure Beaches, and Ocean Isle Beach. However, in the past 10 years, a significant number of federal and non-federal beach nourishment efforts were pursued to provide coastal storm damage reduction along the increasingly developed North Carolina shoreline. Additionally, the number of non-federal permitted beach nourishment projects has increased in recent years in efforts to initiate coastal storm damage reduction measures in the interim of federal projects being authorized and/or funded (i.e. Nags Head, North Topsail Beach, and Topsail Beach). Considering the extent of coastal development and subsequent vulnerability to long and short term erosion throughout the North Carolina shoreline it is likely that the proposed beach nourishment projects within the reasonably foreseeable future will be constructed. Furthermore, the frequency of beach disposal activities for protection of infrastructure will continue throughout the state resulting in cumulative time and space crowded perturbations. However, assuming projects continue to adhere to environmental commitments for the reduction of environmental impacts, and un-developed beaches throughout the state continue to remain undisturbed, it is likely that adjacent un-impacted and/or recovered portions of beach will be available to support dependent species (i.e. surf zone fish, shore birds, etc.) and facilitate recovery of individual project sites to pre-project conditions. Assuming recovery of impacted beaches and the sustainability of un-developed protected beaches (i.e. National/Federal and State Parks and Estuarine Reserves) the potential impact area

from the proposed and existing actions is small relative to the area of available similar habitat on a vicinity and statewide basis.

10. Actions to Reduce Cumulative Impacts

Sections 7.03.6 and 10.06.1 of the Feasibility Report/EIS include environmental commitments and monitoring proposed to minimize project impacts. These actions will also reduce any cumulative impacts related to beach nourishment and offshore borrow activities. Several of the incrementally larger beach projects considered in this assessment including Wilmington Harbor, Bogue Banks (local nourishment project), and Dare County Beaches have conducted significant monitoring components that address beach impacts on northern, central and southern North Carolina beaches. The Dare County Beaches project also has a significant offshore borrow area monitoring component for both pre- and post-borrow activities.

References

Bowen, P.R. & G.A. Marsh. October 1988. Benthic Faunal Colonization of An Offshore Borrow Pit in Southeastern Florida. U.S. Army Corps of Engineers, Dredging Operations Technical Support program. Misc. Rept. D-88-5.

Byrnes, M.R., R.M. Hammer, B.A. Vittor, S.W. Kelley, D.B. Snyder, J.M. Côté, J.S. Ramsey, T.D. Thibaut, N.W. Phillips, and J.D. Wood. 2003. Collection of Environmental Data Within Sand Resource Areas Offshore North Carolina and the Environmental Implications of Sand Removal for Coastal and Beach Restoration. U.S. Department of the Interior, Minerals Management Service, Leasing Division, Sand and Gravel Unit, Herndon, VA. OCS Report MMS 2000-056, Volume I: Main Text 256 pp. + Volume II: Appendices 69 pp.

Cacchione D. A., D. E. Drake, W. D. Grant, and G. B. Tate. 1984. Rippled Scour Depressions on the Inner Continental Shelf Off Central California. *Journal of Sedimentary Petrology*. Vol. 54, No. 4, p. 1280-1291.

Council on Environmental Quality (CEQ). January 1997. Considering Cumulative Effects Under the National Environmental Policy Act.

Hackney, C. T., M. H. Posey, S.W. Ross, and A. R. Norris. 1996. A Review and Synthesis of Data on Surf Zone Fishes and Invertebrates in the South Atlantic Bight and the Potential Impacts from Beach Nourishment. Report to the U.S. Army Corps of Engineers, Wilmington. 110 pp.

Johnson, R.O. and W.G. Nelson. 1985. Biological Effects of Dredging in an Offshore Borrow Area. Biological Sciences. 48 (3): 166-188.

McQuarrie, M.E. 1998. Geologic framework and short-term, storm-induced changes in shoreface morphology: Topsail Beach, NC. *Unpub. M.S. Thesis, Dept. of the Environment, Duke Univ., Durham.* 105p.

Murray A. B. and E. R. Thieler. 2004. A New Hypothesis and Exploratory Model for the Formation of Large-Scale Inner-Shelf Sediment Sorting and "Rippled Scour Depressions." *Continental Shelf Research.* 24: 295-315.

Naqvi, S.M. & C.H. Pullen. 1982. Effects of beach nourishment and borrowing on marine organisms. U.S. Army Corps of Engineers, Coastal Engineering Research Center, Misc. Rept. 82-14.

Posey, M.H. and T.D. Alphin. 2000. Monitoring of Benthic Faunal Responses to Sediment Removal Associated With the Carolina Beach and Vicinity – Area South Project. Final Report. CMS Report No. 01-01.

Saloman, C. H. & S.P. Naughton. 1984. Beach restoration with offshore dredged sand: effects on nearshore macrofauna. U.S. Dept. Commerce, National Oceanic and Atmospheric Administration, NOAA Tech. Mem. NMFS-SEF-133.

Thieler E. R., O. H. Pilkey, Jr., W. J. Cleary, and W. C. Schwab. 2001. Modern Sedimentation on the Shoreface and Inner Continental Shelf at Wrightsville Beach, North Carolina, USA. *Journal of Sedimentary Research.* Vol. 71, No. 6, p. 958-970.

Theiler E.R., P. T. Gayes, W. C. Schwab, and M. S. Harris. 1999. Tracing Sediment Dispersal on Nourished Beaches: Two Case Studies. *Coastal Sediments.* New York, ASCE, p. 2118-2136.

Turbeville, D.B. and G.A. Marsh. 1982. Benthic Fauna of an offshore borrow area in Broward County, FL. US Army Corps of Engineers Coastal Engineering Research Center. Misc. Report. 82-1. pp. 1-43.

U.S. Army Corps of Engineers (USACE), Wilmington District. 2009. Final Integrated General Reevaluation Report and Environmental Impact Statement, Shore Protection, West Onslow Beach and New River Inlet (Topsail Beach), North Carolina. February 2009 (Revised April 2009).

U.S. Army Corps of Engineers (USACE). May 2003. Draft Evaluation Report and Environmental Assessment, Morehead City Harbor Section 933, Carteret County, North Carolina.

U.S. Army Corps of Engineers (USACE). September 2000. Final Feasibility Report and Environmental Impact Statement on Hurricane Protection and Beach Erosion Control, Dare County Beaches (Bodie Island Portion), Dare County, North Carolina Volume I.

U.S. Department of the Interior, Minerals Management Service (DOI). 1999. Environmental Report , Use of Federal Offshore Sand Sources for Beach and Coastal Restoration in New Jersey, Maryland, Delaware, and Virginia. OCS Study MMS 99-0036. Office of International Activities and Marine Minerals. Prepared by The Louis Berger Group, Inc. Contract Number 1435-01-98-RC30820.

Van Dolah, R.F., P.H. Wendt, R.M. Martore, M.V. Levisen, and W.A. Roumillat. 1992. A Physical and Biological Monitoring Study of the Hilton Head Beach Nourishment Project. Marine Resources Division, South Carolina Wildlife and Marine Resources Department, Charleston, South Carolina. March 1992.

Van Dolah, R.F., D.R. Calder, D.M. Knott. 1984. Effects of Dredging and Open-Water Disposal on Benthic Macroinvertebrates in South Carolina Estuary. Estuaries. 7 (1): 28-97.

Wilber, P. and M. Stern. 1992. A Re-examination of Infaunal Studies That Accompany Beach Nourishment Projects. Proceedings of the 5th Annual National Conference on Beach Preservation Technology. 242-257.

Jean Beasley, pers. Comm.

Jutte, P.C. R.F. Van Dolah, and P.T. Gayes. 2002. Recovery of Benthic Communities Following Offshore Dredging, Myrtle Beach, SC. Shore and Beach, Vol. 70, no: 3, pp. 25-30

Jutte, P.C., R.F. Van Dolah, G.Y. Ojeda, and P.T. Gayes. 2001. An Environmental Monitoring Study of the Myrtle Beach Renourishment Project: Physical and Biological Assessment of Offshore Sand Borrow Site, Phase II – Cane South Borrow Area, Final Report, prepared by the South Carolina Marine Resources Research Institute, South Carolina marine Resources Division, Charleston, SC, for the U.S. Army Engineer District Charleston, 70 pp.

Jutte, P.C., R.F. Van Dolah, M.V. Levisen, P. Donovan-Ealy, P.T. Gayes, and W.E. Baldwin. 1999. An Environmental Monitoring Study of the Myrtle Beach Renourishment Project: Physical and biological Assessment of Offshore Sand Borrow Site, Phase I – Cherry Grove Borrow Area, Final Report, prepared by the South Carolina Marine Resources Research Institute, South Carolina Marine Resources Division, C

Feasibility Report
and
Environmental Impact Statement

on

Coastal Storm Damage Reduction

SURF CITY AND NORTH TOPSAIL BEACH
NORTH CAROLINA

Appendix K

Scoping Letters and List of Respondents

Below is a list of agencies/individuals that responded to the NEPA Scoping letter, dated February 14, 2001. Their responses and the NEPA Scoping letter are attached in the same order.

1. U. S. Fish and Wildlife Service, Raleigh Field Office, letter dated 16 March 2001

2. N. C. Department of Cultural Resources, State Historic Preservation Office, letter dated 2 April 2001.

3. N. C. State Clearinghouse, Department of Administration, response dated 19 March 2001

4. PenderWatch & Conservancy, Hampstead, NC, letter dated 13 March 2001

5. N. C. Wildlife Resources Commission, Habitat Conservation Program, letter dated 13 March 2001.

6. N. C. Division of Water Resources, Water Project Section, letter dated 12 March, 2001

7. N. C. Division of Environmental Health, Shellfish Sanitation Section, letter dated 27 February 2001

8. N. C. Division of Environmental Health, Public Health and Pest Management Section, response dated 26 February 2001.

9. N. C. Division of Coastal Management, memorandum dated 23 February 2001

10. N. C. Division of Water Quality, Wilmington Regional Office, response dated 9 March 2001

11. Natural Resources Conservation Service, letter dated 11 February 2002

12. NEPA Scoping letter, letter dated, February 14, 2001

United States Department of the Interior

FISH AND WILDLIFE SERVICE
Raleigh Field Office
Post Office Box 33726
Raleigh, North Carolina 27636-3726

March 16, 2001

Mr. W. Eugene Tickner
Deputy District Engineer
Programs and Project Management
U. S. Army Corps of Engineers
P. O. Box 1890
Wilmington, North Carolina 28402-1890

Dear Mr. Tickner:

This letter is a response to your February 14, 2001, request for scoping comments on a review undertaken by the Wilmington District, U. S. Army Corps of Engineers (Corps) for the communities of North Topsail Beach and Surf City, Onslow and Pender Counties, North Carolina, in the interest of shore protection and related purposes. The Corps is also reinitiating studies necessary to prepare a General Reevaluation Report (GRR) for the community of Topsail Beach in Pender County. An earlier Draft Feasibility Report and Environmental Impact Statement (EIS) (U. S. Army Corps of Engineers [hereafter USACOE] 1988) for Topsail Beach presented a selected plan consisting of a dune constructed to 13 feet above mean sea level and a constructed berm 160 feet wide along a main fill length of approximately 1.9 miles. These three communities are located on Topsail Island, a barrier island (Figure 1). These comments are provided in accordance with provisions of the Fish and Wildlife Coordination Act (48 Stat. 401, as amended; 16 U.S.C. 661-667d) and Section 7 of the Endangered Species Act (ESA) of 1973, as amended (16 U.S.C. 1531-1543). This letter does not constitute the report of the Department of the Interior as required by Section 2(b) of the Fish and Wildlife Coordination Act.

A major concern of the Service is that efforts to reduce storm damage to man-made structures may seriously degrade the habitat values provided by beaches and nearshore marine areas. This concern is most acute in regard to the long-term impacts of engineered structures, e.g., seawalls and artificial beach-dune systems, constructed to allow structures and infrastructure to remain in a fixed location. It is now well known that barrier islands move landward in the face of a rising sea level. Storms and a rising sea may move beaches, but these factors do not eliminate beaches in undeveloped areas (see Figure 2). If a commitment is made to hold man-made structures at a fixed location on islands surrounded by a rising sea, it is likely that temporary measures such as an artificial beach-dune system will inevitably be replaced by larger and larger constructed beaches or harder, permanent structures such as a seawall (see Figure 3). While a seawall would protect structures, the habitat values of the natural beach would inevitably disappear.

The Service also has several concerns regarding the periodic construction of an artificial beach-dune system. The recurring removal of large quantities of sand from offshore and nearshore areas is harmful to the organisms that use such areas. The placement of sand on beaches is harmful to the beach invertebrates living on the beaches and the vertebrates that feed on the beach infauna. The turbidity caused by sand placement and the resulting sedimentation are harmful to nearshore organisms and may adversely impact important hardbottom communities.

The Service believes the single most important planning goal for a storm damage reduction project on Topsail Island should be a rigorous adherence to the procedures contained in the National Environmental Policy Act (NEPA). The current planning effort for all of Topsail Island should not accept the plan selected 13 years ago (USACOE 1988) for construction of an artificial berm and dune system at the southern end of the Island, but take a fresh look at the alternatives available today in light of new information on the impacts to the important biological resources in the project area.

The development of feasible alternatives should be based on a thorough consideration of the rise in sea level. Project planning should use the best available information on present rates of global sea level rise and possible increases in the rate of sea level rise. Titus (1990) notes that estimates of global sea level rise in the 1990-2100 period range from two to seven feet, and considers the effects on barrier islands. Hudgens (1999) notes that predictions of relative sea level rise at Hampton Roads, Virginia, between 1990 and 2100 range from 18 to 45 inches and considers possible adaptions to the National Flood Insurance Program. Titus and Narayanan (1995) write that sea level is most likely to rise six to 13 inches in the 1995-2100 period, but there is a ten percent chance that the rise in this period could be 12 inches by 2050 and 26 inches by 2100. While future projections vary, it is clear that the rate of sea level rise is increasing and that projections based on past evidence are not justified. In developing feasible alternatives for storm damage reduction on North Carolina's barrier islands, the issue of future sea level rise should be addressed with an indication of how the efficacy of each alternative would be affected by various elevations of sea level, e.g., 1, 2, and 3 feet by 2050.

The movement and creation of sediment in Onslow Bay, offshore of Topsail Island „ should also be considered. Cleary (2001) states that much of the shoreline in southeastern North Carolina is "sediment starved ... [with] little storm protection in place and ... marginal or no potential for locating beachfill quality sand on the shoreface for nourishment programs. As a consequence, major sections of some of the high hazard shoreline reaches will have to be abandoned, as relocation to a nearby site is not an option." Most of the sediments in Onslow Bay are created through bioerosion of offshore hardbottoms of limestone and siltstone (e.g., Riggs et al. 1998). Topsail Island and Onslow Beach are well-known for the extensive rock outcrops offshore, including rock ledges and rubble mounds that can be found in 30 feet of water with up to 15 feet in relief (e.g., Riggs 1994, Riggs et al. 1995). "Morphologically prominent hardbottoms are actively being degraded and retreating in response to intense bioerosion by endolithic bivalves, crustaceans, and worms" (Riggs et al. 1996, p. 844). This bioerosion may develop seafloor relief of millimeters to meters to tens of meters depending on the lithology and bioerosional processes

involved (Riggs et al. 1998). The paucity of sand offshore and underneath the island controls the erosion and accretion patterns and storm response of these communities by making them less flexible to movement and absorption of wave energy (e.g., Riggs 1994, Riggs et al. 1995, Cleary 2001).

Your letter indicates that shore protection alternatives include no action, beach nourishment, and non-structural measures (relocation). The Service recommends two additional approaches that could be used either singularly or in combination. First, modification of existing development and infrastructure. This approach includes retrofitting existing structures to withstand storms, elevating houses, and improved placement of roads and utility lines. Second, improved zoning and land use planning. This second approach would include greater avoidance of hazard areas by development, expanded use of setbacks for structures, and overall lower development density. Both alternatives would significantly reduce storm damage.

Of all the barrier islands in North Carolina, Topsail Island is the most in need of innovative storm damage reduction methods. At least three hurricanes in the last four years have severely affected this island, cutting storm breaches through the island and effortlessly rearranging homes and mobile home parks. Pilkey et al. (1998, p. 171) characterize the island following Hurricane Fran in 1996 as resembling a war zone that had been bombed. The south end of the island was redesigned by natural storm processes (e.g., dunes and vegetation removed). Vacant lots currently exist throughout the island, suggesting that relocation of oceanfront structures as needed over time is feasible. Figure 4 shows that new lots are being sold on the sound-side of the island as overwash nourishes the marshes and creates new upland habitat.

The Service requests that special attention be given to one potential type of relocation. This option would consist of a systematic program to use the uplands created by natural island overwash as relocation sites for threatened, oceanfront structures. The Corps has informed the Service that "many acres of marsh" at Topsail Beach have been buried in sand to the extent that these areas have become uplands suitable for buildings (Figure 4). The Service requests that the alternatives analysis quantify the area of buildable uplands created by the hurricanes in the 1996-1999 period and compare that area to the areal extent of oceanfront land lost to shoreline recession. The alternative analysis could then include a detailed description and analysis of a systematic, long-term program for relocating threatened oceanfront structures to uplands created by natural island overwash.

The Service recommends that the Corps ask the Federal Emergence Management Agency (FEMA) to serve as a cooperating agency for this storm damage reduction project. The FEMA deals with the aftermath of storms and the recovery process. This agency has knowledge of storm damage reduction through its Hazard Mitigation Program and the evaluation of land-use and control measures used to rate communities for the National Flood Insurance Program. The cooperation and input from the FEMA, especially in regard to removing structures in high hazard zones, would be a major step in dispelling the idea that the preferred alternative is biased toward the construction of an artificial beach-dune system.

A significant indirect impact that should be addressed in the EIS is the most likely socioeconomic condition of the project area at the end of the 50-year life of the initial storm damage reduction project. We would hope the EIS should specifically discuss: (1) whether storm damage efforts can be allowed to end after 50 years; (2) if storm damage efforts are forced to end after 50 years, what are the mostly likely consequences for structures on Topsail Island; and (3) if storm damages efforts are continued beyond 50-years which alternative, e.g., beach nourishment, relocating structures, etc., has the best chance of success for an additional 50 years. All the environmental factors should be carefully weighed to determine the alternative with the least overall environmental impacts.

The Service has outlined the direct impacts of a major sand mining-beach construction operation (U. S. Fish and Wildlife Service [hereafter USFWS] 2000, Appendix B) in six tables. The EIS needs to consider the environmental consequences of each direct impact listed in these tables. The Service believes that most, if not all, of these physical changes will adversely impact fish and wildlife resources.

Sand mining is likely to alter the bathymetry and substrate characteristics of offshore borrow areas (USFWS 2000, Appendix B, Table 6), sites of significant microalgal biomass where production is concentrated in the surface layer of bottom sediment. Cahoon and Cooke (1992) state that primary production data from Onslow Bay indicate that the sediment-water interface must be viewed as a dynamic part of continental shelf habitat. Benthic microalgae provide a dependable food source for both benthic deposit feeders and suspension feeders. The physical alterations given by the Service produce both direct and indirect impacts on primary productivity and benthic fauna. The direct environmental consequences of removing benthic microalgae as part of any offshore sand mining should be evaluated. The Service is also concerned that greater depths at offshore borrow areas produced by sand mining will result in reduced primary productivity. Cahoon et al (1990) concluded that the presence of benthic chlorophyll *a* indicated a productive benthic microflora in Onslow Bay. While some benthic primary productive exists across the bay, this work indicates that concentrations of chlorophyll *a* decrease as water depth increases, and thus sand mining that produces permanent pits in offshore areas is likely to lower primary productivity. There is also a reduction in the number of algae species with depth and creating pits by mining sand has the potential to lower species diversity (Schneider 1976 as cited in Cahoon et al. 1990).

According to our information, sediment for a long-term nourishment project anywhere along Topsail Island is limited to non-existent. Cahoon et al. (1990) cite Mearns et al. (1988) as finding that the sediment in Onslow Bay is generally a thin veneer overlaying hard substrates. Backstrom et al. (2001), for example, characterize the shoreface offshore of Surf City as not containing "a significant volume of sand ... [for] a viable borrow site" of nourishment sand within the nearest 75 square kilometers. The offshore seafloor consists of extensive hardbottoms covered with a "patchy, thin veneer of interbedded muddy sands and shell units." Backstrom et al. (2001) estimate that over 3.5 million cubic meters of sand would be needed for an initial beach fill project, a volume not available in the area, and they note that Surf City's "central

location along Topsail Beach and the use of the relatively small bordering ebb deltas further minimizes future nourishment." These authors suggest that additional development be discouraged.

Sediment placement during the sea turtle nesting season is likely to adversely affect the reproductive success of these federally-listed species. Sand disposal operations conducted during the nesting and hatching season may result in the burial or crushing of nests or hatchlings or loss of sea turtles through disruption of nesting activity. While a nest monitoring and relocation program would likely reduce these impacts, nests may be inadvertently missed or misidentified as false crawls during daily patrols. Nests may be destroyed by operations at night prior to beach patrols being performed. Under the best of conditions, approximately 7 percent of nests are misidentified as false crawls by experienced sea turtle nest surveyors (Schroeder, 1994).

The EIS should discuss the direct impacts of alternatives other than a beach nourishment program. The EIS would be enhanced by a table that compares the direct impacts of all the alternatives developed.

Indirect impacts, also known as secondary impacts, are those that occur in a different location and at a different time from a given action. The Service has listed the indirect, physical impacts associated with a long-term program of beach nourishment (USFWS 2000, Appendix B). As with direct impacts, the alteration or modification of physical characteristics or processes are very likely to adversely impact fish and wildlife resources. The Service recommends that the environmental staff of the Corps consider the environmental pathways between the physical impacts presented and the habitat values of the project area.

One indirect impact of an artificial berm and dune project is sediment starvation of the sound-side shoreline by preventing cross island overwash of sand during storms. Croft and Leonard (2001) state "coastal development, inlet stabilization, and post-storm bulldozing, disrupt the natural processes of marsh accretion by limiting sediment inputs." All three of these processes already occur on Topsail Island, where both New River and New Topsail Inlets are maintained with navigational dredging and beach bulldozing occurs regularly. Figure 4 illustrates an instance when the natural processes succeeded in nourishing the marsh despite coastal development; the replacement of the bulldozed dune or levee ridge, however, will prevent further nourishment of the marsh until the next large storm. Large-scale nourishment projects that construct and maintain berm and levee systems inhibit this natural process on a grand scale, and such adverse impacts should be addressed.

A major indirect impact of maintaining the island at its present location as sea level rises is the gradual reduction in freshwater supplies to plants and animals (Figure 3). In coastal areas fresh groundwater is found as a lens overlying salt water. The depth to which freshwater extends below sea level in unconfined aquifers is usually estimated to be 40 times the elevation of the water table above mean sea level (Fletcher 1992). As sea level rises the capacity of the freshwater lens is reduced. If the North Carolina barrier islands are held in place and not allowed

to naturally migrate to higher ground as sea level rises, the islands will become similar to ocean coral atolls that cannot migrate. Roy and Connell (1991) have considered the impact of sea level rise on coral atolls. Fletcher (1992) summarizes these concerns by stating:

> "As erosion reduces island size, groundwater lens shrink beneath larger islands and nearly disappear beneath smaller ones. Vegetation and island ecosystems become stressed by the decrease in usable water and the ability to support human habitation is reduced. . . . Storm overwashes would increase in frequency, damaging vegetation and coastal development, and increase the salinization of the fresh ground water lens. Conceivably (Roy and Connell 1991), in the next several decades accelerated coastal erosion on the order of 1-2 m/yr, resulting from accelerated sea-level rise, could reduce the dimensions of some presently inhabited islands to the point where their ground water supplies are no longer able to support a viable ecology or permanent human habitation."

While human habitation of North Carolina barrier islands may not face the same threats as ocean atolls, the communities of plants and animals may be at risk. Human inhabitants are able to bring in freshwater from the mainland and construct artificial barriers to protect structures. However, artificial barriers will not stop the subsurface rise of salt water under the island. In time the shallow freshwater resources on which plants and animals depend may be lost. The 1992 land use plan of Surf City notes that town water is derived from wells supplied by the Castle Haynes limestone aquifer (Surf City 1993). The wells are located about a mile inland because of poor water quality (e.g., iron, chlorides, etc.) in the immediate beach area. The presence of chlorides in water supplies suggests that salt water intrusion is occurring. Development based on the sense of security provided by an artificial beach-dune system would create additional demands on freshwater supplies and wastewater treatment facilities. The future availability of freshwater resources for plant and animal communities under various sea level rise scenarios should be addressed. This would be especially important if efforts to reduce storm damage are based on a plan to hold the island in its present location and prevent natural island migration (Figure 3).

The indirect impacts of removing millions of cubic yards of sand from the seafloor around Topsail Island should also be addressed. Sand removal would create a deeper nearshore environment and allow waves with greater energy to strike the beach. The project EIS should consider the storm damage implications of higher energy waves striking the beach as the offshore area becomes deeper.

The potential for turbidity and sedimentation resulting from sand mining (USFWS 2000, Appendix B, Tables 5 and 6) and beach placement (USFWS 2000, Appendix B, Table 4) may directly harm hardbottoms by covering exposed rock substrate. These types of hardbottoms can support vast macroalgal meadows or no visible biota at all, and are the most abundant type of hardbottom in Onslow Bay (Riggs et al. 1996).

High relief scarped hardbottoms support flourishing reef-fish communities (Riggs et al. 1996). Species diversity and density of infauna and epibenthos increases with the relief of these types of livebottoms.

The availability of specific hardbottoms for development of a benthic community, as well as the structure of that community, are greatly influenced by specific habitat controls including composition, geometry, and morphology (Riggs et al. 1996, p. 844). Surficial sediment patterns control the composition and spatial distribution of benthic communities (Riggs et al. 1998). Thus any project that could remove or add to the surface sediments via dredging and filling will influence the availability of the hardbottom habitats, their benthic communities and the structure of those communities. The Corps has stated that "[B]orrow sites designated solely for nourishment can experience the greatest impact if the borrow activity affects hard bottom communities, or there is a change in sediment composition" (Yelverton 2001). Thus long-term beach construction along this island would affect sensitive hardbottoms and introduce a different sediment composition (quartz sand as opposed to carbonate, silty or rock fragmented material) to the nearshore system. 7

The addition of millions of cubic yards of sediment from beach fill projects poses a significant threat to the sensitive nearshore habitats. Thieler et al. (1995) documented that sediment moves from Wrightsville Beach offshore to at least 17 meters (56 feet) water depth. Approximately 2 million cubic meters (2.6 million cubic yards), or one-fourth, of the nourishment sediment for Wrightsville Beach has accumulated on the lower shoreface and inner shelf in water depths exceeding 9 meters (29 feet) (Thieler et al. 2001). Riggs (1994) states that nourishment sediment has buried hardbottoms off Wrightsville Beach, Carolina Beach and Kure Beach, taking these reefs "out of production" for aquatic resources. A water depth of 9 to 28 meters (29-92 ft) is traditionally not considered to have significant sediment movement in a coastal engineering sense, but this research shows that it does have a significant impact in an ecological sense. Riggs (1994) expresses concern that a beach construction project on Topsail Island could harm offshore hardbottoms. The Corps GRR, feasibility report and EIS should fully consider the adverse impacts that sedimentation due to either dredging or sand placement could have on the highly productive hardbottom communities of Onslow Bay and the fisheries resources that they support.

The long-term adverse impacts on populations of beach macroinvertebrates should be considered in the evaluation of all project alternatives. An earlier planning document (USACOE 1988, p. eis-1-5) states that no long term impacts on beach infauna would occur. This assessment considered a main beachfill of approximately 1.9 miles, and not the approximately 17-18 miles currently under consideration. Smaller linear distances of beach construction allow for greater recruitment from undisturbed adjacent beaches. If beaches receive new sediment every three years, there is a question as whether some areas of the artificial beach will be repopulated at all or ultimately have a greatly reduce invertebrate population. Any determination that a 50-year program of sand disposal for beach construction can be completed without harm to beach invertebrates should be supported with references to the life cycles of these organisms, the timing

of future sand placements, and the direction of the longshore current in relation to adjacent undisturbed beaches.

Project planning should evaluate the ways in which each alternative would influence future development in the project area. For example, a beach nourishment project aimed at providing storm surge protection for hurricanes in categories 1-3 may provide a sense of security that leads to additional development of more and larger structures. All the additional development would be vulnerable to the storm surge of a hurricane in categories 4-5. If the project is designed to protect against hurricanes in categories 1-3, the EIS should clearly describe the socioeconomic impacts associated with the landfall of a major storm, such as a category 5 hurricane, for which protection is not intended.

The species protected by the ESA that are most likely to affected on Topsail Island include the loggerhead sea turtle (*Caretta caretta*), green sea turtle (*Chelonia mydas*), piping plover (*Charadrius melodus*), and seabeach amaranth (*Amaranthus pumilis*). The two sea turtles and the piping plover were the subject of a December 29, 1989, Biological Opinion for the West Onslow Beach and New River Inlet Project.

All five Atlantic sea turtles are protected by the ESA and may occur in the coastal waters of North Carolina. In addition to the threatened loggerhead and green sea turtles, offshore water may be used by federally endangered Kemp's ridley (*Lepidochelys kempi*), hawksbill (*Eretmochelys imbricata*), and leatherback (*Dermochelys coriacea*) sea turtles. Any consideration of sand placement during the sea turtle nesting and incubation period, May 1 through November 15, should include measures to minimize adverse impacts on sea turtle reproduction. Measures to relocate sea turtle nests should discuss the area to which nest would be relocated and the physical differences, e.g., sand grain size, sand color, moisture availability, between the natural nest site and the relocation nest site.

Piping plovers use the project area for nesting, migration, and overwintering (U. S. Fish and Wildlife Service [hereafter USFWS] 1989, p. 23). Nesting piping plovers within the project area are part of the Atlantic Coast population, and are federally listed as threatened. Piping plovers nest above the high tide line on coastal beaches; on sandflats at the ends of sandspits and barrier islands; on gently sloping foredunes; in blowout areas behind primary dunes (overwashes); in sparsely vegetated dunes; and in overwash areas cut into or between dunes. The species requires broad, open, sand flats for feeding, and undisturbed flats with low dunes and sparse dune grasses for nesting. Piping plovers from the Federally endangered Great Lakes population as well birds from the threatened populations of the Atlantic Coast and Northern Great Plains overwinter on North Carolina beaches. Project planning must consider the manner and extent to which each alternative would impact the primary constituent elements of plover overwintering habitat.

Seabeach amaranth, an annual plant, exists adjacent to inlets, along beaches between dunes and the high tide line, and in areas of extreme overwash. The plant helps to trap sand and build dunes. The species is listed as threatened by both the federal government and the State of North

Carolina. Suitable habitat for this plant occurs in the project area. The Service reported that 50 plants were found during a survey of the south end of Topsail Island during the late 1980s (USFWS 1989, p. 26). Service records contain a letter from the Corps dated February 22, 1993, that reports survey data for seabeach amaranth on Topsail Beach during 1992. This survey reported 22,410 plants on Topsail Beach. Therefore, project planning should consider potential impacts of the various alternatives on this species.

The lack of offshore sand may lead to a consideration of sand mining at inlets and estuarine areas. In the mid-1980s planning for berm construction along the southern part of Topsail Beach included excavation of material from estuarine areas in Banks Channel. Sand mining at inlet and estuarine bottoms, especially areas with submerged aquatic vegetation, during the warmer months of the year would pose a risk to the federally endangered West Indian manatee (*Trichechus manatus*), also known as the Florida manatee. Numbers of manatee sightings are very low, but they do occur along the southern coast of North Carolina (Schwartz 1995). Such mining poses a risk to other protected marine mammals. If such areas are considered as possible mining sites, the Corps should assess potential impacts to the marine mammals and fisheries resources that pass through the inlet and/or use estuarine habitats in the project area.

If the Corps determines that the preferred alternative may affect federally-listed species, consultation with the Service must be initiated. Marine mammals, such as whales, seals, porpoises, and dolphins, are under the jurisdiction of the National Marine Fisheries Service and that agency should be contacted regarding these animals.

In addition to federally species, Corps planning should also consider impacts to state protected species. The North Carolina Natural Heritage Program (NCNHP) has a web page (http://www.ncsparks.net/nhp) that provides information on state-listed species by topographic quad. Most of the project area falls within three quads: New River Inlet, Holly Ridge, and Spicer Bay. The table below gives four species of birds and two species of reptiles that occupy habitats occurring in the project area. These species have special status in North Carolina. The Service will address potential impacts to the these species in our Fish and Wildlife Coordination Act Report. However, the Corps may also consider potential impacts during early project planning.

Common Name	Scientific Name	North Carolina Status	General Habitat
Birds			
Bachman's sparrow	*Aimophila aestivalis*	Special Concern	open pine woods with undergrowth of bushes and grass
Black skimmer	*Rynchops niger*	Special Concern	beaches
Gull-billed tern	*Sterna nilotica*	Threatened	marshes, fields, coastal bays
Eastern painted bunting	*Passerina ciris ciris*	Significantly Rare	maritime shrub thicket
Reptiles			
American alligator	*Alligator mississippiensis*	Threatened	brackish waters and marshes
Carolina Diamondback Terrapin	*Malaclemys terrapin centrata*	Special Concern	coastal marsh, tidal flats, brackish waters

The Service has outlined the cumulative physical impacts of the beach nourishment option that may degrade habitat for fish and wildlife resources (USFWS 2000, Appendix B, Tables 1-6). We encourage the Corps to address these impacts in the context of both ongoing and future beach nourishment programs within North Carolina. The Service also recommends that the project EIS consider any cumulative impacts associated with statewide removal of threatened structures, improved construction standards, and zoning restrictions that would reduce the vulnerability of structures to coastal storms. In regard to storm damage reduction projects, the Service recommends that North Carolina be considered the geographic area and the time frame be 50 years, the customary official planning life of federal beach nourishment projects.

Topsail Island already has active beach disposal of navigational dredge spoil (Fig. 1) at both Topsail Beach and North Topsail Beach. Beach scraping or bulldozing occurs on an annual basis and artificial levees are reconstructed after every storm event. Some structures are protected by sandbags. Over 1300 permits have been issued by the Corps for beach scraping and sandbag revetments in North Carolina since 1980 (J. Richter, pers. comm., February 2001). Federal, local and private beach nourishment projects are proposed or ongoing for over half of the North

Carolina shoreline, more than double the proportion of any other state in the southeast (USFWS, unpub. data). The hardbottoms of Onslow Bay have already been adversely impacted by nourishment projects at Wrightsville, Carolina and Kure Beaches. Projects proposed or ongoing at Figure Eight Island, Onslow Beach, and Bogue Banks will further increase the proportion of Onslow Bay coastline artificially manipulated and maintained. Thus the impacts of these proposed projects on Topsail Island pose a cumulative threat to the Onslow Bay coastal and marine ecosystems.

One approach to cumulative impacts analysis is the preparation of an area-wide or programmatic EIS. Such a comprehensive document is particularly useful when similar actions, viewed with other reasonably foreseeable or proposed agency actions, share common timing or geography. The many projects in North Carolina that involve the dredging of sand from offshore, nearshore, and inlets for placement on developed beaches share many important geological and biological characteristics. For these projects that gradually affect a greater proportion of beaches and offshore areas in North Carolina, an overview or area-wide EIS would serve as a valuable analysis of the affected environment and the potential cumulative impacts of reasonably foreseeable actions for storm damage reduction within the state.

The Service requests that the Corps prepare a programmatic EIS for its civil works and regulatory activities along the North Carolina coast prior to proceeding with the development of specific project plans at Topsail Island, Bogue Banks, Dare County Beaches South (Hatteras and Ocracoke Islands Portion), and Brunswick County Beaches (Caswell Beach, Oak Island and Holden Beach Portion). Such a comprehensive effort would yield a coastal management strategy that identifies areas where socioeconomic resources support shoreline stabilization and those where ecological resources support no such activities. The Service would be willing to partner with the Corps in this endeavor.

Overall, the Service requests that planning for storm damage reduction on Topsail Island have a clear, logical path from the project need to the selection of the preferred alternative. The Service also requests that the Corps hold an interagency scoping meeting and interagency planning meetings and for this project. These meetings would allow a full and open dialogue between all of the planning partners and sponsors and allow issues to be addressed early in the planning process rather than creating obstacles at a later date. These meeting should be initiated while alternatives are being developed. At these meetings all affected agencies could discuss information on the value of property to be protected, offshore sand resources, potential areas for sand mining, and details of a phased program of structural relocation. In addition to state and federal resource agencies, the FEMA and North Carolina Department of Emergency Management should attend and present their perspectives on the extent to which the various alternatives would reduce storm damage.

The Service appreciates the opportunity to provide these comments and we look forward to continued involvement with the Corps on this project. Please keep this office informed on progress in the planning process. General questions or comments should be directed to Howard

Hall at 919-856-4520, ext 27, or by e-mail at < howard_hall@fws.gov >. Specific questions regarding the physical environment and impacts of various alternatives may be directed to Ms. Tracy Rice at ext. 12 or at < tracy_rice@fws.gov >.

Sincerely,

Garland B. Pardue
Ecological Services Supervisor

FWS/R4/HHall/March 16, 2001/919-856-4520, ext. 27/C:TB_Scop301fin.wpd

cc:

Bruce Bell, USFWS, Atlanta, GA
Gerald Miller, US EPA, Atlanta, GA
Larry Hardy, NMFS, Beaufort, NC
William Straw, FEMA, Atlanta, GA
Steve Benton, NC Division of Coastal Management, Raleigh, NC
Charles Jones, NC Division of Coastal Management, Raleigh, NC
Preston Pate, NC Division of Marine Fisheries, Morehead City, NC
Frank McBride, NC Wildlife Resources Commission, Raleigh, NC
David Allen, NC Wildlife Resources Commission, Trenton, NC
Joanne Steenhuis, NC Division of Water Quality, Wilmington, NC
Gavin Smith, NC Division of Emergency Management, Raleigh, NC

Literature Cited:

Backstrom, J.T., K.T. Willson, A.M. McLeod, and W.J. Cleary, 2001. A reconnaissance study of shoreface sand resources off a storm impacted barrier: Surf City, North Carolina. Geological Society of America Southeastern Section Annual Meeting, 2001 Abstracts with Program.

Cahoon, L. B. and J. E. Cooke. 1992. Benthic microalgal production in Onslow Bay, North Carolina, USA. Marine Ecology Progress Series. 84:185-196.

_____, R. S. Redman, and C. R. Tronzo. 1990. Benthic microalgal biomass in sediments of Onslow Bay, North Carolina. Estuarine, Coastal and Shelf Science. 31:805-816.

Cleary, W.J., 2001. Availability of offshore sand resources for shoreline restoration in southeastern North Carolina. Geological Society of America Southeastern Section Annual Meeting, 2001 Abstracts with Program.

Croft, A., and L.A. Leonard, 2001. Effects of dredged material disposal on tidal marsh processes. Geological Society of America Southeastern Section Annual Meeting, 2001 Abstracts with Program.

Fletcher, C. H. III. 1992. Sea-level trends and physical consequences: applications to the U.S. shore. Earth Science Reviews. 33:73-109.

Hudgens, D. 1999. Adapting the National Flood Insurance Program to relative sea level rise. Coastal Management. 27:367-375.

Mearns, D. L., A. C. Hine, and S. R. Riggs. 1988. Comparison of sonographs taken before and after Hurricane Diana, Onslow Bay, North Carolina. Geology 16:267-270.

Pilkey, O.H., W. J. Neal, S. R. Riggs, C. A. Webb, D. M. Bush, D. F. Pilkey, J. Bullock, and B. A. Cowan. 1998. The North Carolina Shore and Its Barrier Islands - Restless Ribbons of Sand. Duke University Press. Durham, North Carolina. 318 pp.

Riggs, S. R. 1994. Nonliving resources. pp. 13-19. in Hart, K. (ed.) Managing the Coastal Ocean for the 21th Century: North Carolina's Role. A proceedings from a conference held May 20-21, 1993, University of North Carolina at Wilmington. N.C. Sea Grant Publication UNC-SG-94-02. 54 pp.

_____, W.J. Cleary and S.W. Snyder. 1995. Influence of inherited geologic framework on barrier shoreface morphology and dynamics. Marine Geology. 126:213-234.

_____, S.W. Snyder, A.C. Hine and D.L. Mearns. 1996. Hardbottom morphology and relationship to the geologic framework: Mid-Atlantic continental shelf. Journal of Sedimentary Research. 66(4):830-846.

_____, W.G. Ambrose Jr., J.W. Cook, Scott W. Snyder, and Stephen W. Snyder. 1998. Sediment production on sediment-starved continental margins: The interrelationship between hardbottoms, sedimentological and benthic community processes, and storm dynamics. Journal of Sedimentary Research. 68(1):155-168.

Roy, P. and J. Connell. 1991. Climatic change and the future of atoll states. J. Coastal Research. 7:1057-1075.

Schneider, C. W. 1976. Spatial and temporal distribution of benthic marine algae on the continental shelf of the Carolinas. Bulletin of Marine Science. 26:133-151.

Schroeder, B. A. 1994. Florida index nesting beach surveys: Are we on the right track? Proceedings of the Fourteenth Annual Symposium on Sea Turtle Biology and Conservation. NOAA Technical Memorandum NMFS-SEFSC-351:132-133.

Schwartz, F. J. 1995. Florida manatees, *Trichechus manatus* (Sirenia: Trichechidae), in North Carolina 1919-1994. Brimleyana 22: 53-60.

Surf City. 1993. Land Use Plan - 1992 Update. 75 pp. + Appendices.

Thieler, E. R., A. L. Brill, W. J. Cleary, C. H. Hobbs III, and R. A. Gammisch. 1995. Geology of the Wrightsville Beach, North Carolina shoreface: Implications for the concept of shoreface profile of equilibrium. Marine Geology. 126:271-287.

_____, W.C. Schwab, R.P. Signell, P.T. Gayes, and M.S. Harris, 2001. The shoreface as a source and sink for beach nourishment. Geological Society of America Southeastern Section Annual Meeting, 2001 Abstracts with Program.

Titus, J. G. 1990. Greenhouse effect, sea level rise, and barrier islands: case study of Long Beach Island, New Jersey. Coastal Management. 18:65-95.

_____ and V. Narayanan. 1995. The probability of sea level rise. U. S. Environmental Protection Agency. EPA 230-R95-008. USEPA. Washington, DC. 186 pp.

U. S. Army Corps of Engineers. 1988 (December). (Draft) Feasibility Report and Environmental Impact Statement on Hurricane Protection and Beach Erosion control - West Onslow Beach and New River Inlet, North Carolina (Topsail Beach). Wilmington District, U. S. Army Corps of Engineers, Wilmington, NC. various pagination.

U. S. Fish and Wildlife Service. 1989 (December). Fish and Wildlife Coordination Act Report on Hurricane Protection and Beach Erosion Control at Topsail Beach, Pender County, North Carolina. Raleigh Field Office, Raleigh, NC. 39 pp. + Appendices.

_____. 2000 (August). Drat Fish and Wildlife Coordination Act Report. Brunswick County Beaches Project, Brunswick County, North Carolina. Raleigh Field Office, Raleigh, NC. 174 pp. + Appendices. Attached

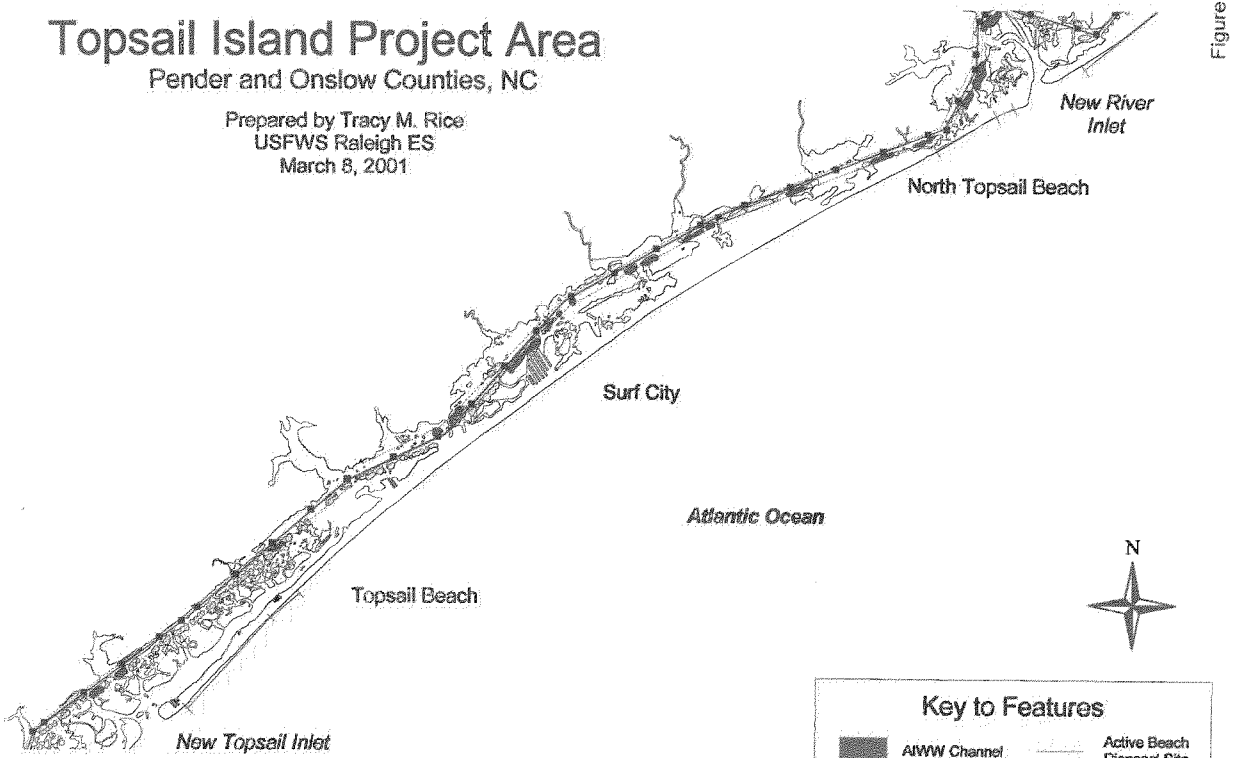
Yelverton, G.F., 2001. Corps of Engineers' views of environmental impacts of beach nourishment. Geological Society of America Southeastern Section Annual Meeting, 2001 Abstracts with Program.

Figure 1

Topsail Island Project Area

Pender and Onslow Counties, NC

Prepared by Tracy M. Rice
USFWS Raleigh ES
March 8, 2001



Data Source: COE Wilmington District AIWW Project for ArcView 3.2

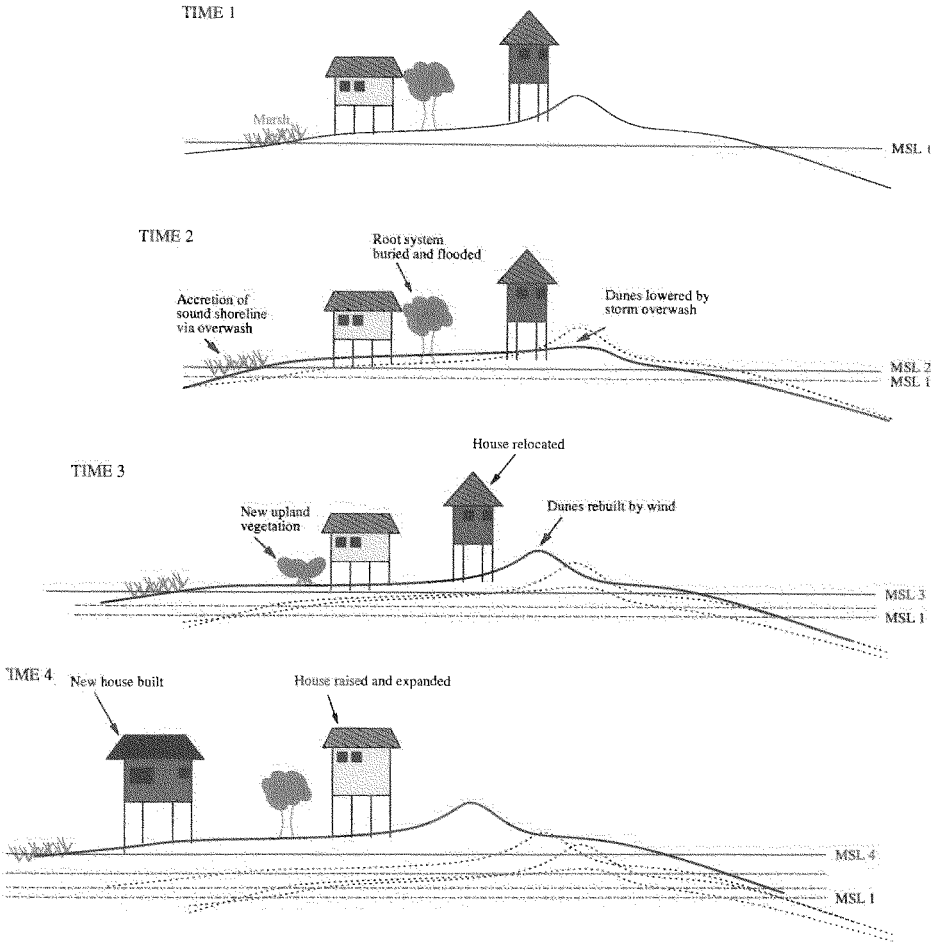


Figure 2. Barrier island migration during a period when sea level is rising at an accelerating rate. Habitat types shift landward (to the left) with the island, but are not permanently lost. Development can be relocated from the ocean–front to the soundside over time.

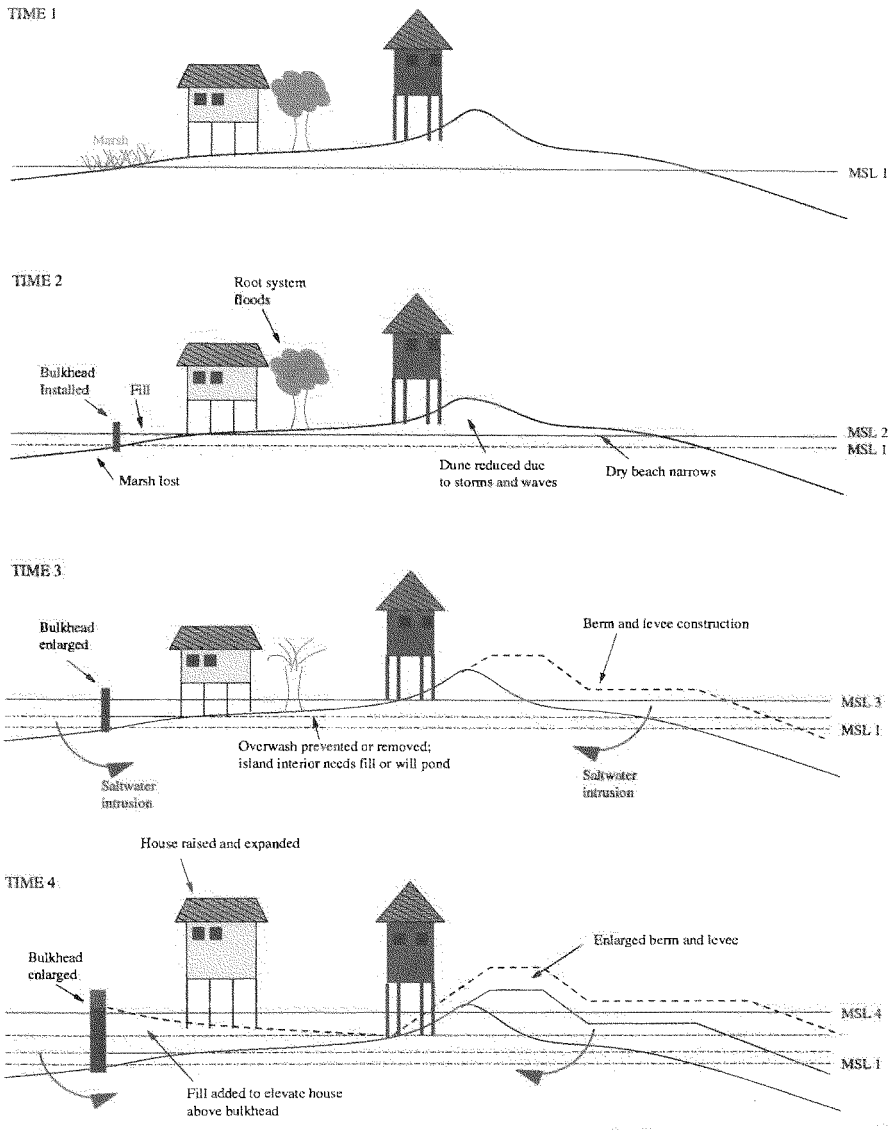
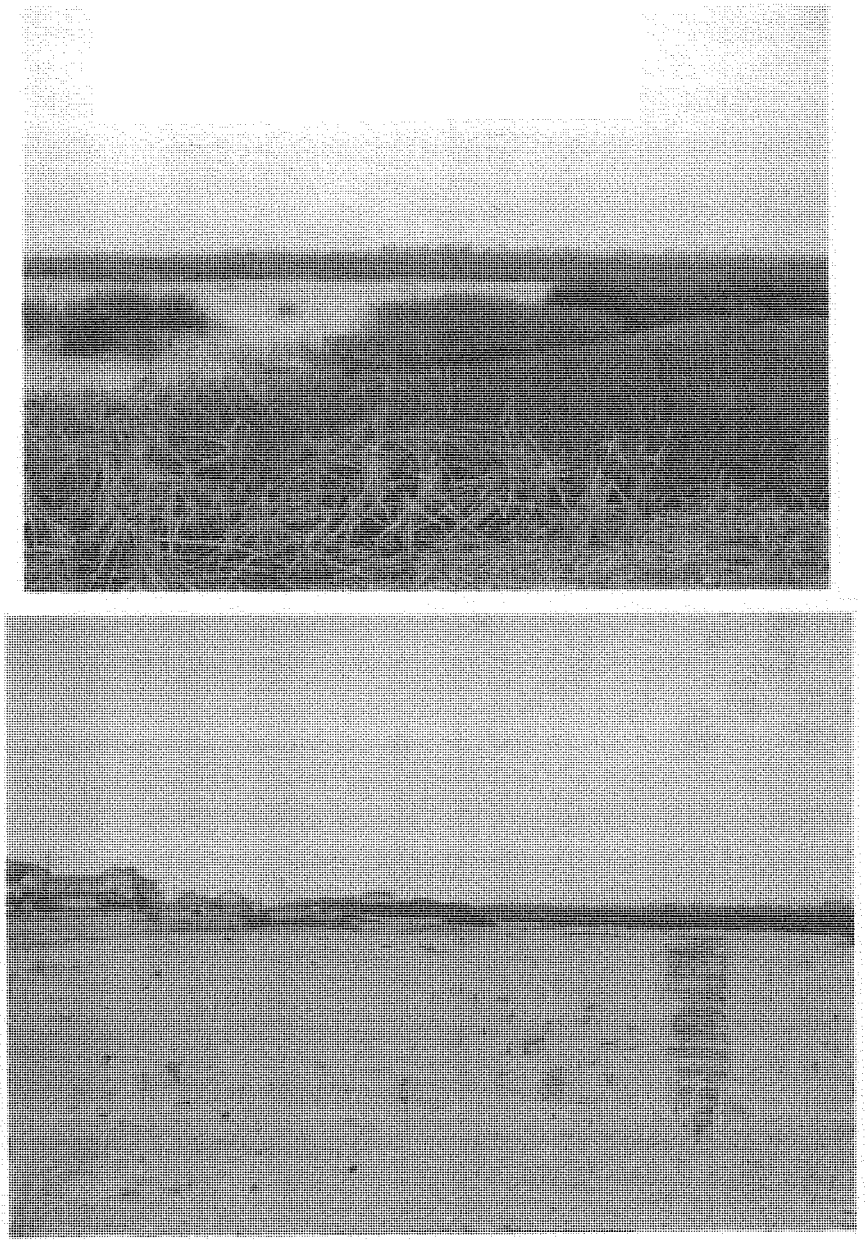


Figure 3. Evolution of a barrier island during a period when sea level is rising at an accelerating rate and the shorelines are stabilized. Habitats are modified and lost, saltwater intrudes on the freshwater table, and a circle of "dikes" replaces island migration processes.

Figure 4. Storm overwash of sand has naturally nourished the sound-side marshes of North Topsail Beach (top), creating new upland habitat that is now listed for sale and development (bottom). Photographs taken February 14, 2001 by U.S. Fish and Wildlife Service.



North Carolina Department of Cultural Resources
State Historic Preservation Office
David L. S. Brook, Administrator

Michael F. Easley, Governor
Lisbeth C. Evans, Secretary

Division of Archives and History
Jeffrey J. Crow, Director

April 2, 2001

Glenn McIntosh
U.S. Army Corps of Engineers
Wilmington District
PO Box 1890
Wilmington, NC 28402-1890

Re: Shore protection activities, Surf City and North Topsail, between New Topsail Inlet and New River Inlet, Pender & Onslow Counties, CH 01-E-0000-0497

Dear Mr. McIntosh:

We have received notification form the State Clearinghouse concerning the above mentioned study area. We would like to take this opportunity to comment.

The shore protection activities, especially beach bulldozing operations involved with re-nourishment, may encounter the remains of vessels lost along the on the beach between New Topsail Inlet and New River Inlet and buried over the last 450 years.

There is one known beach wreck (0001NTB) located within the study area that should be avoided. Our underwater research files also indicate at least five known ship losses between the two inlets.

While the archaeological and historical record does not support a recommendation for a comprehensive archaeological survey, all involved parties should be aware that the possibility that this work may unearth a beached shipwreck. If such an event occurs, work should move to another area and the Underwater Archaeology Branch contacted immediately (910/458-9042). A staff member will be sent to make an assessment of the wreckage and determine the proper course of action. Any questions regarding the wreck 0001NTB can be directed to the Underwater Archaeology Branch (910/458-9042).

The above comments are made pursuant to Section 106 of the National Historic Preservation Act and the Advisory Council on Historic Preservation's Regulations for Compliance with Section 106 codified at 36 CFR Part 800.

Thank you for your cooperation and consideration. If you have questions concerning the above comment, contact Renee Gledhill-Earley, Environmental Review Coordinator, at 919/733-4763.

Sincerely,

Renee Gledhill-Earley

David Brook
Deputy State Historic Preservation Officer

DB:kgc

cc: State Clearinghouse

NORTH CAROLINA STATE CLEARINGHOUSE
DEPARTMENT OF ADMINISTRATION
INTERGOVERNMENTAL REVIEW

STATE NUMBER: 01-E-0000-0497 H05
DATE RECEIVED: 02/14/2001
AGENCY RESPONSE: 03/09/2001
REVIEW CLOSED: 03/14/2001

MS RENEE GLEDHILL-EARLEY
CLEARINGHOUSE COORD
DEPT OF CUL RESOURCES
ARCHIVES-HISTORY BLDG - MSC 4617
RALEIGH NC

RECEIVED
FEB 19
HISTORIC PRESERVATION OFFICE

REVIEW DISTRIBUTION
CAPE FEAR COG
DEHNR - COASTAL MGT
DENR LEGISLATIVE AFFAIRS
DEPT OF CUL RESOURCES
EASTERN CAROLINA COUNCIL

3m 3/5
CS 2/27/01
sgm
See letter

PROJECT INFORMATION
APPLICANT: Dept. of the Army Corps of Engineers
TYPE: National Environmental Policy Act
ERD: Scoping
DESC: Proposal to Determine Necessary Actions Relative to Shore Protection Activities for Surf City and North Topsail Beach in Pender and Onslow Counties

The attached project has been submitted to the N. C. State Clearinghouse for intergovernmental review. Please review and submit your response by the above indicated date. If additional review time is needed, please contact this office at (919)807-2425.

AS A RESULT OF THIS REVIEW THE FOLLOWING IS SUBMITTED:

☐ NO COMMENT

☒ COMMENTS ATTACHED

SIGNED BY: Renee Gledhill-Earley

DATE: 3/26/01

PenderWatch & Conservancy

P.O. Box 662 Hampstead, NC 28443

March 13, 2001

Mr. Glenn McIntosh
U.S. Army Corps of Engineers
Wilmington District
Post Office Box 1890
Wilmington, North Carolina 28402-1890

Dear Mr. McIntosh,

PenderWatch & Conservancy (PW&C) thanks you for providing a copy of the scoping letter (Feb 14. 2001) regarding shore protection for Surf City and North Topsail Beach in Pender and Onslow Counties. PW&C is a Pender County group concerned with the environment and quality of life in Pender County.

Beach renourishment is, and will continue to be, a difficult public policy issue in this community. In the latest issue of our newsletter a guest columnist suggested an approach to the renourishment dilemma. I enclose the article (Todd Miller's essay on p. 4 of the enclosed newsletter). PW&C endorses these guidelines. This letter and Mr. Miller's article will serve as our comment on your scoping notice.

Please place this statement in your record. Also please send us copies of all official actions regarding this proposed project.

Sincerely,

Burt Millette,
President PenderWatch and Conservancy

Cc: North Carolina Coastal Federation

recycled paper

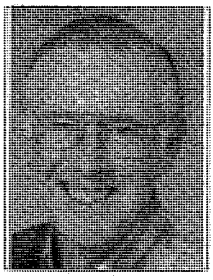
PENDERWATCH

If you are not recycling you are throwing it all away

February, 2001

From the President

Burt Millette



It is an honor to be selected to serve as PW&C President for the year 2001, which incidentally is the fifteenth anniversary of the organization. During this time PW&C has grown to its present level of about 300 dedicated members. One of the goals during the upcoming year will be to both increase the membership and to obtain greater participation from existing members in PW&C affairs. A little help from members will ease the burden on our hard-working Board pf Directors. Your ideas and suggestions are always welcome. Come to a Board meeting (every 2nd Wednesday, 9:00 A.M., at the Hampstead library) or call a Board member with your thoughts. Following Dave Richie in the President's role will be difficult. As President, Dave was dedicated, knowledgeable in environmental affairs and unselfish with his time. He inspired others to get the job done. Fortunately, Dave will stay on the Board and, as evidenced by his message, will continue to be active in PW&C.

From the Past President

Dave Richie

Over sixty PenderWatch and Conservancy members and friends enjoyed a fascinating presentation at our annual meeting, January 17, by Andy Wood, now the Education Coordinator for North Carolina Audubon Society. Andy was supported by some wonderful slides taken by Walker Golder, our originally scheduled speaker, and shared his abundant knowledge about the birds and "critters" that inhabit Lea Island.

Audubon North Carolina will be managing Lea Island primarily to protect nesting birds, while allowing existing recreational activities to continue. They hope to have a resident warden by this summer and expect to have a role for volunteers. Let me know if you are interested. 270-4751.

Andy's talk inspired me to revisit the Holly Shelter sites he interpreted so memorably on our Earth Day trip last April. I was surprised to find Lodge Road in excellent condition, providing access to a wealth of places to walk and explore. The gate in north Hampstead, just beyond the Topsail Baptist Church, will remain open through April. Hunting days are Monday, Wednesday, and Saturday. It is a peaceful, lovely place to be the other four days of the week.

My walk in Holly Shelter reawakened an earlier ambition. If there is enough interest, I would be willing to help organize an informal Friends of Holly Shelter. The main idea would be to share nature-oriented experiences—bird and flower walks, for example. The project could grow into a cooperative, supportive relationship with the Wildlife Resources Commission staff that manages Holly Shelter. There is an evident need for litter pick-up along the roads (not bad, actually, just distracting) and there may be an opportunity to locate a few trails to make it easier to access off-road areas of interest. If you are a potential member of such a group, please call me.

There is one more possible activity I would be willing to help organize. Some of you, I know, are interested in local history, including tangible remnants of earlier human activity. My interest was sparked by an earthen dam near our home that pre-dates the Civil War, and has grown to include traces of old roads in our neighborhood, an old cemetery near Country Club Road and what's left of the railroad right-of-way. It could be

fun to assemble bits and pieces of local history and meet from time to time to share what we learn. Please let me know if you would like to be included.

As many of you know, I have been appointed to the Pender County Planning Board and will now be an advocate for good planning and environmental protection from a different vantage point. It has been a privilege to serve you as President for the last two years.

Long Range Planning Proposal

The Long Range Planning Committee submitted their Growth Management Plan to the Pender County Board of Commissioners. This plan was completed after a year of research and meetings. The committee was formed in order to manage the rapid growth that has occurred in Pender County over the past decade. A panel of fifteen volunteers from around the county was formed to develop a cross section of ideas. Harbeck Associates was also brought to the board as a consultant.

The plan developed by the committee is a document called "Pender 2020, Pender County Growth Management Plan".

The people of Pender County drive this plan. The plan consists of twenty different policies which are broken into three different sections as follows:

Section 1 outlines the history of the project and listed policies, which are the principals, set down for growth management.

These policies include sections and categories for policy recommendation. These are protection for primary nursery areas, controlling stormwater runoff, supporting vegetation buffers, controlling development, flood prevention, planning road projects, developing a master drainage plan and limiting septic tanks in flood plains. These policies are designed to last for 10 years but should be looked at every 5 years.

Section 2 of the plan is the narrative. It explains why each one of the policies is put in place.

Section 3 is a list of twenty goals the committee felt the county should address first.

These can be checked off once they are done. Some of these include preserving agricultural areas, establishing stricter estuarine standards, limiting the use of personal watercraft, preserving state game lands and Moores Creek National Battlefield, monitoring the Cape Fear Basin and ground water quality, looking at options for water and sewer, the use of hydric soil definitions to limit development, promoting buffers, tightening mobile home storage, and enforcing sign regulations.

This plan serves as a guidance policy for the most appropriate use of property. It will make development easier and more predictable. The Committee feels it has developed a good plan that will work.

Commissioners are currently reviewing the plan and will hold public hearings on it.

Copies of the plan are on display at both the Hampstead and Burgaw libraries and at the County Planning office in Burgaw.

PenderWatch Hosts Coastal Caucus

On Tuesday, January 9, PW&C hosted the bimonthly meeting of the Coastal Caucus at the Manor in Olde Point.

The Coastal Caucus is made up of organizations similar in many respects to PenderWatch and shares many of our goals for planned growth and environmental protection.

The Coastal Caucus grew from several meetings organized by the North Carolina Coastal Federation (NCCF) for environmental groups in southeastern North Carolina to stop the loss of thousands of acres of wetlands in our area due to illegal ditching and draining.

PenderWatch was involved in those earlier meetings along with the Coastal Federation, Carteret County Crossroads, Brunswick Environmental Action Team, Cape Fear River Watch, The Southern Environmental Law Center, and interested individuals. This group involved the Environmental Protection Agency, initiated legal action to successfully stop the illegal ditching, and caused much of the ditching to be restored.

From that early beginning, the groups involved believed we could accomplish much more if we worked together on problems we shared in common. Those involved asked the NCCF to take on the task of organizing the initial meetings of groups the Coastal Federation thought would add to the organization. They agreed, and the Caucus was formed.

Representatives from eight groups including NCCF, Carteret County Crossroads, Brunswick Environmental Action Team, ConNet, SBTA, New River Foundation, Concerned Citizens of Southeastern NC and PenderWatch, and invited individuals attended the meeting at Olde Point. The items discussed included the proposed CAMA land use planning rules, stormwater rules, beach renourishment, and suspected pollution

from forestry activities in the Green Swamp area. Priorities were set for a planned meeting in 2001.

The participants were so impressed by the central location of Hampstead as a meeting place and the amenities provide by the Manor at Olde Point that PenderWatch was drafted to host the next meeting planned for March. We look forward to the opportunity.

Adopt-A-Highway

PW&C continues its efforts to make our environs a better place.

Since the last newsletter we conducted two pick-ups. Eleven volunteers picked up Highway 17 on Thursday, October 19. Many thanks to **Bob Julius, Bob Wilfong, Lou Garrard, Clem** and **Marjorie Bribitzer, Terry and Fred Bender, Margaret** and **Raymond Rose, Phyllis Powder** and **Elsa O'Connor.** We picked up 20 bags of trash and 1 bag of aluminum cans. The total was lower than we often collect because a crew of prison inmates had picked up the road early in September. The State gave us a head start, and we were able to get it very clean!

PenderWatch volunteers were out in full force Saturday, February 3, in spite of the cold weather. We picked up 37 bags of trash and one bag of aluminum along Highway 17. We had 11 volunteers donating 25 hours in order to keep Hampstead clean and beautiful. Many thanks to **John** and **Mary Oleshiewicz, Johanna Timberlake, Phyllis Powder, Clem** and **Marjorie Bribitzer, Betty Wolak Howard Sterne, Jim** and **Marilyn Fisher** and **Elsa O'Connor.**

Occasionally we pick up unusual items. Why we almost always find gloves is inexplicable. One volunteer got lucky on the last pick up and found a crisp $10 bill. While we will not guarantee that this will always happen, join us and try your luck.

Please call Elsa O'Connor to volunteer for the next pick up which is Tuesday April 17, 2001.

We make many calls to recruit volunteers for the Adopt-A-Highway program. Often the response is one of sympathy but that physical limitations preclude helping. You can still help the program by making calls. We could use a volunteer to recruit volunteers. Any volunteers? Please call Elsa (270-4946) if you could assist us.

It is not too early to mark your calendars for Beach Sweep, September 15, 2001. We will organize a small flotilla and travel to Lea and Hutaff Island(s) to clean up the beach. We especially need volunteers who have boats. Call Elsa to volunteer.

From the Editors Desk

Clem Bribitzer



A new year. New board members. The same commitment – to protect the environment and our quality of life.

Congratulations to the new Board members, who are introduced in this newsletter! Congratulations to new officers Burt Millette, President, Al Amatruda, 1st Vice President, Clem Bribitzer, 2nd Vice President, Charles Askey, Secretary, and Marion Kurdyla, Treasurer.

In the last year, PW&C has been growing and increasing our influence. One encouraging development is that PW&C is strengthening its relations with other environmental groups. An article contributed by the North Carolina Coastal Federation will be a regular feature in the newsletter.

The annual meeting was well attended. Andy Woods gave an inspiring presentation that was covered by three local newspapers. Andy is now Education Director with Audubon North Carolina, the local arm of the National Audubon Society. He described the Society's plans for protecting wildlife on Lea and Hutaff Islands giving us graphic illustrations of the natural beauty and ecological importance of our own closest barrier islands. Members who would like to support Audubon North Carolina's "Friends of the Coastal Islands Sanctuary" program can send a check made out to "Audubon North Carolina" to National Audubon Society, 3806B Park Avenue, Wilmington, NC 28403. Audubon North Carolina will apply the funds specifically to their activities at Lea and Hutaff islands if you make that designation on your check or accompanying note. Membership categories begin at $25. Larger amounts are welcome.

PW&C is working with the Audubon Society to arrange an educational trip to Lea Island sometime this spring. This could be fun and interesting. We will send out more information as we make firm plans.

To change the subject drastically, as I emptied a plastic bottle of olive oil today, I was reminded that we need guidance as to what can be recycled. The County went to the trouble of seeking a vendor for slick paper, but the arrangement fell through. We should encourage seeking another vendor. It is not clear which plastics are actually recycled and which are eventually trashed. The citizens of Pender county need to know what can or cannot be brought to the disposal facilities for recycling! The County Commissioners promised a new brochure on the subject. Where is it?

Beach Plan Already Exists: Now Let's Carry It Out

Todd Miller
Executive Director
NC Coastal Federation

Tucked away in this year's budget passed by the NC General Assembly is an unfunded mandate for the Department of Environment and Natural Resources to prepare a plan by May 1, 2001 to determine how to fund beach restoration projects in North Carolina.

Pressure to get the State more vested in these projects is coming from oceanfront towns and counties from the Outer Banks to Ocean Isle. Local governments are worried that along more than 160 miles of beach, the ocean may soon undermine homes, rental properties, hotels and condos, as well as the streets, highways and other utilities that service these seaside resorts. Mounting damages include eroding property values, incomes from rental properties, and the tourism economy.

North Carolina knew decades ago that this "day of reckoning" for oceanfront properties was on the way. That's why it adopted formal regulatory policies for how best to respond to continuing and predictable shoreline migration. Land use planning, construction setbacks, building relocation, subdivision rules, management of vegetation, and pumping sand on beaches are preferred responses to erosion – so assert these state policies.

Based upon these regulatory principles, projects designed to respond to erosion should avoid losses to natural heritage and not adversely affect the productivity of our coastal and ocean waters. The public trust right of the public to use the ocean beaches, including traditional recreational uses such as walking, swimming, surf-fishing and commercial fishing, are to be preserved.

It's predictable that oceanfront communities are lobbying for help in paying to put more sand on their beaches. For awhile such projects can reduce property losses and they hold out some hope for maintaining the "status quo" or even allowing more intense oceanfront development. But sea level is now rising at a projected rate of 1.7 feet per century, hurricanes and northeasters are predicted to occur more frequently and at greater intensity, and there are chronic shortages of economical sources of sand along significant portions of our coast. All this means that the ongoing costs of drawing a line in the sand and attempting to hold the beaches where they are today will escalate until it is not technologically or economically feasible to do so.

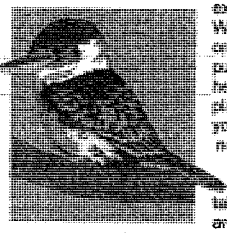
The State should base its new beach restoration strategy on its existing oceanfront policies that require a multi-faceted response to beach migration. In communities where beach renourishment is under consideration, it should only be carried out if the following tests can be met:

- There must be acceptable and adequate sources of sand available;
- The project must be properly planned, timed and executed;
- Adequate habitat and water quality monitoring must occur to evaluate effects on fisheries and water quality;
- Project planners must be completely forthcoming about the long-term costs of renourishment;
- The project must provide adequate public parking;
- The project must include an "exit strategy" to deal with beachfront property when renourishment is no longer feasible due to insufficient funds, sand supplies, and/or future storm activity; and,
- The project must be financed so that it places the burden on the people that benefit from renourishment.

Environmental Corner

Howard Sterne

A week or so ago when I sat down to write this article on cleaning up petroleum-polluted soils, I knew of no local examples. Then the Wilmington *Morning Star*, on January 31, 2001, published a report headlined, "Polluted soil plagues Pender pipeline." If you read the article, you will note that the contamination is difficult to trace because our high water table tends to move it around.



My report uses as sources two articles from Environmental Science and Technology. These are, "The Complicated Challenge of MTBE Cleanups," and "Will Ethanol-Blended Gasoline Affect Groundwater Quality?"

MTBE (methyl *tert*-butyl ether) was initially added to gasoline to increase octane ratings following the U. S. ban on alkyl lead additives in 1979. MTBE's potential for groundwater and surface water contamination was not a significant consideration when the decision was made. It is now known that the chemical is a very mobile and persistent contaminant in aqueous systems because of its high solubility and low biodegradation rates. The pungent turpentine-like odor and taste limit acceptable

levels in drinking water to 5-40 p.p.b. There is, however, significant debate regarding what level is safe.

The movement of MTBE through the ground is very dependent on soil types, soil layering, movement of groundwater, and pumping rates of water wells in an area. In fact, investigators found that when wells stopped pumping, the plume of contamination could change direction. This material can move very quickly; some has been measured moving at 26-43 feet/day. Thus it is important to stop any gasoline leaks quickly and monitor them at various levels and directions from the original site. Seven states have implemented policies to phase out MTBE, and three states are limiting the concentration in gasoline. The federal government is also proposing a reduction or ban through the Toxic Substance Control Act.

The use of ethanol (ethyl alcohol) as a fuel source is often advocated because, as it is obtained from grain, it is a renewable fuel. It is highly biodegradable under both aerobic and anaerobic conditions, and likely will essentially disappear under natural conditions. There is a $0.54/gallon federal excise tax exemption to promote the sale of ethanol, and it is becoming more widely used in concentrations up to 10%.

So we think we have solved the problem? Hold on! There are two issues of great concern. Ethanol in water can create a co-solvent effect, and its biodegradation can deplete the groundwater of nutrients. Both processes can result in increased concentrations of hydrophobic compounds (water haters) such as benzene, increasing the distances these substances could travel from a spill site.

So we are left with a great many underground tanks that either are leaking or have leaked in the past, and that pose a threat to the environment and to our health.

At the beginning of this article, I mentioned contaminated soil in Southwestern Pender County. At the recent County Commissioners' meeting, we heard of waste spillover at the Hampstead and other trash disposal sites. Finally, today, February 3, 2001, while filling my gas tank at the Scotchman at the corner of Rte. 17 and Country Club Drive, I noticed that they are drilling a monitoring well on site. This was ordered by the State Department of Energy and Natural Resources to monitor groundwater because of leaking tanks on the site a few years ago.

We have to be vigilant! Let's keep our eyes open and make sure we report and stay on top of any spills, odors, or other potential groundwater contamination indicators. If we in PenderWatch can help, let us know!

Welcome New Board Members

PenderWatch is very happy to announce the election of six new members to the Board. With their varied backgrounds and fresh talent, 2001 should be a great year! Our new members are:

John Bonitz - John is a native North Carolinian whose career in theatre-related fields has included acting, directing, designing, and eventually becoming a film talent agent. John and his wife Suzanne now live in Hampstead where he lists his hobbies as gardening and traveling.

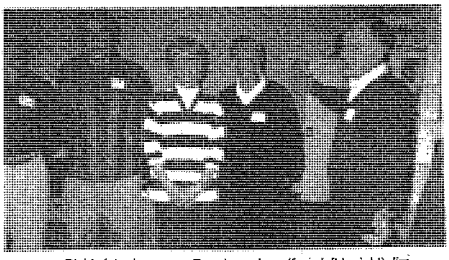
Jim Fisher - Jim is a Licensed Professional Engineer in North Carolina as well as Vermont and his former home, New York. After working for Honeywell, Inc., he joined a small consulting engineering firm in Albany where he rose to become President of the partnership.

Ken Just - Ken is originally from St. Louis but has lived in a number of places in the U. S. and around the world. He is a retired salesman who moved to the Wilmington area in 1993. He is interested in helping PW&C maintain the quality of life that brought him and his wife Mary Ann to Hampstead in 1994.

Marion Kurdyla - Marion is a New Jersey native who retired here with husband Rich in 1995. She lists her accomplishments as raising her family and reaching the post of Administrative Assistant to the Director of the Summit Free Public Library.

Bob Muller - Bob and his wife Joanne moved to Hampstead from Raleigh in 1990. His career with IBM began in upstate New York and brought him to North Carolina by way of Fujisawa, Japan. Among his professional activities, he has conducted management workshops for North Carolina State.

Jim Timberlake -- Jim chose teaching as a profession after spending three years as a stationary engineer. While pursuing his career on Long Island, he did volunteer work for The Nature Conservancy in New York maintaining trails and protecting piping plover nesting sites. He and his wife Johanna moved to Hampstead in 1990.



Dave Richie introduces new Board members (from left to right) Jim Timberlake, Ken Just, Marion Kurdyla and Jim Fisher

PenderWatch Attends Fisheries Workshop

Jim Timberlake and Dave Richie attended "A Workshop for Citizens on Fish Conservation" at the Pine Knoll Shores Aquarium on February 3. Speakers were excellent and good information was provided, including a substantial packet to take home.

The intention was to stimulate more citizen activism on behalf of ocean resources, including habitat protection for fish nurseries and spawning areas in tidal creeks and estuaries, which we have in abundance in Pender County.

Jim Timberlake will be coordinating comments on important habitat protection draft reports by the N.C. Division of Marine Resources, which are due out in the next few months. Members who have a special interest or qualifications in this area are encouraged to contact Jim. 270-3155.

PenderWatch & Conservancy

Printed on Recycled Paper

NON-PROFIT
BULK RATE
US POSTAGE PAID
HAMPSTEAD NC 28443
PERMIT NO.32

PO Box 662
Hampstead NC 28443

BOARD MEMBERS '01

Burt Millette, *President*
Al Amatruda, 1st *Vice President*
Clem Bribitzer, 2nd *Vice President*
Charles Askey*, *Secretary*
Marion Kurdyla, *Treasurer*

John Bonitz
Jim Fisher
Ken Just
Bob Muller
Dave Richie*
Howard Sterne*
Jim Timberlake
Len Winter
Bill Wolak
*Past President

POSTAL PATRON

North Carolina
Department of Administration

Michael F. Easley, Governor

Gwynn T. Swinson, Secretary

March 19, 2001

Mr. Glenn McIntosh
Dept. of the Army Corps of Engineers
Wilmington District
P.O. Box 1890
Wilmington, NC 28402-1890

Dear Mr. McIntosh:

Re: SCH File # 01-E-0000-0497; Scoping Proposal to Determine Necessary Actions Relative to Shore Protection Activities for Surf City and North Topsail Beach in Pender and Onslow Counties

The above referenced project has been reviewed through the State Clearinghouse Intergovernmental Review Process. Attached to this letter are comments made by agencies reviewing this document.

Should you have any questions, please do not hesitate to call me at (919) 807-2425.

Sincerely,

Chrys Baggett

Ms. Chrys Baggett
Environmental Policy Act Coordinator

Attachments

cc: Region O
Region P

North Carolina
Department of Environment and Natural Resources

Michael F. Easley, Governor
William G. Ross Jr., Secretary

NCDENR

MEMORANDUM

TO: Chrys Baggett
State Clearinghouse

FROM: Melba McGee
Environmental Review Coordinator

RE: 01E-0497 Scoping Shore Protection Alternative on Topsail Beach and Surf City, Pender and Onslow Counties

DATE: March 14, 2001

The Department of Environment and Natural Resources has reviewed the proposed information. The attached comments are for the applicant's information and consideration.

Thank you for the opportunity to review.

Attachments

RECEIVED
MAR 15 2001
S.C. STATE CLEARINGHOUSE

1601 Mail Service Center, Raleigh, North Carolina 27699-1601
Phone: 919 – 733-4984 \ FAX: 919 – 715-3060 \ Internet: www.enr.state.nc.us/ENR/

AN EQUAL OPPORTUNITY \ AFFIRMATIVE ACTION EMPLOYER – 50% RECYCLED / 10% POST CONSUMER PAPER



North Carolina Wildlife Resources Commission

Charles R. Fullwood, Executive Director

MEMORANDUM

TO: Melba McGee
Office of Legislative & Intergovernmental Affairs

FROM: Bennett Wynne
Habitat Conservation Program

DATE: March 13, 2001

SUBJECT: Request for scoping comments regarding resources potentially impacted by various shore protection alternatives on Topsail Island, Onslow and Pender Counties, North Carolina. Project Number: 01E-0497.

It is our understanding the Army Corps of Engineers has been directed to determine the need for shoreline protection measures on Topsail Island. Shoreline protection alternatives examined in Environmental Impact Statements would include beach nourishment, non-structural measures (relocation), and no action. We are pleased to see the inclusion of relocation among the alternatives and recommend that it be given serious consideration during preparation of the environmental documents.

State and federally listed (Threatened) sea turtles nest along the entire ocean beach of Topsail Island and the south end of the island is proposed as critical habitat for wintering piping plovers, another listed species (also Threatened). Piping plovers also nested at the south end two years ago, but this past year there was only one piping plover present on the site. The north end of the island also has some use by piping plovers, and even the North Topsail overwash (near Chadwick Bay) has had one sighting of a piping plover.

Both the north and south ends of the island get heavy use by migrating shorebirds and other waterbirds. The south end always has several pairs of nesting Wilson's plovers and American Oystercatchers (both high priority species, and oystercatchers are also State listed as Special Concern). Least terns (State listed as Special Concern) also usually try to nest there, but

Mailing Address: Division of Inland Fisheries • 1721 Mail Service Center • Raleigh, NC 27699-1721
Telephone: (919) 733-3633

predation by house cats is high. There has been a fairly large and successful nesting colony of least terns at the North Topsail overwash in recent years. Several pairs of Wilson's plovers also nest there. The north end of the island gets less use for nesting purposes, but still generally has a couple pairs of Wilson's plovers nesting on the site, and sometimes American oystercatchers. Large numbers of waterbirds use the north end for resting and roosting.

Potential adverse impacts to fish and wildlife resources that should be thoroughly addressed in environmental documents include:

- interference with sea turtle nesting and hatching
- disturbance of colonial nesting birds
- loss of overwash fan habitat
- reduced habitat quality and quantity of sand borrow areas, particularly sand flats associated with the flood tide delta of inlets
- decimation of beach invertebrate populations and effects thereof on dependent shorebirds and fishes
- increased turbidity or other water quality decline
- filling or disturbance of wetlands during sand transport to the beaches
- cumulative impacts related to any of the above associated with this project, subsequent maintenance of this project, and other similar projects

We expect the Corps to include an April 1 to November 15 colonial nesting bird/sea turtle nesting moratorium for the beach nourishment alternative. In addition, all alternatives should take measures to avoid depletion of naturally migrating inlet and overwash habitats. Finally, due to the expanse of the project(s), potential for adverse impacts, and the need for an open exchange of concerns and ideas, we recommend that an interagency scoping meeting be held

Thank you for the opportunity to comment on the project at this early stage. If you have questions, please call me at (252) 514-4738.

Cc: Howard Hall, USFWS
Tracy Rice, USFWS
Ron Sechler, NMFS
Fritz Rohde, NCDMF
Anne Deaton, NCDMF
David Allen, NCWRC

North Carolina
Department of Environment and Natural Resources
Division of Water Resources

Michael F. Easley, Governor
William G. Ross, Jr., Secretary
John Morris, Director

March 12, 2001

MEMORANDUM

TO: Melba McGee, Environmental Coordinator
Office of Legislative and Intergovernmental Affairs

FROM: John Sutherland, Chief
Water Projects Section

SUBJECT: Comments on Scoping Letter for Possible Shore Protection Measures for Surf City, North Topsail Beach, and Topsail Beach, Pender and Onslow Counties by the U.S. Corps of Engineers, Project No. 01E-0497

The Division of Water Resources has worked closely with the Wilmington District, U.S. Army Corps of Engineers, on several shore protection studies for communities susceptible to damage from hurricanes and other major storms. We support the District's effort to determine which, if any, storm protection measures are economically and environmentally feasible in these three communities in Pender and Onslow Counties. We are also committed to providing up to 50 percent of the non-federal cost of the studies to be done, provided that North Carolina General Assembly appropriates the funding for them.

cc: John Morris

1611 Mail Service Center, Raleigh, North Carolina, 27699-1611
Phone: 919 – 733-4064 \ FAX: 919 – 733-3558 \ Internet: www.ncwater.org
AN EQUAL OPPORTUNITY \ AFFIRMATIVE ACTION EMPLOYER – 50% RECYCLED / 10% POST CONSUMER PAPER

State of North Carolina
Department of Environment
and Natural Resources
Division of Environmental Health

James B. Hunt, Jr., Governor
Bill Holman, Secretary
Linda C. Sewall, Director

NCDENR
North Carolina Department of
Environment and Natural Resources

MEMORANDUM

TO: Melba McGee

FROM: Gina Brooks

SUBJECT: National Environmental Policy Act, Department of the Army, Corps of Engineers

DATE: February 27, 2001

The Shellfish Sanitation and Recreational Water Quality Section would have no objection to the above mentioned project provided that the following conditions are met: 1) beach disposal occurs only between November 1st and April 30th when recreational usage is low and 2) clean sand is used and not dredged sand from closed shellfishing areas. If beach disposal was to occur at times other than stated above or if sand from a closed shellfishing area is to be used, a swimming advisory may be posted and a press release may be made. Please notify this office when such disposal occurs.

If you have any questions regarding this matter, please contact me at (252)726-6827 or you may email me at gina.brooks@ncmail.net.

NORTH CAROLINA STATE CLEARINGHOUSE
DEPARTMENT OF ADMINISTRATION
INTERGOVERNMENTAL REVIEW

STATE NUMBER: 01-E-0000-0497 H05
DATE RECEIVED: 02/14/2001
AGENCY RESPONSE: 03/09/2001
REVIEW CLOSED: 03/14/2001

MS MELBA MCGEE
CLEARINGHOUSE COORD
DEHNR - COASTAL MGT
C/O ARCHDALE BLDG
RALEIGH NC

REVIEW DISTRIBUTION
CAPE FEAR COG
DEHNR - COASTAL MGT
DENR LEGISLATIVE AFFAIRS
DEPT OF CUL RESOURCES
EASTERN CAROLINA COUNCIL

PROJECT INFORMATION
APPLICANT: Dept. of the Army Corps of Engineers
TYPE: National Environmental Policy Act
ERD: Scoping
DESC: Proposal to Determine Necessary Actions Relative to Shore Protection Activities for Surf City and North Topsail Beach in Pender and Onslow Counties

The attached project has been submitted to the N. C. State Clearinghouse for intergovernmental review. Please review and submit your response by the above indicated date. If additional review time is needed, please contact this office at (919)807-2425.

AS A RESULT OF THIS REVIEW THE FOLLOWING IS SUBMITTED:

☐ NO COMMENT
☑ COMMENTS ATTACHED - Some areas of salt marsh are home/ mosquito production habitat. Please consult with Onslow Co mosquito control 910 455-0181

SIGNED BY: Allen L. Anderson

DATE: 26/02/01

North Carolina
Department of Environment and Natural Resources
Division of Coastal Management

Michael F. Easley, Governor
William G. Ross Jr., Secretary
Donna D. Moffitt, Director



MEMORANDUM

TO: Melba McGee, NC Division of Policy and Development
FROM: Caroline Bellis, NC Division of Coastal Management
SUBJECT: Review of SCH#01-0497 DATE: 2/23/01

✓ A COPY OF ALL ACENCY COMMENTS RECEIVED IS REQUESTED
___ REVIEWER COMMENTS ARE ATTACHED

Review Comments:

___ This document is being reviewed for consistency with the NC Coastal Management Program pursuant to federal law and or NC Executive Order 15. Agency comments received by SCH are needed to develop the State's consistency position. Project Review Number (if different from above) _____.
A consistency position will be developed based upon our review on or before _____.

✓ A Consistency Determination document ✓ is, or ___ may be required for this project pursuant to federal law and or NC Executive Order 15. Applicant should contact Caroline Bellis in Raleigh, phone (919) 733-2293, for information on proper document format and applicable state guidelines and land use plan policies.

✓ Proposal is in draft form, a consistency response is inappropriate at this time. A Consistency Determination should be included in the final document.

___ A Consistency Determination Document (pursuant to federal law and/or NC Executive Order 15) is not required.
___ A consistency response has already been issued.
Project Number _____ Date Issued _____
___ Proposal involves < 20 Acres and or a structure < 60,000 Square Feet and no AECs or Land Use Plan problems.
___ Proposal is not in the Coastal Area and will have no significant impacts on any land or water use or natural resources of the Coastal Area.

___ A CAMA Permit ___ is, or ___ may be required for all or part of this project. Applicant should contact _____ in _____, phone #_____, for information.

___ A CAMA Permit ___ has already been issued, or ___ is currently being reviewed under separate circulation.
Permit Number_____ Date Issued_____

___ Other (see attached).

State of North Carolina Consistency Position:

___ The proposal is consistent with the NC Coastal Management Program provided that all conditions are adhered to and that all state authorization and/or permit requirements are met prior to implementation of the project.

___ The proposal is inconsistent with the NC Coastal Management Program.

___ Other (see attached).

1638 Mail Service Center, Raleigh, North Carolina 27699-1638
Phone: 919-733-2293 \ FAX: 919-733-1495 \ Internet: http://dcm2.enr.state.nc.us
AN EQUAL OPPORTUNITY \ AFFIRMATIVE ACTION EMPLOYER – 50% RECYCLED / 10% POST CONSUMER PAPER

State of North Carolina
Department of Environment and Natural Resources

Reviewing Office: Wilmington

INTERGOVERNMENTAL REVIEW – PROJECT COMMENTS Project Number: 01E-0497 Due Date: 3/9/01

After review of this project it has been determined that the ENR permit(s) and/or approvals indicated may need to be obtained in order for this project to comply with North Carolina Law. Questions regarding these permits should be addressed to the Regional Office indicated on the reverse of the form. All applications, information and guidelines relative to these plans and permits are available from the same Regional Office.

	PERMITS	SPECIAL APPLICATION PROCEDURES or REQUIREMENTS	Normal Process Time (statutory time limit)
☐	Permit to construct & operate wastewater treatment facilities, sewer system extensions & sewer systems not discharging into state surface waters.	Application 90 days before begin construction or award of construction contracts. On-site inspection. Post-application technical conference usual.	30 days (90 days)
☐	NPDES - permit to discharge into surface water and/or permit to operate and construct wastewater facilities discharging into state surface waters.	Application 180 days before begin activity. On-site inspection. Pre-application conference usual. Additionally, obtain permit to construct wastewater treatment facility-granted after NPDES. Reply time, 30 days after receipt of plans or issue of NPDES permit–whichever is later.	90-120 days (N/A)
☐	Water Use Permit	Pre-application technical conference usually necessary	30 days (N/A)
☐	Well Construction Permit	Complete application must be received and permit issued prior to the installation of a well.	7 days (15 days)
☐	Dredge and Fill Permit	Application copy must be served on each adjacent riparian property owner. On-site inspection. Pre-application conference usual. Filling may require Easement to Fill from N.C. Department of Administration and Federal Dredge and Fill Permit.	55 days (90 days)
☐	Permit to construct & operate Air Pollution Abatement facilities and/or Emission Sources as per 15 A NCAC (2Q.0100, 2Q.0300, 2H.0600)	N/A	60 days
☐	Any open burning associated with subject proposal must be in compliance with 15 A NCAC 2D.1900	N/A	60 days (90 days)
☐	Demolition or renovations of structures containing asbestos material must be in compliance with 15 A NCAC 2D.1110 (a) (1) which requires notification and removal prior to demolition. Contact Asbestos Control Group 919-733-0820.		
☐	Complex Source Permit required under 15 A NCAC 2D.0800		
☐	The Sedimentation Pollution Control Act of 1973 must be properly addressed for any land disturbing activity. An erosion & sedimentation control plan will be required if one or more acres to be disturbed. Plan filed with proper Regional Office (land Quality Sect.) At least 30 days before beginning activity. A fee of $30 for the first acre and $2000 for each additional acre or part must accompany the plan.		20 days (30 days)
☐	The Sedimentation Pollution control Act of 1973 must be addressed with respect to the referenced Local Ordinance.		(30 days)
☐	Mining Permit	On-site inspection usual. Surety bond filed with ENR. Bond amount varies with type mine and number of acres of affected land. Any are mined greater than one acre must be permitted. The appropriate bond must be received before the permit can be issued.	30 days (60 days)
☐	North Carolina Burning permit	On-site inspection by N.C. Division Forest Resources if permit exceeds 4 days	1 day (N/A)
☐	Special Ground Clearance Burning Permit - 22 counties in coastal N.C. with organic soils	On-site inspection by N.C. Division Forest Resources required "if more than five acres of ground clearing activities are involved. Inspections should be requested at least ten days before actual burn is planned."	1 day (N/A)
☐	Oil Refining Facilities	N/A	90-120 days (N/A)
☐	Dam Safety Permit	If permit required, application 60 days before begin construction. Applicant must hire N.C. qualified engineer to: prepare plans, inspect construction, certify construction is according to ENR approved plans. May also require permit under mosquito control program. And a 404 permit from Corps of Engineers. An inspection of site is necessary to verify Hazard Classification. A minimum fee of $200.00 must accompany the application. An additional processing fee based on a percentage or the total project cost will be required upon completion.	30 days (60 days)

	PERMITS	SPECIAL APPLICATION PROCEDURES or REQUIREMENTS	Normal Process Time (statutory time limit)
☐	Permit to drill exploratory oil or gas well	File surety bond of $5,000 with ENR running to State of NC conditional that any well opened by drill operator shall, upon abandonment, be plugged according to ENR rules and regulations.	10 days N/A
☐	Geophysical Exploration Permit	Application filed with ENR at least 10 days prior to issue of permit. Application by letter. No standard application form.	10 days N/A
☐	State Lakes Construction Permit	Application fees based on structure size is charged. Must include descriptions & drawings of structure & proof of ownership of riparian property.	15-20 days N/A
☑	401 Water Quality Certification	N/A	60 days (130 days)
☐	CAMA Permit for MAJOR development	$250.00 fee must accompany application	55 days (150 days)
☐	CAMA Permit for MINOR development	$50.00 fee must accompany application	22 days (25 days)
☐	Several geodetic monuments are located in or near the project area. If any monument need to be moved or destroyed, please noufy: N.C. Geodetic Survey, Box 27687 Raleigh, NC 27611		
☐	Abandonment of any wells, if required must be in accordance with Title 15A, Subchapter 2C.0100.		
☐	Notification of the proper regional office is requested if "orphan" underground storage tanks (USTS) are discovered during any excavation operation.		
☐	Compliance with 15A NCAC 2H 1000 (Coastal Stormwater Rules) is required.		45 days (N/A)
*	Other comments (attach additional pages as necessary, being certain to cite comment authority)		

REGIONAL OFFICES

Questions regarding these permits should be addressed to the Regional Office marked below.

☐ **Asheville Regional Office**
59 Woodfin Place
Asheville, NC 28801
(828) 251-6208

☐ **Fayetteville Regional Office**
225 Green Street, Suite 714
Fayetteville, NC 28301
(910) 486-1541

☐ **Mooresville Regional Office**
919 North Main Street
Mooresville, NC 28115
(704) 663-1699

☐ **Raleigh Regional Office**
3800 Barrett Drive, P.O. Box 27687
Raleigh, NC 27611
(919) 571-4700

☐ **Washington Regional Office**
943 Washington Square Mall
Washington, NC 27889
(252) 946-6481

☒ **Wilmington Regional Office**
127 Cardinal Drive Extension
Wilmington, NC 28405
(910) 395-3900

☐ **Winston-Salem Regional Office**
585 Waughtown Street
Winston-Salem, NC 27107
(336) 771-4600



Committee on Transportation and Infrastructure

Congress of the United States
House of Representatives
Washington, DC 20515

Bud Shuster
Chairman

Jack Schenendorf, Chief of Staff
Michael Stracke, Deputy Chief of Staff

James L. Oberstar
Ranking Democratic Member

David Heymsfeld, Democratic Chief of Staff

COMMITTEE ON TRANSPORTATION AND INFRASTRUCTURE
U.S. HOUSE OF REPRESENTATIVES
WASHINGTON, D.C.

RESOLUTION

Docket 2629

North Topsail Beach, North Carolina

Resolved by the Committee on Transportation and Infrastructure of the United States House of Representatives, That the Secretary of the Army is requested to review the report of the Chief of Engineers on West Onslow Beach and New River Inlet, North Carolina, published as House Document 393, 102nd Congress, 2nd Session, dated September 23, 1992, and other pertinent reports, to determine whether any modifications of the recommendations contained therein are advisable at the present time in the interest of shore protection and related purposes for North Topsail Beach, North Carolina.

Adopted: April 11, 2000

ATTEST: Bud Shuster
BUD SHUSTER
CHAIRMAN

United States Department of Agriculture

NRCS Natural Resources Conservation Service

USDA

4405 Bland Road, Suite 205, Raleigh, NC 27609
Telephone No.: (919) 873-2134
Fax No.: (919) 873-2154

February 11, 2002

Mr. Glenn McIntosh
U. S. Army corps of Engineers
Wilmington District
P O Box 1890
Wilmington NC 28402-1890

Dear Mr. McIntosh:

Thank you for the opportunity to provide comments on Topsail Beach, Surf City, and North Topsail Beach in Pender and Onslow Counties, North Carolina.

The Natural Resources Conservation Service does not have any comments at this time.

Sincerely,

Mary K. Combs
State Conservationist

February 14, 2001

Project Management Branch

Dear Sir or Madam:

The U.S. House of Representatives Committee on Transportation and Infrastructure has directed the Secretary of the Army to review the report of the Chief of Engineers on West Onslow Beach and New River Inlet, North Carolina, published as House Document Number 393, 102nd Congress, 2nd Session, dated September 23, 1992, to determine whether any actions are advisable at the present time in the interest of shore protection and related purposes for Surf City and North Topsail Beach, in Pender and Onslow Counties, respectively, in North Carolina. On this same beach strand, we are also reinitiating studies necessary to prepare a General Reevaluation Report (GRR) for Topsail Beach, in Pender County, North Carolina. The limits of each of these study areas are shown on the attached map.

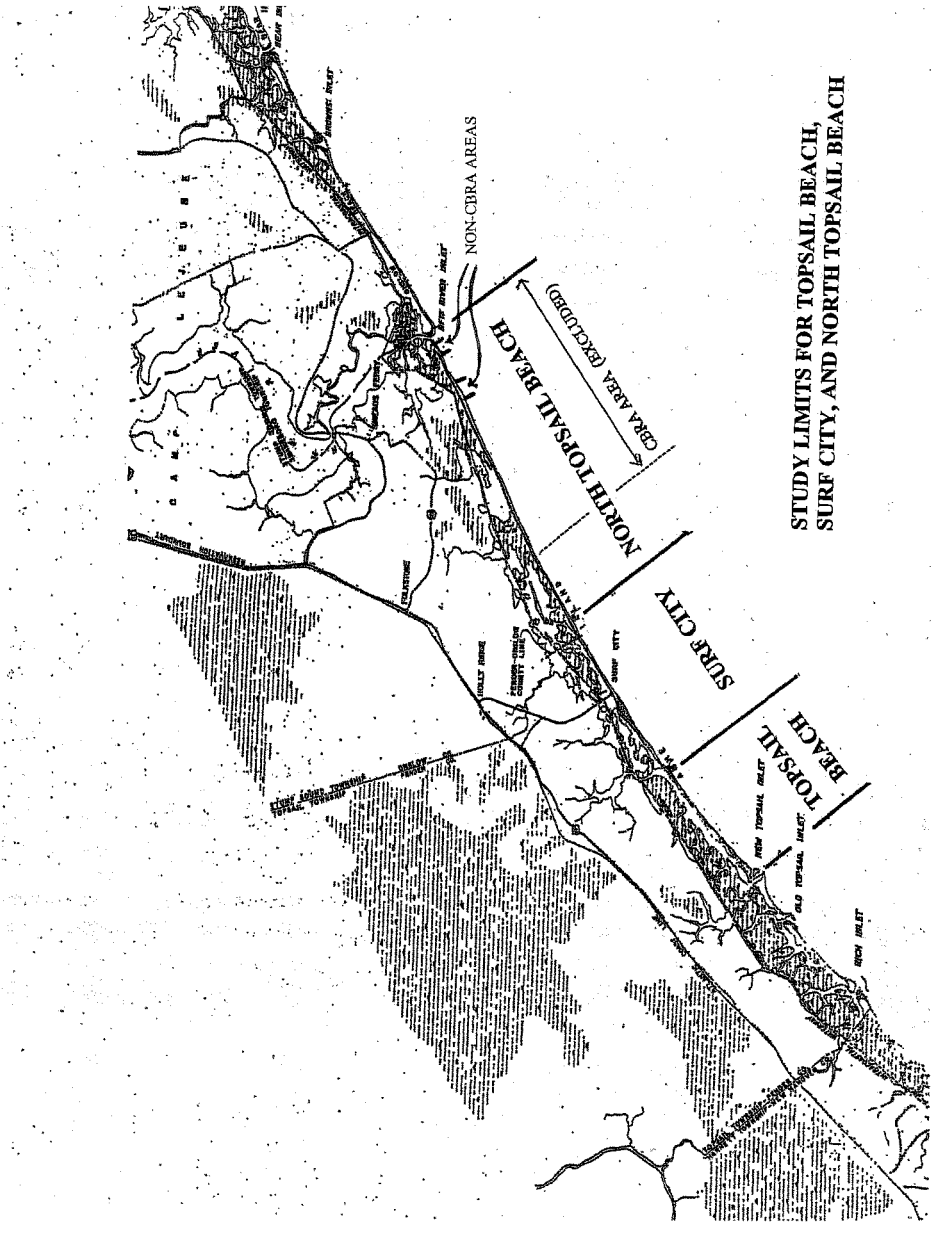
For each study area, various shore protection alternatives will be examined, including beach nourishment, non-structural measures (relocation), and No Action. Areas of North Topsail Beach that are included in the Coastal Barrier Resources Act (CBRA) will be excluded from study. We are requesting comments from agencies, interest groups, and the public to identify significant resources that may occur in these study areas or other issues of concern. Comments received as a result of this scoping letter will be used to help identify potential impacts on the environment, determine appropriate studies to be conducted, and determine the range of alternatives to be examined. These items will be addressed, as needed, in Environmental Impact Statements. No formal scoping meetings are planned; however, based on the responses received, scoping meetings may be held with specific agencies or individuals as required.

We request that you provide written comments on any of these matters within 30 days from the date of this letter. Comments should be addressed to Mr. Glenn McIntosh, U.S. Army Corps of Engineers, Wilmington District, Post Office Box 1890, Wilmington, North Carolina 28402-1890. If you have any questions, please contact Mr. McIntosh at (910) 251-4671 or e-mail address glenn.mcintosh@usace.army.mil.

Sincerely,

W. Eugene Tickner, P.E.
Deputy District Engineer
Programs and Project Management

Enclosure


NON-CBRA AREAS
CBRA AREA (EXCLUDED)
NORTH TOPSAIL BEACH
SURF CITY
TOPSAIL BEACH
STUDY LIMITS FOR TOPSAIL BEACH,
SURF CITY, AND NORTH TOPSAIL BEACH

INTEGRATED

FEASIBILITY REPORT

AND

ENVIRONMENTAL IMPACT STATEMENT

COASTAL STORM DAMAGE REDUCTION PROJECT

SURF CITY AND NORTH TOPSAIL BEACH

NORTH CAROLINA

Appendix L

Final Fish and Wildlife Coordination Act Report

United States Department of the Interior

FISH AND WILDLIFE SERVICE
Raleigh Field Office
Post Office Box 33726
Raleigh, North Carolina 27636-3726

August 19, 2010

Philip M. Payonk
Chief, Environmental Resources Section
Wilmington District, US Army Corps of Engineers
69 Darlington Ave.
Wilmington, NC 28403-1343

Subject: Section 7 consultation on the Coastal Storm Damage Reduction – Surf City and North Topsail Beach Project, Pender and Onslow Counties, North Carolina.

Dear Mr. Payonk:

Based on coordination over the past month with Mr. Doug Piatkowski of your staff, the U. S. Fish and Wildlife Service (Service) has been informed that formal consultation must be re-initiated on the subject project. The project consists of initial construction of a berm and dune system along approximately 9.9 miles of Atlantic shoreline in the central section of Topsail Island with periodic reconstruction of the system at approximately three-year intervals over a period of 50 years. Beachfill material would be dredged from offshore, marine sand deposits. These comments are provided regarding project impacts pursuant to section 7 of the Endangered Species Act (ESA) of 1973, as amended (16 U.S.C. 1531-1543).

The Service has worked with the U. S. Army Corps of Engineers (Corps) in planning this project for more than a decade. During this period we have recommended design features, construction techniques, and monitoring procedures to avoid and assess impacts on federally listed species. Appendix I of the Corps' Draft Environmental Impact Statement (DEIS), dated August 2009, represented a Biological Assessment (BA) for the project. Appendix I listed 12 commitments to reduce impacts to listed species. Based on these commitments the Corps determined (p. I-37) that the proposed work would have either "no effect" or may affect, but was "not likely to adversely affect" the species under the jurisdiction of the Service.

The Service provided the Corps with a Final Fish and Wildlife Coordination Act Report in May 2010. The reported stated that based on the information provided in the DEIS and BA, the Service concurred with the Corps determinations that the proposed action is not likely to adversely affect federally listed species or their critical habitat as defined by the ESA. At that time, the requirements of section 7 (a)(2) of the ESA had been satisfied for this project. However, we stated that the Corps' obligations under the ESA must be reconsidered if: (1) new information identifies impacts of this action that may affect listed species or critical habitat in a manner not previously considered; (2) this action is modified in a manner that was not considered in this review; or, (3) a new species is listed or critical habitat determined that may be affected by the identified action.

On July 22, 2010, Mr. Piatkowski informed the Service by email that the Wilmington Corps had been directed by Corps Headquarters Policy reviewers to remove two monitoring commitments that were identified during the informal consultation process and subsequently included within the DEIS to reduce the potential effects of the subject project on nesting sea turtles and seabeach amaranth germination. One commitment removed, listed as number 9 in the DEIS, involved Corps contribution of funds for the North Carolina Wildlife Resources Commission to continue its temperature studies in order to gather nest temperatures on nourished beaches throughout the state, including Topsail Island, in comparison to non-nourished native sediment temperatures. The Wilmington Corps was interested in understanding the threshold of sediment color change and resultant heat conduction on impacting temperature-dependent sex determination of sea turtles. These data were to be used to help develop management criteria for sediment color guidelines. This would enable managers to modify this and other projects in future years to reduce effects to sea turtles, as appropriate. The second commitment removed, designated as number 11 in the DEIS, involved monitoring for seabeach amaranth on Surf City and North Topsail Beaches to assess the post-nourishment presence of plants. This survey was to be broken down into survey reaches for each town in accordance with the designated Corps seabeach amaranth survey reaches from 1991-2008 in order to maintain consistent data and survey techniques over time. The results were to be provided to the Service as part of our ongoing recovery efforts for this threatened plant. The other nine conservation measures given in the BA were not affected by the Corps Headquarters Policy review.

Subsequent discussions within the Corps led to a decision to retain the two conservation measures on a one-time basis. Essentially, the measures would be employed after initial construction and then discontinued for the remainder of the 50-year project. By email on August 4, 2010, the Wilmington Corps requested the Service's opinion on the status of ESA compliance with the incorporation of the proposed changes into the project.

The Service determined that changes in the project constitute new information that was not considered in the Service's concurrence on the absence of adverse impacts to both sea turtles and seabeach amaranth. After reviewing the overall project, the Service informed the Wilmington Corps on August 10, 2010, that our initial concurrence would remain in effect only during the period when all the original conservation measures continued to be implemented. That is, the Service would concur with the Corps' determination only through the one-time implementation of all 12 conservation measures. This concurrence would apply to the initial beach construction effort, but not to any of the subsequent reconstruction events over the 50-year project period described in the DEIS.

By this letter the Service is informing the Corps that our concurrence with your effects determination applies only to initial construction and post-construction monitoring phase of this project. We recommend that the Corps provide a new determination and seek consultation prior to initiation of subsequent phases. These determinations must be based on a thorough analysis of data gathered after initial construction. None of the proposed reconstruction events should occur prior to a consultation with the Service.

At this time, the Corps has complied with ESA requirements for only the initial construction effort and the required monitoring after that construction. In accordance with the ESA and based on the information provided and other available information, it appears that the one-time, initial beach construction for the subject project is not likely to adversely affect federally listed species or their critical habitat as defined by the ESA. We believe that the requirements of section 7 (a)(2) of the ESA for this limited part of the overall project have been satisfied. However, obligations under the ESA must be reconsidered for the initial construction effort if: (1) new information identifies impacts of this action that may affect listed species or critical habitat in a manner not previously considered; (2) this action is modified in a manner that was not considered in this review; or, (3) a new species is listed or critical habitat determined that may be affected by the identified action.

Additionally, please note that it is not our practice to conclude consultation on something less than a complete project. We are only doing so in this case in the interest of moving the project forward in light of the fact that no take of listed species is anticipated in association with the first phase; and on the assumption that consultation will be re-initiated prior to subsequent phases. We do not intend to do this again for this or other Corps projects, and recommend that future Corps requests for consultation include only those conservation actions to which the Corps is confident they can commit.

The Service appreciates the Corps' commitment to protecting federally listed species that may be impacted by this beach construction project. All conservation measures, even if they may seem minor, contribute to the Federal effort to recover each species. If you have questions regarding this consultation between now and the end of 2010, please contact Howard Hall at (919) 856-4520, extension 27. For consultation in 2011 and beyond, please contact me for the appropriate member of my staff.

Sincerely,

Pete Benjamin
Field Supervisor

cc:

Ron Sechler, NOAA Fisheries, Beaufort, NC
Molly Ellwood, NC Wildlife Resources Commission, Wilmington, NC
Matthew Godfrey, NC Wildlife Resources Commission, Wilmington, NC
Stephen Rynas, Federal and State Consistency Coordinator, NC Division of Coastal Management, Morehead City NC
Anne Deaton, NC Division of Marine Fisheries, Morehead City, NC

FINAL
FISH AND WILDLIFE COORDINATION ACT REPORT
for
SURF CITY – NORTH TOPSAIL BEACH, NORTH CAROLINA, SHORE PROTECTION PROJECT

May 2010

This constitutes the Final Fish and Wildlife Coordination Act (FWCA) Report of the U. S. Fish and Wildlife Service (Service) for the Surf City-North Topsail Beach (SC-NTB), Shore Protection Project, Pender and Onslow Counties, North Carolina. The project consists of initial construction of a berm and dune system along approximately 9.9 miles of Atlantic shoreline in the central section of Topsail Island with periodic reconstruction of the system at approximately three-year interval over a period of 50 years. Beachfill material would be dredged from offshore, marine sand deposits. This report identifies fish and wildlife resources located in the project area and the potential impacts of the Corps' recommended project on these resources. This report constitutes the Service's report in accordance with Section 2(b) of the FWCA (48 Stat. 401, as amended; 16 U.S.C. 661 - 667d) and is provided in accordance with our FY 2010 Transfer Funding Agreement and Scope of Work.

Introduction

The Service has coordinated with the Corps on various beach construction efforts on Topsail Island since the 1990s. On March 16, 2001, The Service provided scoping comments on the SC-NTB project. These comments expressed concerns that efforts to reduce storm damage to man-made structures may seriously degrade the habitat values provided by beaches and nearshore marine areas. This concern is most acute in regard to the long-term impacts of engineered structures (e.g., seawalls and artificial beach-dune systems) constructed to allow structures and infrastructure to remain in a fixed location as global sea level rises. On September 9, 2003, the Service provided a Planning Aid Letter that discussed five adverse, environmental impacts of a beach construction effort. The Service provided a Draft FWCA Report in June 2008 with 15 recommendations to avoid or minimize the adverse impacts of the 50-year program of beach construction using offshore sediment (U. S. Fish and Wildlife Service [hereafter USFWS] 2008). Most recently, the DOI provided comments on March 3, 2010, on the Draft Integrated Feasibility Report and Environmental Impact Statement (U. S. Army Corps of Engineers [hereafter USACE] 2009b).

Project Area and Need

This area represents the central portion of the Topsail Island, a 26-mile long barrier island. The need facing development in the project area is clearly evident from published descriptions of Topsail Island. Pilkey et al. (1998, p. 171) note that Topsail Island has a troublesome geologic setting along its entire length. The island is very narrow and flat with no significant area higher than the 500-year flood elevation. Most of the island lies

on the 100-year floodplain. The U. S. Navy abandoned a missile range on the island because storms and hurricanes repeatedly destroyed buildings and equipment during the mid-1940s and early 1950s (Frankenberg 1997 p. 171). Hurricane Hazel which struck the southern North Carolina coast in 1954 generated a storm surge of 9.5 feet on the island which has an average elevation of nine feet (Pilkey et al. 1998, p. 171). A 1987 evaluation by the North Carolina Department of Emergency Management indicated that the island would be largely underwater in a category 1 or 2 hurricane and would be completely submerged in a category 3 hurricane (Pilkey et al. 1998, p. 173).

The island was severely impacted by two hurricanes within an eight-week period during 1996. Prior to Hurricanes Bertha and Fran, a prominent artificial dune, 12 feet high and 50 feet wide, existed along much of southern Topsail Island (Pilkey et al. 1998, p. 180). Barnes notes (1998, p. 177-178) that large portions of the dunes between Figure Eight Island and Emerald Isle, an area including the current project area, were washed away by the first storm, Bertha, which set the stage for extensive beach erosion and ocean overwash during the second storm, Fran. Hurricane Fran leveled the dune on southern Topsail Island and the entire area was overwashed by the storm surge which deposited up to three feet of overwash sand in some parts of Surf City, (Pilkey et al 1998, p. 180). The storm surge associated with Hurricane Fran, a minimal category 3 storm at landfall, created a storm surge of 8-12 feet along North Carolina's southeastern coast (Barnes, 1998, p. 177).

Since private interests have chosen to develop Topsail Island as an ocean resort community in spite of its history of recurring storm damage, the Service agrees that there is a need to reduce damage to man-made structures in the project area. However, the discussion of the project area and project need is deficient in the lack of any appropriate consideration of global sea level rise. As sea level rises, there are natural geological processes that shift barrier islands landward. These processes allow these areas to persist and maintain natural sandy beaches. When efforts to preserve coastal development seek to prevent the adjustment of coastal areas to sea level rise, the results appear as the chronic erosion, a well recognized problem in the project area. The DEIS correctly notes (USACE 2009b, p. 75) that "substantial portions of the berm and dune system have been lost as the shoreline is being 'squeezed' between the ocean and adjacent development." A basic understanding of the receding shoreline is critical to developing effective, long-term solutions to protecting man-made structures near the ocean.

The Tentatively Selected Alternative

After eliminating a non-structural approach from a thorough evaluation, the Corps indentified a course of action identified as the tentatively selected plan (USACE 2009b pp 100-138). This plan consists of a sand dune constructed to an elevation of 15 feet above the National Geodetic Vertical Datum (NGVD, roughly equivalent to mean sea level, fronted by a 50-foot wide beach berm constructed to an elevation of 7 feet above NGVD. The berm and dune project would extend along a reach of 52,150 feet (9.9 miles) from the southern boundary of Surf City northward to the boundary of a Coastal Barrier Resource System Unit in North Topsail Beach. Depending on endpoint

conditions found at the time of construction, up to 2,000 feet of the berm and dune on each end of the project may be replaced with a tapered transition section.

The proposed borrow sites are located between 1 and 6 miles offshore at depths of 35 to 50 feet below mean lower low water (MLLW). Initial construction would require 11.5 million cubic yards of borrow material. Reconstruction would require 1.6 million cubic yards of borrow material at 4 year intervals. In total, about 31.1 million cubic yards of dredge material would be required for the 50-year project.

Several important conservation measures incorporated in the plan are provided (USACE 2009b, pp. 192-194) in Section 10.06.1. These commitments to reduce impacts to listed species include limiting hopper dredging to the period from December 1 through March 31, but only to the "maximum extent practicable." There would also be a commitment to use sediment compatible with the existing beach along with measures to assess and rectify any sediment compaction or escarpment formation.

Fish and Wildlife Resources in the Project Area

The general fish and wildlife resources in the area of the SC-NTB project have been discussed in prior reports by the Service (USFWS 2007, pp. 23-26; USFWS 2008, pp. 11-13). These prior reports provide a sufficient basis for the concerns and recommendations discussed in this report.

Evaluation of Environmental Impacts of the Tentatively Selected Plan

The Corps has provided a detailed discussion of the anticipated environmental effects of implementing the tentatively selected plan (USACE 2009b, pp. 139 - 185). In general, all the major resources are considered and the likely impacts of initial construction and the early reconstruction events are considered. However, the discussion seems based on the assumption that present environmental conditions will continue throughout the 50 years of the authorized project.

Current planning documents appear to lack a consideration of adverse environmental impacts that could occur in the final decades of the project if sea level rise is greater than currently predicted. For example, the plan assumes a consistent four-year reconstruction cycle throughout the project (USACE 2009b, p. 103). Plans for initial construction (USACE 2009b, pp. 100-101) indicate that a portion of the beachfill would be below mean low water, approximately -1.9 feet NGVD. Placing beachfill below the low tide line is essentially putting sand in the ocean. As sea level rises over the decades of the project, efforts to save the existing ocean front structures would result in a greater portion of imported sediment for each reconstruction event being placed in an area that would be open ocean under natural conditions.

Sediment placed below the natural low tide line is likely to be less stable than that placed on an intertidal or dry beach. Any accelerated loss of imported material is very likely to result in a reduction of the reconstruction interval. Such a reduction could pose a risk to

beach macroinvertebrates that form an important base on the coastal food chain. Literature dating back to the early 1970s along the southeast coast indicates that opportunistic infauna species (ex. *Emerita* and *Donax*) found in the beachfill areas are subject to direct mortality from burial; but recovery often occurs within one year (USACE 2009b, p. 143 and references therein). More frequent reconstruction operations along with post-storm, emergency sand placements would provide less time for these organisms to recover and maintain healthy population levels.

Over time, beach reconstruction at intervals less than four years would pose a risk to sea turtle reproductive success. The Biological Assessments states that, in most cases, sea turtle nesting success decreases during the year following beachfill operations as a result of escarpments obstructing beach accessibility, altered beach profiles, and increased compaction (USACE 2009b, Appendix I, p. 14). In Florida a decrease in nesting success was documented in the year following construction with an increase in loggerhead sea turtle (*Caretta caretta*) nesting success rates during the second season post-construction (Brock 2005 as cited in USACE 2009b, p. I-16). This was attributed to increased habitat availability following the equilibration process of the seaward crest of the berm. This study suggested that, if compatible sediment and innovative design methods are utilized to minimize post-construction impacts documented in previous studies, then the decrease in nesting success without the presence of escarpment formations, compaction, etc. may indicate an absence of abiotic and or biotic factors that cue the female to initiate nesting. That is to say, even constructed beach that appear to offer easy access for nesting sea turtles may lack some unknown factor necessary for nesting.

Overall, the literature indicates that there are inherent changes in beach characteristics as a result of importing beachfill to construct artificial dunes and berms. These changes can result in short-term decreases in sea turtle nesting success and/or alterations in nesting processes. The abundance of important beach invertebrates may be reduced (Peterson et al. 2000). Any decrease in the reconstruction interval on Topsail Island could result in less time for the imported material to assume the natural characteristics of beaches necessary for successful sea turtle reproduction and healthy populations of beach macrofauna.

Service Recommendations

The Service offered 15 specific recommendations in the Draft FWCA Report of June 2008 (USFWS 2008, pp. 42-47). The Corps has provided an official response to each recommendation (USACE 2009b, pp. 211-222). These 15 recommendations still form the basis for avoiding and minimizing adverse environmental impacts. This report offers the following additional information on the aspects of the project related to the Service's recommendations

The second recommendation of the Service requested a greater consideration of future sea level rise in assessing the environmental impacts of the proposed 50-year program of beach construction. Sea level in the final decades of the project may have a profound influence on the severity of environmental impacts. In order to provide full consideration

of the direct and indirect physical effects of a range of possible sea level change scenarios, the Corps released Circular No. 1165-2-211 (circular), entitled "Water Resources Policies and Authorities Incorporating Sea-Level Change Considerations Into Civil Works Programs" (USACE 2009a). The circular refers to the work of the U. S. Climate Change Science Program (CCSP 2009) and states that sea-level change can cause a number of impacts in coastal and estuarine zones, including changes in shoreline erosion, inundation or exposure of low-lying coastal areas, changes in storm and flood damages, shifts in extent and distribution of wetlands and other coastal habitats, changes to groundwater levels, and alterations to salinity intrusion into estuaries and groundwater systems (USACE 2009a, p. B-1). It is clear that the natural resources of barriers islands, such as Topsail Island, would benefit from being allow to naturally adapt to sea level rise by gradually move landward and upward on the coastal plain. A 50-year program of beach construction may provide some protection during smaller storms, but the longer-term net benefits are uncertain.

The circular states that sea level change must be considered in every Corps coastal activity as far inland as the extent of estimated tidal influence (USACE 2009a, p. 1). Furthermore, planning studies and engineering designs should consider alternatives that are developed and assessed for the entire range of possible future rates of sea level change (USACE 2009a, p. 2). The circular requires an evaluation of alternatives using "low," "intermediate," and "high" rates of future sea-level change for both "with" and "without" project conditions. The historic rate of sea level change will be considered as the "low" rate. The circular provides guidance in determining the intermediate and high rates of sea level rise.

Planning for the SC-NTB Project is based on a projected rate of sea level rise of 9.6 inches (0.8 of a foot) over the next 100 years (USACE 2009b, p. 212) and notes that this figure is within the likely range of sea level rise reported for all but the most pessimistic scenarios of the Intergovernmental Panel on Climate Change (IPCC). However, the Corps' circular requires a consideration of both the most recent IPCC projections and modified National Research Council (NRC) projections (National Research Council 1987). These projections should be added to the local rate of vertical land movement.

The Corps' circular notes (USACE 2009a, p. B-9) that the NRC report includes a range of possible future sea-level rise scenarios that is much greater than those presented by the IPCC (Intergovernmental Panel on Climate Change [hereafter IPCC] 2007). The 2007 IPCC report has received some criticism for not fully considering the possibility of rapid ice loss in Antarctica due to massive failures of the West Antarctic Ice Sheet. Including the upper scenarios from the NRC report allows planners and engineers to consider the possibility of much greater rates of sea-level rise than those presented in the 2007 IPCC report and to thus accommodate some of the criticism directed at the 2007 IPCC report. Overall, the "high" rate of sea level rise mandated by the recent Corps circular for use in project planning exceeds the upper bounds of IPCC estimates from both 2001 and 2007 to accommodate for the potential rapid loss of ice from Antarctica and Greenland (USACE 2009a, p. 2).

For the current project, the Corps should consider that since 1990, observed sea level has followed the uppermost uncertainty limit of the IPCC Third Assessment Report of 2002 (Rahmstorf 2007). Sea level is expected to rise as the ocean takes up heat and ice starts to melt, until a new equilibrium sea level is reached. Rahmstorf (2007) presents a semi-empirical approach for predicting future sea level rise. Based on temperature increases projected by the IPCC, Rahmstorf (2007) projects that sea level in 2100 may be one-half meter (1.64 feet) to 1.4 meters (4.59 feet) above the 1990 level.

The third recommendation of the Service requested a more comprehensive discussion of any Corps conclusion that the proposed project complied with Executive Order 11988. This EO was enacted to avoid, to the extent possible, the long- and short-term adverse impacts associated with the occupancy and modification of floodplains and to avoid direct or indirect support of floodplain development wherever there is a practicable alternative (USACE 2009b, p. 194). Most of Topsail Island is in the 100-year floodplain (Pilkey et al. 1998, p. 171) and most of the island would be largely underwater in a category one or two hurricane and nearly completely submerged in a category three hurricane (Pilkey et al. 1998, p. 173). Except for some dune areas, the entire SC-NTB project area is subject to hurricane storm surge flooding (USACE 2006b, p. 9).

In considering compliance with EO 11988, the Corps should realize that the most significant environmental impacts of the proposed 50-year program of periodic beach construction are likely to come in the final decades of the project. These adverse impacts would emerge as efforts are made to save existing development as sea level rises. The DEIS states (USACE 2009b, p. 212) that it is likely that the without-project condition (with its diminished dune and berm) would be more sensitive to sea level rise than the with-project condition, and thus the net benefits for the beachfill project would be increased. This statement is based on the premise that resources will be available to effectively protect existing development for decades to come. Since the offshore area, Onslow Bay, is a sediment starved system consisting mostly of a thin patchy veneer of three to six feet of modern sediments covering the low relief Oligocene limestone and siltstone (USACE 2009b, p. 24), fill material may become limited in the final decades of the project.

The Corps responded (USACE, 2009b, p. 195) that beach nourishment has been accepted as a valuable tool in moderating flooding and protecting floodplains. Placement of beachfill will occur in the floodplain of area beaches. This placement will be conducted specifically for its beneficial effect in offsetting erosion and restoring damaged beaches, and is, therefore judged acceptable. The action is expected to have an insignificant effect on the floodplain. The Corps concludes, therefore, that the proposed action is in compliance with the requirements of EO 11988 and with State/local flood plain protection standards.

The Service believes that the 50-year program of sediment disposal will have adverse impacts on the Topsail Island floodplain, especially if the time interval between reconstruction events is reduced in the final decades of the project. Important beach infauna would have less time to recover between reconstruction events. Important

nearshore fishes and shorebirds may lose part of important food resource if infaunal populations are not given sufficient time to recover.

If the Corps has a broad mandate to reduce storm damage and protect human lives in the project area (as opposed to preserving current development and facilitating additional development), then there should be a consideration of whether development on the low lying and flood-prone barrier island represents wise use of this floodplain. As noted by Frankenberg (1997, p. 171) the military abandoned its missile testing operations on Topsail Island because storms and hurricanes repeatedly destroyed buildings and equipment. It is only a matter of time before a storm similar to Hurricane Hazel (1954) strikes. That storm destroyed 210 of the 230 houses in what was then the community of New Topsail Beach (Barnes 1998, p. 100). Past history and the likelihood of more intense storms should be considered in the Corps' compliance with EO 11988.

In determining whether a given course of federal action would comply with EO 11988 there should be a consideration of conditions at the northern end of the island which is within the Coastal Barrier Resource System (CBRS). The CBRS was established by the Coastal Barrier Resources Act (CBRA) of 1982. In the legislation Congress declared (16 U.S.C. § 3501(a)(3)) that "coastal barriers serve as natural storm protective barriers and are generally unsuitable for development because they are vulnerable to hurricanes and other storm damage and because natural shoreline recession and the movement of unstable sediments undermine manmade structures." Furthermore, "certain actions and programs of the Federal government have subsidized and permitted development on coastal barriers and the result has been the loss of barrier resources, threats to human life, health, and property, and the expenditure of millions of tax dollars each year" (16 U.S.C. § 3501(a)(4)).

The CBRA seeks to minimize the loss of human life, wasteful federal expenditures, and damage to fish, wildlife, and other natural resources associated with coastal barriers. The areas placed within the CBRS included "undeveloped coastal barriers." More than seven miles at the northern end of Topsail Island are included within the CBRS. Therefore, Congress has determined that development within certain areas at the northern end of the island pose a risk to human life and such development has the potential for requiring wasteful federal expenditures. The project area for this federal action was excluded from the CBRS due to the level of existing development at the time the CBRS was enacted. It was correctly determined that it would be unfair to retroactively deny federal assistance, including federal flood insurance, to existing property owners in the more developed central and southern parts of the island. The exclusion of all but the northern part of the island from the CBRS was based on the level of existing development, not on any determination that there was less risk to human life or the potential for wasteful federal expenditures. Considering the spatial extent of major hurricanes at landfall, the variation in storm damage between the northern, central, and southern portion of this 26-mile-long barrier island are likely to be slight to none.

Compliance with EO 11988 requires a consideration of whether the SC-NTB project area shares the same characteristics as the CBRS area directly north of project area. If the

project area does have the same level of risk as the adjacent area, does the proposed 50 years of beach construction, which seeks to preserve development, comply with the intent of EO 11988? The Service is not suggesting in any way that the restrictions on federal funding applicable to areas within the CBRS be applied to areas outside the system. We are suggesting that the conditions which led to the inclusion of northern Topsail Island in the CBRS be considered for the current proposal for beach construction in the context of EO 11988. The CBRA and EO 11988 are entirely different factors to be considered by the Corps. That is to say, Congress has declared that federal expenditures for development on the northern part of the island (within the designated CBRA Unit) could contribute to the loss of human life, wasteful federal expenditures, damage to fish, wildlife, and other natural resources. Therefore, when viewed from the perspective of EO 11988, federal expenditures for constructing and maintaining an artificial beach may contribute to additional development directly south of the CBRS Unit and thereby support the "unwise use" of a floodplain.

Unless a storm damage reduction strategy is implemented to provide protection against storms such as Hazel and Fran, the area will continue to have repeated cycles of destruction and rebuilding. The question to be answered in regard to EO 11988 is whether such repeated destruction and rebuilding represents unwise floodplain development which should not be supported by actions of the executive branch. Whether state and local funds would be periodically provided to construct the beach is not the issue, the issue is whether actions by the Corps, as part of the executive branch of the federal government, maintain existing development and support additional development in an inherently dangerous location.

The DEIS states that an Independent External Peer Review (IEPR) will be conducted following the Agency Team Review (USACE 2009b, p. iv). The IEPR will be conducted by a non-USACE national team of experts in the field, and coordinated by the National Planning Center of Expertise in Coastal Storm Damage Reduction, North Atlantic Division, U. S. Army Corps of Engineers. Comments and responses will accompany the report to the Assistant Secretary of the Army for Civil Works (ASA(CW)) and the Office of Management and Budget (OMB). Documentation of IEPR certification will accompany the final report. The Corps should ensure that the IEPR fully considers a low, medium, and high rate of sea level rise over the course of the project life. The long-term viability of existing and future development on the floodplain of Topsail Island under each sea level rise scenario should be fully evaluated in light of the mandate of EO 11988. That is, a determination should be made on whether existing and future development represent the wise use of the floodplain under each sea level rise scenario.

Both the Corps and the IEPR should conduct a broad reevaluation of the merits of structural versus non-structural alternatives for reducing storm damage in the project area. The Corps stated that in analyzing potential measures, the study team considered both structural and non-structural measures in all cases where technically sound and environmentally feasible (USACE 2009b, p. iv). Nonstructural measures, such as removal and relocation, were found to be of greater cost than benefits, and therefore, were not recommended for the purposes of storm damage reduction.

However, the study team's recommendations that accompany all structural recommendations for dune and berm construction include continued and vigilant attention to the need for pro-active hurricane and coastal storm threat education, coastal storm and hurricane warning and evacuation planning procedures, floodplain management, and other non-structural activities directed at both damage reduction and preservation of life and safety. These actions are recommended, although many do not fall within current Corps implementation authorities.

A new evaluation in light of the potential for a high rate of sea level rise may reveal that a program of periodic beach construction will not adequately protect development on the Topsail Island floodplain. The carefully planned implementation of non-structural actions, including phased removal and relocation of buildings, may provide greater long-term economic and social benefits.

Federally Protected Species

Recommendations 12 through 15 of the Service's Draft FWCA Report addressed conservation measures for federally protected species. The Corps responded to each recommendation (USACE 2009b, pp. 211-222). Additional consideration of federally protected species is given in the DEIS (USACE 2009b, Appendix I). This appendix represents the Biological Assessment (BA) of the Corps. The species considered in the BA (Table 2, p. I-4) includes all the federally protected species likely to be directly or indirectly impacted by the tentatively selected plan. The BA separates these species into those which could be impacted by in-water dredging activities and those which could be impacted by onshore sediment placement and beach construction. The former group, primarily those found exclusively in a marine environment, is under the jurisdiction of the National Marine Fisheries Service. The latter group, those likely to be impacted by beach construction, is under the jurisdiction of the Service. Protection of sea turtles is divided between these agencies with the Service being responsible for sea turtles when they come ashore to nest. The species considered by the Service include the West Indian manatee (*Trichechus manatus)*, piping plover (*Charadrius melodus*), seabeach amaranth (*Amaranthus pumilus*), and three species of sea turtles, the loggerhead (*Caretta caretta*), green (*Chelonia mydas*), and leatherback (*Dermochelys coriacea*).

The BA accurately states that dredging operations, beach placement of material, and associated construction operations (i.e. operation of heavy equipment, pipeline route, etc.) may adversely affect some species and their habitat (USACE 2009b, p. I-5). Potential impacts vary according to the type of equipment used, the nature and location of sediment discharged, the time period in relation to life cycles of organisms that could be affected, and the nature of the interaction of a particular species with the dredging activities.

The two most critical factors of any beach construction effort that influence the degree of impacts are the physical compatibility of the material used for beach construction (i.e., the degree of sediment compatibility) and the time of year that the work is conducted. The BA addresses these and other conservation measures in Section 4 of the BA,

Commitments to Reduce Impacts to Listed Species. These commitments are also provided in the DEIS (USACE 2009b, pp. 192-194).

Current plans state that initial construction and each nourishment interval will avoid the sea turtle nesting season (USACE 2009b, p. 193). The proposed dredging and beach construction schedule extends from December 1 through March 31 for both initial construction and each reconstruction event (USACE 2009b, p. 220). If, due to unforeseen circumstances, construction extends into the nesting season, the Corps will implement a sea turtle nest monitoring and avoidance/relocation plan through coordination with Service and the North Carolina Wildlife Resources Commission

Current plans state that beachfill material will comply with grain size and percent weight requirements specified in 15A NCAC 07H .0312, Technical Standards for Beach Fill Projects (USACE 2009b, p. 214). The Technical Standards require compatibility of the native beach with borrow sources in regards to the percentage of silt, granular sediment, gravel, and calcium carbonate (or shell content for projects initiated before implementation of the rules). Furthermore, the Corps intends to perform rigorous boring analyses of proposed borrow areas in order to minimize the risk of placing incompatible material on the beach (USACE 2009b, p. 214). Throughout the duration of construction operations, the Corps will employ full-time construction inspection personnel to perform on-sight inspections of the project operations to assure quality control and compliance with contract specifications. The Corps will receive daily production reports from the contractor that provide detailed information pertaining to the Contractor's daily operations. Corps construction inspection personnel will inspect the beach for any significant amount of incompatible material within the project limits throughout the contract duration, and if any incompatible material is identified within the placement area, the Corps will coordinate with the appropriate agencies to identify the quantity of material and discuss the methods of removal and disposal prior to the sea turtle nesting season.

The Corps summarizes the effects of in-water dredging activities and beach placement activities in a table in Appendix I (USACE 2009b, p. I-37). While in-water dredging is likely to adversely affect the five species of sea turtles, such impacts are considered by the National Marine Fisheries Service. Among the species under the jurisdiction of the Service, including all sea turtles that come ashore to nest, the proposed work is expected to have either no effect or is not likely to adversely affect on these species. The table correctly notes that there is no formally designated critical habitat in the project area.

Overall, based on the information provided in the DEIS and BA, the Service concurs with the Corps determinations that the proposed action is not likely to adversely affect federally listed species or their critical habitat as defined by the Endangered Species Act (ESA) of 1973, as amended (16 U.S.C. 1531-1543). Therefore, the requirements of section 7 (a)(2) of the ESA have been satisfied for this project. However, the Corps' obligations under the ESA must be reconsidered if: (1) new information identifies impacts of this action that may affect listed species or critical habitat in a manner not previously considered; (2) this action is modified in a manner that was not considered in

this review; or, (3) a new species is listed or critical habitat determined that may be affected by the identified action.

With regard to project modification, the Corps should contact the Service if beachfill must be extended outside the proposed schedule of December 1 through March 31 or the material to be used for the beachfill deviates significantly from the standards proposed in the DEIS. Furthermore, significant placements of beachfill between the scheduled reconstruction operations given in Table 7.11 (USACE 2009b, p. 126) would represent modification of the proposed effort. The Corps should contact the Service if more than 1.6 million cubic yards of material, the standard reconstruction volume, are placed on project area beaches between established reconstruction events.

Summary of Findings and Position of the Service

Overall, the DEIS presents an excellent review of the resources in the project area and the potential adverse impacts of offshore dredging and beach construction under present day conditions. However, the DEIS states (USACE 2009b, p. 83) that the planning process is subject to limitations imposed by certain restraints. These restraints include current limits of knowledge, information, and predictive ability. These limitations are critically important in regard to the future rise of sea level and the real possibility of more frequent storms of greater magnitude. Therefore, the Service recommends that the policies outlined in the Corps' July 2009 circular be applied to the current project. Specifically, over the 50 years of proposed beach construction efforts (from approximately 2014 to the early 2060s) the effectiveness of the artificial beach and environmental impacts of maintaining such a beach should be evaluated for a low, intermediate, and high projection of sea level rise. The low projection would be essentially the rate of rise observed in the recent past. For the high projection, and to a lesser extent the intermediate projection, the reconstruction intervals should be carefully evaluated in the final decades of the project. It is very likely that significant sea level rise would result in much shorter reconstruction intervals that would create adverse environmental impacts not considered in the current DEIS.

Barrier islands and spits are inherently dangerous places for any man-made structures such as roads, houses, or utility infrastructure. The islands are subject to the full force of both tropical hurricanes and winter storms (nor'easters). Early residents recognized this fact of coastal living and built their homes as far from the ocean as possible. On the Outer Banks, development was limited to the sound side of the islands until the mid-1880s (Frankenberg 1995, p. 118). Current beach front development occupies an extremely hazardous location as shown by the devastation seen in North Carolina by Hurricane Hazel in 1954 and the Gulf Coast by Hurricane Katrina in August 2005.

The threat to all development on barrier islands is increased by the rise in global sea level. While the causes of sea level rise may be debated, the increase has been well documented (see Appendix B, USACE 2009a) and is likely to continue for many decades, perhaps at an increasing rate of rise. The intensity of hurricanes may also increase as ocean waters become warmer. Therefore, both the threat of damage during

storms and the gradual inundation of the coastline can be expected to continue throughout the proposed 50 years of the beach construction effort and beyond.

While it may appear that even calm ocean waters are destroying the beaches through erosion, this is not correct. Barrier islands are not fixed, stationary landforms. These islands are unconsolidated masses of gravel, sand, and mud surrounded by ocean and estuarine waters. They are characterized by low elevation, narrow width, and fragile vegetation cover (Bush et al. 1996, p. 11).

When global sea level is rising, natural processes push the islands landward and allow them to survive. One of these natural processes is the movement of sand from the beaches across the island to the sound side. From the perspective of a beachfront structure, this process of island overwash appears to represent the destruction of the beach. If artificial dunes block the island overwash process, the sand may be lost to deeper offshore waters rather than contributing to the survival of the island. Pilkey et al. (1998, p. 4) state that "when sea level is rising, as it is today, barrier islands do not stay in one place; they migrate in order to survive."

Therefore, it should be understood that while hurricanes cause tremendous damage to fixed, man-made structures, they do not create long-term damage to barrier islands. In fact, the forces that occur during major storms and are so destructive to man-made structures are necessary for barrier islands to respond to sea level rise and ultimately continue to exist. The wide natural beaches that are so important to the tourist economy are not destroyed as the islands move landward. They merely change location. The current loss of the beach in the project area results from the area being squeezed between a rise ocean and a fixed line of structures.

All man-made structures near the rising ocean are unquestionably in danger. If governments at all levels take no action to hold back the rising ocean, individual property owners will probably undertake short-term efforts (e.g., beach bulldozing, sandbag walls) to save structures near the ocean. These efforts are likely to be ineffective in the long term and the width of the beaches would continue to diminish (USACE 2006a, p. B-32).

Therefore, while government action is not needed to save the beach, action is needed to save beach front development. Government action can be categorized as either non-structural or structural. A non-structural approach involves a number of actions to remove or relocate structures threatened by storms and coastal inundation. This type of response is based on the premise that storm damage is reduced when there is nothing to be damaged. These measures would require consideration of suitable relocation sites and compensation for property owners. The approach would also restore valuable barrier island habitats, such as overwash areas, that have been lost by effort to stop the landward movement of barrier islands.

On the other hand, structural responses consist primarily of construction to either hold existing sand in place (seawalls, groins, jetties, sandbags, etc) or the periodic placement of imported beachfill to replace the sand that has washed away. These approaches

generally produce numerous short-term adverse impacts on fish and wildlife resources. There are design features and construction techniques to minimize the some of the adverse impact of actual beach construction at the present sea level. The use of highly compatible beach fill, a restricted work schedule, and a reconstruction interval of four years would retain most of the habitat functions of the beach and dune communities.

The most significant question with regard to the long-term conservation of fish and wildlife resources is whether beach construction efforts which provide limited security in the short run can be maintained over 50 years and beyond as sea level continues to rise. Over many decades, a greater portion of the beach fill used to reconstruct the beach at its present location will actually be below what would be the natural low tide level. The artificial beach, partially built in the ocean, will wash away in ever shorter time intervals over the life of the project. There is a concern that over many decades the escalating costs of more frequent beach replacement along with diminishing supplies of available beachfill will lead to demands for rock seawalls to protect the ever increasing value of shoreline property. Where seawalls are built, the beach is eventually lost (Pilkey et al. 1980, p. 10).

In light of the findings discussed above, the Service believes that action must be taken to reduce the periodic destruction of man-made structures in the project area. However, implementation of a long-term program of beach construction is not likely to remain effective as sea level continues to rise. The environmental issues surrounding a long-term program of beach and dune construction involve much more than just offshore sediment extraction and beach construction. The most significant issues are the consequences of attempting to hold the island in place as the ocean rises around it. When beachfill no longer provides cost effective protection, rock seawalls would be required to hold back the rising water. Eventually the beaches and salt marshes of the sound would be lost. Pilkey et al. (1998, p. 102) have summarized the issue by stating that "in the long run, North Carolinians must make a decision. They can have beaches or they can have beachfront buildings; they can't have both. If we opt in favor of buildings, the beaches will be lost – and so, ultimately will the buildings."

Our review of the available information regarding this project leads us to believe that the long-term success of the proposed approach is questionable and it is likely that other structural or non-structural measures will need to be implemented during the life of the project. Furthermore, we note that non-structural measures would be more successful at conserving the natural resources of the project area.

The Service again recommends that planning for the current project should give greater consideration to EO 11988 which seeks to avoid federal support for unwise development within floodplains which can result in both high costs for reconstruction and danger to human life and safety. The SC-NTB project is immediately south of a CBRS unit and shares the same storm damage risks as the CBRS unit. Current plans acknowledge (USACE 2009b, p. 129) that structures will continue to be subject to damage from hurricane winds and windblown debris. Damages from flooding and winds are expected to decrease as older structures are replaced with those meeting floodplain ordinances and

wind hazard building construction standards. But even new construction is not immune from storm damage, especially from major hurricanes. Therefore, the Corps should carefully consider whether this federal effort, currently proposed as a 50-years program of beach construction, is in compliance with EO 11988 which seeks to reduce the loss of human life, wasteful federal expenditures, and damage to fish, wildlife, and other natural resources by avoiding unwise development of floodplains.

Literature Cited

Barnes, J. 1998. North Carolina's Hurricane History – Revised and Updated Edition. The University of North Carolina Press. Chapel Hill. 256 pp.

Brock, K. 2005. Effects of a shore protection project on loggerheads and green turtle nesting activity and reproduction in Brevard County, Florida. M.S. Thesis, University of Central Florida, Orlando, Florida. 66 p.

Bush, D. M., O. H. Pilkey, Jr., and W. J. Neal. 1996. Living by the Rules of the Sea. Duke University Press. Durham, North Carolina. 179 pp.

CCSP, 2009: Coastal Sensitivity to Sea-Level Rise: A Focus on the Mid-Atlantic Region. A report by the U.S. Climate Change Science Program and the Subcommittee on Global Change Research. [James G. Titus (Coordinating Lead Author), K. Eric Anderson, Donald R. Cahoon, Dean B. Gesch, Stephen K. Gill, Benjamin T. Gutierrez, E. Robert Thieler, and S. Jeffress Williams (Lead Authors)]. U.S. Environmental Protection Agency, Washington D.C., USA, 320 pp. . Available at (< http://www.climatescience.gov/Library/sap/sap4-1/final-report/default.htm >).

Frankenberg, D. 1995. The Nature of the Outer Banks: Environmental Processes, Field Sites, and Development Issues, Corolla to Ocracoke. The University of North Carolina Press. Chapel Hill. 157pp.

_____. 1997. The Nature of North Carolina's Southern Coast: Barrier Islands, Coastal Waters, and Wetlands. The University of North Carolina Press. Chapel Hill. 250 pp.

Intergovernmental Panel on Climate Change (IPCC). 2007. Climate Change 2007: The Physical Science Basis, Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K. B. Averyt, M. Tignor, and H. L. Miller (eds.). Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA. Available at < http://ipcc-wg1.ucar.edu/wg1/wg1-report.html >

National Research Council. 1987: Responding to Changes in Sea Level: Engineering Implications. National Academy Press, Washington DC, 148 pp.

Peterson, C. H., D.H.M. Hickerson, and G.G. Johnson. 2000. Short-term Consequences of Nourishment and Bulldozing on the Dominant Large Invertebrates of the Sandy Beach. Journal of Coastal Research. 16(2):368-378.

Pilkey, O. H., W. J. Neal, O. R. Pilkey, Sr., and S. R. Riggs. 1980. From Currituck to Calabash: Living with the North Carolina's Barrier islands. Duke University Press. Durham, NC. 244 pp.

_____, _____, S. R. Riggs, C. A. Webb, D. M. Bush, D. F. Pilkey, J. Bullock, and B. A. Cowan. 1998. The North Carolina Shore and Its Barrier Islands - Restless Ribbons of Sand. Duke University Press. Durham, North Carolina. 318 pp.

Rahmstorf, S. 2007 (January). A semi-empirical approach to projecting future sea level rise. Science 315:368-370.

U. S. Army Corps of Engineers. 2006a (June). Draft General Reevaluation Report and Environmental Impact Statement – Shore Protection – West Onslow Beach and New River Inlet (Topsail Beach), North Carolina. Wilmington District, U. S. Army Corps of Engineers, Wilmington, North Carolina. Various pagination.

_____ . 2006b (August). Feasibility Report – Surf City and North Topsail Beach, North Carolina, Shore Protection Project. Alternative Formulation Briefing – Preconference Material. Wilmington District, U. S. Army Corps of Engineers. Wilmington, NC.

_____. 2009a (July). Water Resource Policies and Authorities Incorporating Sea-Level Change Considerations in Civil Works Programs. Circular No. 1165-2-211. U. S. Army Corps of Engineers, Washington, DC. 3 pp. + Appendices A-C. Available at < http://140.194.76.129/publications/eng-circulars/ec1165-2-211/ec1165-2-211.pdf >

_____. 2009b (August). Draft Integrated Feasibility Report and Environmental Impact Statement, Coastal Storm Damage Reduction, Surf City and North Topsail Beach, North Carolina. Wilmington District, U. S. Army Corps of Engineers. Wilmington, NC. 249 pp. + Appendices A-U.

U. S. Fish and Wildlife Service. 2007. West Onslow Beach and New River Inlet Project (Topsail Beach). Pender County, North Carolina. Final Fish and Wildlife Coordination Act Report. U. S. Fish and Wildlife Service. Raleigh Field Office, Raleigh, NC. 79 pp.

_____. 2008 (June). Draft Fish and Wildlife Coordination Act Report, Surf City-North Topsail Beach, Shore Protection Project. Raleigh (NC) Field Office, U. S. Fish and Wildlife Service. Raleigh, NC. 52 pp.

FEASIBILITY REPORT

AND

ENVIRONMENTAL IMPACT STATEMENT

COASTAL STORM DAMAGE REDUCTION PROJECT

SURF CITY AND NORTH TOPSAIL BEACH

NORTH CAROLINA

Appendix M

Real Estate

Contents

REAL ESTATE SUMMARY

SECTION 1. GENERAL

1.1 Guidance

1.1.1 Engineer Regulations 2

1.1.2 Engineer Circulars 2

1.1.3 United State Code 2

1.1.4 Code of Federal Regulations 2

SECTION 2. THE REAL ESTATE REPORT

2.1 Statement of Purpose 3

2.2 Study Authority 3

2.3 Project Location 3

2.4 Project Description 5

2.5 Real Estate Requirements 9

2.6 Utility/Facility Relocation 15

2.7 Exisiting Projects 15

2.8 Environmental Impacts 15

2.9 Hazardous, Toxic, and Radioactive Waste (HTRW) 15

2.10 Project Sponsor Responsibilities and Capabilities 15

2.11 Government Owned Property 16

2.12 Historical Significance 16

2.13 Mineral Rights 16

2.14 Public Law 91-646, Relocation Assistance Benefits 17

2.15 Attitude of Property Owners 17

2.16 Acquisition Schedule 17

2.17 Estates for Proposed Project 17

2.18 Real Estate Estimate 18

2.19 Chart of Accounts 21

Exhibits 23

SECTION 1. GENERAL

1.1. Guidance

1.1.1 Engineer Regulations

1. ER 405-1-12, Chapter 5 - Acquisition, 5 September 1978, Draft Revision, 9 June 2003
2. ER 405-1-12, Chapter 6 - Relocation Assistance Program, 23 March 1979, Draft Revision, 2 May 2003
3. ER 405-1-12, Chapter 12 - Real Estate Roles and Responsibilities for Civil Works: Cost Shared and Full Federal Projects, 1 May 1998, Draft Revision, 8 March 2003

1.1.2 Engineer Circulars

1. EC 405-1-11, Real Estate Acquisition, 30 December 2003

1.1.3 United States Code

1. 42 USC, Chapter 61 - Uniform Relocation Assistance and Real Property Acquisition Policies for Federal and Federally Assisted Programs

1.1.4 Code of Federal Regulations

1. Code of Federal Regulations, Title 49, Part 24 - Uniform Relocation Assistance and Real Property Acquisition for Federal and Federally-Assisted Programs

SECTION 2. THE REAL ESTATE REPORT

2.1 Statement of Purpose

This report is tentative in nature and is to be used for planning purposes only. The report is written based on specific data from Wilmington District and the tax assessor's office in Edgecombe County, North Carolina. There may be modifications to the plans that occur during Planning, Engineering and Design (PED) phase, thus changing the final acquisition area(s) and/or administrative and land cost. The Real Estate Appendix is intended to support the General Feasibility Report for the subject project. The author of this report has viewed the Project areas. This report pertains specifically to the Towns of Surf City and North Topsail Beach who are the non-Federal sponsors for the project.

2.2 Study Authority

Surf City and North Topsail Beach is a coastal storm damage reduction project. The project is authorized by the following resolutions:

"Resolved by the Committee on Transportation and Infrastructure of the United States House of Representatives, That the Secretary of the Army is requested to review the report of the Chief of Engineers on West Onslow Beach and New River Inlet, North

Carolina, published as House Document 393, 102nd Congress, 2nd session, dated September 23, 1992, and other pertinent reports, to determine whether any modifications of the recommendations contained therein are advisable at the present time in the interest of shore protection and related purposes for Surf City, North Carolina; (Resolution Docket 2617, Surf City, North Carolina, adopted February 16, 2000)

"Resolved by the Committee on Transportation and Infrastructure of the United States House of Representatives, That the Secretary of the Army is requested to review the report of the Chief of Engineers on West Onslow Beach and New River Inlet, North Carolina, published as House Document 393, 102nd Congress, 2nd session, dated September 23, 1992, and other pertinent reports, to determine whether any modifications of the recommendations contained therein are advisable at the present time in the interest of shore protection and related purposes for North Topsail Beach, North Carolina; (Resolution Docket 2629, North Topsail Beach, North Carolina, adopted April 11, 2000).

2.3 Project Location

Surf City, located in Onslow and Pender Counties, and North Topsail Beach, located in Onslow County, North Carolina, are on a barrier island located between New River Inlet to the north and New Topsail Inlet to the south. The barrier island is approximately 22 miles in length, with the Atlantic Ocean to the east and Topsail Sound, Stump Sound, Alligator Bay, Chadwick Bay, and the Atlantic Intracoastal Waterway to the west. From north to south, the communities of North Topsail beach (12 miles of ocean shoreline), Surf city (5.5 miles of ocean shoreline) and Topsail Beach (4.5 miles of ocean shoreline) are located on Topsail Island. Surf City was incorporated in 1949, and has a population of approximately 1,500 year round residents. North Topsail Beach was incorporated in 1990, and has a population of approximately 844 year round residents. A seasonal influx of tourists increases the population to thousands in the summer months. Each town has a fishing pier. A vicinity map of Topsail Island is at Figure 2.3-1 which also shows the study limits.

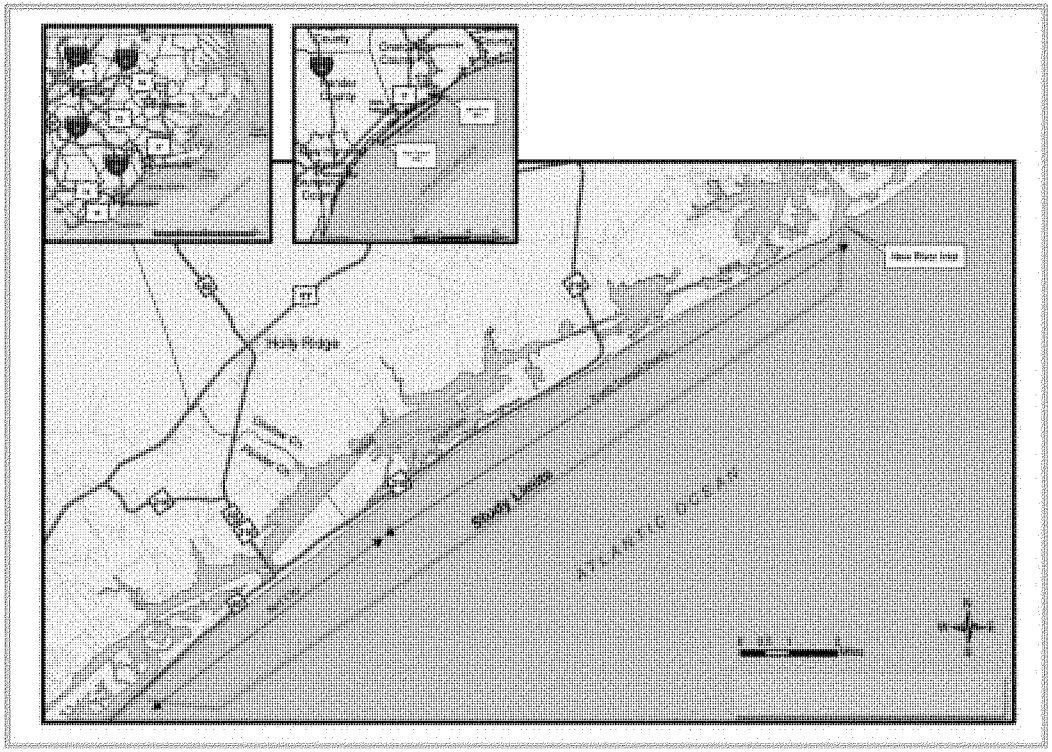


Figure 2.3-1. Project Vicinity/Location and Study Limits Map

2.4 Project Description

An array of plans were formulated and considered for the project. This Real Estate Appendix will focus on the recommended National Economic Development (NED) Plan, which is the 1550. A typical profile is shown for Surf City and for North Topsail Beach at Figure 2.4-2 and Figure 2.4-3. In concept, the project will consist of the construction and maintenance of a berm and dune system that will tie into the existing dunes and vegetation line. The 1550 plan is a beachfill plan with a 25-foot wide dune at elevation 15 feet National Geodetic Vertical Datum (NGVD), fronted by a 50-foot wide berm at elevation 7 feet NGVD. The project begins in Surf City with reach 26 and extends through the majority of reach 78 in North Topsail Beach. The total project is approximately 52,150 feet or 9.88 miles in length. Frequency of maintenance is estimated to be every four years. The constructed berm, will serve two primary purposes: as a stockpile of sand on the beach to serve as sacrificial material to reduce the erosion of the high ground beach during storm events and to provide storm damage reduction to beachfront structures by moving the point of erosion seaward, away from the structures.

Twenty offshore borrow areas have been identified as sources of sand for the project. They are shown at Figure 2.4-4. Detailed discussion on the borrow areas is found in the Geotechnical Analysis and in the Sand Compatibility Analysis. Some of the areas are within State waters which by definition are within three nautical miles of the shore, and some of the areas are outside the three nautical mile zone that defines the boundary. For those offshore borrow sites that are in the Outer Continental Shelf (OCS), a Memorandum of Agreement between the U. S. Army Corps of Engineers and Minerals Management Service (MMS) is necessary, and a noncompetitive lease between the sponsor and MMS must be negotiated. The OCS is a zone that generally extends from 3 nautical miles seaward of the coastal State boundaries out to 200 nautical miles. Any required permitting to borrow from sources within the OCS will be addressed during the National Environmental Policy Act (NEPA) and Environmental Impact Statement (EIS) process.

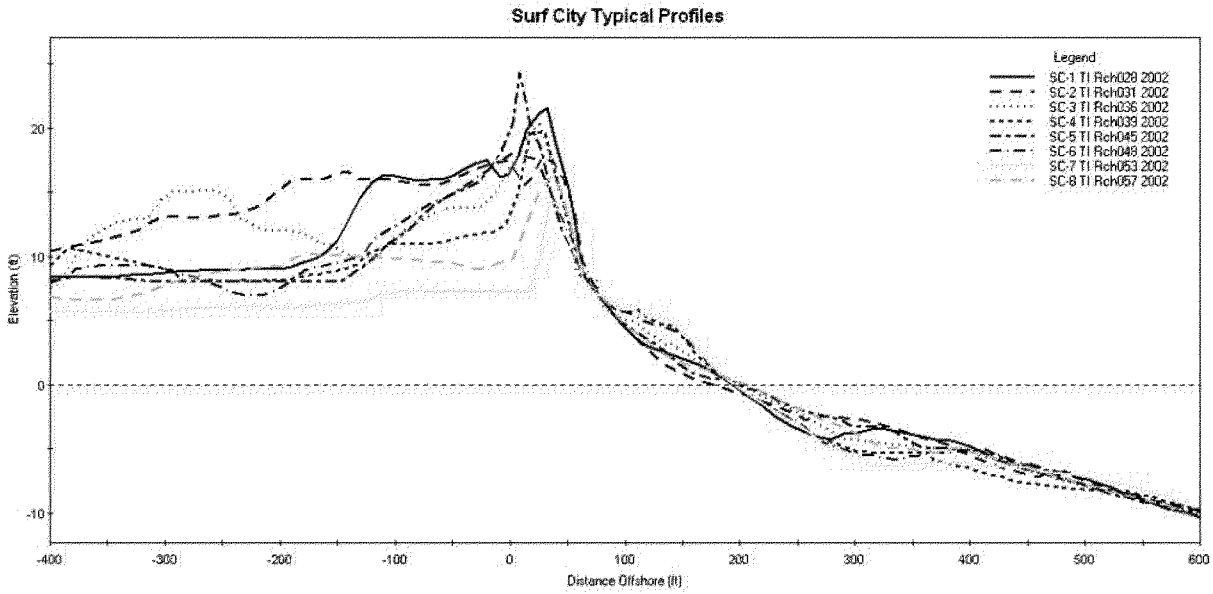


Figure 2.4.2 Surf City Typical Profile

869

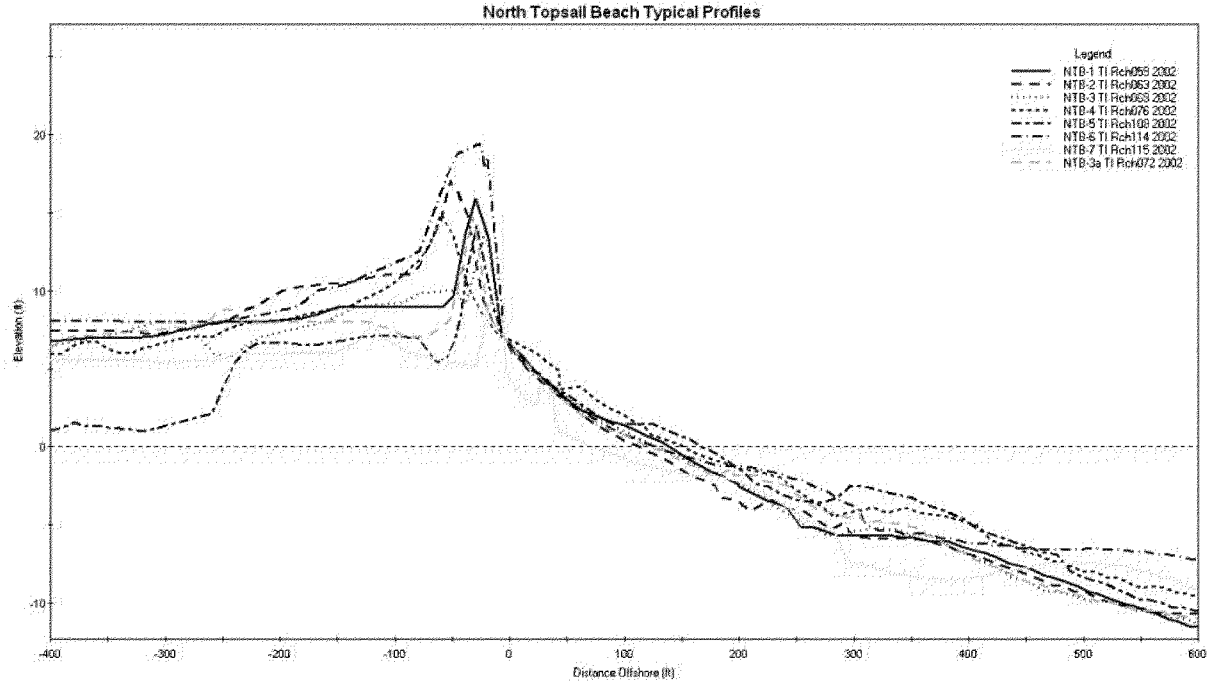


Figure 2.4-3 North Topsail Beach Typical Profile

870

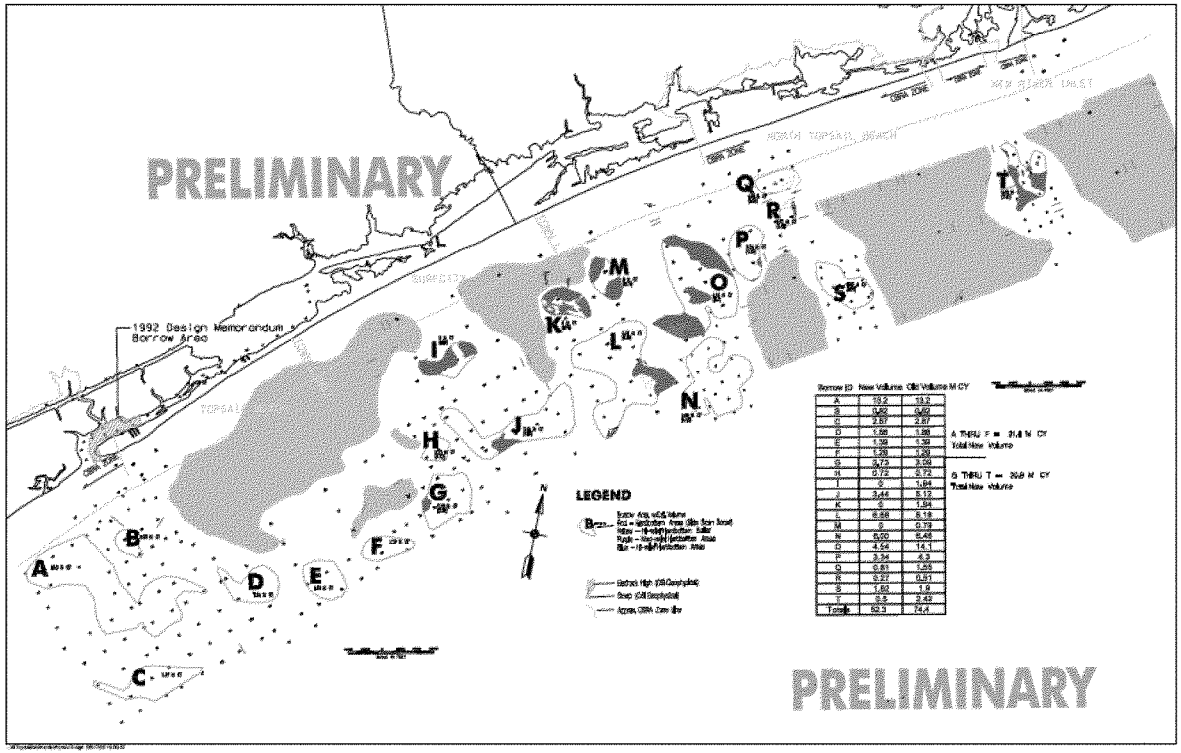


Figure 2.4-4 Offshore Borrow Areas

2.5 Real Estate Requirements

The requirements for lands, easements, rights-of-way and relocations, and disposal/borrow areas (LERRD's) include the right to construct a dune and berm system along the shoreline of Surf City and North Topsail Beach northward to reach 78. The Coastal Barrier Resources Act (CBRA) protects numerous zones along the North Topsail Beach shoreline. A CBRA zone begins at the northern part of reach 78 and the project will stop at that point. Privately owned properties included in the Project are considered to be in fee simple ownership. Included within the project limits are single family residential units, multi family and condominium units, and commercial properties, including the fishing piers. Exercise of Navigation Servitude is not applicable to the subject project as the focus of the project is for storm damage rather than for commerce related purposes and there is no nexus to navigation.

According to the project maps, and on the ground examination, one structure in Surf City, and two structures in North Topsail Beach may possibly be impacted by the project. There is precedence for allowing part of a structure to remain in the project foot print. However, based on ground inspection, it appears that the structures will impact the integrity of the proposed dune system and will need to be acquired. Based on data found in public records, these structures appear to be seasonal residences or possibly rental units, so if the lands must be purchased the project will not displace owners from permanent residences. This will have to be confirmed. The value of the land and improvements to be acquired at Surf City is estimated at $594,078 and the value of land and improvements to be acquired at North Topsail is estimated at $701,410.

Figure 2.5-1 shows a typical reach of oceanfront where structures are present. Widths of lots vary within the project, but an average lot width is estimated to be 50 feet. The average distance from the landward toe of the existing dune to the existing Mean High Water (MHW) line is 60 feet. Based on a ground examination, it appears that there will be no adverse impact to the upland portion of ownership. Improvements other than those noted above in the proposed easement area are walkways, beach access crossovers and the fishing piers. Private landowners have the option to remove their walkways to the beach prior to the start of project construction if they so desire in an effort to avoid damage to the walkways during construction. However, after construction of the project, the landowner would have to obtain a permit from the local authority to replace the walkway. It is noted that any walkway that may be damaged during construction would most probably be at least partially located within the proposed easement area. Within the easement area we have the right to remove any structures if necessary that may impact construction of the project. While every effort will be made to avoid damage to an existing walkway, no guarantee can be made that no damage will occur. Should damage occur to a walkway, a landowner is not entitled to any compensation for such damage and repair to a walkway is not considered to be a creditable item. The Storm Damage Reduction Easement does allow owners to build and maintain walkover structures subject to sponsor approval. It is noted that walkovers constructed by landowners after project construction may be subject to impact by subsequent nourishment events.

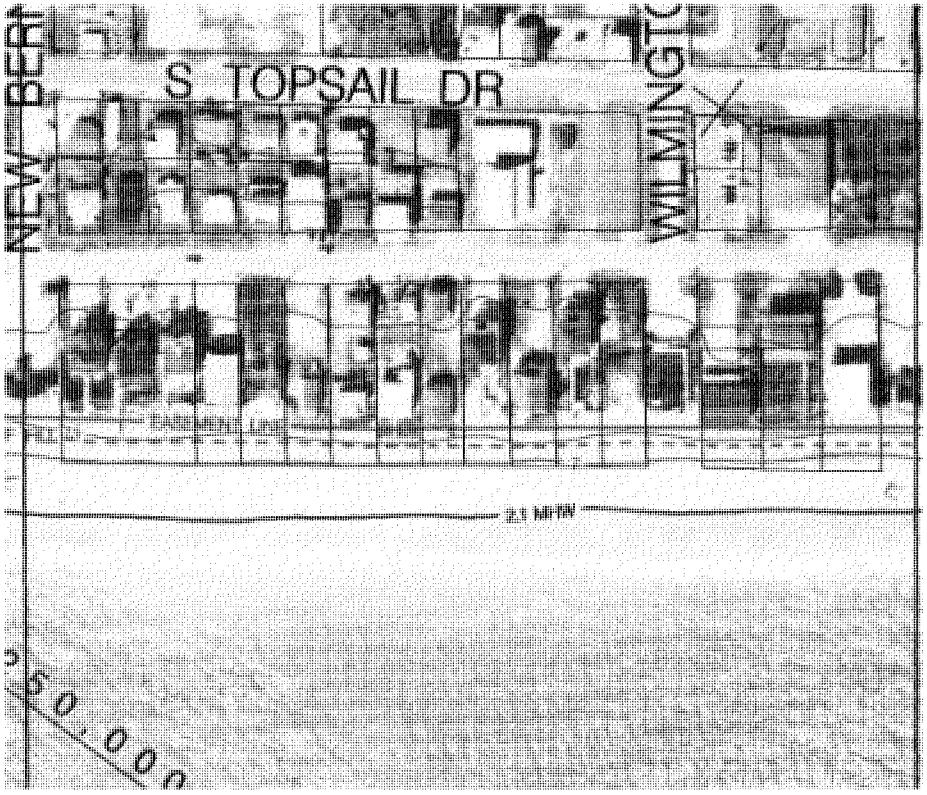


Figure 2.5-1 Typical Reach

873

Several parcels have been identified in North Topsail Beach as being available for use as staging areas. Some are owned by the town and an oceanfront parcel owned by the County may be available for use as well. These parcels are identified on Figure 2.5-2. Specific parcels have yet to be identified for Surf City, but the Town is aware that it will have to provide a site. If the Town does not provide a site owned by the Town, the Town will have to obtain a staging area site from a private landowner. Final site selection will be determined based on needs of the contractor. For planning purposes, an average cost of $29,000 was estimated as being a fair rental for staging/work area use for a period of 18 months to 2 years. The Federal rules of valuation were applied in determining value. It is possible that a proper valuation under the Federal rules may conclude that the benefits do not fully offset the value of the easement. Due to environmental windows, Temporary Work Area Easements will be necessary over 3.5 construction periods for purposes of project construction and for mobilization and de-mobilization of equipment.

Additionally, it is estimated that 501 Perpetual Beach Storm Damage Reduction Easements will be acquired within the Surf City portion of the project and 327 Perpetual Beach Storm Damage Reduction Easements will be acquired within the North Topsail Beach portion of the project for a total number of 828 easements to be acquired for the project. When final plans and specs are completed and the ground survey is completed, a definitive decision will be made if the three ownerships will have to be acquired. If not, this will increase the number of easements by three. All lands lying below MHW are lands of the State, and easements are not required to place fill below MHW. General procedure is to obtain a letter permit from the North Carolina Department of Administration State Property Office for those lands below MHW.

In summary, approximately 71.83 acres will be required in Perpetual Storm Damage Reduction Easements and approximately 2 ± acres will be required for Temporary Work Area Easements for staging areas. Approximately 0.41 acres may be acquired in fee simple.

Surf City and North Topsail Beach both have condemnation authority. Also NC law makes provision for towns to acquire and perform maintenance on real estate interests outside their boundaries for certain reasons. (North Carolina General Statutes (NCGS) 40A-3(b1) "Local Public Condemnors – Modified Provision for Certain Localities. – For the public use or benefit, the governing body of each municipality or county shall possess the power of eminent domain and may acquire by purchase, gift or condemnation any property or interest therein, either inside or outside its boundaries, for the following purposes. (10) Engaging in or participating with other governmental entities in acquiring, constructing, reconstructing, extending, or otherwise building or improving beach erosion control or flood and hurricane protection works, including but not limited to, the acquisition of any property that may be required as a source for beach renourishment.") As a point of interest, in October 2004, local governments of Topsail Island joined together to form the Topsail Island Shoreline Protection Commission. The participants are the Towns of North Topsail Beach, Surf City, and Topsail Beach, and the Counties of Pender and Onslow. The purpose of the Commission is to establish cooperation among the members to plan and implement programs and projects directed toward the preservation and maintenance of the ocean beaches. The Topsail Island Shoreline Protection Commission is noted in this report to show the strong desire of the members to work in unison to protect and preserve Topsail Island.

There are no easements for public water or power located within the proposed Project area. Surf City, North Topsail Beach and the State of North Carolina have lands located within the project boundaries. The Town interests include the ends of roads, maintained by the Town, which extend to the ocean, Coastal Area Management Act (CAMA) access points and beachfront properties maintained for public use. The State of North Carolina lands include the ends of dedicated roads and lands located below the mean high water line.



Figure 2.5-2. Potential Staging Areas in North Topsail Beach

An assumption is made that the town interests include all road ends within the project area, so street ends and public access points are not included in the estimated number of easements required for the project. According to the tax maps and verbal information from the towns, Surf City has 30 public access points, 25 of which are at street ends within the project limits, and North Topsail Beach has 29 public access points with 24 of those being at street ends in the project limits. In the event that it is determined that a road end or public access should be privately owned, an easement would have to be obtained thus increasing the estimated number of easements.

Access to the Project will be by public roads and rights of way. There are sufficient access areas along the beach at the ends of public streets and at public access areas for contractors to move pipe and construction equipment onto the beach. All staging and placement of pipe is expected to be within public areas or acquired easements. Permits and/or consent agreements for sand removal from borrow areas will be from appropriate state and/or federal agencies.

There are two piers, Surf City Ocean Pier (Surf City) and Seaview Fishing Pier (North Topsail), located within the study area. Only the Surf City Ocean Pier is within the limits that will receive fill. Pictures of the Surf City Ocean Pier are at Figures 2.5-3 and 2.5-4. Historically, in prior projects in North and South Carolina, fishing piers and their associated buildings have not been acquired, regardless of their location in relation to project lines. The primary reason is the significant economic impact that it would have on the community. Traditionally easements are acquired up to the face of the structures and beneath the pier. For purposes of this report, it is assumed that neither the pier nor appurtenances will be acquired. No values have been estimated for these structures. Some pier support cross-bracing may need to be removed to facilitate equipment shaping the beachfill and to improve longshore pedestrian access after construction.



Figure 2.5-3. - Surf City Ocean Pier

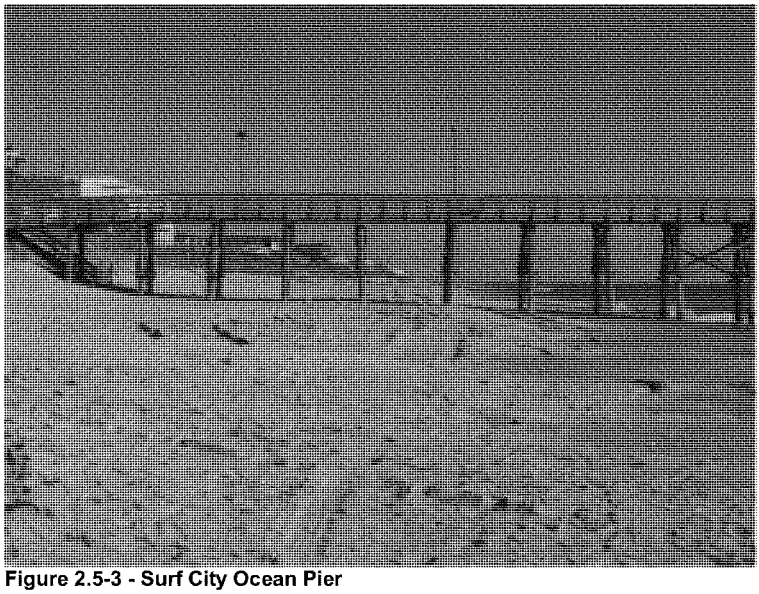


Figure 2.5-3 - Surf City Ocean Pier

Acquisition of lands under the proposed Perpetual Beach Storm Damage Reduction Easement will be along the existing dune system. In the absence of such a system, such as in areas of high erosion, the property has already been damaged by nature. No damages will likely result from the construction of the proposed dune and berm in conjunction with this project. Improvements (other than the Surf City Ocean Pier and the three structures mentioned as possibly being impacted) within the project include walkover structures that allow beach access from private and public property. It is noted in the easement that walkovers will be allowed, once the project is in place. It is common in the area that landowners have private walkovers from residences over the dunes to access the beach. In cases where new walkovers need to be constructed, the owners will have to obtain the necessary approvals from the Towns of Surf City and North Topsail Beach to construct an approved walkover upon completion of the project.

Project maps were used to identify the number of easements that may be required to construct the project. After careful consideration a determination was made to count each parcel within the project limits as a potential easement acquisition. The project maps show parcel lines based on subdivision plats. In randomly pulling deeds on different tax parcels, it is noted that some deeds reference ownership based on reference to a lot and block number as shown on a recorded subdivision plat or an actual metes and bounds description and reference to a particular plat map. They do not specifically state ownership to MHW of the Atlantic Ocean. However, some parcels are indicated on the project maps or tax maps as having lot lines as shown by a subdivision line but the deed references ownership to MHW of the Atlantic Ocean. Without searching title to each oceanfront parcel it cannot be determined who actually owns the property to MHW. In view of this, it seems prudent for planning purposes to assume that an easement may be needed from each property owner in the project. Although this may inflate the real estate acquisition cost, there is the possibility that the actual cost may be lower, but should not exceed the projected cost.

The North Carolina Coastal Area Management Act enacted in 1974 and amended 1 April 1987, designated sensitive environmental areas within its 20-county coastal jurisdiction as Areas of Environmental Concern (AEC). Within an AEC, development must conform to specific regulations, which are designated to promote and protect environmental values as set out in CAMA and in the AEC development regulations. There are four categories of AECs: the estuarine system, the ocean hazard system, public water supplies, and natural and cultural resource areas. All of the properties within the project boundaries will probably fall within the ocean hazard system AEC. The most important requirement of this AEC is that no construction is permitted within 60 feet of the first line of stable natural vegetation. The effect of the 60-foot CAMA (rear) setback coupled with the zoning setback for front yards has effectively rendered some lots undevelopable since the remaining buildable land is too small to permit construction of most structures.

Local sponsors must meet requirements for public access to participate in cost sharing with the Federal Government. Public access must be available every one-half mile, and parking must be within one-quarter mile of any access for which the sponsor desires to take credit. Engineer Regulation 1165-2-130 sets forth the requirements for public access. Surf City and North Topsail Beach currently do not meet this requirement. The sponsors are working toward meeting this requirement and understand that they must provide additional access points/ parking prior to signing the Project Partnership Agreement (PPA) to be eligible for full Federal cost sharing. These areas should be acquired either in fee or perpetual easement. Acquisition of public beach access points that are necessary for compliance in cost sharing is strictly a sponsor responsibility and is not considered a project cost. Accordingly, any cost incurred with the acquisition of public access points is not considered a creditable expense towards project cost.

2.6 Utility/Facility Relocation

There will be no utility relocations.

2.7 Existing Projects

A number of Federal navigation projects are near the study area. They are listed and briefly described at section **1.09 Existing Federal and Non-Federal Projects** in the main Feasibility Report.

2.8 Environmental Impacts

The project is not expected to have adverse environmental impacts.

2.9 Hazardous, Toxic and Radioactive Wastes (HTRW)

There are no documented active or inactive hazardous waste sites on Topsail Island. See Section 8.08.3 in the main Feasibility Report for a full discussion of HTRW.

2.10 Project Sponsor Responsibilities and Capabilities

The Towns of Surf City and North Topsail Beach will be the Project Sponsors (PS). The PS has the responsibility to acquire all real estate interests required for the Project. The PS shall accomplish all alterations and relocations of facilities, structures and improvements determined by the government to be necessary for construction of the Project. The sponsors currently do not have the staff

required for a large number of acquisitions. The sponsors are considering using the services of a contractor to perform the easement acquisitions required for the project. A presentation was made for the sponsors by SAS Real Estate that discussed the real estate acquisition process and set forth requirements for federal projects under P.L. 91-646. The sponsors have been advised of the possible risks of acquiring real estate prior to project approval and authorization of funding.

Title to any acquired real estate will remain vested in the Project Sponsor's name and will not be conveyed to the United States Government. Prior to advertisement of any construction contract, the PS shall furnish to the government an Authorization for Entry for Construction (Exhibit "B") to all lands, easements and rights-of-way, as necessary. The PS will also furnish to the government evidence supporting their legal authority to grant rights-of-way to such lands. Surf City and North Topsail Beach have specific condemnation authority for beach erosion control.

The PS shall comply with applicable provisions of the Uniform Relocation Assistance and Real Property Acquisition Policies Act of 1970, Public Law 91-646, approved

2 January 1971, and amended by Title IV of the Surface Transportation Uniform Relocation Assistance Act of 1987, Public Law 100-17, effective 2 April 1989, in acquiring real estate interests for the Project, and inform all affected persons of applicable benefits, policies, and procedures in connection with said Act(s). Assessments of the Non-Federal Sponsors' Real Estate Acquisition Capability are at (Exhibit C).

The non-Federal sponsor is entitled to receive credit against its share of project costs for the value of lands it provides and the value of the relocations that are required for the project. Generally, for the purpose of determining the amount of credit to be afforded, the value of the LER is the fair market value of the real property interest, plus certain incidental costs of acquiring those interests, that the non-federal sponsor provided for the project as required by the Government. In addition, the specific requirements relating to valuation and crediting contained in the executed PPA for a project must be reviewed and applied. For shore damage reduction projects, lands subject to shore erosion, that are required for project purposes and that must be provided by the non-federal sponsor must be appraised for crediting purposes considering special benefits in accordance with relevant Federal statutes and Department of Justice guidance.

2.11 Government Owned Property

There are no lands owned by the Federal Government within the proposed project.

2.12 Historical Significance

The area is rich in folklore which claims the name, Topsail, originated during the 1700's when pirate ships roamed the coastal waters. Historians explain that marauding pirates hid their ships in the channel behind the island and waited for passing merchant ships loaded with goods. The pirates would pursue and attack the merchants, claiming the cargoes as their own. Eventually the merchants became aware of this infamous hiding place and began to watch for the tops of the pirates' sails showing over the rolling dunes – hence the name Topsail Island. In the 1940's the island was a part of Operation Bumblebee, which was the beginning of the space program for the United States Government. Over 200 rocket launchings took place on the island between 1946 and 1948. Many of the original military structures are still standing today.

2.13 Mineral Rights

There are no known mineral activities within the scope of the proposed project.

2.14 Public Law 91-646, Relocation Assistance Benefits

Public Law 91-646, Uniform Relocation Assistance provides entitlement for various payments associated with federal participation in acquisition of real property. Title II makes provision for relocation expenses for displaced persons. If the proposed dune and berm system is constructed, there is a possibility that three (3) landowners may be impacted. According to public records, the structures appear to be seasonal residences rather than permanent residences. During acquisition phase this of course will have to be confirmed. Based on the assumption that the residences are seasonal, the landowners would not be entitled to replacement housing payments. The only benefit due to the landowners under Public Law 91-646 would be moving expenses for personal property. A landowner may choose a commercial move performed by a professional mover or a self-move that would be performed by the displaced person. The self-move may be based on the Fixed Residential Moving Cost Schedule (based on the number of rooms in the dwelling) or may be an actual cost move that would have to be supported by receipted bills for labor and equipment. If the self-move option is elected, the landowner would assume responsibility for the move. An estimate of $4,000 for moving costs is made based on the Fixed Residential Moving Cost Schedule, published by the Federal Highway Administration.

2.15 Attitude of Property Owners

The overall attitude of the property owners within the Project area has been favorable toward the proposed project.

2.16 Acquisition Schedule

Provided that a contractor provides real estate services for the sponsor, it is estimated that the real estate acquisition will take approximately 18-24 months after completion of the survey. However, if the project sponsors decide to use their in house staffs to acquire real estate interests required for the project, it is projected that the acquisitions will take at least 36 months. This projection is made with the assumption that if in house employees should perform acquisition, they will be fully dedicated to the acquisition work. The sponsors are considering using the services of a private contractor to perform real estate acquisition. The Project Sponsor, Project Manager and Real Estate Technical Manager will formulate the milestone schedule upon project approval to meet dates for advertisement and award of a construction contract.

2.17 Estates for Proposed Project

The standard Perpetual Beach Storm Damage Reduction Easement will be used for those parcels where easements are required to construct the project. The Temporary Work Area Easement will be used for the staging areas. The Fee Estate will be used for the acquisition of any parcels where dwellings will be impacted by construction of the project. A non–standard estate (NSE) for use in the project if necessary has been approved by the Chief of Real Estate, Savannah District. The NSE and approval memorandum is at Exhibit A.

PERPETUAL BEACH STORM DAMAGE REDUCTION EASEMENT.

A perpetual and assignable easement and right-of-way in, on, over and across (the land described in Schedule A) (Tract No. __) for use by the (Sponsor), its representatives, agents, contractors, and assigns, to construct; preserve; patrol; operate; maintain; repair; rehabilitate; and replace; a public beach a dune system, and other erosion control and storm damage reduction measures together with appurtenances thereto, including the right to deposit sand; to accomplish any alterations of contours on said land; to construct berms and dunes; to nourish and renourish periodically; to move,

store and remove equipment and supplies; to erect and remove temporary structures; and to perform any other work necessary and incident to the construction, periodic renourishment and maintenance of the **Surf City/North Topsail Beach Coastal Storm Damage Reduction Project**, together with the right of public use and access; to plant vegetation on said dunes and berms; to erect, maintain and remove silt screens and sand fences; to facilitate preservation of dunes and vegetation through the limitation of access to dune areas; to trim, cut, fell, and remove from said land all trees, underbrush, debris, obstructions, and any other vegetation, structures and obstacles within the limits of the easement (except *); reserving, however, to the grantor(s), (his) (her) (its) (their) (heirs), successors and assigns, the right to construct dune overwalk structures in accordance with any applicable Federal, State or local laws or regulations, provided that such structures shall not violate the integrity of the dune in shape, dimension or function, and that prior approval of the plans and specifications for such structures is obtained from the (designated representative of the Project Sponsor) and provided further that such structures are subordinate to the construction, operation, maintenance, repair, rehabilitation and replacement of the project; and further reserving to the grantor(s), (his) (her) (its) (their) (heirs), successors and assigns all such rights and privileges as may be used and enjoyed without interfering with or abridging the rights and easements hereby acquired; subject however to existing easements for public roads and highways, public utilities, railroads and pipelines.

TEMPORARY WORK AREA EASEMENT

A temporary easement and right-of-way in, over and across (the land described in Schedule A) (Tracts Nos. _____, _____, and _____), for a period not to exceed _____, beginning with date possession of the land is granted to the United States, for use by the United States, its representatives, agents, and contractors as a (borrow area) (work area), including the right to (borrow and /or deposit fill, spoil and waste material thereon) (move, store and remove equipment and supplies, and erect and remove temporary structures on the land and to perform any other work necessary and incident to the construction of the **Surf City/North Topsail Beach Coastal Storm Damage Reduction Project**, together with the right to trim, cut, fell and remove therefrom all trees, underbrush, obstructions, and any other vegetation, structures, or obstacles within the limits of the right-of-way; reserving, however, to the landowners, their heirs and assigns, all such rights and privileges as may be used without interfering with or abridging the rights and easement hereby acquired; subject, however, to existing easements for public roads and highways, public utilities, railroads and pipelines.

Fee Estate

The fee simple title to (the and described in Schedule A) (Tracts Nos. , and), Subject, however, to existing easements for public roads and highways, public utilities, railroads and pipelines.

2.18 Real Estate Estimate

Due to offsetting benefits, the Perpetual Beach Storm Damage Reduction Easements are determined to have a $0 value. As a matter of policy the Federal Rule of offsetting benefits is applied in determining credit for storm damage reduction projects. The North Carolina Court of Appeals in June 2000, held in NC Department of Transportation V. Rowe, (97-1470-2) that special project benefits may offset compensation due for a taking and that general project benefits may not offset compensation. This interpretation of North Carolina general statutes is consistent with the Federal Rule.

In the valuation of lands for the project, it is assumed that all lots are buildable in the before value. Since the before value and the after value of the lots will remain the same, or possibly increase due to an improved dune structure, the Before Value and the After Value are identical. In the after value, the lands will be subject to a perpetual beach renourishment easement. Though data at other beaches has shown an increase in value of lots once they were protected by a renourishment project, no local data was available which suggests the "After Value" of the land will be higher as a result of this project. There is an indication that the lots would have superior damage reduction from storm damage and, therefore, would not have a lower value.

The estimated real estate costs include land and improvement values, damages, mineral rights, resettlement cost, and federal as well as non-federal administrative costs. The land costs that are listed are due to the projected costs for staging areas. Costs are estimated individually for Surf City (Table 2.18-1) and North Topsail (Table 2.18-2) Beach, and then combined for a total project cost (Table 2.18-3). The administrative costs are based on historical costs of prior projects constructed along the east coast in South Atlantic Division. A 25% contingency is applied to the estimate. All costs are October 2008 price levels and are constant dollar.

Table 2.18- 1. Surf City Project Cost

a. Lands		
1 Ownership - Temporary Work Area Easement		
(Staging Area) - Estimated		$ 29,000
1 Ownership - Purchase Fee		$ 526,500
	subtotal	$ 555,500
b. Improvements		$ -
(Residential)		$ 67,578
(Commercial)		$ -
c. Mineral Rights		$ -
d. Damages		$ -
e. P.L. 91-646 Relocation costs		$ 1,800
f. Acquisition Cost - Admin (502 ownerships)		$ 1,706,800
1 parcel in fee, 501 in easement		
Federal	$ 200,800	
Non-federal	$1,506,000	
	$1,706,800	
Sub-Total		$ 2,331,678
Contingencies (25%)		$ 582,920
TOTAL		**$ 2,914,598**
ROUNDED TO		**$ 2,915,000**

Table 2.18-2. North Topsail Beach Project Cost

a. Lands		
1 Ownership - Temporary Work Area Easement (Staging Area) - Estimated		$ 29,000
2 Ownerships - Fee Purchase		$ 631,800
	subtotal	$ 660,800
b. Improvements		$ -
(Residential) 2 ownerships in Fee		$ 69,610
(Commercial)		$ -
c. Mineral Rights		$ -
d. Damages		$ -
e. P.L. 91-646 Relocation costs		$ 2,200
f. Acquisition Cost - Admin (329 ownerships)		$ 1,118,600
2 parcels in Fee, 327 in easements		
Federal $ 131,600		
Non-federal $ 987,000		
$1,118,600		
Sub-Total		$ 1,851,210
Contingencies (25%)		$ 462,803
TOTAL		**$ 2,314,013**
ROUNDED TO		**$ 2,314,000**

Table 2.18-3. Total Project Cost

a. Lands		
2 Ownerships - Temporary Work Area Easement		
(Staging Area) - Estimated		$ 58,000
3 Ownerships - Fee Purchase		$ 1,158,300
	subtotal	$ 1,216,300
b. Improvements		$ -
(Residential) 3 ownerships in		
Fee		$ 137,188
(Commercial)		$ -
c. Mineral Rights		$ -
d. Damages		$ -
e. P.L. 91-646 Relocation costs		$ 4,000
f. Acquisition Cost - Admin (831		
ownerships)		$ 2,825,400
3 parcels in Fee, 828 in easements		
Federal	$ 332,400	
Non-federal	$2,493,000	
	$2,825,400	
Sub-		
Total		$ 4,182,888
Contingencies (25%)		$ 1,045,722
TOTAL		**$ 5,228,610**
ROUNDED TO		**$ 5,229,000**

2.19 Chart of Accounts

The cost estimate for all Federal and non-Federal real estate activities necessary for implementation of the project after completion of the feasibility study for land acquisition, construction, LERRD, and other items are coded as delineated in the Cost Work Breakdown Structure (CWBS). This real estate cost estimate is then incorporated into the Total Current Working Estimate utilizing the Microcomputer Aided Cost Engineering System (MCACES) and shown in the Chart of Accounts at Table 2.19-1.

Table 2.19-1. Chart of Accounts

01A	PROJECT PLANNING	FEDERAL	NON-FEDERAL	TOTALS
	Other			
	Project Cooperation Agreement	$	$	$
01AX	Contingencies (25%)	$	$	$
	Subtotal	$	$	$
01B	LANDS AND DAMAGES			
01B40	Acquisition Review of PS	$ 332,400.00	$	$ 332,400.00
01B20	Acquisition by PS	$	$ 2,493,000.00	$ 2,493,000.00
01BX	Contingencies (25%)	$ 83,100.00	$ 623,250.00	$ 706,350.00
	Subtotal	$ 415,500.00	$ 3,116,250.00	$ 3,531,750.00
01H	AUDIT			
01H10	Real Estate Audit	$	$	$
01HX	Contingencies (25%)	$	$	$
	Subtotal	$	$	$
01R	REAL ESTATE LAND PAYMENTS			
01R1B	Land Payments by PS	$	$ 1,353,488.00	$ 1,353,488.00
01R2B	PL91-646 Relocation Payment by PS	$	$ 4,000.00	$ 4,000.00
01R2D	Review of PS	$	$	$
01RX	Contingencies (25%)	$	$ 339,372.00	$ 339,372.00
	Subtotal	$	$ 1,696,860.00	$ 1,696,860.00
	TOTALS	$ 415,500.00	$ 4,813,110.00	$ 5,228,610.00
	ROUNDED TO			**$5,229,000.00**

Exhibits

CESAS-RE – Non-standard Estate Approval Memorandum Date: 27 May 2010

Project: Surf City and North Topsail Beach Coastal Storm Damage Reduction Project

Non-Standard Perpetual Beach Storm Damage Reduction Easement Estate

A perpetual and assignable easement and right-of-way in, on, over and across (the land described in Schedule A) (Tract No. __) for use by the (Sponsor), its representatives, agents, contractors, and assigns, to construct; preserve; patrol; operate; maintain; repair; rehabilitate; and replace; a public beach a dune system, and other erosion control and storm damage reduction measures together with appurtenances thereto, including the right to deposit sand; to accomplish any alterations of contours on said land; to construct berms and dunes; to nourish and renourish periodically; to move, store and remove equipment and supplies; to erect and remove temporary structures; and to perform any other work necessary and incident to the construction, periodic renourishment and maintenance of the **Surf City/North Topsail Beach Coastal Storm Damage Reduction Project**, together with the right of public use and access; to plant vegetation on said dunes and berms; to erect, maintain and remove silt screens and sand fences; to facilitate preservation of dunes and vegetation through the limitation of access to dune areas; to trim, cut, fell, and remove from said land all trees, underbrush, debris, obstructions, and any other vegetation, structures and obstacles within the limits of the easement (except *); reserving, however, to the grantor(s), (his) (her) (its) (their) (heirs), successors and assigns, the right to construct dune overwalk structures in accordance with any applicable Federal, State or local laws or regulations, provided that such structures shall not violate the integrity of the dune in shape, dimension or function, and that prior approval of the plans and specifications for such structures is obtained from the (designated representative of the Project Sponsor) and provided further that such structures are subordinate to the construction, operation, maintenance, repair, rehabilitation and replacement of the project; and further reserving to the grantor(s), (his) (her) (its) (their) (heirs), successors and assigns all such rights and privileges as may be used and enjoyed without interfering with or abridging the rights and easements hereby acquired; subject however to existing easements for public roads and highways, public utilities, railroads and pipelines.

*** the right to remove or demolish the existing fishing pier and appurtenances thereto;**

Exhibit A Page 1

In accordance with the provisions of paragraph 12-10c. of ER 405-1-12, I approve the use of the above non-standard estate for the Surf City and North Topsail Coastal Storm Damage Reduction project. The estate serves the intended project purpose, substantially conforms with and does not materially deviate from the corresponding standard estate contained in the Real Estate Handbook and does not increase the costs nor potential liability of the Government.

Date: 27 May 2010

Ralph J. Werthmann
Chief, Real Estate, Savannah District

Exhibit A Page 2

AUTHORIZATION FOR ENTRY FOR CONSTRUCTION

I _____, _____ for the
(Name of accountable official) (Title)

(Sponsor Name)_____, do hereby certify that the ___(Sponsor Name) has acquired the real property interest required by the Department of the Army, and otherwise is vested with sufficient title and interest in lands to support construction for (Project Name, Specifically identified project features, etc.). Further, I hereby authorize the Department of the Army, its agents, employees and contractors, to enter upon _____
(identify tracts)

to construct (Project Name, Specifically identified project features, etc.) as set forth in the plans and specifications held in the U. S. Army Corps of Engineers' (district, city, state)

WITNESS my signature as _____ for the
(Title)

(Sponsor Name) this __ day of _____, 20_____.

BY: _____
(Name)

_____
(Title)

ATTORNEY'S CERTIFICATE OF AUTHORITY

I, _____ , _____ for the
(Name) (Title of legal officer)

(Sponsor Name), certify that _____ has
(Name of accountable official)

authority to grant Authorization for Entry; that said Authorization for Entry is executed by the proper duly authorized officer; and that the Authorization for Entry is in sufficient form to grant the authorization therein stated.

WITNESS my signature as _____ for the
(Title)

(Sponsor Name), this_____day of_____, 20____.

BY: _____
(Name)

_____
(Title)

Exhibit B

Assessment of Non-Federal Sponsor's

Real Estate Acquisition Capability
Surf City

I. Legal Authority:

a. Does the sponsor have legal authority to acquire and hold title to real property for project purposes? **Yes**

b. Does the sponsor have the power to eminent domain for this project? **Yes-Condemnation Authority is granted by legislation with specific provision for improving beach erosion control or flood and hurricane protection works.**

c. Does the sponsor have "quick-take" authority for this project? **Yes**

d. Are any of the land/interests in the land required for this project located outside the sponsor's political boundary? **No**

e. Are any of the lands/interests in land required for the project owned by an entity whose property the sponsor cannot condemn? **No**

II. Human Resource Requirements:

a. Will the sponsor's in-house staff require training to become familiar with the real estate requirements of Federal projects including P. L. 91-646, as amended? **N/A Sponsor is considering hiring a contractor to perform acquisition of real estate for the project.**

b. If the answer to II.a. is "yes", has a reasonable plan been developed to provide such training? **N/A sab.**

c. Does the sponsor's in-house staff have sufficient real estate acquisition experience to meet its responsibilities for the project? **No**

d. Is the sponsor's projected in-house staffing level sufficient considering its other work load, if any, and the project schedule? **No**

e. Can the sponsor obtain contractor support, if required in a timely fashion? **Yes**

f. Will the sponsor likely request USACE assistance in acquiring real estate? **No**

Exhibit C Page 1

Surf City Continued

III. Other Project Variables:

a. Will the sponsor's staff be located within reasonable proximity to the project site? **Yes**

b. Has the sponsor approved the project/real estate schedule/milestones? **No – Real Estate Schedule and Milestones will be developed upon project approval as a joint effort among RE, project manager and sponsor.**

IV. Overall Assessment:

a. Has the sponsor performed satisfactory on other USACE projects? **N/A**

b. With regard to the project, the sponsor is anticipated to be: **Moderately Capable**

V. Coordination:

a. Has this assessment been coordinated with the sponsor? **Yes**

b. Does the sponsor concur with this assessment? **Yes**

Prepared by:

Belinda S. Estabrook
Realty Specialist

Reviewed and approved by:

Ralph J. Werthmann
Chief, Real Estate Division

Exhibit C Page2

Assessment of Non-Federal Sponsor's

Real Estate Acquisition Capability
North Topsail Beach

I. Legal Authority:

a. Does the sponsor have legal authority to acquire and hold title to real property for project purposes? **Yes**

b. Does the sponsor have the power to eminent domain for this project? **Yes-Condemnation Authority is granted by legislation with specific provision for improving beach erosion control or flood and hurricane protection works.**

c. Does the sponsor have "quick-take" authority for this project? **Yes**

d. Are any of the land/interests in the land required for this project located outside the sponsor's political boundary? **No; However, several parcels identified as a potential staging area are owned by the County, but full cooperation is expected from the county.**

e. Are any of the lands/interests in land required for the project owned by an entity whose property the sponsor cannot condemn? **Yes – The town cannot condemn county owned lands, but as stated above full cooperation with the county is expected**

II. Human Resource Requirements:

a. Will the sponsor's in-house staff require training to become familiar with the real estate requirements of Federal projects including P. L. 91-646, as amended? **N/A Sponsor is considering hiring a contractor to perform acquisition of real estate for the project.**

b. If the answer to II.a. is "yes", has a reasonable plan been developed to provide such training? **N/A sab.**

c. Does the sponsor's in-house staff have sufficient real estate acquisition experience to meet its responsibilities for the project? **No**

d. Is the sponsor's projected in-house staffing level sufficient considering its other work load, if any, and the project schedule? **No**

e. Can the sponsor obtain contractor support, if required in a timely fashion? **Yes**

f. Will the sponsor likely request USACE assistance in acquiring real estate? **No**

Exhibit C Page 3

North Topsail Continued

III. Other Project Variables:

a. Will the sponsor's staff be located within reasonable proximity to the project site? **Yes**
b.
c. Has the sponsor approved the project/real estate schedule/milestones? **No – Real Estate Schedule and Milestones will be developed upon project approval as a joint effort among RE, project manager and sponsor.**

IV. Overall Assessment:

a. Has the sponsor performed satisfactory on other USACE projects? **N/A**

b. With regard to the project, the sponsor is anticipated to be: **Moderately Capable**

V. Coordination:

a. Has this assessment been coordinated with the sponsor? **Yes**

b. Does the sponsor concur with this assessment? **Yes**

Prepared by:

Belinda S. Estabrook
Realty Specialist

Reviewed and approved by:

Ralph J. Weithmann
Chief, Real Estate Division

Exhibit C Page 4

FOR THE CONTINUATION OF HOUSE DOCUMENT 112-21
SURF CITY NORTH TOPSAIL BEACH
INTEGRATED FEASIBILITY REPORT
SEE PART 2

Feasibility Report
and
Environmental Impact Statement

on

Coastal Storm Damage Reduction

SURF CITY and NORTH TOPSAIL BEACH
NORTH CAROLINA

Appendix N

Project Costs

Appendix N: Cost Engineering

SURF CITY and NORTH TOPSAIL BEACH NORTH CAROLINA

1. The Cost Engineering Appendix project costs were prepared to identify the Current Working Estimate (CWE) for the National Economic Development (NED) Plan for the Surf City/North Topsail Beach, Feasibility Report – Coastal Storm Damage Reduction.

The NED Plan is the alternative selected plan which has the greatest net benefits. The NED Plan is to construct a sand dune to elevation 15-ft (25-ft top width) and a berm to the ocean at elevation of 7-ft (50-ft wide). The NED plan for SCNT is often referred to as the 15/50 plan. Material for placement on the beach will come from offshore borrow areas. Hopper dredges will excavate material, travel to offshore pump out stations, and pump material on the beach.

2. The TOTAL CURRENT WORKING ESTIMATE (CWE) for Initial Construction of beach nourishment is $101,495,000, October 2010 pricing ($123,135,000 with 21 percent contingencies). Initial Construction will take 4 years during the periods (seasons) December 1 thru March 31 using 2-hopper dredges.

Future or subsequent Periodic Nourishments are estimated to average $28,270,000, OCT 2010 pricing ($34,207,000 with 21% contingencies). The periodic nourishments are anticipated every six (6) years after Initial Construction. The periodic nourishments will take 1 season using 2 or 3-hopper dredges.

The CWE costs, for construction and non-construction items, were established to be the Baseline Cost Estimate at October 2010 price levels.

3. Baseline CWE's are shown in the attached MCACES (Microcomputer Aided Cost Engineering System) summary sheets. The summary sheets are formatted into a Code of Accounts framework for reporting. The costs included under each Code of Accounts are described below.

The Cost Estimates were prepared under guidance given in the Corps of Engineers Regulation ER 1110-2-1302, CIVIL WORKS COST ENGINEERING and Engineering Instructions, EI 01D010, CONSTRUCTION COST ESTIMATES.

4. CODE OF ACCOUNTS

CODE OF ACCOUNT 01 – LANDS AND DAMAGES: The estimated costs were prepared and furnished by the Real Estate Division, Savannah District as discussed in the Real Estate Appendix.

CODE OF ACCOUNT 17 – BEACH REPLENISHMENT: This account includes project costs for mobilization and demobilization, dredging, beach fill shaping, beach tilling, dune vegetation, and dune walkover structures.

Emphasis was placed on accuracy of dredging costs during evaluation of alternative plans to develop the NED Plan. The location and features of borrow areas in relation to the project, as well as historical production of dredges for similar projects, were used in conjunction with the Corps of Engineers Dredge Estimating Program (CEDEP).

CEDEP considers details of borrow area characteristics, depth of borrow, effective production time, distances from borrow sites, costs of dredge plant ownership, operating and repair, fuel consumption, and other economic adjustments for labor and equipment.

a. For Initial Construction it was determined that offshore Borrow Areas H, J, O, L, and P would be most suitable for hopper dredges to use and place sand on the beach. Therefore, mobilization, demobilization of dredge equipment, pipe and beach fill equipment, as well as, dredging and beach fill average unit costs are based on 2-hopper dredges with pump out stations located offshore about 3,000 feet. The unit price of $6.93 per cubic yard ($8.38/cy with contingency) represents the average cost using all borrow areas mentioned above. The average travel distance 1-way to the pump out stations is approximately 3.5 miles for initial construction.

The initial construction time for placement of 11,855,175 cubic yards is estimated to take approximately 16 months based on using 2-hoppers with pump out to the beach. The environmental window for hopper dredges is December 1 through March 31 or about 4 months for this project. Therefore, construction costs include 4 mobs/demobs for 2-hoppers to complete the initial construction which will occur over four years (4-seasons). Additional time for mob/demob and set up pipe on the beach needs to be added for each season. Mobilization is typically estimated at approximately 30 days prior to beginning initial placement and 30 days demobilization of pipe and equipment off the beach, as well as beach tilling.

Two hoppers were considered to be typical of past project equipment availability that would be used for construction. More than 2-hoppers could be used for Initial construction and could reduce construction time. Pipeline suction

cutterhead dredges were considered more expensive for construction, based on multiple borrow areas, shallow borrow depths for pipeline inefficiencies, average pipeline lengths of 4 to 5 miles to reach the beach, and then over 10 miles of beach length to place material. However, the solicitation for construction will not limit the type of equipment to construct the project.

b. For Periodic Nourishments periods 2 thru 6 of 2,642,000 cy, it was determined that hopper dredges with pump out would be the most suitable method to place sand on the beach. This was also based on the borrow area depths and proximity to the beach. A pumpout station located approximately 3,000 feet offshore was assumed. The average travel distance from borrow areas to the pumpout for periodic nourishment is approximately 7 miles. Once the pumpout pipe reaches shore, it was estimated placement would be 3,000 feet in each direction from a tee valve on shore (or 6,000 LF total pump out distance). The unit price of $7.52 per cubic yard ($9.10/cy with contingencies) represents the average pumping costs using all borrow areas throughout the life of the project.

The periodic nourishment construction time for placement of 2,642,000 cubic yards is estimated to take approximately one environmental season from December 1 through March 31 in addition to mobilization and set up of pipe/pumpout locations on the beach. Mobilization would be another 30 days and 30 days for demobilization.

c. It should be noted and has been anticipated that the First Periodic Nourishment (or the 6th season following Initial Construction) will not require the full periodic nourishment volume. The first periodic nourishment is anticipated to be approximately 2,000,000 cubic yards. The average unit price of $7.17/cy ($8.67/cy with contingencies) is expected and will take only 1-season with 2-hopper dredges.

A final periodic nourishment will require 3,523,000 cubic yards at the average unit price of $9.70/cy ($11.75/cy with contingencies).

Beach fill costs are included as part of the hopper dredging unit price. Beach fill consists of shaping the dredged material with dozers to the required cross section while the dredge is pumping material onto the beach.

d. The costs for Beach Tilling were based on historical costs for similar projects. The costs for Dune Vegetation were based on historical pricing and discussions with North Carolina extension services. The price for Dune Walkover Structures was based on detailed cost estimates used for similar structures and historical costs on similar projects.

A contingency was included to represent unanticipated conditions or uncertainties not known at the time the estimate was developed. There is a

better than average level of confidence in the dredge pricing, because of the detailed geotechnical investigations of borrow areas, similarities of other beach nourishment projects, and the historical costs for similar projects. A contingency of 21% was included for ACCOUNT 17 and developed during the Cost/Risk Analysis through the Cost Center of Expertise in Walla Walla, Washington.

CODE OF ACCOUNT 30 – PLANNING, ENGINEERING AND DESIGN: The costs included in this account were furnished by those responsible for performing each activity. This account includes plans and specifications, field investigations and surveys, cost estimates, engineering during construction, environmental monitoring, and project management. A 25% contingency was assigned to ACCOUNT 30.

CODE OF ACCOUNT 31 – CONSTRUCTION MANAGEMENT – This account includes supervision and administration of the contracts by construction management, hydrologic surveys during construction and contracting personnel during construction. A 25% contingency was assigned to ACCOUNT 31.

SAW – SURF CITY BEACH AND NORTH TOPSAIL BEACH FEASABILITY REPORT
PRESENTED BY:
USACE- WILMINGTON DISTRICT

COST ENGINEERING DX TPCS ATR CERTIFICATION

The Walla Walla Cost Dx representatives have provided an adequate Agency Technical Review (ATR) of the 2012 Budget Year and Total Project Cost, studying the project scope, report, cost estimates, schedules, escalation, risk analysis and contingency development in accordance with ER 1110-2-1150 Engineering and Design for Civil Works Projects and ER 1110-2-1302 Civil Works Cost Engineering.

As of 9 November, 2010, the Walla Walla District, Cost Engineering Directory of Expertise (Dx) for Civil Works, certifies the Surf City Beach and North Topsail Feasibility Report presented by USACE Wilmington District. The Cost DX agency technical review (ATR) resulted in the total project cost estimated values of:

First Costs 1 Oct 2012 Price Level:	$124,986,000
First Costs Fully Funded Amount:	$135,339,000
O&M Cost 1 Oct 2012 Price Level:	$208,642,000
O&M Fully Funded Amount:	$372,471,000

It is the responsibility of the District to correctly reflect these cost values within the Final Report.

11/9/2010
Date

John P. Skarbek
Chief, Cost Engineering
Walla Walla District

****** TOTAL PROJECT COST SUMMARY ******

PROJECT: SURF CITY BEACH AND NORTH TOPSAIL BEACH
LOCATION: NORTH CAROLINA

DISTRICT: WILMINGTON DISTRICT PREPARED: 10/5/2010
POC: CHIEF, COST ENGINEERING, Don Carmen

This Estimate reflects the scope and schedule in report; FEASIBILITY REPORT DATED NOVEMBER 2010

Estimate Prepared: 5-Oct-10
Effective Price Level: 1 OCT 10

Program Year (Budget EC): 2012
Effective Price Level Date: 1 OCT 11

TOTAL INITIAL CONSTRUCTION SUMMARY

WBS NUMBER	Civil Works Feature & Sub-Feature Description	COST ($K)	CNTG ($K)	CNTG (%)	TOTAL ($K)	ESC (%)	COST ($K)	CNTG ($K)	TOTAL ($K)
A	B	C	D	E	F	G	H	I	J
17	BEACH REPLENISHMENT	$93,332	$19,600	21%	$112,932	1.4%	$94,677	$19,882	$114,559
	CONSTRUCTION ESTIMATE TOTALS:	$93,332	19,600		$112,932	1.4%	$94,677	$19,882	$114,559
01	LANDS AND DAMAGES	$4,182	1,046	25%	$5,228	1.4%	$4,242	$1,061	$5,303
30	PLANNING, ENGINEERING & DESIGN	$2,454	614	25%	$3,068	3.0%	$2,527	$632	$3,159
31	CONSTRUCTION MANAGEMENT	$1,527	382	25%	$1,909	3.0%	$1,573	$393	$1,966
	PROJECT CONSTRUCTION COST TOTALS:	$101,495	21,640	21%	$123,135	1.5%	$103,019	$21,968	$124,986

FULLY FUNDED CONSTRUCTION ESTIMATE

Spent Thru: 1-Oct-10 ($K)	K	L	MidPt AUG 2016 COST ($K)	CNTG ($K)	FULL ($K)
			$102,625	$21,551	$124,176
			$102,625	$21,551	$124,176
			$4,350	$1,087	$5,437
			$2,895	$674	$3,569
			$1,885	$471	$2,357
			$111,555	$23,784	$135,339

ESTIMATED FEDERAL FIRST COST: **$87,970**
ESTIMATED NON-FEDERAL FIRST COST: **$47,369**
ESTIMATED TOTAL PROJECT COST INITIAL CONSTRUCTION: $135,339

Estimate Prepared: 5-Oct-10
Effective Price Level: 1 OCT 10

Program Year (Budget EC): 2012
Effective Price Level Date: 1 OCT 11

TOTAL OPERATIONS AND MAINTENANCE SUMMARY

WBS NUMBER	Feature & Sub-Feature Description	COST ($K)	CNTG ($K)	CNTG (%)	TOTAL ($K)	ESC (%)	COST ($K)	CNTG ($K)	TOTAL ($K)
17	BEACH REPLENSIHMENT 2021-2057	$162,215	$34,065	21%	$196,280	1.4%	$164,552	$34,556	$199,108
	PERIODIC RENOURISHMENT TOTAL:	$162,215	$34,065		$196,280		$164,552	$34,556	$199,108
30	PLANNING, ENGINEERING & DESIGN	$4,605	$1,152	25%	$5,758	3.0%	$4,744	$1,186	$5,930
31	CONSTRUCTION MANAGEMENT	$2,800	$700	25%	$3,500	3.0%	$2,884	$721	$3,605
	PROJECT RENOURISHMENT TOTALS:	$169,621	$35,917	21%	$205,538	1.5%	$172,180	$36,463	$208,642

FULLY FUNDED O&M ESTIMATE

Spent Thru: 1-Oct-10 ($K)	MidPt AUG 2039 COST ($K)	CNTG ($K)	FULL ($K)
	$284,085	$59,658	$343,743
	$284,085	$59,658	$343,743
	$14,107	$3,527	$17,634
	$8,875	$2,219	$11,093
	$307,067	$65,403	$372,471

ESTIMATED FEDERAL O&M COST: **$242,106**
ESTIMATED NON-FEDERAL O&M COST: **$130,365**
ESTIMATED TOTAL RENOURISHMENT COSTS 2021-2057: $372,471

_____ CHIEF, COST ENGINEERING,

_____ PROJECT MANAGER,

_____ CHIEF, REAL ESTATE,

Filename: Final TPCS_INITIAL_CONST_NOV_5__2010x.xls
TPCS

SURFCITY-NTOPSAIL-INITIAL OCT'10
INITIAL CONSTRUCTION
SUMMARY OF COSTS
CURRENT WORKING ESTIMATE (CWE)
CODE OF ACCOUNTS

Designed By: USACE - WILMINGTON DISTRICT
Estimated By: CESAW-TS-EE

Prepared By: John C. Caldwell
CESAW-TS-EE

Preparation Date: 10/05/10
Effective Date of Pricing: 10/01/10

Sales Tax: 0.00%

This report is not copyrighted, but the information
contained herein is For Official Use Only.

M C A C E S G O L D E D I T I O N
Composer GOLD Software Copyright (c) 1985-1994
by Building Systems Design, Inc.
Release 5.30

	QUANTY	UOM	CONTRACT	CONTINGN	TOTAL COST	UNIT
1 Summary of Initial Construction						
1.01 LANDS AND DAMAGES			4,182,000	1,046,000	5,228,000	
1.17 BEACH REPLENISHMENT - INITIAL			93,331,000	19,600,000	112,931,000	
1.30 PLANNING, ENGINEERING & DESIGN			2,454,000	614,000	3,068,000	
1.31 CONSTRUCTION MANAGEMENT			1,527,000	382,000	1,909,000	
TOTAL Summary of Initial Construction			101,494,000	21,640,000	123,135,000	

	QUANTY	UOM	CONTRACT	CONTINGN	TOTAL COST	UNIT
1 Summary of Initial Construction						
1.01 LANDS AND DAMAGES						
1.01. 1 LANDS OWNERSHIP			1,216,000	304,000	1,520,000	
1.01. 2 IMPROVEMENTS			137,000	34,000	171,000	
1.01. 3 PL 91-646 RELOCATION COSTS			4,000	1,000	5,000	
1.01. 4 AQUISITION COST-FEDERAL			332,000	83,000	415,000	
1.01. 5 AQUISITION COST- NON-FEDERAL			2,493,000	623,000	3,116,000	
TOTAL LANDS AND DAMAGES			4,182,000	1,046,000	5,228,000	
1.17 BEACH REPLENISHMENT - INITIAL						
1.17.01 MOB AND DEMOB- 4ea @ $1,900,000			7,600,000	1,596,000	9,196,000	
1.17.02 DREDGING and BEACH PLACEMENT	1,855,175	CY	82,102,000	17,241,000	99,344,000	8.38
1.17.03 TILLING	150.00	ACR	113,000	24,000	137,000	911.53
1.17.04 DUNE VEGETATION	165.00	ACR	1,650,000	347,000	1,997,000	12100
1.17.05 DUNE WALKOVER STRUCTURES	60.00	EA	1,866,000	392,000	2,258,000	37631
TOTAL BEACH REPLENISHMENT - INITIAL			93,331,000	19,600,000	112,931,000	
1.30 PLANNING, ENGINEERING & DESIGN						
1.30. A ENGINEERING			1,164,000	291,000	1,455,000	
1.30. B ENVIRONMENTAL			6,000	2,000	8,000	
1.30. C PROJECT MGT			60,000	15,000	75,000	
1.30. D Geotechnical Investigations			1,176,000	294,000	1,470,000	
1.30. E Procurment-Contracting			40,000	10,000	50,000	
1.30. F Construction Mgt			8,000	2,000	10,000	
TOTAL PLANNING, ENGINEERING & DESIGN			2,454,000	614,000	3,068,000	
1.31 CONSTRUCTION MANAGEMENT						
1.31. A ENGINEERING			245,000	61,000	306,000	
1.31. B ENVIRONMENTAL			100,000	25,000	125,000	
1.31. C PROJECT MGT			80,000	20,000	100,000	
1.31. D Geotechnical Investigations			28,000	7,000	35,000	
1.31. E Procurment-Contracting			40,000	10,000	50,000	
1.31. F Construction Mgt			1,034,000	259,000	1,293,000	
TOTAL CONSTRUCTION MANAGEMENT			1,527,000	382,000	1,909,000	
TOTAL Summary of Initial Construction			101,494,000	21,640,000	123,135,000	

SCN TOPSAIL-First PeriodicJUNE10
1ST PARTIAL PERIODIC NOURISHMENT
CONSTRUCTION- SUMMARY OF COSTS
CURRENT WORKING ESTIMATE (CWE)
CODE OF ACCOUNTS

Designed By: USACE - WILMINGTON DISTRICT
Estimated By: CESAW-TS-EE

Prepared By: John C. Caldwell
CESAW-TS-EE

Preparation Date: 10/05/10
Effective Date of Pricing: 10/01/10

Sales Tax: 0.00%

This report is not copyrighted, but the information
contained herein is For Official Use Only.

M C A C E S G O L D E D I T I O N
Composer GOLD Software Copyright (c) 1985-1994
by Building Systems Design, Inc.
Release 5.30

	QUANTITY	UOM	CONTRACT	CONTINGN	TOTAL COST	UNIT
2 Sum of 1ST Periodic Construction						
2.17 BEACH REPLENISHMENT -PERIODIC			16,152,000	3,392,000	19,543,000	
2.30 PLANNING, ENGINEERING & DESIGN			658,000	165,000	823,000	
2.31 CONSTRUCTION MANAGEMENT			400,000	100,000	500,000	
TOTAL Sum of 1ST Periodic Construction			17,210,000	3,656,000	20,866,000	

	QUANTITY UOM	CONTRACT	CONTINGN	TOTAL COST	UNIT
2 Sum of 1ST Periodic Construction					
2.17 BEACH REPLENISHMENT -PERIODIC					
2.17.01 MOB AND DEMOB		1,900,000	399,000	2,299,000	
2.17.02 DREDGING and BEACH PLACEMENT	1981665.00 CY	14,202,000	2,982,000	17,184,000	8.67
2.17.03 TILLING	66.00 ACR	50,000	10,000	60,000	912
TOTAL BEACH REPLENISHMENT -PERIODIC		16,152,000	3,392,000	19,543,000	
2.30 PLANNING, ENGINEERING & DESIGN					
2.30. A ENGINEERING		152,000	38,000	190,000	
2.30. B ENVIRONMENTAL		4,000	1,000	5,000	
2.30. C PROJECT MGT		30,000	8,000	38,000	
2.30. D GEOTECHNICAL INVESTIGATIONS		450,000	113,000	563,000	
2.30. E Procurment-Contracting		20,000	5,000	25,000	
2.30. F Construction Management		2,000	1,000	3,000	
TOTAL PLANNING, ENGINEERING & DESIGN		658,000	165,000	823,000	
2.31 CONSTRUCTION MANAGEMENT					
2.31. A ENGINEERING		28,000	7,000	35,000	
2.31. B ENVIRONMENTAL		40,000	10,000	50,000	
2.31. C PROJECT MGT		40,000	10,000	50,000	
2.31. D GEOTECHNICAL INVESTIGATIONS		13,000	3,000	16,000	
2.31. E Procurment-Contracting		20,000	5,000	25,000	
2.31. F Construction Management		259,000	65,000	324,000	
TOTAL CONSTRUCTION MANAGEMENT		400,000	100,000	500,000	
TOTAL Sum of 1ST Periodic Construction		17,210,000	3,656,000	20,866,000	

SURFCITY & NTOPSAIL,NC PERIOD2-6
PERIODIC NOURISHMENTS 2 thru 6
CONSTRUCTION- SUMMARY OF COSTS
CURRENT WORKING ESTIMATE (CWE)
CODE OF ACCOUNTS

Designed By: USACE - WILMINGTON DISTRICT
Estimated By: CESAW-TS-EE

Prepared By: John C. Caldwell
CESAW-TS-EE

Preparation Date: 10/19/10
Effective Date of Pricing: 10/01/10

Sales Tax: 0.00%

This report is not copyrighted, but the information
contained herein is For Official Use Only.

M C A C E S G O L D E D I T I O N
Composer GOLD Software Copyright (c) 1985-1994
by Building Systems Design, Inc.
Release 5.30

	QUANTITY	UOM	CONTRACT	CONTINGN	TOTAL COST	UNIT
2 Summary of Periodic Construction						
2.17 BEACH REPLENISHMENT -PERIODIC			21,819,000	4,582,000	26,401,000	
2.30 PLANNING, ENGINEERING & DESIGN			658,000	165,000	823,000	
2.31 CONSTRUCTION MANAGEMENT			400,000	100,000	500,000	
TOTAL Summary of Periodic Construction			22,878,000	4,847,000	27,724,000	

	QUANTITY	UOM	CONTRACT	CONTINGN	TOTAL COST	UNIT
2 Summary of Periodic Construction						
2.17 BEACH REPLENISHMENT -PERIODIC						
2.17.01 MOB AND DEMOB			1,900,000	399,000	2,299,000	
2.17.02 DREDGING and BEACH PLACEMENT	2,642,225.00	CY	19,870,000	4,173,000	24,042,000	9.10
2.17.03 TILLING	66.00	ACR	50,000	10,000	60,000	912
TOTAL BEACH REPLENISHMENT -PERIODIC			21,819,000	4,582,000	26,401,000	
2.30 PLANNING, ENGINEERING & DESIGN						
2.30. A ENGINEERING			152,000	38,000	190,000	
2.30. B ENVIRONMENTAL			4,000	1,000	5,000	
2.30. C PROJECT MGT			30,000	8,000	38,000	
2.30. D GEOTECHNICAL INVESTIGATIONS			450,000	113,000	563,000	
2.30. E Procurment-Contracting			20,000	5,000	25,000	
2.30. F Construction Management			2,000	1,000	3,000	
TOTAL PLANNING, ENGINEERING & DESIGN			658,000	165,000	823,000	
2.31 CONSTRUCTION MANAGEMENT						
2.31. A ENGINEERING			28,000	7,000	35,000	
2.31. B ENVIRONMENTAL			40,000	10,000	50,000	
2.31. C PROJECT MGT			40,000	10,000	50,000	
2.31. D GEOTECHNICAL INVESTIGATIONS			13,000	3,000	16,000	
2.31. E Procurment-Contracting			20,000	5,000	25,000	
2.31. F Construction Management			259,000	65,000	324,000	
TOTAL CONSTRUCTION MANAGEMENT			400,000	100,000	500,000	
TOTAL Summary of Periodic Construction			22,878,000	4,847,000	27,724,000	

SURF CITY & NTOPSAIL, NC PERIOD
7th PERIODIC NOURISHMENT
CONSTRUCTION- SUMMARY OF COSTS
CURRENT WORKING ESTIMATE (CWE)
CODE OF ACCOUNTS

Designed By: USACE - WILMINGTON DISTRICT
Estimated By: CESAW-TS-EE

Prepared By: John C. Caldwell
CESAW-TS-EE

Preparation Date: 10/05/10
Effective Date of Pricing: 10/01/10

Sales Tax: 0.00%

This report is not copyrighted, but the information
contained herein is For Official Use Only.

M C A C E S G O L D E D I T I O N
Composer GOLD Software Copyright (c) 1985-1994
by Building Systems Design, Inc.
Release 5.30

	QUANTITY	UOM	CONTRACT	CONTINGN	TOTAL COST	UNIT
2 Summary of Periodic Construction						
2.17 BEACH REPLENISHMENT -PERIODIC	36,967,000		7,763,000	44,730,000		
2.30 PLANNING, ENGINEERING & DESIGN	658,000		165,000	823,000		
2.31 CONSTRUCTION MANAGEMENT	400,000		100,000	500,000		
TOTAL Summary of Periodic Construction	38,025,000		8,028,000	46,053,000		

	QUANTITY UOM	CONTRACT	CONTINGN	TOTAL COST	UNIT
2 Summary of Periodic Construction					
2.17 BEACH REPLENISHMENT -PERIODIC					
2.17.01 MOB AND DEMOB		2,728,000	573,000	3,301,000	
2.17.02 DREDGING and BEACH PLACEMENT	3523000.00 CY	34,173,000	7,176,000	41,349,000	11.74
2.17.03 TILLING	87.00 ACR	66,000	14,000	79,000	912
TOTAL BEACH REPLENISHMENT -PERIODIC		36,967,000	7,763,000	44,730,000	
2.30 PLANNING, ENGINEERING & DESIGN					
2.30. A ENGINEERING		152,000	38,000	190,000	
2.30. B ENVIRONMENTAL		4,000	1,000	5,000	
2.30. C PROJECT MGT		30,000	8,000	38,000	
2.30. D GEOTECHNICAL INVESTIGATIONS		450,000	113,000	563,000	
2.30. E Procurment-Contracting		20,000	5,000	25,000	
2.30. F Construction Management		2,000	1,000	3,000	
TOTAL PLANNING, ENGINEERING & DESIGN		658,000	165,000	823,000	
2.31 CONSTRUCTION MANAGEMENT					
2.31. A ENGINEERING		28,000	7,000	35,000	
2.31. B ENVIRONMENTAL		40,000	10,000	50,000	
2.31. C PROJECT MGT		40,000	10,000	50,000	
2.31. D GEOTECHNICAL INVESTIGATIONS		13,000	3,000	16,000	
2.31. E Procurment-Contracting		20,000	5,000	25,000	
2.31. F Construction Management		259,000	65,000	324,000	
TOTAL CONSTRUCTION MANAGEMENT		400,000	100,000	500,000	
TOTAL Summary of Periodic Construction		38,025,000	8,028,000	46,053,000	

****** TOTAL PROJECT COST SUMMARY ******

PROJECT: SURF CITY BEACH AND NORTH TOPSAIL BEACH
LOCATION: NORTH CAROLINA

DISTRICT: WILMINGTON DISTRICT PREPARED: 10/5/2010
POC: CHIEF, COST ENGINEERING, Don Carmen

This Estimate reflects the scope and schedule in report, FEASIBILITY REPORT DATED NOVEMBER 2010

TOTAL INITIAL CONSTRUCTION SUMMARY

Program Year (Budget EC): 2012
Effective Price Level Date: 1 OCT 11

ESTIMATED MIDPOINT AUG 2016
FULLY FUNDED PROJECT ESTIMATE

WBS NUMBER	Civil Works Feature & Sub-Feature Description	COST ($K)	CNTG ($K)	CNTG (%)	TOTAL ($K)	ESC (%)	COST ($K)	CNTG ($K)	TOTAL ($K)	Spent Thru: 1-Oct-09 ($K)		COST ($K)	CNTG ($K)	FULL ($K)
A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
17	BEACH REPLENISHMENT	$93,332	19,600	21%	$112,932	1.4%	$94,677	$19,882	$114,559			$102,625	$21,551	$124,176
	CONSTRUCTION ESTIMATE TOTALS:	$93,332	19,600		**$112,932**	1.4%	$94,677	$19,882	$114,559			$102,625	$21,551	**$124,176**
01	LANDS AND DAMAGES	$4,182	1,046	25%	$5,228	1.4%	$4,242	$1,061	$5,303			$4,350	$1,087	$5,437
30	PLANNING, ENGINEERING & DESIGN	$2,454	614	25%	$3,068	1.5%	$2,490	$622	$3,112			$2,574	$644	$3,218
31	CONSTRUCTION MANAGEMENT	$1,527	382	25%	$1,909	1.5%	$1,549	$387	$1,936			$1,672	$418	$2,090
	PROJECT COST TOTALS:	$101,495	21,640	21%	**$123,135**	1.4%	$102,958	$21,952	$124,910			$111,221	$23,700	$134,921

_____ CHIEF, COST ENGINEERING,

_____ PROJECT MANAGER,

_____ CHIEF, REAL ESTATE,

_____ CHIEF, PLANNING,

_____ CHIEF, ENGINEERING,

_____ CHIEF, OPERATIONS,

_____ CHIEF, CONSTRUCTION,

_____ CHIEF, CONTRACTING,

_____ CHIEF, PM-PB,

_____ CHIEF, DPM,

ESTIMATED FEDERAL COST: **$87,699**
ESTIMATED NON-FEDERAL COST: $47,222
ESTIMATED TOTAL PROJECT COST: **$134,921**

ESTIMATED TOTAL PROJECT PERIODIC NOURISHMENT COST FOR 50 YEARS: **$359,293**
YEARS 2021 THRU 2057 FULLY FUNDED WITH 21% CONTINGENCY

Filename: TPCS_INITIAL_CONST_OCT_19_2010x.xls
TPCS

**** CONTRACT COST SUMMARY ****

PROJECT: SURF CITY BEACH AND NORTH TOPSAIL BEACH
LOCATION: NORTH CAROLINA
This Estimate reflects the scope and schedule in report; FEASIBILITY REPORT DATED NOVEMBER 2010

DISTRICT: WILMINGTON DISTRICT PREPARED: 10/5/2010
POC: CHIEF, COST ENGINEERING,

Estimate Prepared: 5-Oct-10
Effective Price Level: 1 OCT 11

Program Year (Budget EC): 2012
Effective Price Level Date: 1 OCT 11

WBS NUMBER	Civil Works Feature & Sub-Feature Description	COST ($K)	CNTG ($K)	CNTG (%)	TOTAL ($K)	ESC (%)	COST ($K)	CNTG ($K)	TOTAL ($K)	FULLY FUNDED PROJECT ESTIMATE Mid-Point Date	ESC (%)	COST ($K)	CNTG ($K)	FULL ($K)
A	B	C	D	E	F	G	H	I	J	P	L	M	N	O
	INITIAL CONSTRUCTION YEAR 1 - DEC 2014 til MAR 2015													
17	BEACH REPLENISHMENT	$ 23,333	$ 4,900	21%	$ 28,233	1.4%	$23,669	$4,971	$28,640	2015Q2	5.6%	$24,994	$5,249	$30,243
	CONSTRUCTION ESTIMATE TOTALS:	23,333	4,900	21%	**28,233**		$23,669	$4,971	$28,640			$24,994	**$5,249**	$30,243
01	LANDS AND DAMAGES	$ 4,182	$ 1,046	25%	$ 5,228	1.4%	$4,242	$1,061	$5,303	2013Q3	2.5%	$4,350	**$1,087**	$5,437
30	PLANNING, ENGINEERING & DESIGN													
	PLANNING, ENGINEERING & DESIGN	1,854	$ 464	25%	2,318	1.5%	$1,881	$470	$2,351	2013Q2	2.1%	$1,920	$480	$2,400
31	CONSTRUCTION MANAGEMENT													
	Construction Management	382	$ 95	25%	477	1.5%	$387	$97	$484	2015Q2	5.4%	$408	$102	$510
	CONTRACT COST TOTALS:	29,751	6,504		**36,255**		$30,180	$6,598	$36,778			$31,671	**$6,918**	**$38,589**

Filename: TPCS_INITIAL_CONST_OCT_19_2010x.xls
TPCS

**** CONTRACT COST SUMMARY ****

PROJECT: SURF CITY BEACH AND NORTH TOPSAIL BEACH
LOCATION: NORTH CAROLINA
This Estimate reflects the scope and schedule in report: FEASIBILITY REPORT DATED NOVEMBER 2010

DISTRICT: WILMINGTON DISTRICT PREPARED: 10/5/2010
POC: CHIEF, COST ENGINEERING,

Estimate Prepared: 5-Oct-10
Effective Price Level: 1 OCT 11

Program Year (Budget EC): 2012
Effective Price Level Date: 1 OCT 11

WBS NUMBER	Civil Works Feature & Sub-Feature Description	COST ($K)	CNTG ($K)	CNTG (%)	TOTAL ($K)	ESC (%)	COST ($K)	CNTG ($K)	TOTAL ($K)	FULLY FUNDED PROJECT ESTIMATE Mid-Point Date	ESC (%)	COST ($K)	CNTG ($K)	FULL ($K)
A	B	C	D	E	F	G	H	I	J	P	L	M	N	O
	INITIAL CONSTRUCTION YEAR 2 - DEC 2015 til MAR 2016													
17	BEACH REPLENISHMENT	$ 23,333	$ 4,900	21%	$ 28,233	1.4%	$23,669	$4,971	$28,640	2016Q2	7.4%	$25,419	$5,338	$30,757
	CONSTRUCTION ESTIMATE TOTALS:	23,333	4,900	21%	**28,233**		$23,669	$4,971	$28,640			$25,419	$5,338	$30,757
01	LANDS AND DAMAGES	$ -	$ -	25%	$ -									
30	PLANNING, ENGINEERING & DESIGN													
	PLANNING, ENGINEERING & DESIGN	200	$ 50	25%	250	1.5%	$203	$51	$254	2015Q3	5.8%	$215	$54	$268
31	CONSTRUCTION MANAGEMENT													
	Construction Management	382	$ 95	25%	477	1.5%	$387	$97	$484	2016Q2	7.0%	$415	$104	$518
	CONTRACT COST TOTALS:	23,915	5,045		**28,960**		$24,259	$5,118	$29,377			$26,048	$5,495	**$31,543**

Filename: TPCS_INITIAL_CONST_OCT_19_2010x.xls
TPCS

PROJECT: SURF CITY BEACH AND NORTH TOPSAIL BEACH
LOCATION: NORTH CAROLINA
This Estimate reflects the scope and schedule in report; FEASIBILITY REPORT DATED NOVEMBER 2010

DISTRICT: WILMINGTON DISTRICT PREPARED: 10/5/2010
POC: CHIEF, COST ENGINEERING,

Estimate Prepared: 5-Oct-10
Effective Price Level: 1 OCT 11

Program Year (Budget EC): 2012
Effective Price Level Date: 1 OCT 11

WBS NUMBER	Civil Works Feature & Sub-Feature Description	COST ($K)	CNTG ($K)	CNTG (%)	TOTAL ($K)	ESC (%)	COST ($K)	CNTG ($K)	TOTAL ($K)	FULLY FUNDED PROJECT ESTIMATE Mid-Point Date	ESC (%)	COST ($K)	CNTG ($K)	FULL ($K)
A	B	C	D	E	F	G	H	I	J	P	L	M	N	O
	INITIAL CONSTRUCTION YEAR 3 - DEC 2016 til MAR 2017													
17	BEACH REPLENISHMENT	$ 23,333	$ 4,900	21%	$ 28,233	1.4%	$23,669	$4,971	$28,640	2017Q2	9.3%	$25,873	**$5,433**	**$31,307**
	CONSTRUCTION ESTIMATE TOTALS:	23,333	4,900	21%	**28,233**		$23,669	$4,971	$28,640			$25,873	**$5,433**	**$31,307**
01	LANDS AND DAMAGES	$ -	$ -	25%	$ -									
30	PLANNING, ENGINEERING & DESIGN													
	PLANNING, ENGINEERING & DESIGN	200	$ 50	25%	250	1.5%	$203	$51	$254	2016Q3	7.5%	$218	**$55**	**$273**
31	CONSTRUCTION MANAGEMENT													
	Construction Management	362	$ 95	25%	477	1.5%	$387	$97	$484	2017Q2	8.8%	$421	**$105**	**$527**
	CONTRACT COST TOTALS:	23,915	5,045		**28,960**		$24,259	$5,118	$29,377			$26,513	**$5,593**	**$32,106**

**** CONTRACT COST SUMMARY ****

PROJECT: SURF CITY BEACH AND NORTH TOPSAIL BEACH
LOCATION: NORTH CAROLINA
This Estimate reflects the scope and schedule in report; FEASIBILITY REPORT DATED NOVEMBER 2010

DISTRICT: WILMINGTON DISTRICT PREPARED: 10/5/2010
POC: CHIEF, COST ENGINEERING,

Estimate Prepared: 5-Oct-10
Effective Price Level: 1 OCT 11

Program Year (Budget EC): 2012
Effective Price Level Date: 1 OCT 11

WBS NUMBER	Civil Works Feature & Sub-Feature Description	COST ($K)	CNTG ($K)	CNTG (%)	TOTAL ($K)	ESC (%)	COST ($K)	CNTG ($K)	TOTAL ($K)	FULLY FUNDED PROJECT ESTIMATE Mid-Point Date	ESC (%)	COST ($K)	CNTG ($K)	FULL ($K)
A	*B*	*C*	*D*	*E*	*F*	*G*	*H*	*I*	*J*	*P*	*L*	*M*	*N*	*O*
	INITIAL CONSTRUCTION YEAR 4 - DEC 2017 til MAR 2018													
17	BEACH REPLENISHMENT	$ 23,333	$ 4,900	21%	$ 28,233	1.4%	$23,669	$4,971	$28,640	2018Q2	11.3%	$26,339	**$5,531**	**$31,870**
	CONSTRUCTION ESTIMATE TOTALS:	23,333	4,900	21%	**28,233**		$23,669	$4,971	$28,640			$26,339	**$5,531**	**$31,870**
01	LANDS AND DAMAGES	$ -	$ -	25%	$ -									
30	PLANNING, ENGINEERING & DESIGN													
	PLANNING, ENGINEERING & DESIGN	$200	$ 50	25%	250	1.5%	$203	$51	$254	2017Q3	9.2%	$222	**$55**	**$277**
31	CONSTRUCTION MANAGEMENT													
	Construction Management	$382	$ 95	25%	477	1.5%	$387	$97	$484	2018Q2	10.6%	$428	**$107**	**$535**
	CONTRACT COST TOTALS:	$23,915	5,045		**28,960**		$24,259	$5,118	$29,377			$26,989	**$5,694**	**$32,682**

Filename: TPCS_INITIAL_CONST_OCT_19_2010x.xls
TPCS



US Army Corps of Engineers®

Hurricane Protection and Beach Erosion Control
Surf City and North Topsail Beach, North Carolina
Feasibility Report and Environmental Impact Statement
Project Cost and Schedule Risk Analysis Report

Prepared for:

U.S. Army Corps of Engineers,
Wilmington District

Prepared by:

U.S. Army Corps of Engineers
Cost Engineering Directory of Expertise, Walla Walla

November 23, 2010

TABLE OF CONTENTS

EXECUTIVE SUMMARY **ES-1**

1. PURPOSE **1**

2. BACKGROUND **1**

3. REPORT SCOPE **1**

3.1 Project Scope 1
3.2 USACE Risk Analysis Process 1

4. METHODOLOGY/PROCESS **2**

4.1 Identify and Assess Risk Factors 3
4.2 Quantify Risk Factor Impacts 4
4.3 Analyze Cost Estimate Contingency 5

5. PROJECT ASSUMPTIONS **5**

6. .RISK ANALYSIS RESULTS **6**

6.1 Risk Register 7
6.2 Cost Risk Analysis - Cost Contingency Results 7

7. MITIGATION RECOMMENDATIONS **8**

APPENDIX

APPENDIX A includes

Detailed Risk Analysis

- Risk Register Summary
- Sensitivity Charts
- Total Project Cost Presentation
- Project Confidence Curves

EXECUTIVE SUMMARY

Under the auspices of the US Army Corps of Engineers (USACE), Wilmington District, this report presents a recommendation for the total project cost and schedule contingencies for the Surf City and North Topsail Beach Feasibility Report and Environmental Impact Statement. In compliance with Engineer Regulation (ER) 1110-2-1302 CIVIL WORKS COST ENGINEERING, dated September 15, 2008, a formal risk analysis study was conducted for the development of contingency on the total project cost. The purpose of this risk analysis study was to establish project contingencies by identifying and measuring the cost and schedule impact of project uncertainties with respect to the estimated total project cost.

Specific to the Surf City and North Topsail Beach project, the most likely project cost is estimated at approximately $101 Million. Based on the results of the analysis, the Cost Engineering Directory of Expertise for Civil Works (Walla Walla District) recommends a contingency value of $22 Million, or 21%.

The Project Delivery Team (PDT) conducted a series of brainstorming sessions in February 2009 to identify the risks associated with the project. The expert judgment of estimator and the risk analyst also helped to identify and define the risks. Walla Walla Cost Dx performed risk analysis using the Monte Carol technique, producing the aforementioned contingencies and identifying key risk drivers.

The following table ES-1 portrays the development of contingencies for the project. The contingency is based on an 80% confidence level, as per accepted USACE Civil Works guidance.

Table ES-1. Contingency Development Summary

Most Likely Cost Estimate	**$101,494,800**	
Confidence Level	**Value ($$)**	**Contingency (%)**
5%	$101,911,908	0.41%
50%	$115,734,303	14.03%
80%	**$123,033,021**	**21.22%**
95%	$129,928,279	28.01%

The following table ES-2 portrays the full costs of the recommended alternative based on the anticipated contracts. The costs are intended to address the congressional request of estimates to implement the project. The contingency is based on an 80% confidence level, as per accepted USACE Civil Works guidance.

Table ES-2. Contingency Analysis Table

SURF CITY AND NORTH TOPSAIL BEACH		COST ($1,000)	CNTG ($1,000)	TOTAL ($1,000)
01	LANDS AND DAMAGES	4,182	1,046	5,228
17	BEACH REPLENISHMENT	93,332	19,600	112,932
30	PLANNING, ENGINEERING AND DESIGN	2,454	614	3,068
31	CONSTRUCTION MANAGEMENT	1,527	382	1,909
	TOTAL PROJECT COSTS	**101,495**	**21,640**	**123,135**

Notes:
1) Construction costs include the recommended contingency of 21%. Lands and Damages (01), Planning, Engineering and Design (30), and Construction Management (31) Accounts include contingencies of 25%, as provided by others.
2) Costs exclude O&M and Life Cycle Cost estimates.

KEY FINDINGS/OBSERVATIONS RECOMMENDATIONS

The key cost risk drivers identified through sensitivity analysis are Programmatic Risk EXT-1 (Market Conditions), Contract Risks EST-4 (Two-Dredge Productivity) and EST-3 (Fuel), which together contribute 82 percent of the statistical cost variance. Other notable cost risk drivers are Contract Risks EST-1 (Dredge, Number & Size) and CON-1 (Contract Modifications) which each contribute 5.9 percent to the statistical cost variance.

Recommendations, as detailed within the main report, include the implementation of contingencies, further iterative study of risks throughout the project life-cycle, potential mitigation throughout the PED phase, and proactive monitoring and control of risks identified in this study.

Risk is comprised of cost and schedule risk elements. This analysis considers schedule elements within the cost analysis, as this project is not susceptible to uncaptured escalation nor significant recurring monthly costs. The following tables tabulate the results of the risk analysis currently identified as a 20.75%

Figure ES-1. Cumulative Frequency Chart

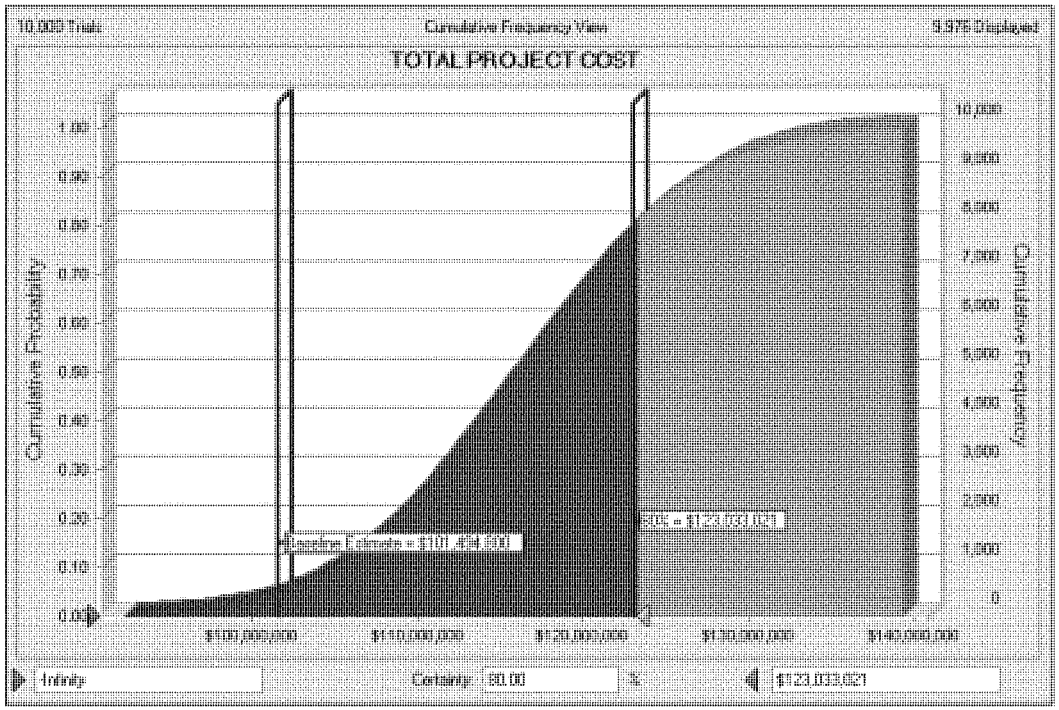
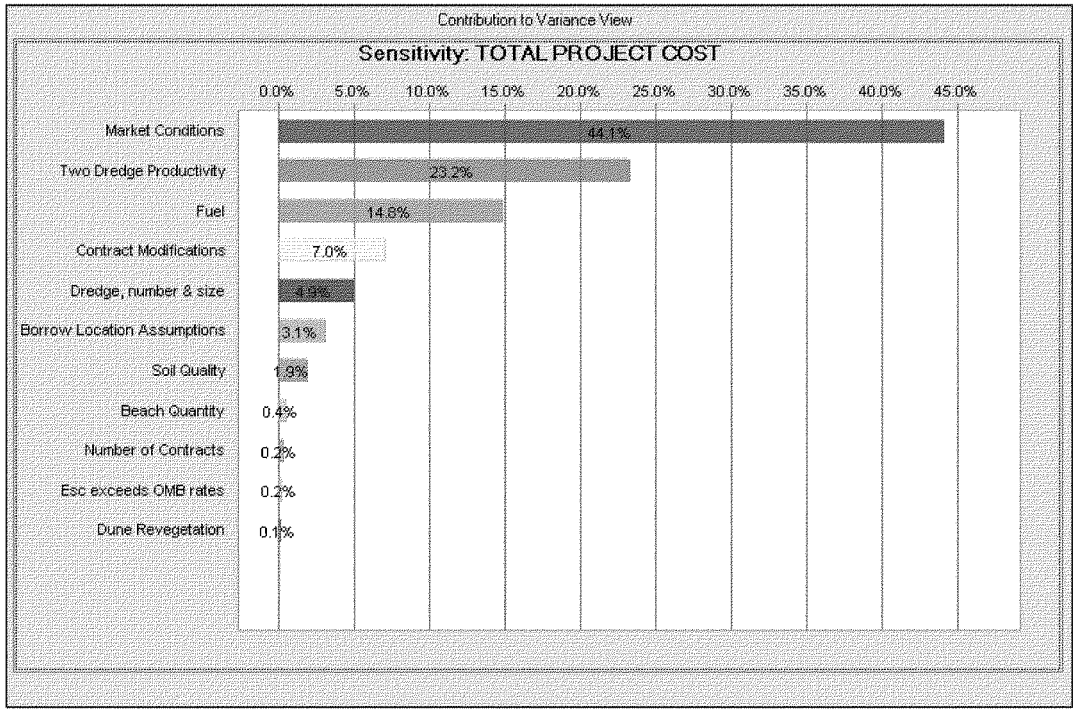


Figure ES-2. Sensitivity Chart



925

1. PURPOSE

Risk Analysis is based on SURF CITY AND NORTH TOPSAIL BEACH FEASIBILITY REPORT AND ENVIRONMENTAL IMPACT STATEMENT. The purpose for a cost and schedule risk analysis (CSRA) is to briefly present discussion of the studied elements related to cost and schedule with an outcome contingency calculation at the recommended confidence level for both cost and schedule that are measured in terms of dollars. The most common and recommended contingency has been established at 80% confidence.

2. BACKGROUND

The NED Plan is the alternative selected plan which has the greatest net benefits. The NED Plan is to construct a sand dune to elevation 15-ft (25-ft top width) and a berm to the ocean at elevation of 7-ft (50-ft wide). The NED plan for Surf City and North Topsail Beach (SCNT) is often referred to as the 15/50 plan. Material for placement on the beach will come from offshore borrow areas. Hopper dredges will excavate material, travel to offshore pumpout stations, and pump material onto the beach.

3. REPORT SCOPE

The scope of the risk analysis report is to calculate and present the cost and schedule contingencies at the 80 percent confidence level using the risk analysis processes, as mandated by U.S. Army Corps of Engineers (USACE) Engineer Regulation (ER) 1110-2-1150, Engineering and Design for Civil Works, ER 1110-2-1302, Civil Works Cost Engineering, and Engineer Technical Letter 1110-2-573, Construction Cost Estimating Guide for Civil Works. The report presents the contingency results for cost risks for all project features. The study and presentation can include or exclude consideration for operation and maintenance or life cycle costs, depending upon the program or decision document intended for funding.

3.1 Project Scope

The scope of this study addresses the identification of problems, needs, opportunities and potential solutions that are viable from an economic, environmental, and engineering viewpoint

3.2 USACE Risk Analysis Process

The risk analysis process follows the USACE Headquarters requirements as well as the guidance provided by the Cost Engineering Directory of Expertise for Civil Works (Cost Dx). The risk analysis process reflected within the risk analysis report uses probabilistic cost and schedule risk analysis methods within the framework of the Crystal Ball software. The risk analysis results are intended to serve several functions – one being the establishment of reasonable contingencies reflective of an 80 percent confidence level to successfully accomplish the project work within that established contingency amount. Furthermore, the scope of the report includes the identification and

communication of important steps, logic, key assumptions, limitations, and decisions to help ensure that risk analysis results can be appropriately interpreted.

Risk analysis results are also intended to provide project leadership with contingency information for scheduling, budgeting, and project control purposes, as well as provide tools to support decision making and risk management as the project progresses through planning and implementation. To fully recognize its benefits, cost and schedule risk analyses should be considered as an ongoing process conducted concurrent to, and iteratively with, other important project processes such as scope and execution plan development, resource planning, procurement planning, cost estimating, budgeting, and scheduling.

In addition to broadly defined risk analysis standards and recommended practices, the risk analysis is performed to meet the requirements and recommendations of the following documents and sources:

- Cost and Schedule Risk Analysis Process guidance prepared by the USACE Cost Dx.
- Memorandum from Major General Don T. Riley (US Army Director of Civil Works), dated July 3, 2007.
- Engineering and Construction Bulletin issued by James C. Dalton, P.E. (Chief, Engineering and Construction, Directorate of Civil Works), dated September 10, 2007.
- Engineering Regulation ER 1110-2-1150 dated August 31, 1999.
- Engineering Regulation ER 1110-2-1302 dated September 15, 2008.
- Engineering Technical Letter 1110-2-573 dated September 30, 2008.

4. METHODOLOGY/PROCESS

The Cost Dx assembled a team, also relying on local Wilmington District staff to further augment labor, expertise and information gathering. The Cost Dx team consisted of two senior civil cost engineers. The Wilmington staff included cost support from the cost engineer as well as coordination support from project management and the assigned project delivery team (PDT).

The Cost Dx Team facilitated a risk identification and qualitative analysis meeting with the Wilmington PDT via teleconference on February 24, 2009. Several meetings via teleconference were conducted during that time frame to further develop the risk register. The risk identification and qualitative analysis process resulted in recommendations for revisions to the estimate, both for the ATR cost review process and for the inputs to the cost and schedule risk analysis.

The cost risk model was completed and results reported on April 15, 2009.

The risk analysis process for this study is intended to determine the probability of various cost outcomes and quantify the required contingency needed in the cost estimate to achieve any desired level of cost confidence.

In simple terms, contingency is an amount added to an estimate to allow for items, conditions or events for which the occurrence or impact is uncertain and that experience suggests will likely result in additional costs being incurred or additional time being required. The amount of contingency included in project control plans depends, at least in part, on the project leadership's willingness to accept risk of project overruns. The less risk that project leadership is willing to accept the more contingency should be applied in the project control plans. The risk of overrun is expressed, in a probabilistic context, using confidence levels.

The Cost Dx guidance for cost and schedule risk analysis generally focuses on the 80-percent level of confidence (P80) for cost contingency calculation. It should be noted that use of P80 as a decision criteria is a risk averse approach (whereas the use of P50 would be a risk neutral approach, and use of levels less than 50 percent would be risk seeking). Thus, a P80 confidence level results in greater contingency as compared to a P50 confidence level.

The risk analysis process uses *Monte Carlo* techniques to determine probabilities and contingency. The *Monte Carlo* techniques are facilitated computationally by a commercially available risk analysis software package (Crystal Ball) that is an add-in to Microsoft Excel. Cost estimates are packaged into an Excel format and used directly for cost risk analysis purposes. The level of detail recreated in the Excel-format schedule is sufficient for risk analysis purposes that reflect the established risk register, but generally less than that of the native format.

The primary steps, in functional terms, of the risk analysis process are described in the following subsections. Risk analysis results are provided in section 6.

4.1 Identify and Assess Risk Factors

Identifying the risk factors via the PDT is considered a qualitative process that results in establishing a risk register that serves as the document for the quantitative study using the Crystal Ball risk software. Risk factors are events and conditions that may influence or drive uncertainty in project performance. They may be inherent characteristics or conditions of the project or external influences, events, or conditions such as weather or economic conditions. Risk factors may have either favorable or unfavorable impacts on project cost and schedule.

Checklists or historical databases of common risk factors are sometimes used to facilitate risk factor identification. However, key risk factors are often unique to a project and not readily derivable from historical information. Therefore, input from the entire PDT is obtained using creative processes such as brainstorming or other facilitated risk assessment meetings. In practice, a combination of professional judgment from the PDT and empirical data from similar projects is desirable and is considered.

Formal PDT meetings are held for the purposes of identifying and assessing risk factors. The meetings should include capable and qualified representatives from multiple project team disciplines and functions, for example:

- Project/Program managers
- Contracting/acquisition
- Real Estate
- Relocations
- Environmental
- Civil and Coastal Design
- Cost and schedule engineers
- Construction
- Key Sponsors

The initial formal meetings should focus primarily on risk factor identification using brainstorming techniques, but also include some facilitated discussions based on risk factors common to projects of similar scope and geographic location. Subsequent meetings should focus primarily on risk factor assessment and quantification.

Additionally, numerous conference calls and informal meetings are conducted throughout the risk analysis process on an as-needed basis to further facilitate risk factor identification, market analysis, and risk assessment.

4.2 Quantify Risk Factor Impacts

The quantitative impacts of risk factors on project plans are analyzed using a combination of professional judgment, empirical data, and analytical techniques. Risk factor impacts are quantified using probability distributions (density functions), because risk factors are entered into the Crystal Ball software in the form of probability density functions.

Similar to the identification and assessment process, risk factor quantification involves multiple project team disciplines and functions. However, the quantification process relies more extensively on collaboration between cost engineering, designers, and risk analysis team members with lesser inputs from other functions and disciplines.

The following is an example of the PDT quantifying risk factor impacts by using an iterative, consensus-building approach to estimate the elements of each risk factor:

- Maximum possible value for the risk factor.
- Minimum possible value for the risk factor.
- Most likely value (the statistical mode), if applicable.
- Nature of the probability density function used to approximate risk factor uncertainty.
- Mathematical correlations between risk factors.
- Affected cost estimate and schedule elements.

The resulting product from the PDT discussions is captured within a risk register as presented in section 6 for both cost and schedule risk concerns. Note that the risk register records the PDT's risk concerns, discussions related to those concerns, and potential impacts to the current cost and schedule estimates. The concerns and

discussions are meant to support the team's decisions related to event likelihood, impact, and the resulting risk levels for each risk event.

4.3 Analyze Cost Estimate and Schedule Contingency

Contingency is analyzed using the Crystal Ball software, an add-in to the Microsoft Excel format of the cost estimate and schedule. *Monte Carlo* simulations are performed by applying the risk factors (quantified as probability density functions) to the appropriate estimated cost and schedule elements identified by the PDT. Contingencies are calculated by applying only the moderate and high level risks identified for each option (i.e., low-level risks are typically not considered, but remain within the risk register to serve historical purposes as well as support follow-on risk studies as the project and risks evolve).

For the cost estimate, the contingency is calculated as the difference between the P80 cost forecast and the baseline cost estimate. Each option-specific contingency is then allocated on a civil works feature level based on the dollar-weighted relative risk of each feature as quantified by *Monte Carlo* simulation. Standard deviation is used as the feature-specific measure of risk for contingency allocation purposes. This approach results in a relatively larger portion of all the project feature cost contingency being allocated to features with relatively higher estimated cost uncertainty.

5. PROJECT ASSUMPTIONS

The following data sources and assumptions were used in quantifying the costs associated with the with- and without-project conditions at Surf City and North Topsail Beach.

a. Two medium size Hopper dredges were used to developed cost estimates using CEDEP. The hopper dredges would dredge material from the borrow areas and haul material to pump out locations approximately 3,000 LF offshore. On the beach, the material would be placed from a wye/tee for 3,000 LF in each direction or a total of 6,000 lf on the beach.

b. Hopper dredges were assumed because the distance from the borrow areas to the beach averages approximately 3 to 5 miles, and the borrow area contours show relatively shallow depths of sand (bank height is generally less than 5 feet in most cases). It was determined that the conditions above would not be efficient for pipeline cutter head suction dredges. However, pipeline cutter head suction dredges will not be restricted from the competitive bids.

c. The entire length of the beach to be renourished is approximately 10 miles. Initial nourishment will require 11,500,000 CY and subsequent periodic nourishments will require 1,639,000 CY.

d. Hopper dredge operations are limited to environmental windows and are only allowed to dredge during the period from December 1 through March 31.

e. The unit prices are based on historical effective work times for offshore borrow areas with pumping to the beach.

f. The cost comparisons and risk analyses performed and reflected within this report are based upon design scope and estimates that are considered to be fairly well developed and designed.

g. The schedule was not analyzed for impact to the total project cost, as this project is not susceptible to uncaptured escalation (local market inflation notably higher than national average) or recurring monthly costs (unavoidable fixed contract costs and/or languishing federal administration costs incurred continuously throughout delay).

h. The Cost Dx guidance generally focuses on the eighty-percent level of confidence (P80) for cost contingency calculation. For this risk analysis, the eighty-percent level of confidence (P80) was used. It should be noted that the use of P80 as a decision criteria is a moderately risk averse approach, generally resulting in higher cost contingencies. However, the P80 level of confidence also assumes a small degree of risk that the recommended contingencies may be inadequate to completely capture actual project costs.

i. Only high and moderate risk level impacts, as identified in the risk register, were considered for the purposes of calculating cost contingency. Low level risk impacts should be maintained in project management documentation, and reviewed at each project milestone to determine if they should be placed on the risk "watch list" for further monitoring and evaluation.

6. RISK ANALYSIS RESULTS

The following table tabulates the results of the risk analysis currently identified as a 21.22% contingency amount based on 80% confidence level. The complete list of tables and figures are included within Appendix A.

Table 1. Cost Contingency Summary

Contingency on Base Estimate	80% Confidence Project Cost
Total Construction Cost (Most Likely) ->	$101,494,800
Construction Cost Contingency Amount ->	$21,538,221
Total Construction Cost (80% Confidence) ->	$123,033,021

6.1 Risk Register

A risk register is a tool commonly used in project planning and risk analysis. The actual risk register is provided in Appendix A. The complete risk register includes low level risks, as well as additional information regarding the nature and impacts of each risk.

It is important to note that a risk register can be an effective tool for managing identified risks throughout the project life cycle. As such, it is generally recommended that risk registers be updated as the designs, cost estimates, and schedule are further refined, especially on large projects with extended schedules. Recommended uses of the risk register going forward include:

- Documenting risk mitigation strategies being pursued in response to the identified risks and their assessment in terms of probability and impact.
- Providing project sponsors, stakeholders, and leadership/management with a documented framework from which risk status can be reported in the context of project controls.
- Communicating risk management issues.
- Providing a mechanism for eliciting risk analysis feedback and project control input.
- Identifying risk transfer, elimination, or mitigation actions required for implementation of risk management plans.

6.2 Cost Risk Analysis - Cost Contingency Results

Table 2 provides the construction cost contingencies calculated for the P80 confidence level and rounded to the nearest thousand. The construction cost contingencies for the P50 and P100 confidence levels are also provided for illustrative purposes.

Contingency was quantified as approximately $22 Million at the P80 confidence level (about 21% of the base cost estimate). For comparison, the cost contingency at the P50 and P100 confidence levels was quantified as 14% and 42% of the baseline cost estimate, respectively.

Table 2. Base Estimate Cost Contingency Summary

Risk Analysis Forecast	Base Estimate	Total Contingency[1] ($)	Total Contingency (%)
50% Confidence Level			
Total Project Cost	$101,495	$14,240	14.03%
80% Confidence Level			
Total Project Cost	$101,495	$21,538	21.22%
100% Confidence Level			
Total Project Cost	$101,495	$42,090	41.47%

Notes:
1) Includes cost contingency, but not schedule contingency impacts.

7. MITIGATION RECOMMENDATIONS

Risk Management is an all-encompassing, iterative, and life-cycle process of project management. The Project Management Institute's (PMI) *A Guide to the Project Management Body of Knowledge (PMBOK® Guide), 4th edition*, states that "project risk management includes the processes concerned with conducting risk management

planning, identification, analysis, responses, and monitoring and control on a project." Risk identification and analysis are processes within the knowledge area of risk management. Its outputs pertinent to this effort include the risk register, risk quantification (risk analysis model), contingency report, and the sensitivity analysis.

The intended use of these outputs is implementation by the project leadership with respect to risk responses (such as mitigation) and risk monitoring and control. In short, the effectiveness of the project risk management effort requires that proactive management of risks does not conclude with the study completed in this report.

The Cost and Schedule Risk Analysis (CSRA) produced by the PDT identifies issues that require the development of subsequent risk response and mitigation plans. This section provides a list of recommendations for continued management of the risks identified and analyzed in this study. Note that this list is not all inclusive and should not substitute a formal risk management and response plan.

1. Key Risk Drivers: The key cost risk drivers identified through sensitivity analysis are Programmatic Risk EXT-1 (Market Conditions), Contract Risks EST-4 (Two-Dredge Productivity) and EST-3 (Fuel), which together contribute 82 percent of the statistical cost variance. Other notable cost risk drivers are Contract Risks EST-1 (Dredge, Number & Size) and CON-1 (Contract Modifications) which each contribute 5.9 percent to the statistical cost variance.

Whereas the developed contingency, itself, is a response to the potential for these risks, these risks warrant consideration of other potential responses and proactive monitoring and control.

a) Market Conditions: With respect to Market Conditions (Risk EXT-1), Cost Dx recommends continuous monitoring of the price fluctuations and behaviors in the regional dredging industry in the PDT's ongoing market research. Project leadership should craft the acquisition strategy with relation to the market trends to minimize the impact of the industry contraction and maximize competition on the project.

b) Two-Dredge Productivity: With respect to two-dredge productivity (Risk EST-4), Cost Dx recommends further research into the likelihood of the use of this model scenario. This research should parallel ongoing market research.

c) Fuel: With respect to fuel prices (Risk EST-3), Cost Dx recommends proactive market research to identify trends and their effect on the project cost.

2. Risk Management: Cost Dx recommends use of the outputs created during the risk analysis effort as tools in future risk management processes. The risk register should be updated at each major project milestone. The results of the sensitivity analysis may also be used for response planning strategy and development. These tools should be used in conjunction with regular risk review meetings, as discusses in section 6.1.

3. Risk Analysis Updates: Project leadership should review risk items identified in the original risk register and add others, as required, throughout the project life-cycle. Risks should be reviewed for status and reevaluation (using qualitative measure, at a minimum) and placed on risk management watch lists if any risk's likelihood or impact significantly increases. Project leadership should also be mindful of the potential for secondary (new risks created specifically by the response to an original risk) and residual risks (risks that remain and have unintended impact following response).

APPENDIX A

SURF CITY AND NORTH TOPSAIL BEACH, NC - RISK REGISTER

Risk Level

Likelihood of Occurrence	Negligible	Marginal	Significant	Critical	Crisis
Very Likely	Low	Moderate	High	High	High
Likely	Low	Moderate	High	High	High
Unlikely	Low	Low	Moderate	Moderate	High
Very Unlikely	Low	Low	Low	Low	High

Impact or Consequence of Occurrence

Risk No.	Risk/Opportunity Event (logic by feature, contract, responsibility)	PDT Event Concerns (include all to archive)	PDT Discussions (support the likelihood and impact)	Responsibility/POC	Project Cost: Likelihood*	Project Cost: Impact*	Project Cost: Risk Level*	Project Schedule: Likelihood*	Project Schedule: Impact*	Project Schedule: Risk Level*	Cost Impact ($)	Variance Distribution (Cost)	Schedule Impact (mo)	Variance Distribution (Schedule)	Correlation to Others (minimize)	Affected Project Component	Cost Comments	Schedule Comments
	Contract Risks (Internal Risk Items are those that are generated, caused, or controlled within the PDT's sphere of influence.)																	
	PROJECT & PROGRAM MGMT																	
PPM-1	Congressional Funding - Feasibility	Adequate Congressional funding to complete the feasibility study.	PM feels that adequate PED funding has been made available to support Feasibility study and report as well as initiate PED phase.	PM	Very Unlikely	Marginal	Low	Very Unlikely	Marginal	Low	Less Than 1%	Low Risk - Not Studied	Less Than 1%	*Schedule Risks Not Formerly Studied		Project Cost & Schedule		
PPM-2	Congressional Funding - PED	Concern is that the PED Congressional funding is uncertain, post feasibility.	Anticipated needs of $1.5-2M to complete PED, but not certain all needed Congressional funding will be made available in a timely manner for FY 2010.	PM	Likely	Negligible	Low	Likely	Marginal	Moderate	Less Than 1%	Low Risk - Not Studied	+12 mo	*Schedule Risks Not Formerly Studied	PPM-3, PPM-8	Project Schedule		Up front authorization and funding delays could impact PED start and consequently the construction start. There is a potential that funding is delayed a year, causing a year lost. We study PPM-3 separately/inline.
PPM-3	Congressional Funding Construction	Concern is that construction funding is incremental per FY and can be impacted by budget delays such as continuing resolutions. We can no longer award a continuing contract.	Based on extended construction value, the PDT feels it unlikely that total construction will be funded all at once. This could result in additional PED expenses as well as escalation in schedule growth. Some risk mitigation could occur by breaking the project into seasonal contracts, but the Dec-Mar seasonal construction is dependent upon the FY budget appropriation each FY. Delays in budget approval can impact the Dec start. The converse argument is that IF authorization has already been received, even if the construction funding is delayed, that funding will add the OMB escalation onto the funding request.	PM and Contracting	Very Likely	Negligible	Low	Very Likely	Marginal	Moderate	Less Than 1%	Low Risk - Not Studied	+24 mo	*Schedule Risks Not Formerly Studied	PPM-2, PPM-8, CA-2	Project Schedule		Construction activities dependent upon receiving the PED funds AND the PED activities prior to construction. The construction could then be delayed more months if construction funding is not all received at the construction start. Since there may be as many as four contracts, we assumed incremental funding that has a potential of one or more years.
PPM-4	Stakeholder funding capability	2 sponsors: Surf City and North Topsail Beach; having adequate funding support for their shares.	Sponsors must fund portion of 50% feasibility, 25% PED and 35% initial construction plus 100% real estate acquisition. Breaking construction into 3-4 separate contracts lessens funding risks. Sponsors feel confident that their budget shares are not a critical constraint and that the Federal shares and funding are a greater concern.	Sponsor	Very Unlikely	Negligible	Low	Very Unlikely	Marginal	Low	Less Than 1%	Low Risk - Not Studied	Less Than 1%	*Schedule Risks Not Formerly Studied		Project Cost		
PPM-5	Adequate PDT Resources	Several PDT members scheduled for near term retirement.	The District feels that there is adequate District support and team development for future efforts.	PM	Unlikely	Negligible	Low	Unlikely	Negligible	Low	Less Than 1%	Low Risk - Not Studied	Less Than 1%	*Schedule Risks Not Formerly Studied		Project Schedule		
PPM-6	Sponsor Support	Sponsor support and agreement with the project plan.	Sponsor coordination and support is healthy, alleviated with monthly meetings that include PDT and sponsors.	PM	Unlikely	Negligible	Low	Unlikely	Negligible	Low	Less Than 1%	Low Risk - Not Studied	Less Than 1%	*Schedule Risks Not Formerly Studied		Project Cost & Schedule		
PPM-7	Schedule quality	Concern whether current schedule is realistic, optimistic.	PDT feels the schedule is not overly optimistic and there is adequate time available. The PED is confident of the schedule for PED and construction durations. The construction durations reflect a conservative estimate approach and establish the construction schedule.	PM	Unlikely	Negligible	Low	Unlikely	Negligible	Low	Less Than 1%	Low Risk - Not Studied	Less Than 1%	*Schedule Risks Not Formerly Studied		Project Schedule		
	Opportunity													*Schedule Risks Not Formerly Studied				
PPM-9	Construction Schedule - 4 years	Construction duration expectation is 4 seasons (1 Dec - 31 Mar) due to Environmental Window for hopper dredge. The estimate choice for assumed equipment establishes the duration. Opportunities may exist within the contract solicitation package or further estimate study to decrease the schedule and resulting costs.	Historically, 2 dredges have occurred based on market availability and quantities. The construction estimate assumes 2 medium-sized dredges. Hopper dredge size and number of dredges is commonly established by quantity within the contract. Market study and contract development could result in opportunity.	Estimator	Likely	Marginal	Moderate	Very Likely	Significant	High	SEE EST-1	Uniform		*Schedule Risks Not Formerly Studied	EST-1	Contract Cost & Schedule	Direct relationship to EST-1. Modeled under EST-1.	Direct relationship to EST-1. Modeled under EST-1.
	Contract Acquisition																	
CA-1	Contract Acquisition Strategy	The acquisition strategy could impact the construction cost and schedule.	Work type is not complicated. It is likely that it will be a FFP large business, based on historical and small business does not have capability. The contract packages will contain the estimate schedule projections related to productivity.	PM/KO	Unlikely	Negligible	Low	Unlikely	Negligible	Low	Less Than 1%	Low Risk - Not Studied	Less Than 1%	*Schedule Risks Not Formerly Studied		Contract Cost & Schedule		
CA-2	Number of Contracts	Possibility of single or multiple contracts.	Multiple contracts are likely, which would reduce risks related to bid competition and funding availability. However, multiple contracts will result in more PED and Contracting efforts.	PM/KO	Likely	Marginal	Moderate	Likely	Negligible	Low	$40 + $300k/contract for 3 contracts	Uniform	Less Than 1%	*Schedule Risks Not Formerly Studied	PPM-3, PPM-8	Contract Cost	PED costs are ~ $1.5M. Approx $800K of the $1.5M is for subsurface investigations. There is an additional $300K for final plans and specs prep. Assuming $150K for P&S and $150K for subsurface investigations per contract.	Schedule risk is low because PED work can be performed concurrently with construction contracts.
	Technical																	
T-1	Soil Quality	Concern that the quality soil may be insufficient in quantity to construct project because soil characterization is not complete. State has new, more stringent, criteria related to material quality.	This potential problem is more likely to occur in the long term, unlikely in the short term but dependent upon further study. 30% soil characterization is complete. Further study is significant, but scheduled for PED phase and the initial contracts have adequate borrow resources available. Greater risk is in the out years because the current activities would simply result in a total rerun due to another borrow source.	PM/Geotech	Unlikely	Marginal	High	Likely	Significant	High	$5,474,000 MORE	Triangular	NOT SIGNIFICANT	*Schedule Risks Not Formerly Studied	T-2	Contract Cost & Schedule	MOST LIKELY: Estimate assumes 10% losses from borrow areas to the beach fill based on geotech studies. BEST CASE: Assume Most Likely. WORSE CASE: 25% losses total OR 7% INCREASE IN QUANTITY	Schedule risk is low because EACH additional season would be approx 4 days outside window which is very little risk.
T-2	Beach Quantity	Scope definition is excellent, but quantities can change over time due to beach erosion during the PED phase and geotechnical overfill ratios. Additionally funding delays may increase quantities.	Contract quantities are currently established by dredged borrow assumptions related to quantity and overfill ratios for payment, based on borrow surveys underwater. Storms can change profile bottom, but PDT feels the borrow sources are outside the storm impact zone. Borrow surveys must occur asap to establish the site. Surveys can result in claims and mods, but further beach erosion could also increase the borrow needs. Also could be more quantity due to funding delays.	Coastal/Geotech	Likely	Significant	High	Likely	Significant	High	$2,724,000 MORE	Triangular	NOT SIGNIFICANT	*Schedule Risks Not Formerly Studied	T-1	Contract Cost & Schedule	MOST LIKELY: Estimate assumes funding for FY 13 and subsequent erosion until that FY 13. BEST CASE: Assume same as Most Likely. WORSE CASE: 91,500 cy erosion each year beyond scheduled year FY 13. Assume 4 years delay or about 400,000 cy.	Schedule risk is low because EACH additional season would be approx 4 days outside window which is very little risk.
T-3	Non-Compatible Soil	Concern that non-satisfactory soil is brought onto beach.	Plan is to monitor during dredging process. Mitigation would require contractor removal. Hopper dredge and screening possible before beach placement. PED stage with added borings would better clarify. Must determine if the estimates include any monitoring costs and potential disposal.	Geotech	Unlikely	Marginal	Low	Unlikely	Marginal	Low	Less Than 1%	Low Risk - Not Studied	Less Than 1%	*Schedule Risks Not Formerly Studied		Contract Cost & Schedule		
T-4	Hard Bottom Encounter	Hard bottoms may be uncovered later in out years.	Sand bottom may be covering hard bottoms, leaving a risk in the borrow quantity available at each site. It could damage the hopper dredge. Risk is increased in the out years, because in the near term the dredge can usually relocate. Better clarification should occur during PED phase with better surveys.	Geotech	Unlikely	Marginal	Low	Unlikely	Marginal	Low	Less Than 1%	Low Risk - Not Studied	Less Than 1%	*Schedule Risks Not Formerly Studied		Contract Cost & Schedule		
	Real Estate																	
RE-1	Acquire real estate	Concern that RE cannot acquire real estate timely to support the construction contracts.	Historically, a good track record and relocations are minor.	RE	Unlikely	Negligible	Low	Unlikely	Negligible	Low	Less Than 1%	Low Risk - Not Studied	Less Than 1%	*Schedule Risks Not Formerly Studied		Project Schedule		
RE-2	Real Estate Estimate	Real Estate estimate may cause cost impact.	Historical information is good. The estimate currently includes a 25% contingency. This should be re-evaluated within the risk analysis outcome.	RE	Unlikely	Negligible	Low	Unlikely	Negligible	Low	Less Than 1%	Low Risk - Not Studied	Less Than 1%	*Schedule Risks Not Formerly Studied		Project Cost		

COMPLETED BY RISK ANALYST AFTER PDT DISCUSSIONS

	Environmental																			
ENV-1	Entrapment in small pipes	HYDRA - Hydraulically the benthic worms can get in a local PIPE into encroaching center. Small pipes fling off plant may result in encountering some small pipes material	In 1994 USACE surveyed beach only. Off shore not surveyed. There is potential of encountering rock dredging and associated side bench. Blasting may be required if encountered.	Environmental	Unlikely	Negligible	Low	Unlikely	Negligible	Low		Less Than 1%	Low-Risk - Not Studied	Less Than 1%	*Schedule Risks Not Formally Studied		Contract Cost			
ENV-2	Side Turtle Sea Takes	Hopper dredge may impact sea turtle population	Winter work window not feasible so sea turtle concern. Work to be completed, but not be concurrent even that dover work activity for a period, requiring potentially extended time costs.	Environmental	Unlikely	Marginal	Low	Unlikely	Negligible	Low		Less Than 1%	Low-Risk - Not Studied	Less Than 1%	*Schedule Risks Not Formally Studied		Contract Cost & Schedule			
ENV-3	SAD Turtle Incidental Take	Other protected species may be listed.	Other SAD projects or "takes" can impact this project. Take items shall stored could occur (identify take related impact)	Environmental	Unlikely	Marginal	Low	Unlikely	Marginal	Low		Less Than 1%	Low-Risk - Not Studied	Less Than 1%	*Schedule Risks Not Formally Studied		Contract Cost & Schedule			
ENV-4	Bird Nesting	Bird nesting impacts construction	Winter work window not feasible so bird nesting concern. Work to be completed, but can be concurrent into shell dover work activity as a permit or like.	Environmental	Unlikely	Marginal	Low	Unlikely	Marginal	Low		Less Than 1%	Low-Risk - Not Studied	Less Than 1%	*Schedule Risks Not Formally Studied		Contract Cost & Schedule			
ENV-5	Impact Whale Predation	Encounter potential impacts dredge fleet speed	Probably of the 10 knot speed restriction is low. Larger hopper dredges have a higher speed that could be impacted. Vision may not require this restriction on a federal project and for cost benefit. Mitigation may be required with observer. Estimate 1 observer per dredge per day. Estimate must accommodate speed restrictions, affecting the productivity. The estimate will be redeveloped to accommodate the speed restrictions.	Environmental	Unlikely	Marginal	Low	Unlikely	Marginal	Low		Less Than 1%	Low-Risk - Not Studied	Less Than 1%	*Schedule Risks Not Formally Studied		Contract Cost & Schedule			
ENV-6	Entrainment of Mysticetes	Environmental monitoring required during dredging	Dredge restriction to window two months year would be required if impacts are found. Environmental group will have a separate monitoring contract. The monitoring could have been combined with the EIS	Environmental	Unlikely	Marginal	Low	Unlikely	Negligible	Low		Less Than 1%	Low-Risk - Not Studied	Less Than 1%	*Schedule Risks Not Formally Studied		Contract Cost & Schedule			
ENV-7	Dune Revegetation	Dune revegetation may be required	It denotes includes dune vegetation. Dune revegetation assessment is likely and may not be adequately covered within the estimate.	Environmental	Likely	Marginal	Moderate	Likely	Negligible	Low		$100,000 to 499	Medium	Less Than 1%	*Schedule Risks Not Formally Studied		Contract Cost			
ENV-8	Archeological	Concern that there may be unrecovered archeological finds during the underwater excavations	There are wrecks have been well established with adequate investigations to determine this is not a concern. If anything was discovered, another available nearby borrow source, already identified and studied, would be the next source.	Coastal/Geotech	Very Unlikely	Marginal	Low	Very Unlikely	Negligible	Low		Less Than 1%	Low-Risk - Not Studied	Less Than 1%	*Schedule Risks Not Formally Studied		Contract Cost & Schedule			

	Estimate																	
EST-1	Dredge, number & size	Estimate choice can effect efficiency and productivity, causing a change to the estimate.	Estimate assumed two medium-sized hopper dredges but equipment is not restrictive w/in contract. The chosen estimate hopper size and number can affect the cost and productivity. Hopper dredges accommodate poor weather better than pipeline dredges. A large hopper results in greater efficiency as compared to two smaller hoppers, but less available and may be impacted by speed restrictions. Estimate hopper dredge choice is more common at 77% efficiency and based on historical occurrence. Further study is still necessary.	Estimator	Likely	Marginal	Moderate	Likely	Marginal	Moderate	$7,178,000 LESS	Uniform	ALL WORK IN 2 SEASONS INSTEAD OF 4 SEASONS and reflected in reduced $7.178mil	*Schedule Risks Not Formerly Studied	EST-4, PPM-8	Contract Cost & Schedule	MOST LIKELY: Base estimate assumes 2 medium sized hopper dredges at a productivity rate of 77% = 2.9 Million CY/season (4 mo) based on average historical data. BEST CASE: 4.3 million CY/season assuming 3 various-sized hopper dredges. WORST CASE: Same as most likely.	MOST LIKELY: Base estimate assumes 2 medium sized hopper dredges at a productivity rate of 77% = 2.9 Million CY/season (4 mo) based on average historical data. BEST CASE: 4.3 million CY/season assuming 3 various-sized hopper dredges. WORST CASE: Same as most likely.
EST-2	Pipeline dredge	The potential that a pipeline dredge is used in lieu of the estimated hopper dredge could impact the bid cost.	The estimate assumes hopper dredge as more cost efficient for this project based on distance between borrow source, beach location and historical experience. Assuming bidding interest, the pipeline dredge is no real cost benefit.	Estimator	Unlikely	Marginal	Low	Unlikely	Marginal	Low	Less Than 1%	Low Risk - Not Studied	Less Than 1%	*Schedule Risks Not Formerly Studied		Contract Cost & Schedule		
EST-3	Fuel	Fuel fluctuations can impact dredging costs.	On dredging projects, fuel is a major cost driver for equipment. Fuel has fluctuated drastically in the past 18 months. It is now back on the upswing. Study should be for time of funding date estimate.	Estimator	Likely	Significant	High	Unlikely	Marginal	Low	$11,298,000 MORE	Triangular	Less Than 1%	*Schedule Risks Not Formerly Studied	EXT-5	Contract Cost	MOST LIKELY: Base estimate assumes $2.60/gal based on historical data and projection studies that eliminate anomalies. BEST CASE: $1.59/gal at Feb 23 2009. WORST CASE: $6.00/gal based on studies projections 2010 standby authorization. $4.50/gal experienced in 2008.	
EST-4	Two Dredge Productivity	The estimate assumes a certain productivity based on two medium sized dredge. Productivity may vary.	The current estimate makes assumptions at the size and productivity for two medium sized hopper dredges with a 3.2 mile haul. These estimate assumptions establish the schedule. Productivity of two hopper dredges can vary due to various possibilities.	Estimator	Likely	Significant	High	Likely	Negligible	Low	$18,966,000 MORE AT 60% EWT AND $10,290,000 LESS AT 93% EWT	Triangular	All work for 60% will require 5 mobilization seasons AND for 93% will require 3 mobilization seasons	*Schedule Risks Not Formerly Studied	EST-1, PPM-8	Contract Cost	MOST LIKELY: Base estimate assumes 2 medium sized hopper dredges at a productivity rate of 77% EWT = 2.9 Million CY/season (4 mo) based on average historical data. BEST CASE: Assuming 2 medium hopper dredges at a productivity rate 93% EWT. WORST CASE: 2 medium sized hopper dredges at a 60% EWT.	MOST LIKELY: Base estimate assumes 2 medium sized hopper dredges at a productivity rate of 77% EWT = 2.9 Million CY/season (4 mo) based on average historical data. BEST CASE: Assuming 2 medium hopper dredges at a productivity rate 93% EWT. WORST CASE: 2 medium sized hopper dredges at a 60% EWT + 1 extra hopper season at $500,000.
EST-5	Borrow Location Assumptions	The estimate makes assumptions as to which borrow areas will be used to support the beach locations.	There may be a potential that the assumed locations are not the ones approved for each contract. The estimate assumed the best case of closer locations, but there is a possibility that borrow sources farther from the beach will be used. This could impact productivity and remobilization costs.	Coastal/Geotech	Likely	Marginal	Moderate	Likely	Negligible	Low	$5,326,000 MORE	Triangular	Less Than 1%	*Schedule Risks Not Formerly Studied	CON-1	Contract Cost	MOST LIKELY: Assumes the closest borrow to the closest pumpout station averaging a 3.2-mile haul distance. BEST CASE: Same as most likely case. WORSE CASE: Average haul distance of 5 miles based on using Borrow Areas "L" and "J" as initial construction.	
	Construction																	
CON-1	Contract Modifications	There may be modification issues that have not been captured in current risks.	The normal modifications for dredging is quantities. This is considered elsewhere. Each contract will likely carry the intended quantities per contract, but is restricted by the work window. Competing work, loss of dredges, quantity assumption can cause modifications such as remobilizations and delays. Other modification potentials could include borrow source remobilization resulting from environmental impacts.	Estimator	Likely	Marginal	Moderate	Unlikely	Significant	Moderate	$1,799,000 MORE	Uniform	+12 mo	*Schedule Risks Not Formerly Studied	Y-2, EST-5	Contract Cost & Schedule	MOST LIKELY: Base estimate. BEST CASE: Same as most likely. WORSE CASE: Remobilization into next season.	Modifications may go beyond work window, causing work into the next season.
CON-2	Pipeline Dredge	The estimate assumes a hopper dredge because of longer pipeline distances and depth to borrow.	Reviewing the project, the hopper dredge seems the most likely choice. Dredge shortages may result in pipeline dredges bidding. This could increase the cost. Schedule would be affected by mobilization distances, but better productivity.	Estimator	Unlikely	Marginal	Low	Unlikely	Marginal	Low	Less Than 1%	Low Risk - Not Studied	Less Than 1%	*Schedule Risks Not Formerly Studied		Contract Cost & Schedule		
					Project Cost			**Project Schedule**			**COMPLETED BY RISK ANALYST**							
Risk No.	**Risk/Opportunity Event**	**Concerns**	**PDT Discussions**	**Responsibility/POC**	**Likelihood***	**Impact***	**Risk Level***	**Likelihood***	**Impact***	**Risk Level***	**Cost Impact ($)**	**Variance Distribution (Cost)**	**Schedule Impact (mo)**	**Variance Distribution (Schedule)**	**Correlation to Others)**	**Affected Project Component**		
EXT-1	Market Conditions	Market conditions and competing projects may impact bid competition.	Currently, there are a lot of projects planned when considering the number of dredges available. There are more hopper dredges than pipeline dredges. It is a tough bidding climate based on environmental time-line restrictions. Construction start is scheduled for 2014.	Estimator	Likely	Significant	High	Likely	Negligible	Low	$29,736,000 MORE	Triangular	Less Than 1%	*Schedule Risks Not Formerly Studied		Contract Cost	MOST LIKELY: Base estimate. BEST CASE: 5% less than most likely based on GAO audit. WORSE CASE: 25% above most likely estimate (25% w/o profit) due to lack of dredging companies and dredges for competing projects because of the work window restrictions.	
EXT-2	External Opposition	External opposition may cause scope or schedule change.	Feds adhering to the environmental requirements. Sponsors in favor of project. No serious historical intervention because it is a beach renourishment project.	PM	Unlikely	Marginal	Low	Unlikely	Marginal	Low	Less Than 1%	Low Risk - Not Studied	Less Than 1%	*Schedule Risks Not Formerly Studied		Project Cost & Schedule		
EXT-3	Acts of God	Severe weather may impact cost or schedule.	Nor'easter storms or hurricanes could impact construction as well as beach profile. Construction occurs in low periods of weather risks, however, storms are still a potential. As long as the estimate and schedules assume some inefficiency, it should not be a serious issue.	Geo	Likely	Negligible	Low	Likely	Negligible	Low	Less Than 1%	Low Risk - Not Studied	Less Than 1%	*Schedule Risks Not Formerly Studied		Project Cost & Schedule		
EXT-4	Borrow Competition	External entities may compete for the borrow sources.	For initial construction this is unlikely. Long term competition is likely. The long term competition does not impact initial appropriation needs and feasibility funding request. Future projects must consider this potential as it occurs in future contracts.	PM	Unlikely	Marginal	Low	Unlikely	Marginal	Low	Less Than 1%	Low Risk - Not Studied	Less Than 1%	*Schedule Risks Not Formerly Studied		Contract Cost		
EXT-5	Esc exceeds OMB rates	Over longer periods of time, the actual market may be greater than the OMB rates, impacting contract costs.	Volatile fuel, being a larger risk on dredging projects, may not correlate with the OMB rates and may be higher as time goes into the 4th contract year.	Estimator	Likely	Marginal	Moderate	Unlikely	Negligible	Low	$1,051,725 MORE	Uniform	Less Than 1%	*Schedule Risks Not Formerly Studied	EST-3	Project Cost	Assumes fuel is the greatest cost driver that may cause actual costs to go beyond the OMB rates. The study will focus on fuel projections connected to escalation and prices as the measurement made against the OMB rates.	

*Likelihood, Impact, and Risk Level to be verified through market research and analysis (conducted by cost engineer).
1. Risk/Opportunity identified with reference to the Risk Identification Checklist and through deliberation and study of the PDT.
2. Concerns and Discussions elaborate on Risk/Opportunity Events and includes any assumptions or findings (discussion to support the event rating).
3. The responsibility or POC is the entity responsible as the Subject Matter Expert (SME) for action, monitoring, or information on the PDT for the identified risk or opportunity.
4. Likelihood is measured as likelihood of impacting cost or schedule.
5. Impact is a measure of the event's effect on project objectives with relation to scope, cost, and/or schedule -- **Negligible, Marginal, Significant, Critical**, or **Crisis**. Impacts on Project Cost may vary in severity from impacts on Project Schedule.
6. Risk Level is the resultant of Likelihood and Impact **Low, Moderate**, or **High**. Refer to the matrix located at top of page.
7. Variance Distribution refers to the behavior of the individual risk item with respect to its potential effects on Project Cost and Schedule. For example, an item with clearly defined parameters and a solid most likely scenario would probably follow a
8. Correlation recognizes those risk events that may be related to one another. Care should be given to ensure the risks are handled correctly without a "double counting."
9. Affected Project Component identifies the specific item of the project to which the risk directly or strongly correlates.
10. Project Implications identifies whether or not the risk item affects project cost, project schedule, or both. The PDT is responsible for conducting studies for both Project Cost and for Project Schedule.
11. Results of the risk identification process are studied and further developed by the Cost Engineer, then analyzed through the Monte Carlo Analysis Method for Cost (Contingency) and Schedule (Escalation) Growth.

^ Can not assess these items

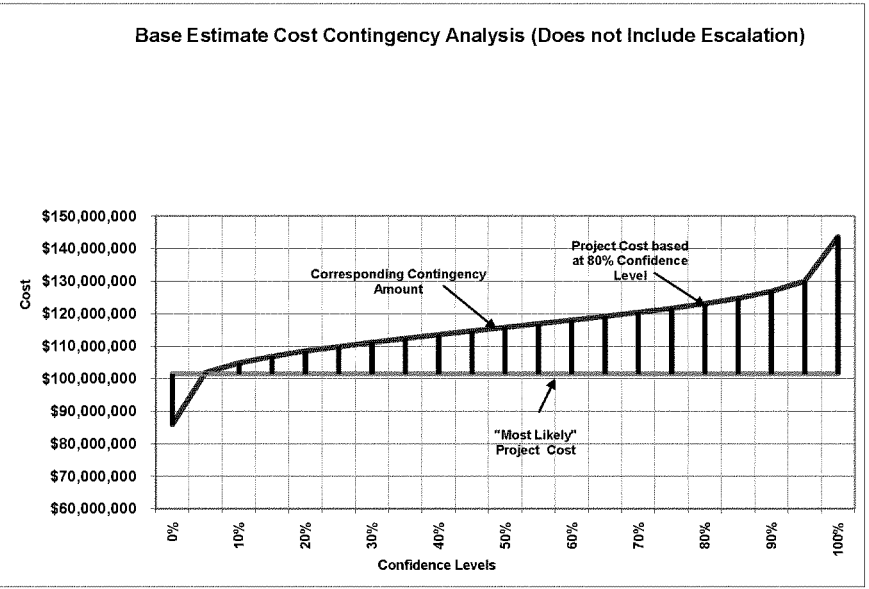
^ Schedule impacts are captured within the Cost Risk Analysis (Risk EXT 5), as this project is not otherwise susceptible to uncaptured escalation or notable "Hotel" costs.

Contingency on Base Estimate	80% Confidence Project Cost
Total Construction Cost (Most Likely) ->	$101,494,800
Construction Cost Contingency Amount ->	$21,538,221
Total Construction Cost (80% Confidence) ->	$123,033,021

- CONSTRUCTION COST CONTINGENCY DEVELOPMENT -

Contingency Analysis

Most Likely Cost Estimate	$101,494,800	
Confidence Level	Value	Contingency
0%	$85,925,481	-15.34%
5%	$101,911,908	0.41%
10%	$104,795,243	3.25%
15%	$106,814,070	5.24%
20%	$108,499,275	6.90%
25%	$109,841,194	8.22%
30%	$111,138,419	9.50%
35%	$112,343,382	10.69%
40%	$113,477,724	11.81%
45%	$114,679,638	12.99%
50%	$115,734,303	14.03%
55%	$116,877,628	15.16%
60%	$117,966,618	16.23%
65%	$119,114,634	17.36%
70%	$120,364,594	18.59%
75%	$121,596,135	19.81%
80%	$123,033,021	21.22%
85%	$124,677,058	22.84%
90%	$126,882,131	25.01%
95%	$129,928,279	28.01%
100%	$143,584,335	41.47%



SURF CITY AND NORTH TOPSAIL BEACH, NC - Cost Risk Analysis Model

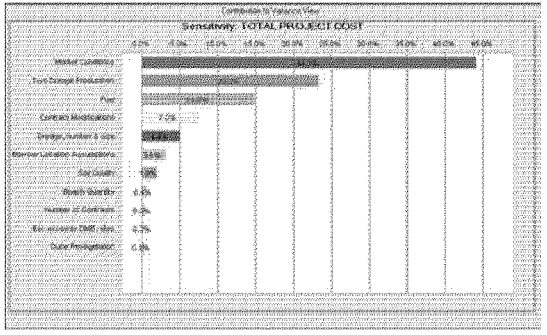
Risk No.	Risk/Opportunity Event	Concerns	Discussion	Project Cost: Likelihood*	Project Cost: Impact*	Project Cost: Risk Level*	Variance Distribution	Correlation to Other(s)	Crystal Ball Simulation: Expected Values ($$$): Low	Most Likely	High	Crystal Ball Simulation: Expected Values (%): Low	Most Likely	High
Contract Risks (Items of risk, future and those that are generated, created, or controlled within the PSC's sphere of influence.)														
PROJECT & PROGRAM MGMT														
OPPORTUNITIES														
PPM-9	Construction Schedule- 4 years	Construction duration expectations is 4 seasons (1 Dec - 31 Mar) due to Environmental Window for hopper dredge. The estimate choice for assumed equipment establishes the duration. Opportunities may exist within the contract solicitation package or further estimate study to decrease the schedule and resulting costs.	Historically, 2 dredges have occurred based on market availability as well quantities. The construction estimate assumes 2 medium-sized dredges. Hopper dredge size and number of dredges is commonly established by quantity within the contract. Market study and contract development could result in opportunity.	Likely	Marginal	Moderate	Uniform	EST-1	($1,578,000)	$0	$0	7.3%	0.0%	0.0%
CONTRACT ACQUISITION RISKS														
CA-2	Number of Contracts	Possibility of single or multiple contracts	Multiple contracts are likely, which would reduce risks related to bid competition and funding availability. However, multiple contracts will result in more PED and Contracting efforts.	Likely	Marginal	Moderate	Uniform	PPM-6	$0	$0	$1,200,000	0.0%	0.0%	1.2%
TECHNICAL RISKS														
T-1	Soil Quality	Concern that fine quality soil may be insufficient in quantity to construct project because soil characterization is not complete. Shale has new, more stringent, criteria related to material quality.	This potential problem is more likely to occur in the long term, unlikely in the short term but dependent upon further study. 35% soil characterization is complete. Further study is significant, but scheduled for PED phase and the initial contracts have adequate borrow sources available. Greater risk is in the out years because the current activities would simply result in a local remote to another borrow source.	Unlikely	Marginal	High	Triangular	T-2	$93,332,000	$93,332,000	$98,465,200	0.0%	0.0%	5.5%
T-2	Beach Quantity	Scope definition is excellent, but quantities can change over time due to beach erosion during the PED phase and geotechnical overfill ratios- additional funding dollars may increase quantities.	Contract quantities are currently established by dredged borrow assumptions related to quantity and overfill ratios for payment, based on borrow surveys underwater. Storms can change profile bottom, but PDT feels the borrow sources are outside the storm.	Likely	Significant	High	Triangular	T-1	$93,332,000	$93,332,000	$95,665,300	0.0%	0.0%	2.5%
ENVIRONMENTAL RISKS														
ENV-7	Dune Revegetation	Dune revegetation may be required.	Estimate includes first vegetation. Dune revegetation requirement is likely and may not be adequately covered within the estimate.	Likely	Marginal	Moderate	Uniform		$0	$0	$838,699	0.0%	0.0%	0.9%
ESTIMATE RISKS														
EST-1	Dredge, number & size	Estimate choice can effect efficiency and productivity, causing a change to the estimate.	Estimate assumed two medium-sized hopper dredges but equipment is not restrictive with contract. The chosen estimate hopper size and number can affect the cost and productivity. Hopper dredges accommodate poor weather better than pipeline dredges. A large hopper results in greater efficiency as compared to two smaller hoppers, but less available and may be impacted by speed restrictions. Estimate hopper dredge choice is more common at 77% efficiency and based on historical occurrence. Further study is still necessary.	Likely	Marginal	Moderate	Uniform	EST-4, PPM-8	($6,331,240)	$0	$0	6.7%	0.0%	0.0%
EST-3	Fuel	Fuel fluctuations can impact dredging costs.	equipment. Fuel has fluctuated drastically in the past 18 months. It is now back on the upswing. Study should be for time of funding date estimate.	Likely	Significant	High	Triangular	EST-5	$95,086,047	$93,332,000	$104,988,500	-3.5%	0.0%	12.5%
EST-4	Two Dredge Productivity	The estimate assumes a certain productivity based on two medium sized dredge. Productivity may vary.	The current estimate makes assumptions in the size and productivity for two medium sized hopper dredges with a 3.2 mile haul. Those estimate assumptions establish the schedule. Productivity of two hopper dredges can vary due to various productivities.	Likely	Significant	High	Triangular	EST-1, PPM-8	$83,632,140	$93,332,000	$104,531,840	-10.5%	0.0%	12.0%
EST-5	Borrow Location Assumptions	as to which borrow areas will be used to support the beach for efforts.	the ones approved for each contract. The estimate assumed the best case of closer locations, but there is a possibility that borrow sources further from the beach will be	Likely	Marginal	Moderate	Triangular	CON-1	$83,332,000	$93,332,000	$99,399,500	0.0%	0.0%	6.5%
CONSTRUCTION RISKS														
CON-1	Contract Modifications	There may be modification issues that have not been captured in current risks.	The normal modifications for dredging is quantities. This is considered elsewhere. Each contract will likely carry the intended quantities per contract, but is restricted by the work window. Compelling work, loss of dredger, quantity assumption can cause modifications such as remobilizations and delays. Other modification potentials could include borrow source remobilization resulting from environmental impacts.	Likely	Marginal	Moderate	Uniform	T-1, EST-5	$0	$0	$7,612,110	0.0%	0.0%	7.0%

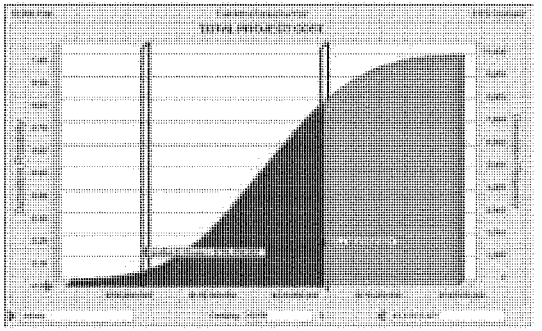
Assumed maximum market capacity by Risk EST-1

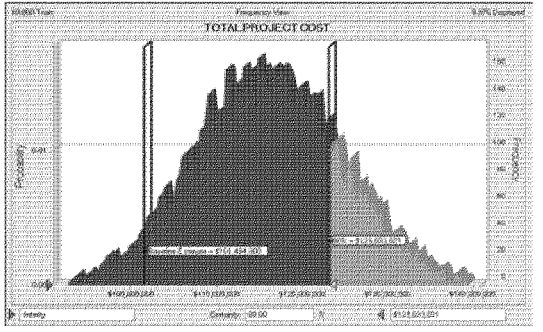
Percentages are calculated as the variance from the assumption value to facilitate iteration of the model should the cost values change throughout the project phases. Uniform distribution percentages reflect variation from the total project cost.

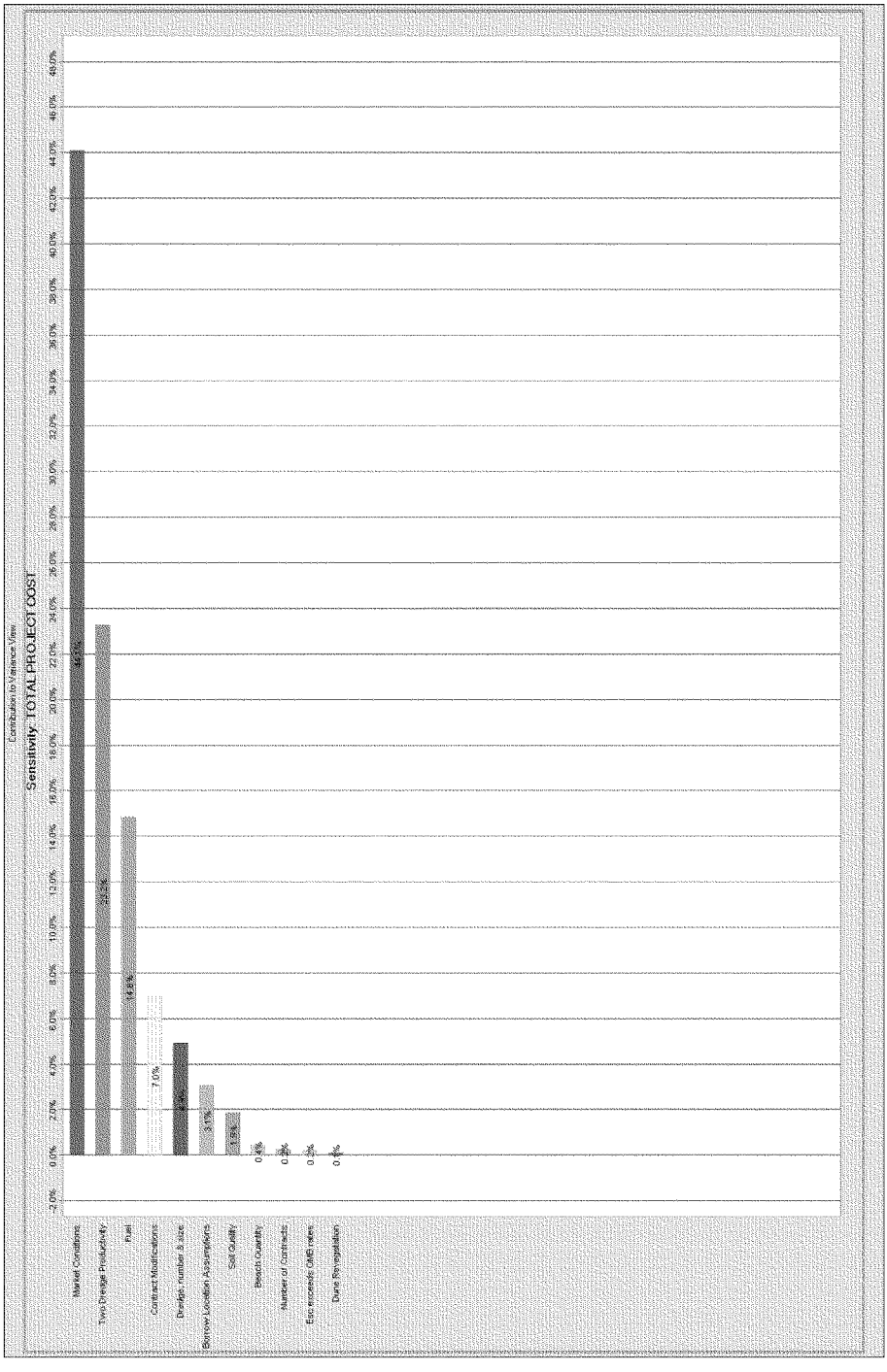
Programmatic Risks (E.g. minor work items and those that are considered unique or individual enough to justify the PDT's options of inclusion.)															
EXT-1	Market Conditions	Market conditions and competing projects may impact bid competition.	Currently, there are a lot of projects planned when considering the number of dredges available. There are more hopper dredges than pipeline dredges. It is a tough bidding climate based on environmental time-line restrictions. Construction start is scheduled for 2014.	Likely	Significant	High	Triangular		($5,979,476)	$0	$13,701,798		5.5%	0.0%	14.0%
EXT-5	Esc exceeds OMB rates	Over longer periods of time, the actual market may be greater than the OMB rates, impacting contract costs.	Volatile fuel, being a larger risk on dredging projects, may not correlate with the OMB rates and may be higher as time goes into the 4th contract year.	Likely	Marginal	Moderate	Uniform	EST-3	$9	$0	$1,420,927		0.6%	0.0%	1.4%
	All Other Project Costs		Placeholder for costs not captured in summation of risks being studied.							$101,494,800		Not Part of Study - Placeholder for Project Summation Purposes Only			

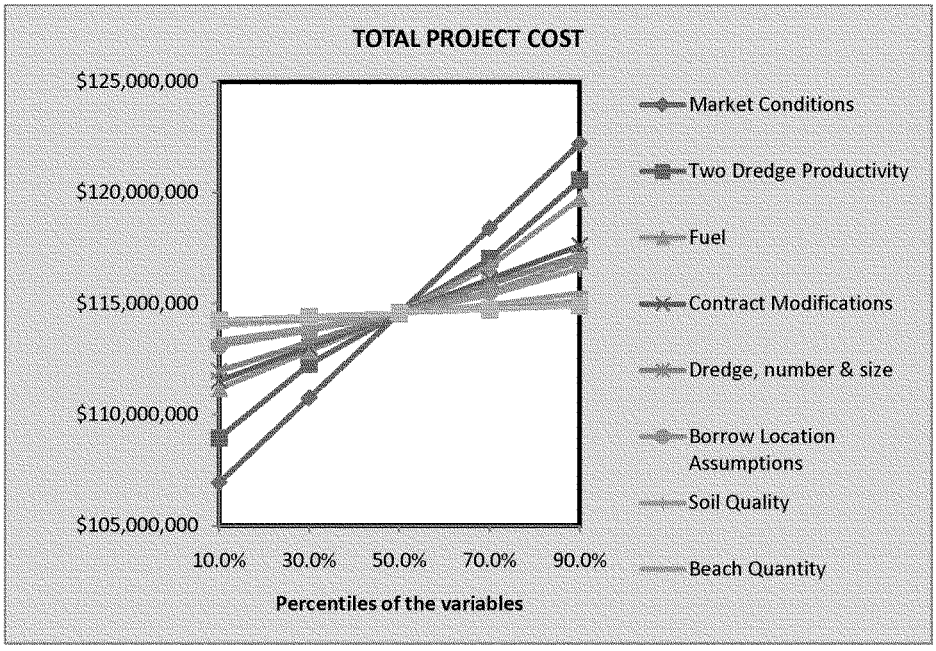
TOTAL PROJECT COST	Percentile	Forecast values	Contingency Amount	Contingency %
	0%	$85,925,491	($15,569,319)	-15.34%
	5%	$101,911,908	$417,108	0.41%
	10%	$104,795,243	$3,300,443	3.26%
	15%	$106,814,070	$5,319,270	5.24%
	20%	$108,499,275	$7,004,475	6.90%
	25%	$109,841,194	$8,346,394	8.22%
	30%	$111,138,419	$9,643,619	9.50%
	35%	$112,343,382	$10,848,582	10.69%
	40%	$113,477,724	$11,982,924	11.81%
	45%	$114,675,638	$13,184,838	12.99%
	50%	$115,734,203	$14,239,603	14.03%
	55%	$116,877,828	$15,382,828	15.16%
	60%	$117,966,818	$16,471,818	16.23%
	65%	$119,114,834	$17,619,834	17.36%
	70%	$120,364,594	$18,869,794	18.59%
	75%	$121,586,135	$20,101,335	19.81%
	80%	$123,033,021	$21,538,221	21.22%
	85%	$124,677,058	$23,182,258	22.84%
	90%	$126,862,131	$25,367,331	25.01%
	95%	$129,928,279	$28,433,479	28.01%
	100%	$143,584,935	$42,089,535	41.47%



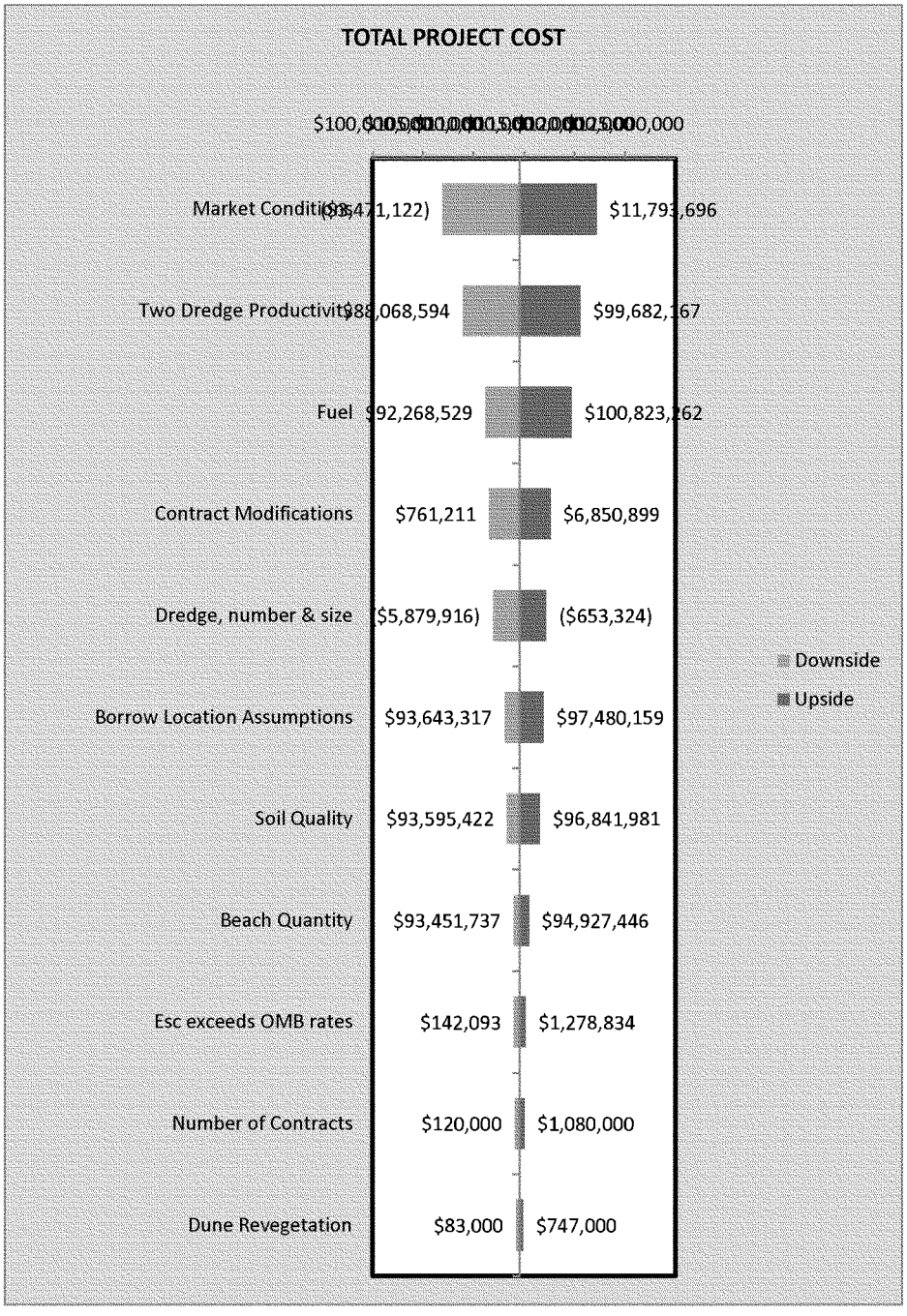





Contribution to Variance View
Sensitivity: TOTAL PROJECT COST
-2.0%
0.0%
2.0%
4.0%
6.0%
8.0%
10.0%
12.0%
14.0%
16.0%
18.0%
20.0%
22.0%
24.0%
26.0%
28.0%
30.0%
32.0%
34.0%
36.0%
38.0%
40.0%
42.0%
44.0%
46.0%
48.0%
Market Conditions
Two Dredge Productivity
Fuel
Contract Modifications
Dredge Number & Size
Borrow Location Assumptions
Soil Quality
Beach Quality
Number of Contracts
Esc exceeds OMB rates
Dune Reinstatement
7.0%
3.1%
1.5%
0.4%
0.2%
0.2%
0.1%


TOTAL PROJECT COST
$125,000,000
$120,000,000
$115,000,000
$110,000,000
$105,000,000
10.0%
30.0%
50.0%
70.0%
90.0%
Percentiles of the variables
Market Conditions
Two Dredge Productivity
Fuel
Contract Modifications
Dredge, number & size
Borrow Location Assumptions
Soil Quality
Beach Quantity

	TOTAL PROJECT COST				
Variable	*10.0%*	*30.0%*	*50.0%*	*70.0%*	*90.0%*
Market Conditions	$106,938,367	$110,754,571	$114,570,776	$118,386,980	$122,203,185
Two Dredge Productivity	$108,951,728	$112,272,642	$114,570,776	$117,015,094	$120,565,301
Fuel	$111,176,921	$112,860,250	$114,570,776	$116,675,167	$119,731,654
Contract Modifications	$111,525,932	$113,048,354	$114,570,776	$116,093,198	$117,615,620
Dredge, number & size	$111,957,480	$113,264,128	$114,570,776	$115,877,424	$117,184,072
Borrow Location Assumptions	$113,105,232	$113,784,831	$114,570,776	$115,537,693	$116,942,075
Soil Quality	$113,330,701	$113,905,745	$114,570,776	$115,388,936	$116,577,259
Beach Quantity	$114,007,105	$114,268,489	$114,570,776	$114,942,667	$115,482,814
Esc exceeds OMB rates	$114,002,405	$114,286,590	$114,570,776	$114,854,961	$115,139,147
Number of Contracts	$114,090,776	$114,330,776	$114,570,776	$114,810,776	$115,050,776
Dune Revegetation	$114,238,776	$114,404,776	$114,570,776	$114,736,776	$114,902,776


TOTAL PROJECT COST
Market Conditions
($5,471,122)
$11,793,696
Two Dredge Productivit
$88,068,594
$99,682,167
Fuel
$92,268,529
$100,823,262
Contract Modifications
$761,211
$6,850,899
Dredge, number & size
($5,879,916)
($653,324)
Borrow Location Assumptions
$93,643,317
$97,480,159
Soil Quality
$93,595,422
$96,841,981
Beach Quantity
$93,451,737
$94,927,446
Esc exceeds OMB rates
$142,093
$1,278,834
Number of Contracts
$120,000
$1,080,000
Dune Revegetation
$83,000
$747,000
Downside
Upside

	TOTAL PROJECT COST			Input	
Variable	*Downside*	*Upside*	*Range*	*Downside*	*Upside*
Market Conditions	$106,938,367	$122,203,185	$15,264,818	($3,471,122)	$11,793,696
Two Dredge Productivity	$108,951,728	$120,565,301	$11,613,573	$88,068,594	$99,682,167
Fuel	$111,176,921	$119,731,654	$8,554,733	$92,268,529	$100,823,262
Contract Modifications	$111,525,932	$117,615,620	$6,089,688	$761,211	$6,850,899
Dredge, number & size	$111,957,480	$117,184,072	$5,226,592	($5,879,916)	($653,324)
Borrow Location Assumptions	$113,105,232	$116,942,075	$3,836,842	$93,643,317	$97,480,159
Soil Quality	$113,330,701	$116,577,259	$3,246,559	$93,595,422	$96,841,981
Beach Quantity	$114,007,105	$115,482,814	$1,475,708	$93,451,737	$94,927,446
Esc exceeds OMB rates	$114,002,405	$115,139,147	$1,136,742	$142,093	$1,278,834
Number of Contracts	$114,090,776	$115,050,776	$960,000	$120,000	$1,080,000
Dune Revegetation	$114,238,776	$114,902,776	$664,000	$83,000	$747,000

Base Case
$4,161,287
$93,687,642
$95,662,384
$3,806,055
($3,266,620)
$95,108,860
$94,835,497
$94,015,408
$710,464
$600,000
$415,000

Risk Refer No.	Risk Event	Low	Most Likely	High	
PPM-8	Construction Schedule - 4 years	($7,178,000)	$0	$0	*Removed from risk model - captured by Risk EST-1*

Notes: This item captures the opportunity that using larger dredges may result in substantial savings due to dredging over fewer seasons (2 instead of 4).

Likely This risk item follows a uniform distribution behavior -- no change to most likely cost. Base estimate assumes 2 medium sized hopper dredges at a productivity rate of 77% = 2.9 Million CY/season (4 mo) based on average historical data.

Low Low assumes 4.3 million CY/season assuming 3 various-sized hopper dredges, creating efficiencies and requiring fewer seasonal mobilizations.

High High assumes that no opportunity is realized, yielding no savings.

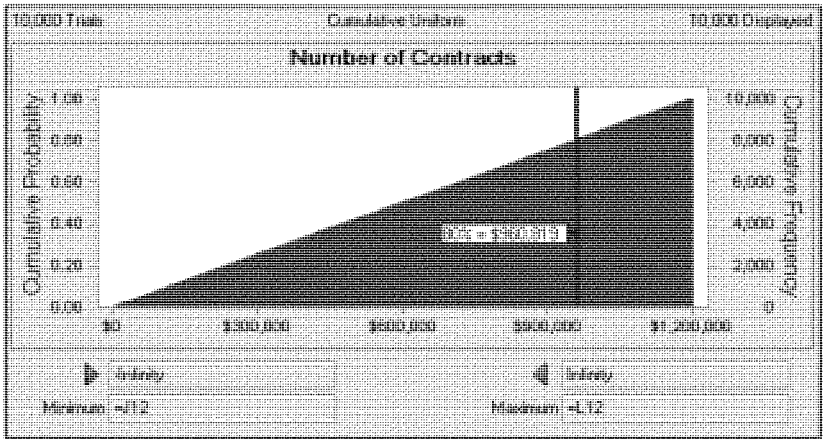
Risk Refer No.	Risk Event	Low	Most Likely	High
CA-2	Number of Contracts	$0	$0	$1,200,000

Notes: Multiple contracts are likely, which would reduce risks related to bid competition and funding availability. However, multiple contracts will result in more PED and Contracting efforts. This item captures the risk that multiple contracts increases total project cost.

Likely This risk item follows a uniform distribution behavior -- no change to most likely cost.

Low Low assumes no adverse effects from utilizing multiple contracts.

High High assumes up to an additional $1.2 M due to utilizing multiple contracts. PED costs are ~ $2.4M. Approx $800K of the $2.4M is for subsurface investigations. There is an additional $200K for final plans and specs prep. Assuming $150K for P&S and $150K for subsurface investigations per contract.



Assumption: Number of Contracts		Resulting Item
Percentile	**Assumption values**	**Contingency**
0%	$85	$85
10%	$119,567	$119,567
20%	$236,080	$236,080
30%	$355,774	$355,774
40%	$476,420	$476,420
50%	$598,628	$598,628
60%	$723,087	$723,087
70%	$839,531	$839,531
80%	$960,819	$960,819
90%	$1,073,717	$1,073,717
100%	$1,199,752	$1,199,752

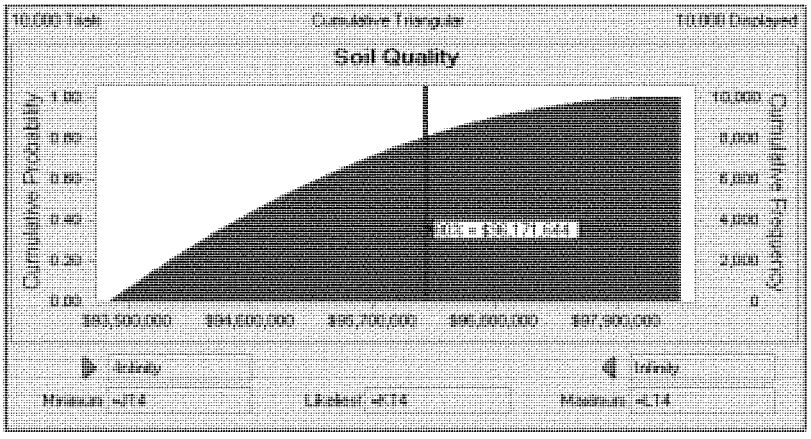
Risk Refer No.	Risk Event	Low	Most Likely	High
T-1	Soil Quality	$93,332,000	$93,332,000	$98,465,260

Notes: This item captures the risk of cost growth due to soil characterization contributing to greater losses than anticipated in the base estimate.

Likely Most likely estimate assumes 18% losses from borrow area to the beach fill based on geotech studies.

Low Low assumes no change from Most Likely.

High High assumes that there are up to 25% losses total OR 7% INCREASE IN QUANTITY.



Assumption: Soil Quality

Percentile	Assumption values	Resulting Item Contingency
0%	$93,332,354	$354
10%	$93,610,179	$278,179
20%	$93,883,300	$551,300
30%	$94,181,871	$849,871
40%	$94,509,621	$1,177,621
50%	$94,855,579	$1,523,579
60%	$95,250,174	$1,918,174
70%	$95,664,835	$2,332,835
80%	$96,171,644	$2,839,644
90%	$96,821,387	$3,489,387
100%	$98,446,161	$5,114,161

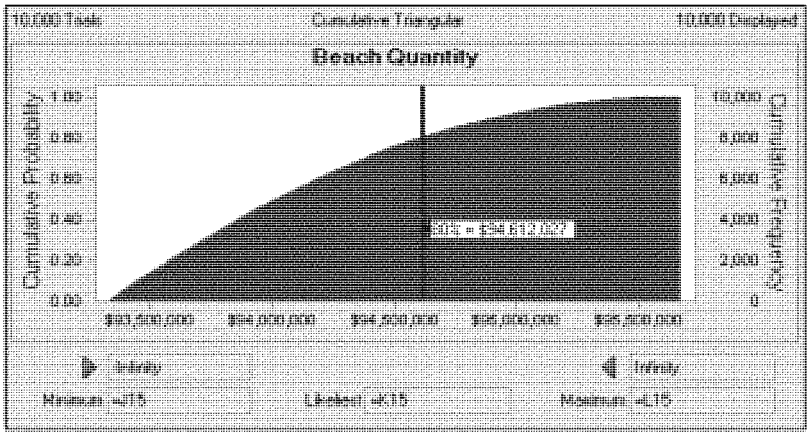
Risk Refer No.	Risk Event	Low	Most Likely	High
T-2	Beach Quantity	$93,332,000	$93,332,000	$95,665,300

Notes: This item captures the risk that quantities will significantly differ from those in the current baseline estimate.

Likely The most likely estimate assumes funding for FY 13 and subsequent erosion until that FY 13.

Low Low assumes no change from Most Likely.

High High assumes that there is 91,500 cy erosion each year beyond scheduled year FY 13. Assume 4 years delay or about 400,000 cy.



Assumption: Beach Quantity

Percentile	Assumption values	Resulting Item Contingency
0%	$93,332,149	$149
10%	$93,448,663	$116,663
20%	$93,581,072	$249,072
30%	$93,717,369	$385,369
40%	$93,860,127	$528,127
50%	$94,019,015	$687,015
60%	$94,188,354	$856,354
70%	$94,382,589	$1,050,589
80%	$94,612,027	$1,280,027
90%	$94,927,387	$1,595,387
100%	$95,638,677	$2,306,677

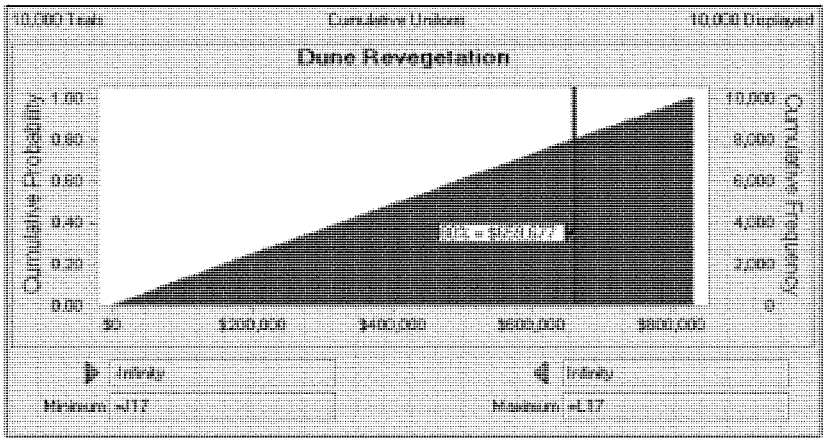
Risk Refer No.	Risk Event	Low	Most Likely	High
ENV-7	Dune Revegetation	$0	$0	$830,000

Notes: Estimate includes first vegetation. This item captures the risk that dune revegitation requirement is likely and may not be adequately covered within the estimate.

Likely The estimate currently includes initial planting, no revegetation if first planting fails.

Low Low assumes no replanting.

High High assumes replanting 60% of initial.



Assumption: Dune Revegitation		Resulting Item Contingency
Percentile	Assumption values	
0%	$47	$47
10%	$79,934	$79,934
20%	$161,964	$161,964
30%	$246,165	$246,165
40%	$329,147	$329,147
50%	$413,633	$413,633
60%	$494,615	$494,615
70%	$578,574	$578,574
80%	$659,677	$659,677
90%	$746,922	$746,922
100%	$829,970	$829,970

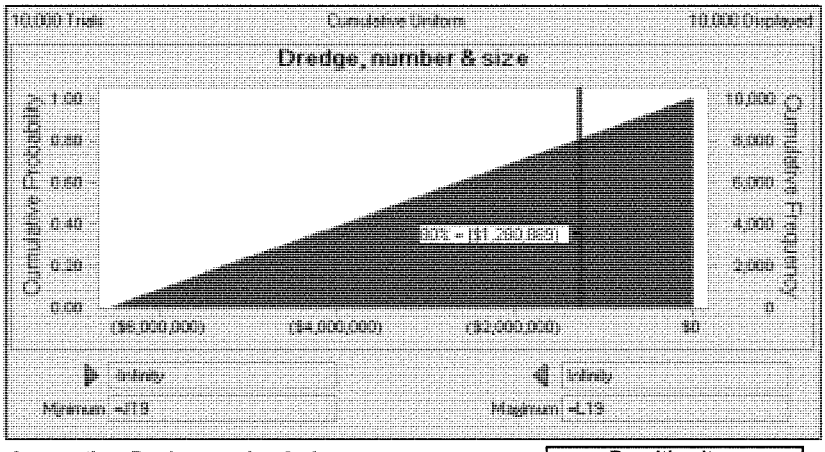
Risk Refer No.	Risk Event	Low	Most Likely	High
EST-1	Dredge, number & size	($6,533,240)	$0	$0

Notes: This item captures the opportunity that using larger dredges may result in substantial savings due to dredging over fewer seasons (2 instead of 4).

Likely This risk item follows a uniform distribution behavior -- no change to most likely cost. Base estimate assumes 2 medium sized hopper dredges at a productivity rate of 77% = 2.9 Million CY/season (4 mo) based on average historical data.

Low Low assumes 4.3 million CY/season assuming 3 various-sized hopper dredges, creating efficiencies and requiring fewer seasonal mobilizations.

High High assumes that no opportunity is realized, yielding no savings.



Assumption: Dredge, number & size		Resulting Item Contingency
Percentile	Assumption values	
0%	($6,533,066)	($6,533,066)
10%	($5,896,579)	($5,896,579)
20%	($5,263,201)	($5,263,201)
30%	($4,567,773)	($4,567,773)
40%	($3,903,151)	($3,903,151)
50%	($3,275,336)	($3,275,336)
60%	($2,626,523)	($2,626,523)
70%	($1,967,556)	($1,967,556)
80%	($1,280,889)	($1,280,889)
90%	($641,121)	($641,121)
100%	($1,953)	($1,953)

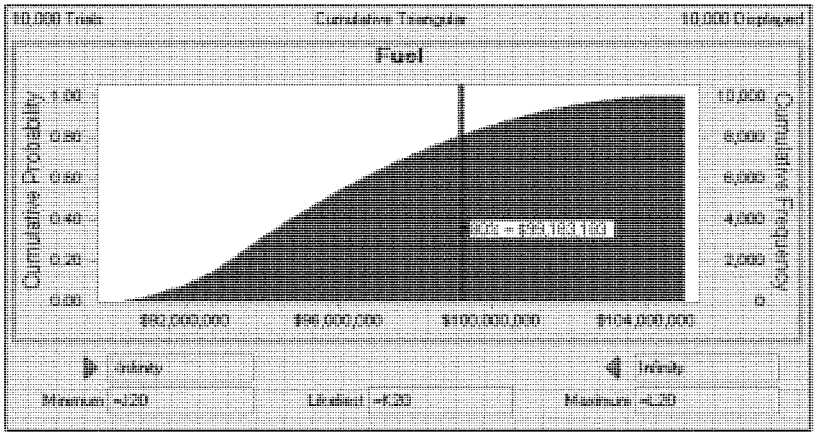
Risk Refer No	Risk Event	Low	Most Likely	High
EST-3	Fuel	$90,056,047	$93,332,000	$104,998,500

Notes: This item captures the risk that fuel prices will significantly fluctuate either higher or lower, contributing to increased or decreased dredging cost.

Likely The most likely baseline estimate assumes $2.80/gal based on historical data and projection studies that eliminate anomallies.

Low Low assumes that fuel prices could be as low as $1.50/gal (Feb 23 2009).

High High assumes that fuel prices could be as high as $6.00/gal based on studied projection to 2010 feasibility authorization. $4.50/gal experienced in 2008.

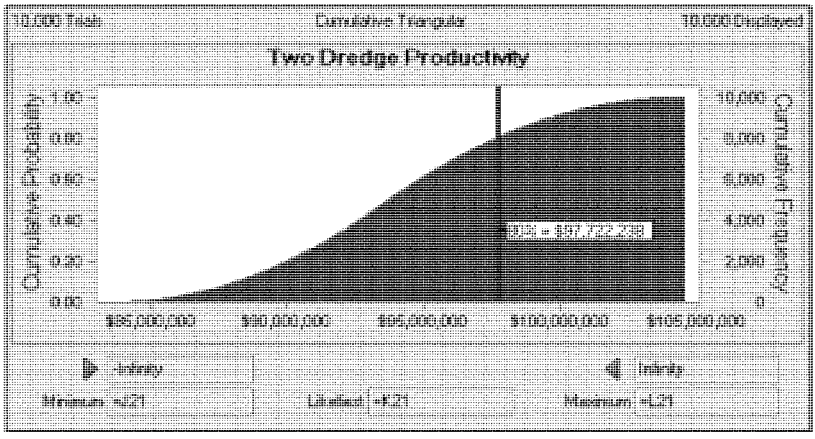


Assumption: Fuel

Percentile	Assumption values	Resulting Item Contingency
0%	$90,114,194	($3,217,806)
10%	$92,293,751	($1,038,249)
20%	$93,213,973	($118,027)
30%	$93,968,640	$636,640
40%	$94,800,497	$1,468,497
50%	$95,698,478	$2,366,478
60%	$96,692,820	$3,360,820
70%	$97,882,182	$4,550,182
80%	$99,183,183	$5,851,183
90%	$100,933,557	$7,601,557
100%	$104,890,295	$11,558,295

Risk Refer No.	Risk Event	Low	Most Likely	High
EST-4	Two Dredge Productivity	$83,532,140	$93,332,000	$104,531,840

Notes: This item captures the risk that the cost may significantly increase or decrease based on the effective work time of the assumed dredging system.
Likely The most likely baseline estimate assumes 2 medium sized hopper dredges at a
Low Low assumed 2 medium hopper dredges at a productivity rate 88% EWT.
High High assumed 2 medium sized hopper dredges at a 60% EWT.



Assumption: Two Dredge Productivity		
Percentile	**Assumption values**	**Resulting Item Contingency**
0%	$83,683,870	($9,648,130)
10%	$88,220,185	($5,111,815)
20%	$90,025,502	($3,306,498)
30%	$91,466,759	($1,865,241)
40%	$92,693,409	($638,591)
50%	$93,717,470	$385,470
60%	$94,910,261	$1,578,261
70%	$96,138,059	$2,806,059
80%	$97,722,238	$4,390,238
90%	$99,689,817	$6,357,817
100%	$104,413,830	$11,081,830

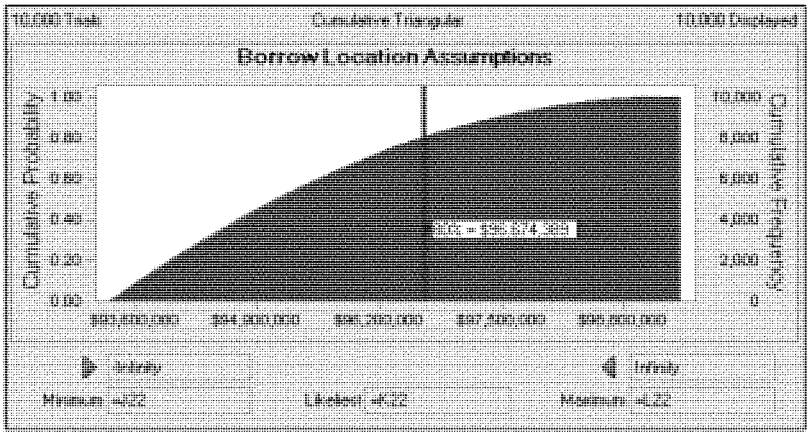
Risk Refer No.	Risk Event	Low	Most Likely	High
EST-5	Borrow Location Assumptions	$93,332,000	$93,332,000	$99,398,580

Notes: This item captures the risk that the dredging and haul costs could increase if the borrow locations are further away than assumed in the current baseline estimate.

Likely The most likely baseline estimate assumes the closest borrows to the closest pumpout

Low Low assumes that closer borrow locations are not available, and hence no savings based on favorable conditions.

High High assumed that the average haul distance of 5 miles based on using Borrow Areas "L" and "J" as initial construction.



Assumption: Borrow Location Assumptions		
Percentile	**Assumption values**	**Resulting Item Contingency**
0%	$93,332,170	$170
10%	$93,663,035	$331,035
20%	$94,007,639	$675,639
30%	$94,365,139	$1,033,139
40%	$94,757,349	$1,425,349
50%	$95,162,030	$1,830,030
60%	$95,595,223	$2,263,223
70%	$96,081,964	$2,749,964
80%	$96,674,389	$3,342,389
90%	$97,503,736	$4,171,736
100%	$99,337,115	$6,005,115

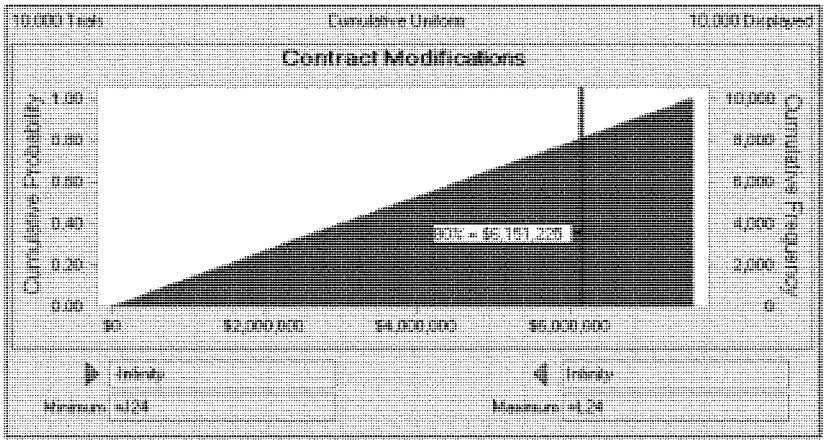
Risk Refer No.	Risk Event	Low	Most Likely	High
CON-1	Contract Modifications	$0	$0	$7,612,110

Notes: This item captures the risk that contract modifications will require additional mobilizations and a 7% increase in quantity.

Likely This risk item follows a uniform distribution behavior -- no change to most likely cost.

Low Low assumes that there are no modifications, and hence, no impact to cost.

High High assumes that an additional mobilization is required, plus a 7% increase in the quantity to be dredged.



Assumption: Two Dredge Productivity		Resulting Item
Percentile	Assumption values	Contingency
0%	$833	$833
10%	$735,228	$735,228
20%	$1,519,396	$1,519,396
30%	$2,255,865	$2,255,865
40%	$3,012,223	$3,012,223
50%	$3,799,454	$3,799,454
60%	$4,556,553	$4,556,553
70%	$5,330,454	$5,330,454
80%	$6,151,225	$6,151,225
90%	$6,863,962	$6,863,962
100%	$7,611,320	$7,611,320

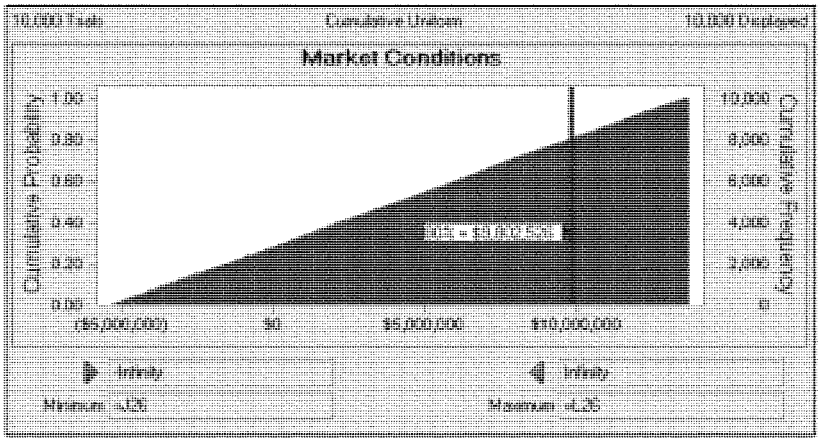
Risk Refer No.	Risk Event	Low	Most Likely	High
EXT-1	Market Conditions	($5,379,224)	$0	$13,701,798

Notes: Currently, there are a lot of projects planned when considering the number of dredges available. There are more hopper dredges than pipeline dredges. It is a tough bidding climate based on environmental time-line restrictions. Construction start is scheduled for 2014. This item captures the risk that there will be significant fluctuations in prices due to market conditions.

Likely Most likely is the total project cost in the baseline estimate.

Low Low assumes that the project could be up to 5% below the most likely based on GAO audit.

High High assumes that the project could be up to 15% above most likely estimate (25% w/o profit) due to lack of dredging companies and dredges for competing projects because of the work window restrictions.



Assumption: Market Conditions		Resulting Item
Percentile	Assumption values	Contingency
0%	($5,378,966)	($5,378,966)
10%	($3,488,380)	($3,488,380)
20%	($1,528,574)	($1,528,574)
30%	$381,014	$381,014
40%	$2,178,275	$2,178,275
50%	$4,145,267	$4,145,267
60%	$6,029,642	$6,029,642
70%	$7,825,916	$7,825,916
80%	$9,802,526	$9,802,526
90%	$11,670,214	$11,670,214
100%	$13,696,819	$13,696,819

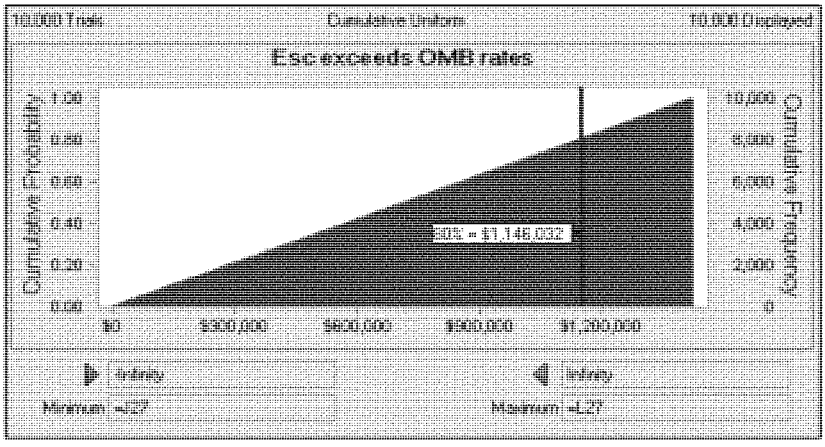
Risk Refer No.	Risk Event	Low	Most Likely	High
EXT-5	Esc exceeds OMB rates	$0	$0	$1,420,927

Notes: Fuel is the greatest cost driver that may cause annual costs to go beyond the OMB rates. The study will focus on fuel projections converted to excavation unit prices as the measurement made against the OMB rates. This item captures the risk that there will be significant cost increase due to inflation above OMB rates.

Likely This risk item follows a uniform distribution behavior -- no change to most likely cost.

Low Low assume no increase or decrease from the base estimate based on inflation.

High High assumes up to an overall $1,051,725 increase based on a fuel rate of $6.00/gallon for marine diesel. This was calculated as the difference betweent he baseline estimate using 2.1% OMB escalation rates vs. the estimate using $6.00/gallon.



Assumption: Esc exceeds OMB rates		Resulting Item
Percentile	**Assumption values**	**Contingency**
0%	$219	$219
10%	$139,869	$139,869
20%	$282,891	$282,891
30%	$430,263	$430,263
40%	$576,785	$576,785
50%	$721,585	$721,585
60%	$864,503	$864,503
70%	$1,004,855	$1,004,855
80%	$1,146,032	$1,146,032
90%	$1,282,695	$1,282,695
100%	$1,420,847	$1,420,847

Final Report Cost-Risk Analysis - Surf City.xlsx

Crystal Ball Report - Full
Simulation started on 11/23/2010 at 3:11 PM
Simulation stopped on 11/23/2010 at 3:12 PM

Run preferences:	
Number of trials run	10,000
Monte Carlo	
Seed	999
Precision control on	
Confidence level	95.00%
Run statistics:	
Total running time (sec)	12.54
Trials/second (average)	797
Random numbers per sec	8,772
Crystal Ball data:	
Assumptions	11
Correlations	0
Correlated groups	0
Decision variables	0
Forecasts	1

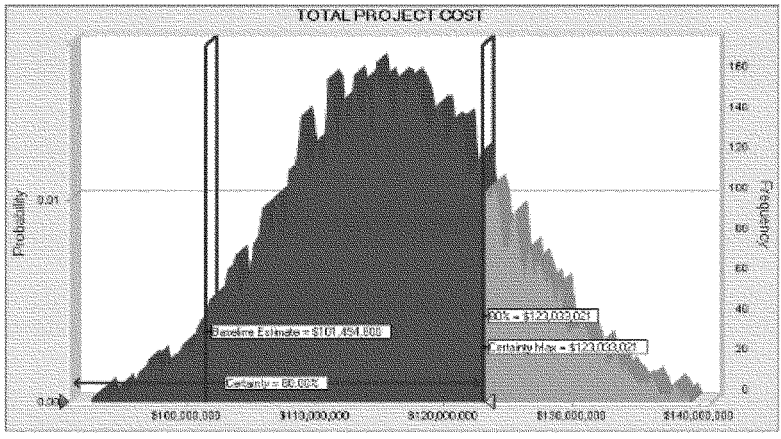
Final Report Cost-Risk Analysis - Surf City.xlsx

Forecasts

Worksheet: [Final Report Cost-Risk Analysis - Surf City.xlsx]Cost Risk Model

Forecast: TOTAL PROJECT COST **Cell: K29**

Summary:
Certainty level is 80.00%
Certainty range is from -Infinity to $123,033,021
Entire range is from $85,925,481 to $143,584,335
Base case is $101,494,800
After 10,000 trials, the std. error of the mean is $84,715



Forecast: TOTAL PROJECT COST (cont'd) **Cell: K29**

Statistics:	Forecast values
Trials	10,000
Base Case	$101,494,800
Mean	$115,794,232
Median	$115,734,772
Mode	---
Standard Deviation	$8,471,509
Variance	$71,766,457,130,160
Skewness	0.0466
Kurtosis	2.74
Coeff. of Variability	0.0732
Minimum	$85,925,481
Maximum	$143,584,335
Range Width	$57,658,854
Mean Std. Error	$84,715

Percentiles:	Forecast values
0%	$85,925,481
10%	$104,795,243
20%	$108,499,275
30%	$111,138,419
40%	$113,477,724
50%	$115,734,303
60%	$117,966,618
70%	$120,364,594
80%	$123,033,021
90%	$126,882,131
100%	$143,584,335

End of Forecasts

Final Report Cost-Risk Analysis - Surf City.xlsx

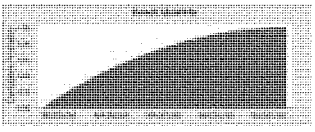
Assumptions

Worksheet: [Final Report Cost-Risk Analysis - Surf City.xlsx]Cost Risk Model

Assumption: Beach Quantity — **Cell: K15**

Triangular distribution with parameters:

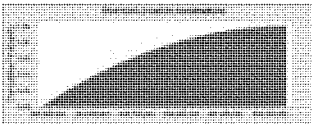
Minimum	$93,332,000	(=J15)
Likeliest	$93,332,000	(=K15)
Maximum	$95,665,300	(=L15)



Assumption: Borrow Location Assumptions — **Cell: K22**

Triangular distribution with parameters:

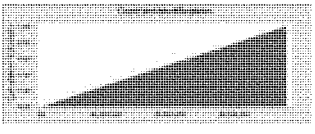
Minimum	$93,332,000	(=J22)
Likeliest	$93,332,000	(=K22)
Maximum	$99,398,580	(=L22)



Assumption: Contract Modifications — **Cell: K24**

Uniform distribution with parameters:

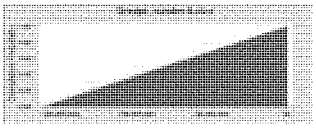
Minimum	$0	(=J24)
Maximum	$7,612,110	(=L24)



Assumption: Dredge, number & size **Cell: K19**

Uniform distribution with parameters:

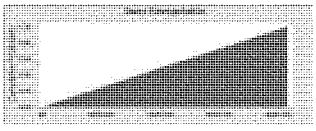
Minimum	($6,533,240)	(=J19)
Maximum	$0	(=L19)



Assumption: Dune Revegetation **Cell: K17**

Uniform distribution with parameters:

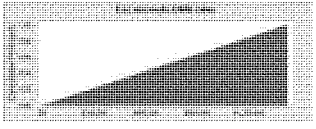
Minimum	$0	(=J17)
Maximum	$830,000	(=L17)



Assumption: Esc exceeds OMB rates **Cell: K27**

Uniform distribution with parameters:

Minimum	$0	(=J27)
Maximum	$1,420,927	(=L27)

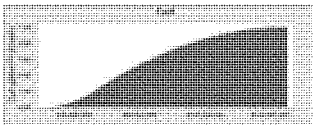


Assumption: Fuel **Cell: K20**

Triangular distribution with parameters:

Minimum	$90,056,047	(=J20)
Likeliest	$93,332,000	(=K20)
Maximum	$104,998,500	(=L20)

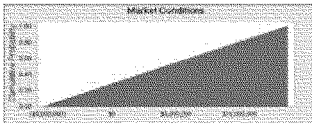
Assumption: Fuel (cont'd) **Cell: K20**



Assumption: Market Conditions **Cell: K26**

Uniform distribution with parameters:

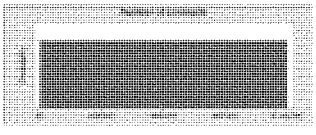
Minimum	($5,379,224)	(=J26)
Maximum	$13,701,798	(=L26)



Assumption: Number of Contracts **Cell: K12**

Uniform distribution with parameters:

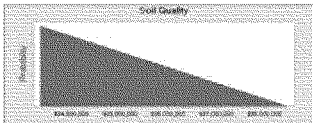
Minimum	$0	(=J12)
Maximum	$1,200,000	(=L12)



Assumption: Soil Quality **Cell: K14**

Triangular distribution with parameters:

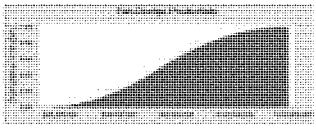
Minimum	$93,332,000	(=J14)
Likeliest	$93,332,000	(=K14)
Maximum	$98,465,260	(=L14)



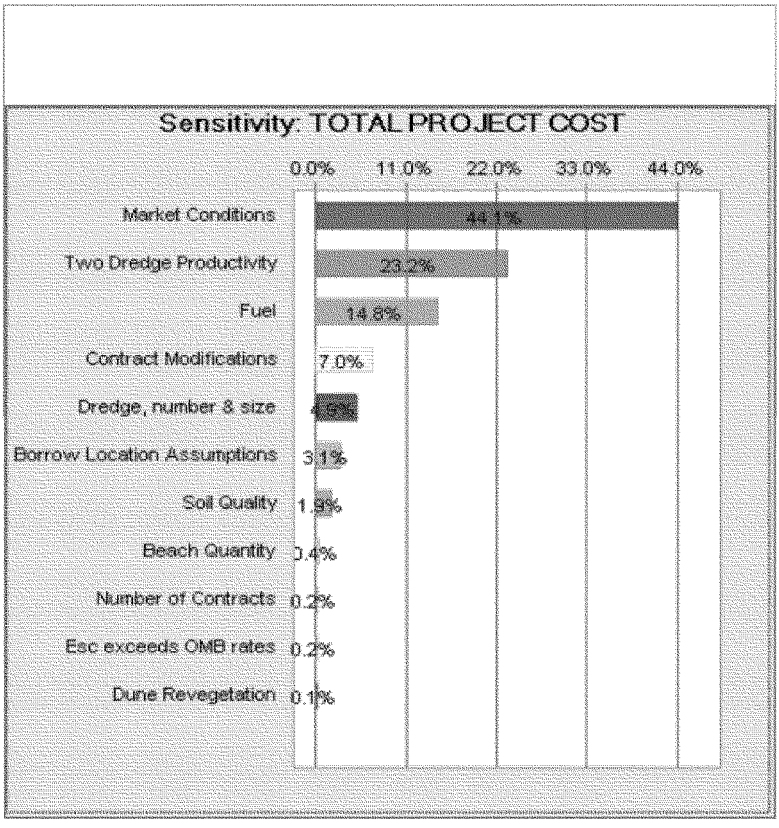
Assumption: Two Dredge Productivity **Cell: K21**

Triangular distribution with parameters:

Minimum	$83,532,140	(=J21)
Likeliest	$93,332,000	(=K21)
Maximum	$104,531,840	(=L21)



End of Assumptions



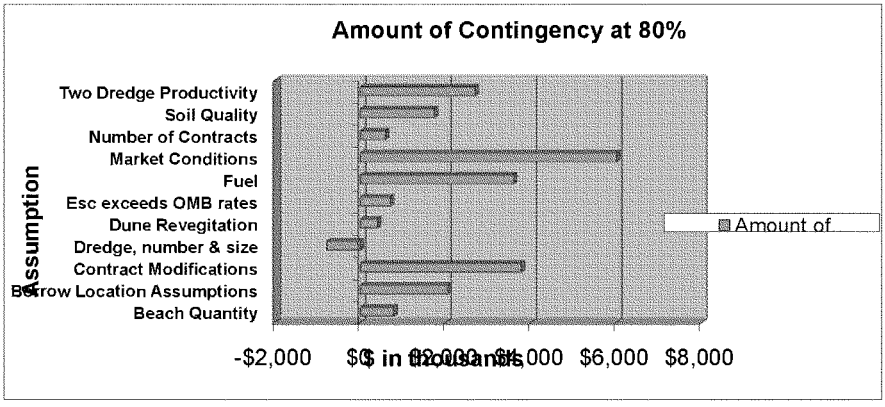
End of Sensitivity Charts

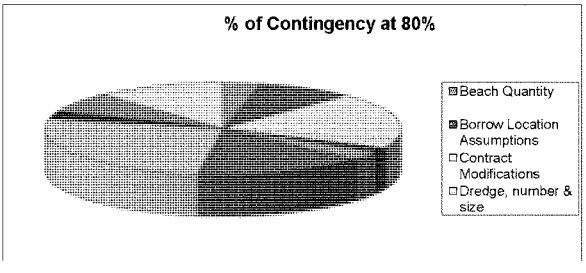
Statistics	TOTAL PROJECT COST	Beach Quantity	Borrow Location Assumptions	Contract Modifications	Dredge, number & size	Dune Revegetation	Esc exceeds OMB rates
Trials	10000	10000	10000	10000	10000	10000	10000
Base Case	$101,494,800	$93,332,000	$93,332,000	$0	$0	$0	$0
Mean	$115,794,232	$94,109,564	$95,379,434	$3,807,960	($3,268,939)	$412,324	$715,928
Median	$115,734,772	$94,019,062	$95,162,337	$3,799,856	($3,273,791)	$413,653	$721,607
Mode	---	---	---	---	---	---	---
Standard Deviation	$8,471,509	$548,512	$1,418,883	$2,209,804	$1,696,686	$240,285	$413,623
Variance	$71,766,457,130,160	$300,865,468,059	$2,013,171,590,523	$4,883,235,699,451	$3,597,419,377,029	$57,736,975,623	$170,257,493,460
Skewness	0.0466	0.5683	0.5541	0.0061	-0.0025	0.0082	-0.0231
Kurtosis	2.74	2.43	2.42	1.79	1.80	1.80	1.79
Coeff. of Variability	0.0732	0.0058	0.0149	0.5803	-0.5802	0.5828	0.5783
Minimum	$85,925,481	$93,332,149	$93,332,170	$833	($6,533,066)	$47	$219
Maximum	$143,584,335	$95,638,677	$99,337,115	$7,611,320	($1,953)	$829,970	$1,420,847
Range Width	$57,658,854	$2,306,528	$6,004,944	$7,610,487	$6,531,114	$829,922	$1,420,628
Mean Std. Error	$84,715	$5,485	$14,189	$22,098	$18,967	$2,403	$4,126

Percentiles	TOTAL PROJECT COST	Beach Quantity	Borrow Location Assumptions	Contract Modifications	Dredge, number & size	Dune Revegetation	Esc exceeds OMB rates
0%	$85,925,481	$93,332,149	$93,332,170	$833	($6,533,066)	$47	$219
5%	$101,911,908	$93,387,362	$93,509,265	$395,437	($6,284,857)	$40,704	$67,478
10%	$104,795,243	$93,448,663	$93,663,035	$735,228	($5,896,579)	$79,934	$130,869
15%	$106,814,070	$93,516,227	$93,830,783	$1,123,442	($5,573,568)	$121,857	$214,127
20%	$108,499,275	$93,581,072	$94,007,639	$1,519,396	($5,263,201)	$161,964	$282,891
25%	$109,841,194	$93,647,935	$94,185,167	$1,884,323	($4,933,211)	$203,660	$358,519
30%	$111,138,419	$93,717,369	$94,365,139	$2,255,865	($4,567,773)	$246,185	$430,263
35%	$112,343,382	$93,789,689	$94,554,352	$2,638,788	($4,253,655)	$287,208	$502,751
40%	$113,477,704	$93,860,127	$94,757,349	$3,012,223	($3,903,151)	$329,147	$576,785
45%	$114,679,638	$93,937,546	$94,955,009	$3,420,388	($3,589,584)	$370,997	$645,003
50%	$115,734,303	$94,019,015	$95,162,030	$3,799,454	($3,275,336)	$413,633	$721,585
55%	$116,877,828	$94,106,939	$95,371,355	$4,206,517	($2,945,558)	$455,387	$793,676
60%	$117,966,618	$94,188,354	$95,585,223	$4,556,553	($2,626,523)	$494,815	$864,503
65%	$119,114,634	$94,281,646	$95,837,116	$4,947,315	($2,276,489)	$536,830	$929,149
70%	$120,364,594	$94,382,589	$96,081,964	$5,330,454	($1,967,556)	$578,574	$1,004,855
75%	$121,596,135	$94,483,899	$96,341,286	$5,731,179	($1,638,311)	$618,479	$1,077,997
80%	$123,033,021	$94,612,027	$96,674,389	$6,151,225	($1,280,889)	$659,677	$1,148,032
85%	$124,677,068	$94,754,476	$97,050,782	$6,500,223	($950,131)	$703,114	$1,215,138
90%	$126,882,131	$94,927,387	$97,503,736	$6,863,962	($641,121)	$748,922	$1,282,695
95%	$129,928,279	$95,147,995	$98,085,048	$7,258,299	($321,527)	$789,372	$1,351,933
100%	$143,584,335	$95,638,677	$99,337,115	$7,611,320	($1,953)	$829,970	$1,420,847

Sensitivity Data Assumptions	TOTAL PROJECT COST
Beach Quantity	0.06
Borrow Location Assumptions	0.17
Contract Modifications	0.26
Dredge, number & size	0.22
Dune Revegetation	0.03
Esc exceeds OMB rates	0.04
Fuel	0.38
Market Conditions	0.65
Number of Contracts	0.05
Soil Quality	0.14
Two Dredge Productivity	0.47

	Raw Amount of Contingency at 80%	% of Contingency at 80%	Normalized Amount of Contingency at 80%	% of Contingency at 80%	
Beach Quantity	$1,280,027	5.94%	$784,498	3.64%	$784
Borrow Location Assumptions	$3,342,389	15.52%	$2,048,470	9.51%	$2,048
Contract Modifications	$8,151,225	28.58%	$3,769,938	17.50%	$3,770
Dredge, number & size	($1,280,889)	-5.95%	-$785,026	-3.64%	-$785
Dune Revegetation	$659,677	3.06%	$404,300	1.88%	$404
Esc exceeds OMB rates	$1,146,032	5.32%	$702,375	3.26%	$702
Fuel	$5,851,183	27.17%	$3,586,049	16.65%	$3,586
Market Conditions	$9,802,526	45.51%	$6,007,733	27.89%	$6,008
Number of Contracts	$960,819	4.46%	$588,863	2.73%	$589
Soil Quality	$2,839,644	13.18%	$1,740,350	8.08%	$1,740
Two Dredge Productivity	$4,390,238	20.38%	$2,690,671	12.49%	$2,691





Fuel	Market Conditions	Number of Contracts	Soil Quality	Two Dredge Productivity
10000	10000	10000	10000	10000
$93,332,000	$0	$0	$93,332,000	$93,332,000
$96,176,219	$4,123,882	$598,864	$95,051,747	$93,852,451
$95,698,712	$4,145,384	$598,728	$94,855,791	$93,717,909
---	---	---	---	---
$3,237,913	$5,468,780	$346,169	$1,201,484	$4,246,218
$10,484,080,826,956	$29,885,686,105,848	$119,832,825,985	$1,443,563,169,538	$18,030,370,597,084
0.4332	-0.0052	-0.0044	0.5422	0.0581
2.35	1.81	1.79	2.38	2.42
0.0337	1.33	0.5780	0.0126	0.0452
$90,114,194	($5,378,986)	$85	$93,332,354	$83,683,870
$104,890,295	$13,696,819	$1,199,752	$98,446,161	$104,413,830
$14,776,102	$19,075,785	$1,199,668	$5,113,807	$20,729,960
$32,379	$54,568	$3,462	$12,015	$42,462

Fuel	Market Conditions	Number of Contracts	Soil Quality	Two Dredge Productivity
$90,114,194	($5,378,986)	$85	$93,332,354	$83,683,870
$91,555,112	($4,417,817)	$82,853	$93,467,452	$86,849,274
$92,293,751	($3,488,380)	$119,567	$93,610,179	$88,220,185
$92,811,861	($2,545,180)	$178,057	$93,744,054	$89,218,372
$93,213,973	($1,528,574)	$236,080	$93,883,300	$89,925,502
$93,582,272	($544,021)	$296,103	$94,031,622	$90,780,278
$93,968,640	$381,014	$355,774	$94,181,871	$91,466,759
$94,380,732	$1,291,811	$415,879	$94,336,242	$92,107,277
$94,800,497	$2,178,275	$476,420	$94,509,821	$92,693,409
$95,233,788	$3,189,540	$541,123	$94,679,784	$93,243,992
$95,698,478	$4,145,287	$598,628	$94,855,579	$93,717,470
$96,182,005	$5,178,260	$663,952	$95,044,738	$94,306,252
$96,692,820	$6,029,642	$723,087	$95,250,174	$94,910,261
$97,261,985	$6,928,295	$782,225	$95,454,115	$95,468,831
$97,882,182	$7,825,916	$839,531	$95,664,835	$96,138,059
$98,512,717	$8,794,387	$899,853	$95,897,701	$96,882,058
$99,183,183	$9,902,526	$960,819	$96,171,844	$97,722,238
$99,975,214	$10,779,036	$1,015,492	$96,457,919	$98,562,979
$100,933,557	$11,670,214	$1,073,717	$96,821,387	$99,699,817
$102,138,957	$12,624,277	$1,138,108	$97,302,148	$101,018,210
$104,890,295	$13,696,819	$1,199,752	$98,446,161	$104,413,830

Feasibility Report
and
Environmental Impact Statement

on

Coastal Storm Damage Reduction

SURF CITY AND NORTH TOPSAIL BEACH, NORTH CAROLINA

Appendix O

Recreation Analysis

Surf City & North Topsail Beach Recreation Analysis

Abstract

Full and accurate valuation of public goods is essential for appraising projects and policies affecting the use of environmental resources. Under-valuation of recreational resources can bias beach recreation value in directions that are not consistent with maximizing economic welfare. A measure of the economic value of beach improvement is the amount of money an individual is willing to pay (WTP) to attain the improvement and which leaves the individual just as well off as if there were no improvement to the beach and no payment. A positive WTP for an initial beach improvement beyond the existing condition suggests that beach nourishment can be considered an economic good and is therefore a candidate for cost-benefit analysis of a beach fill project. This study estimates WTP of a beach day for the average visitor within a travel cost model (TCM) framework. Onsite visitation data for seventeen North Carolina beaches were collected between July and August 2003 and a telephone survey conducted in May 2004, with a target population based upon the results of the onsite survey conducted in 2003. Estimation results for the TCM measure the incremental value of having access to a particular beach when other substitute beaches are available, and the value of changes in beach characteristics, such as beach width. Additionally, the data was used to predict annual and peak visitation at the subject beaches and parking and access requirements to handle projected visitation. Finally, the National Economic Development (NED) benefits for the with-project conditions for the subject beaches were estimated. The expected average annual benefit (AAB) for Surf City and North Topsail beaches for the with-project condition tentatively selected alternative of 1550 plan are approximately $12,709,000 and $7,796,000, respectively. The 1550 design plan will add an additional beach width of 65 feet and 73 feet for Surf City and North Topsail beaches.

1.0 INTRODUCTION

In December of 2002 the Wilmington District United States Army Corps of Engineers (USACE) contracted with the University of North Carolina at Wilmington (UNCW) to collect data and develop methodologies for an in-depth and multi-faceted study of the recreation demand and benefits of visitors to four barrier islands on the North Carolina Coast: Bogue Banks, Topsail Island, Oak Island, and Holden Beach.

Planning and Guidance (P&G) describes recreation benefits as incidental benefits of the National Economic Development Account. As described in ER 1105-2-100: Single purpose shore protection projects are formulated exclusively for hurricane and storm damage reduction (HSDR) and recreation is an incidental benefit. Recreation benefits can be included in the benefit/cost ratio for a project. However, HSDR benefits must account for at least half of the total benefits required to justify the project or the federal government will not share the project costs for that shoreline reach. Therefore, when calculating net benefits for a storm damage reduction project, recreation benefits are added into the net benefits after the storm damage reduction benefits have been estimated from coastal and economic models and after a plan has been selected.

The focus of this collaborative study effort was on day trip visitors who use public access and parking facilities. This study employed multiple methodologies that incorporated:

- An on-site field survey administered during the summer vacation season of 2003
- A telephone survey of residents living in eastern North Carolina within a 120 mile radius of each beach community incorporated into the survey instrument in the spring of 2004 (Office of Management and Budget approved, control number 0710-0001, Attachment 2)
- A focus group session with each municipality and representatives from its major business organizations
- A secondary data literature search, and aerial photography and parking counts of the project area on the days that the on site surveys were conducted.

This study focused on four projects. These are:

- West Onslow Beach and New River Inlet GRR study
- Surf City/North Topsail Beach feasibility study
- Bogue Banks feasibility study
- Brunswick County Beaches feasibility study

The non-Federal sponsors for the four projects are, respectively, the town of Topsail Beach; the town of Surf City and the town of North Topsail Beach; Carteret County; and the town of Caswell Beach, the town of Oak Island, and the town of Holden Beach.

A telephone survey instrument was used to gather comparative data for New Hanover County Beaches including Wrightsville Beach, Carolina Beach, Kure Beach, Masonboro Island, and Fort Fisher State Park; the remaining Brunswick County beaches including Ocean Isle and Sunset Beach, and the Fort Macon State Park at Bogue Banks.

This report will provide an outline methodology that will be used to analyze data collected from the on-site survey, telephone survey, parking counts, and aerial photography. The final analysis will be used to determine the peak recreation demand for each beach community under study in the without project condition, the latent and expected future demand in the with project condition, and the recreational benefits of the with and without project conditions that will be calculated using the travel cost method (TCM) and the contingent valuation method (CVM).

This analysis will answer the following key questions for the reader:

- What is an individual beach recreationist's willingness to pay (WTP) per day trip for each of the beaches in our study region?
- How would the number of beach trips made by an individual beach recreationist to each of the beaches change with a change in beach width?
- How would WTP for an individual beach recreationist change with a change in beach width?
- What would be the change in value in aggregate WTP across all recreationists visiting a particular beach should a change occur in beach width? For example, what would be the increase in recreation value (i.e., aggregate WTP) associated with a 50 feet increase in beach width at Surf City or at North Topsail Beach?

Additionally, this report will provide an overview of how the data will be used to establish baseline parking and access needs for Surf City and North Topsail Beach and project future parking needs in the with project condition.

2.0. METHODOLOGY

A multi-method approach was used in examining this studies research questions. The primary methods included on-site and telephone surveys and econometric analyses to examine data within the framework of TCM and CVM. Historically, Wilmington District has used the unit day value (UDV) method to determine recreation benefits for Hurricane and Storm Damage Reduction projects. The UDV method for estimating recreation benefits relies on expert or informed opinion and judgment to approximate the average willingness to pay of users of a particular project. However, given sufficient data, the UDV can be replaced with the TCM and the CVM estimates to provide a more valid and reliable monetary value of the recreation benefits for each project under feasibility study.

Questions on both the on-site survey and the telephone survey were specifically designed to generate data necessary to employ the TCM and the CVM. Survey data obtained from telephone and on-site survey invariably suffer from spurious records coming from missing values, outliers, and duplicate values, etc. Basic analytic methods for surveying data required first and foremost scrubbing the data and removing outliers. LIMDEP (2002)[1], a statistical software having specialized features for the statistical analysis of complex survey data, will be employed to analyze the survey data. The analysis will be accomplished by fitting nonlinear econometric models to observed data. These

econometric models differ from standard regression models in that they can be adapted to handle the unique characteristics of survey data. In addition, the econometric models are developed to estimate economic values, such as a beach recreationist's willingness to pay, or the amount of money the recreationist would be willing to spend for a day of beach recreation.

One objective of this study is to estimate peak and latent demand of the beaches under study. Latent or potential demand is the number of individuals who would come to the beach if conditions were more conducive for recreation. This demand is modeled from the stated preference of the respondent versus their revealed preference. The recommended methodology and data collected from the surveys was used to develop a model to estimate the number of trips taken to each beach in 2003 and the additional trips that the respondent would take if the width of the beach were increased. The model was also used to predict a decrease in trips with a decrease in beach width caused by erosion of the beach.

Table O-1. 2003 Demographic Information

Variable	Demographic Areas		On Site Survey Models		Telephone Survey Models	
Name	North Carolina	Phone Sampling	WTP Simple	WTP Clogit	Analysis 1	Analysis 2
Mean Age	36*	37	Respondents over 18 years old		42	42
Mean Household Income	$42,536*	$36,072*	$54,255	$68,081	$58,833	$59,153
Sex						
Female	51%	51%	54%	57%	63%	62%
Male	49%*	49%*	46%	43%	37%	38%
Race						
White	72%	64%	Not used in model		81%	82%
Minority	28%*	36%*			19%	18%
Population / Observations	8,421,050	3,891,199	571	2,131		3,424

*All variables are in 2003 values except those notated with asterisks and described below (http://www.nist.gov/itl/div898/strd/).

North Carolina Demographics Age from July 2004 from NC State Demographics website.
North Carolina Demographics Sex and Race are from the 2000 US Census.
North Carolina Demographics Household Income was inflated to 2003 value from 1999 value from the 2000 US Census.

Telephone Sampling Area Demographics Sex and Race are from the 2000 US Census.
Telephone Sampling Area Demographics Household Income was inflated to 2003 value from 1999 value from the 2000 US Census.

The 2003 beach width was used as a baseline for this study. The without project condition assumed that the baseline condition remains constant over an equivalent period of time to the expected life of the selected alternative for a hurricane and storm damage

reduction project. The average annual benefits were calculated for a 50 feet decrease in beach width to capture the effects of erosion on recreation. Long term erosion and hurricane impacts were evaluated separately from the recreation analysis using coastal storm damage models.

Data collected from the aerial photography counts, parking counts and demographic data were employed in this model. Table 1 presents the demographic information of North Carolina and the sampling area.

3.0 ESTIMATING AVERAGE ANNUAL BENEFITS

This section of the appendix will detail the steps that will be taken to derive average annual benefits (AAB) of recreation for Surf City and North Topsail Beach and the other beaches included in the surveys. Willingness to pay for beach improvement was used in calculating AAB. It was hypothesized that changes in beach characteristics such as beach width will lead to an increase/decrease in the expected number of day user trips per household per year. Changes in the expected number of day user trips per household per year due to changes in beach characteristics were found by calculating the difference between the expected number of trips per household under baseline conditions and the expected number of trips per household under alternative beach conditions. Since recreationists' responses to changes in beach improvement cannot be observed from market data, we use the contingent valuation method to estimate the WTP.

3.1 On Site Survey (OSS) - Estimating Willingness to Pay Using Contingent Valuation Method (CVM)

The first step in developing average annual benefits (AAB) of recreation is to determine a person's willingness to pay (WTP) for a visit to the beach and how certain factors will increase or decrease the likelihood that they pay more or less to visit a certain beach. Contingent valuation survey questions focus on specific environmental service(s) and the context that is clearly defined and understood by survey respondents. To determine the average day-user's net willingness to pay (WTP) for beach recreation for each project, we used a binomial probit model (Haab and McConnell 2002, Chapter 2). In this study, we used the procedure to generate an equation that expresses willingness to pay (WTP) as a function of a set of socioeconomic and attitudinal variables. We specify WTP as a function of gender, age, income, beach width in feet, number of parking spaces per mile of beach length, weather condition and holiday.

Binomial probit regression models are often used to describe the effect of one or more explanatory variables on a binary response variable. In this situation the binary dependent variable is a "yes/no" or "1/0" rather than a continuous variable. The dependent variable for this model is a "yes=1 and no=0", survey variable Q15. Question 15 asks whether or not the user would be willing to pay a specified dollar amount ($5, $10, $15, $25, $50, or $75, depending on the survey version), more than he or she is currently paying to access the beach.

The independent variables used in the model explain the respondent's "yes/no" response to the willingness to pay question. The variables include: BID amount ($5, $10, $15, $25, $50, or $75, depending on the survey version); GENDER, a categorical variable (M=1, F=0); ALTACT, a categorical variable describing the recreation's alternative activity; MILES traveled to the beach; PARTYSZ, the number of people in the recreation's party; BWIDTH, the width of the beach in feet; PKPERMIL, the number of parking spaces per mile of beach length; RAIN, a dummy variable for rain; and HOLIDAY, a dummy variable to indicate whether the day was a holiday. ALTACT='1' indicated that the recreationist had an alternative activity (survey question Q17=2, 3, or 4), and ALTACT='0' if the recreationist indicated that he or she did not have an alternative activity (i.e., the recreationist would stay home, survey question Q17=1). RAIN='1' would be a response to whether there was 'light rain' or 'heavy rain', and RAIN='0' otherwise. HOLIDAY='1' would be a response to whether the date of the survey was conducted on the 4th of July or Labor Day weekends, and HOLIDAY='0' otherwise. [ii][iii]

Independent variables with missing observations were dropped from the data set. In all 571 observations were used in the binomial probit regression analysis. Descriptive statistics for the regression variables are presented in Table O-2.

Table O-2. Descriptive Statistics for Binomial Probit Regression Model Variables

Descriptive Statistics					
Variable	Mean	Std.Dev.	Min.	Max.	Observations
DEPENDENT VARIABLE	0.33275	0.471611	0	1	571
BID	27.1366	24.43191	5	75	571
GENDER	0.457093	0.498592	0	1	571
ALTACT	0.742557	0.437609	0	1	571
MILES	69.62263	146.5457	2.00E-02	3000	571
PARTYSZ	3.569177	3.224908	1	60	571
BWIDTH	106.6392	21.88758	80	135	571
PKPERMIL	74.23218	36.01124	29.41176	135.102	571
RAIN	0.161121	0.367965	0	1	571
HOLIDAY	0.478109	0.499959	0	1	571

Table O-3 gives the coefficients and standard errors of the binomial probit regression. Based on the regression results, the significant likelihood ratio chi-square test indicates that the model overall is significant at the 1% level. However, only explanatory variables BID, GENDER and PARTYSZ are statistically significant at the 1% and 5% level, while PKPERMIL is significant at the 10% level.

Table O-3. Estimation Results for Probit Model

Index function parameters					
Variable	Coeff.	Std.Err.	t-ratio	P-value	Mean
Constant	-1.28048***	0.350445	-3.654	0.0003	1
BID	2.99E-02***	2.56E-03	11.66	0	27.1366
GENDER	-0.25633**	0.12309	-2.082	0.0373	0.457093
ALTACT	-7.08E-02	0.140267	-0.505	0.6136	0.742557
MILES	-2.65E-04	3.33E-04	-0.795	0.4267	69.62263
PARTYSZ	-6.65E-02**	3.02E-02	-2.206	0.0274	3.569177
BWIDTH	7.68E-04	3.12E-03	0.247	0.8053	106.6392
PKPERMIL	3.07E-03*	1.78E-03	1.724	0.0847	74.23218
RAIN	8.33E-02	0.193155	0.431	0.6663	0.161121
HOLIDAY	0.101767	0.137109	0.742	0.4579	0.478109

Notes: ***,**, and * refer to significance at the 1%, 5%, and 10% levels, respectively. The chi-square and overall likelihood ratio statistics are 21.67 and 164.04, respectively. Number of observations =699. Dependent variable: YES=1/NO=0 Binomial variable.

For all model variables except BID, positive coefficients estimates indicate that higher variable values increase the likelihood that respondent would answer, "yes" to the WTP. Hence, being male decreases mean WTP, larger party sizes decrease WTP, and a larger number of parking spaces per mile of beach length marginally increase WTP. In the binomial probit model specification, a positive BID coefficient estimate suggests that higher BID amounts *decrease* the likelihood that respondents will answer "yes" to the willingness to pay question (as expected). Its effect on respondent's choices generally agrees with *a priori* expectations. For the purpose of estimating mean net WTP, BID is the key variable. The estimated coefficient on BID is highly significant and of the expected sign.

Mean WTP per day trip in the binomial probit model is given by (see Haab and McConnell 2002, Chapter 2):

$$Mean-WTP-per-day-trip = (\beta_{constant} + \beta_{gender} * GENDER + \beta_{altact} * ALTACT + \beta_{miles} * MILES + \beta_{partysz} * PARTYSZ + \beta_{bwidth} * BWIDTH + \beta_{pkpermil} * PKPERMIL + \beta_{rain} * RAIN + \beta_{holiday} * HOLIDAY) / (-\beta_{bid}) \Rightarrow\Rightarrow (1)$$

where the estimated β coefficients are given in Table O-3 and the variable values are either mean values across all beaches (see Mean column in regression results Table O-3) or mean value by beach, depending on whether one desires a mean WTP estimate across all beaches or WTP estimates for each beach.

Mean values across all beaches were used for GENDER, ALTACT, PARTYSZ, RAIN, and HOLIDAY. Beach-specific mean values were used for MILES, BWIDTH, and PKPERMIL. Estimates of mean WTP per day trip and associated 95% confidence intervals by beach are presented in Table O-4.

Table O-4. Estimates of Average (Mean) WTP per Day Trip by Beach (2003 $'s))

Beach	Mean WTP Per Day Trip	95% Confidence intervals
Atlantic Beach	$38.05	$29.44 - $46.65
Caswell Beach	$48.82	$41.14 - $56.50
Emerald Isle	$46.71	$38.45 - $54.97
Indian Beach	$47.98	$41.64 - $54.32
Holden Beach	$49.71	$42.33 - $57.09
North Topsail Beach	$42.88	$34.94 - $50.82
Oak Island Beach	$40.45	$34.31 - $46.59
Pine Knoll Shores	$47.82	$41.26 - $54.38
Salter Path	$47.67	$41.43 - $53.91
Surf City Beach	$47.23	$41.17 - $53.29
Topsail Beach	$46.17	$40.85 - $51.49

The WTP estimates for each particular beach in Table O-4 represent the amount of money that the average beach visitor, surveyed on that particular beach would be willing to pay per day trip to visit that particular beach. However, each value gives the total of two components: the value of visiting any beach in the study region and the additional value of visiting the particular beach on which the individual was surveyed. The additional value of visiting a particular beach will be addressed in estimating WTP for site access using TCM.

3.2 OSS – Estimating WTP for Site Access Using Travel Cost Method (TCM)
The binomial probit regression WTP estimates presented in the preceding section measure the value of beach day trips in the study region to beach recreationists. This section develops two additional measures of beach value using a conditional logit regression model (Haab and McConnell 2002, Chapter 8). The conditional logit regression model allows estimation of "site access" values and the value of changes in beach characteristics, such as beach width. WTP for site access is the incremental value of having access to a particular beach when other substitute beaches are available. Assuming that the substitute beaches are not perfect substitutes for the beach in question (due to differences across beaches in location and other beach characteristics) WTP for site access is positive. Alternatively, WTP for site access measures the loss in value associated with losing access to a beach, given that other (imperfect) substitute beaches are available.

In developing the conditional logit model we make three assumptions: (1) the proportion of all trips in the survey sample made to a particular beach is the same as the proportion of all trips made to that beach by the targeted population of beach visitors, (2) the 'independence of irrelevant alternatives' assumption holds (see Haab and McConnell, 2002) and (3) the indirect utility function is linear in its arguments.

The conditional logit model attempts to explain the proportions of beach visitors in a survey sample visiting each beach as a function of beach characteristics such as beach length, beach width, the number of parking spaces at each beach, the weather forecast for

each beach and, importantly, the cost of traveling to each beach known as the 'access price.' WTP for site access may be estimated based on the estimated proportions. Because travel cost (access price) is used to predict beach choice, this model is a type of "travel cost model" (TCM).

The dependent variable for the conditional logit model is a dummy variable, BEACH. For each survey respondent, BEACH=1 if the respondent was interviewed on that beach and BEACH=0 otherwise. The conditional logit regression procedure in LIMDEP creates ten additional observations for each observation in the original dataset, one observation for each of the ten beaches not visited by the survey respondent on the date of the survey. Ultimately, the conditional logit model utilizes eleven observations for each survey respondent, the original observation containing BEACH=1 and the original data for all other variables, and ten additional observations containing BEACH=0 and copies of the original data for all other variables.

Additional non-survey data were collected to create the beach characteristics vector used in the model. Average beach width was estimated using USACE aerial photography from 2002 and was from the mean sea level (msl) to the first line of vegetation. Because the 2002 hurricane season did not significantly impact southeastern North Carolina beaches, USACE determined that average beach widths in 2002 would be adequate estimates of 2003 beach widths. Average beach length was obtained from the Wilmington District GIS database. Parking access points and parking spaces were also collected from USACE project data and the parking data collected by UNCW.

Data was collected from the National Weather Service for the weather station closest to each beach surveyed (only Morehead City and Wilmington stations were used). This data described weather forecasts for each day the on site surveys were administered. Air temperature and wind speed variables were used for each beach as well as variables describing the cloud cover and precipitation. Four dummy variables were created to represent the cloud cover and precipitation for each beach on each day of the survey. These variables include: 1.) partly cloudy, 2.) mostly cloudy, no showers or storms, 3.) partly cloudy with scattered or isolated showers or storms, and 4.) mostly cloudy with numerous showers and storms. Values for these variables are '1' if those conditions are present and '0' otherwise. The default weather condition, if none of the variables listed above have values of '1', is mostly sunny.

The access price for each beach is different for each survey respondent, depending on the travel distance between the respondent's home and each beach, and the opportunity cost of the respondent's time. Travel distances and average travel speeds between each

survey respondent's home zip code and every beach zip code included in the study were calculated using PCMiler (2005) software[1].

Distance, speed, and income or estimated income were used to calculate the access price, or a round trip travel cost for each survey respondent from their home zip code to each study area zip code. The cost per mile used was $0.37, the national average automobile driving cost, which includes only the variable costs and no fixed costs for 2003 as reported by American Automobile Association (AAA) (AAA Personal communication, 2005). As is common in recreation studies, one third of the wage rate (income/2000 hours/3) was used to value leisure time for each respondent. For each survey respondent, *i*, and each beach, access price of respondent was derived by the following:

$$ACCPRI_{i,j} = ((0.37 * 2 * DIST_{i,j}) + (((1/3) * (INCOME_j / 2000)) * (2 * DIST_{i,j} / SPED_{i,j})) \Rightarrow\Rightarrow (2)$$

The conditional logit regression model was estimated using LIMDEP procedures. The dependent variable BEACH was regressed on access price (PRICE), beach length (BLENGTH), beach width (BWIDTH), the number of beach access points (BACCESS), the number of parking spaces (BPARKSP), a dummy variable for rain occurrence (FCRAIN), a dummy for air temperature (FCTEMP), and a dummy for wind speed (FCWIND). The regression results are presented in Table O-5:

Table O-5. Conditional Logit Regression Results

Independent Variable	Parameter Estimate	Std. Error	T-Ratio	P-value
PRICE	-.0241***	0.001	-23.37	0
BLENGTH	0.1665***	0.014	12.025	0
BWIDTH	0.0201***	0.001	15.253	0
BACCESS	-0.0088***	0.002	-4.561	0
BPARKSP	0.0002	9.757E-05	1.548	0.1216
FCRAIN	-0.3020**	0.136	-2.218	0.0266
FCTEMP	0.0844***	0.026	3.249	0.0012
FCWIND	0.03064	0.027	-1.134	0.257

Notes: ***,**, and * refer to significance at the 1%, and 5% levels, respectively. The chi-square and overall likelihood ratio statistics are respectively 20.09 and 672. Number of observations = 2131. Dependent variable: BEACH.

[1] The software calculates distances and average speeds for travel between specified zip codes. This program is helpful for developing the costs of individuals' travel used in travel cost models. The travel distance for each respondent to each of the eleven beaches in the study was calculated using the 'miles' function of PCMiler with the default setting 'prac,' which is the setting for the individual choosing the most practical route. Average travel speed (mph) for each respondent to each beach was calculated by dividing distance by average drive time to each beach.

The signs on the estimated coefficients give the qualitative effects of the regressors on the probability that a beach recreationist selects a particular beach. For example, the negative estimated coefficient on PRICE indicates that as the access price increases for a particular beach, the probability that a beach recreationist chooses to visit that particular beach decreases. Hence, the impact of increasing access price on the probability of beach selection is negative and significant. Increases in beach length or width have positive and significant impacts on the probability of beach selection. An increase in the number of available parking spaces has a positive, though marginally significant (p=0.1216), impact on the probability of beach selection. Perhaps surprisingly, the number of beach access points has a negative and significant impact on beach selection. However, the number of beach access points may be a proxy measure of "commercial development," which may be negatively related to the probability of beach selection if most recreationists desire a more solitary beach experience. Finally, the weather variables have the expected signs, with a forecast of rain and temperature having significant effects and a forecast of wind having an insignificant effect on the probability of beach selection. In all, the overall regression is significant at the 1% level of significance.

Measures of WTP for site access are calculated from the conditional logit regression results (Haab and McConnell 2002). WTP for site access to beach *i* is given by:

$$WTP_i = \left(\frac{1}{\beta PRICE}\right) \ln(1 - \mathrm{Pr}_i^0) \Rightarrow\Rightarrow (3)$$

Where Pr_i^0 is the predicted probability of an individual selecting beach *i* under baseline conditions and $\beta price$ is the coefficient on the access price. The values of Pr_i^0 and WTP for site access for each beach are presented in Table O-6:

Table O-6. Site Access Values

Beach		Pr_i^0	(2003 $'s / trip)
0	Caswell Beach	0.03264	$1.38
1	Oak Island Beach	0.1094	$4.82
2	Holden Beach	0.09103	$3.97
3	North Topsail Beach	0.12304	$5.46
4	Surf City Beach	0.06635	$2.85
5	Topsail Beach	0.0813	$3.53
6	Pine Knoll Shores Beach	0.08142	$3.53
7	Salter Path Beach	0.02958	$1.25
8	Indian Beach	0.02809	$1.18
9	Emerald Isle Beach	0.22641	$10.67
10	Atlantic Beach	0.13072	$5.83

The site access WTP values in Table O-6 are the portion of WTP attributable to the beach on which the individual was surveyed. In other words, if the individuals were prevented from visiting that particular beach but were able to visit another beach within the study region, the beach visitor would experience a reduction in value equal to that in Table O-6. The values in Table O-6 are smaller than the WTP values in the preceding section because the site access WTP values give only the additional (marginal) value to the

recreationist of visiting the chosen beach over the next-best substitute beach in the study region. This value is in addition to the value of visiting simply any beach within the study region. The WTP values in the preceding section of the report give the total of both value components: the value of visiting any beach in the study region and the additional value of visiting the particular beach on which the beach visitor was surveyed. The WTP values in Table O-6 are similar to those found by Parsons, Massey and Tomasi (1999), who used a conditional logit model to study beach recreation trips made by Delaware residents to New Jersey, Delaware and Virginia beaches in the fall of 1997.

3.3 OSS - Estimating WTP for Changes in Beach Quality Using TCM

The conditional logit model developed in the preceding section may also be used to estimate WTP for changes in beach quality, such as changes in beach width or the number of available parking spaces. WTP for a change in beach quality characteristic q at beach *i* from an original level of the characteristic q^0 to a new level of the characteristic q' is given by:

$$WTP_i = \left(\frac{1}{\beta PRICE}\right)\{\ln[1 - \Pr_i'(q')] - \ln[1 - \Pr_i^0(q^0)]\} \Rightarrow\Rightarrow (4)$$

Where $Pr_i^0(q^0)$ is the simulated probability of a beach visitor selecting that beach i when the level of beach quality characteristic q at beach i is q^0, and $Pr_i'(q')$ is the simulated probability of a beach visitor selecting beach i when the level of beach quality characteristic q at beach i is q' (Haab and McConnell 2002). The simulated probabilities Pr_i^0 and Pr_i' are calculated using the conditional logit model regression results presented in the preceding section.

3.4. Project Scenarios

Several alternative policy scenarios involving changes in beach quality characteristics can be evaluated using the conditional logit model results. This analysis will focus only on the change in beach width effecting WTP. The purpose of developing project scenarios is to calculate WTP for specified changes in beach width compared to the 2003 base year. Beach width changes of –50ft, +50ft, +100ft, and +150ft are the selected scenarios. Econometric regression analyses were performed for each beach separately, which allowed us to investigate the impact of changes in beach width of one town while assuming that the beach widths at the other towns remain constant at the 2003 base year levels.

The simulated probability of an individual selecting a particular beach varies depending on the changes in width. Equation 4 was used to estimate the WTP for changes in beach width. The conditional logit model estimates of changes in WTP per trip resulting from changes in beach width (BWIDTH) are reported in Table O-7.

Table O-7. Changes in WTP per Trip Resulting from Changes in Beach Width

	Changes in WTP per Trip (2003 $'s) Resulting From Changes in Beach Width(BWIDTH)			
	-50 feet	+50 feet	+100 feet	+150 feet
Caswell Beach	-$0.84	$2.05	$6.47	$14.61
Oak Island	-$3.17	$5.43	$14.69	$28.92
Holden Beach	-$2.38	$5.20	$14.94	$30.51
North Topsail Beach	-$3.34	$7.77	$23.07	$47.36
Surf City	-$1.77	$4.39	$14.13	$32.06
Topsail Beach	-$2.18	$5.30	$16.64	$36.53
Pine Knoll Shores	-$2.17	$5.14	$15.65	$33.22
Indian Beach	-$0.73	$1.91	$6.61	$16.74
Salter Path	-$0.77	$2.01	$6.93	$17.43
Emerald Isle	-$6.31	$12.63	$33.03	$60.13
Atlantic Beach	-$3.52	$7.72	$21.81	$42.91

It can be deduced from Table 0-7 that the average recreationist would be willing to pay an additional $5.30 per trip to enjoy a beach width of 160 ft at Topsail Beach as opposed to a beach width of 110 ft. This $5.30 value is not a "per foot of beach width" measure; rather, it is the willingness to pay for entire increase in beach width at Topsail Beach from 110 ft to 160 ft. Although not shown in Table O-7 an increase in beach width at a particular beach alone results in the attraction of some beach visitors to that beach and away from other beaches in the sample region. Observe that a decrease in beach width at a particular beach results in fewer trips to that beach and more trips to other beaches in the sample region.

Note that the values presented in Table O-7 reflect the effect of increased beach width at one particular beach only. If beach width were improved at all beaches simultaneously, then the increase in trips to that one particular beach would be smaller, as fewer individuals would be attracted away from other beaches in the study region to that beach.

4.0. TELEPHONE SURVEY (TS)

The site survey data was used to estimate recreation value per trip (net willingness to pay). The following section is devoted to the estimation of annual visitation model for each beach based on telephone survey data.

4.1. TS - Annual Visitation Model Using TCM

Thus far, this analysis has determined the recreationist's WTP for a trip to the beach using data from the on site survey. The final requirement necessary to calculate the average annual benefits (AAB) of recreation is to determine the annual visitation for each beach. The telephone survey data was used to estimate an annual visitation model for each beach. To address the fact that the dependent variable, trips per household per year, is an integer variable, a Poisson/negative binomial regression model framework was used (Haab and McConnell, 2002, pp 164-174; LIMDEP Chapter E20). The Poisson regression model is appropriate unless the data are over-dispersed. The data are

overdispersed when the variance in trips per year is greater than mean trips per year. If the data are over-dispersed, the negative binomial model is appropriate.

Each of the 1,067 respondents in the data set reported the number of recreational beach trips taken to each of 17 beaches in southeastern North Carolina during the summer of 2003. The 1,067 respondents reported a total of 9,002 trips as shown in Table O-8.

Table O-8. Beach Trips made by 1,067 Telephone Survey Respondents to Southeastern North Carolina Beaches in 2003

Beach Number	Beach Name	2003 Beach Trips	
		Number in Sample	Proportion of Sample
00	Caswell Beach	163	0.02
01	Oak Island	163	0.02
02	Holden Beach	183	0.02
03	North Topsail Beach	719	0.08
04	Surf City	279	0.03
05	Topsail Beach	245	0.03
06	Pine Knoll Shores	143	0.02
08	Salter Path and Indian Beach	135	0.01
09	Emerald Isle	1083	0.12
10	Atlantic Beach	919	0.10
11	Fort Macon	251	0.03
12	Carolina Beach	1502	0.17
13	Kure Beach	360	0.04
14	Fort Fisher	404	0.04
15	Ocean Isle Beach	353	0.04
16	Sunset Beach	153	0.02
17	Wrightsville Beach	1947	0.22
	Total Trips	9002	1.00

For modeling purposes, the data for each survey respondent were expanded into 17 rows of data, one row for each beach. The data set used for the Poisson regression therefore has 1,067*17 = 18,139 rows of data, with 17 rows for each survey respondent. Each row of data consists of the number of trips taken to a particular beach (TRIPS), the access price for that respondent and beach (ACCPRI), beach width (BWIDTH), beach length (BLENGTH), beach parking spaces (BSPACES), beach access points (BACCESS), respondent's household income in $1,000's (INCOME), the respondent's age (AGE), age squared (AGESQ), the number of children in the respondent's household (NUMKIDS), and dummy variables indicating whether the respondent was female, married, or a member of a racial minority. A system of dummy variables labeled DD01 through DD17 was created to allow each beach to have a separate slope coefficient for the variable ACCPRI, which allows the effect of access price on trips to vary by beach. Dummy variable DD07 was omitted because the relatively few data from beach 07 were pooled with the data from adjacent beach 08 for the analysis. To avoid the dummy variable trap, the dummy DD00 corresponding to Caswell Beach was omitted. The coefficient on

ACCPRI is the coefficient corresponding to Caswell Beach, and the coefficients on the dummy variables shift the coefficient on ACCPRI as appropriate for the other beaches. Allowing the effect of access price to vary by beach is necessary in order to obtain separate estimates of willingness to pay for each beach.

Travel distances and average travel speeds between each survey respondent's home zip code and every beach zip code included in the study were calculated using PCMiler Software. If distance = 0, then the speed would be zero. In this case, speed was set equal to 2 mph to correspond to average walking speed and distance was set to equal 1 mph. Distance, speed, and estimated hourly wage (reported/estimated household income divided by 2000 work hours per year) were used to calculate the access price (ACCPRI), or a round trip travel cost, for each survey respondent from the home zip code to every beach zip code. The cost per mile used was $0.37, the national average automobile driving cost for 2003 as reported by American Automobile Association (AAA) (AAA Personal communication 2005). The AAA cost per mile estimate is based on 15,000 miles driven per year for three typical cars, which only includes the variable costs and no fixed costs. One third of the wage rate was used to value leisure time for each respondent. For each survey respondent, *i*, beach-specific access price were calculated as follows:

$$ACCPRI_{i,j} = ((2 * 0.37) * DIST_{i,j}) + (((1/3) * (INCOME_j / 2000)) * (2 * DIST_{i,j} / SPED_{i,j}))) \Rightarrow\Rightarrow (5)$$

General descriptive statistics of the respondents are listed in Table O-9.

Table O-9. Descriptive Statistics for the Poisson Regression Model

Variable	Mean	Std.Dev.	Minimum	Maximum	Observations
TRIPS	0.496279	5.875066	0	200	18139
ACCPRI	160.4209	135.8946	0	1169.75	18139
BWIDTH	129.5294	73.24627	80	400	18139
BLENGTH	4.547059	2.896755	1.1	11.5	18139
BSPACES	448.1765	353.8989	56	1479	18139
BACCESS	27.47059	19.93018	2	69	18139
INCOME	58.83318	28.50739	15	110	18139
FEMALE	0.633552	0.481847	0	1	18139
MARRIED	0.715089	0.451384	0	1	18139
NUMKIDS	0.940019	1.140643	0	8	18139
MINORITY	0.192127	0.393984	0	1	18139
AGE	42.42737	14.91017	18	104	18139
AGESQ	2022.382	1403.119	324	10816	18139

Since the surveying was done by telephone and the dependent variable in the TCM is the number of trips a respondent has taken in the past twelve months, statistical efficiency is improved by using a count data estimator. The number of trips taken is a non-negative

integer, rather than a continuous variable as assumed in the normal distribution. The count data model estimated has a Poisson distribution with the following specification:

$$TRIPS_{i,j} = EXP[\beta_c + (\beta_a + \beta_{xx} DDD_{xx}) ACCPRI_{i,j} + \beta_{18} * BWIDTH_i + \beta_{19} * BLENGTH_i + \beta_{20} * BSPACES_i + \beta_{21} * BACCESS_i + \beta_{22} * INCOME_j + \beta_{23} * FEMALE_j + \beta_{24} * MARRIED_j + \beta_{25} * NUMKIDS_j + \beta_{26} * MINORITY_j + \beta_{27} * AGE_j + \beta_{28} * AGESQ_j + \varepsilon_{i,j}] \Rightarrow\Rightarrow (6)$$

Where "EXP" is the exponentiation operator, "xx" is a beach index variable, ACCPRI, BWDTH, BLENGTH, BSPACES, BACCESS, INCOME, FEMALE, MARRIED, NUMKIDS, MINORITY, AGE, and AGESQ are as defined and $\varepsilon_{i,j}$ is normally distributed error term.

The results of the Poisson equation are listed in Table O-10.

Table O-10. Poisson/Negative Binomial Cluster Regression Results

Variable	Coeff.	Std.Err.	t-ratio	p-value	Variable Mean
Constant	-1.09355	0.968624	-1.129	0.2589	1
ACCPRI	-0.02553***	0.006365	-4.011	0.0001	160.4209
DDD01	-0.01683	0.011313	-1.488	0.1368	10.45277
DDD02	-.902962D-04	0.007629	-0.012	0.9906	9.215456
DDD03	-0.00515	0.009826	-0.524	0.6003	8.580884
DDD04	-0.00186	0.00739	-0.252	0.8008	8.292163
DDD05	-0.00631	0.009542	-0.661	0.5083	8.292163
DDD06	0.000829	0.006838	0.121	0.9035	9.93717
DDD08	0.002027	0.006035	0.336	0.737	9.910301
DDD09	0.002177	0.0105	0.207	0.8357	9.656682
DDD10	0.011904**	0.005727	2.079	0.0377	9.93717
DDD11	0.001691	0.006004	0.282	0.7782	9.93717
DDD12	0.009143	0.006296	1.452	0.1465	8.714047
DDD13	-.297979D-04	0.005936	-0.005	0.996	8.961451
DDD14	-0.00026	0.009382	-0.028	0.9777	8.961451
DDD15	0.005259	0.005899	0.892	0.3726	10.5665
DDD16	-0.009	0.010376	-0.868	0.3856	10.48006
DDD17	0.005387	0.006758	0.797	0.4253	8.072745
BWIDTH	0.002394	0.002572	0.931	0.352	129.5294
BLENGTH	0.025076	0.119415	0.21	0.8337	4.547059
BSPACES	0.000493	0.000452	1.091	0.2754	448.1765
BACCESS	0.017385	0.019619	0.886	0.3755	27.47059
INCOME	0.019647***	0.005355	3.669	0.0002	58.83318
FEMALE	-0.25952	0.240868	-1.077	0.2813	0.633552
MARRIED	-0.36621*	0.218787	-1.674	0.0942	0.715089
NUMKIDS	0.091765	0.100994	0.909	0.3635	0.940019
MINORITY	-0.65093**	0.287471	-2.264	0.0236	0.192127
AGE	0.038489	0.030273	1.271	0.2036	42.42737
AGESQ	-0.00046	0.000314	-1.462	0.1437	2022.382

Notes: ***,**, and * refer to significance at the 1%, 5%, and 10% levels, respectively. The chi-square and overall likelihood ratio statistics are 48.3 and 22373, respectively. Number of observations =699. Dependent variable: TRIPS.

Two tests of over-dispersion for the Poisson regression model results indicate that the data are not over-dispersed. Therefore, results of the Poisson version of the model in Table O-10 are retained, and the negative binomial regression model was not pursued. In general, the estimated coefficients in the regression results are of the anticipated signs and are statistically significant. Higher access prices ACCPRI reduce the number of expected beach TRIPS, while higher incomes INCOME increase expected TRIPS. Increases in beach width BWIDTH, beach length BLENGTH, the number of parking spaces BSPACES, or the number of beach accesses BACCESS increase expected TRIPS, while being MARRIED, having a larger number of children (NUMKIDS), being a member of a MINORITY group, or being older (AGE), decrease the number of expected TRIPS.

5.0 – CALCULATING PROJECT AVERAGE ANNUAL BENEFITS (AAB)

The average annual benefits (AAB) of recreation under baseline 2003 conditions at each of the project beaches are calculated using estimates of annual trips to each beach, based on the telephone survey data, and estimates of recreation value per trip (net willingness to pay,) based on the on site survey data.

Estimates of the number of day user recreation trips to each project beach during the 2003 baseline season are developed from the telephone survey data. These estimated trips account only for trips originating from the geographic "area of influence" identified using the on site survey data. The "area of influence" is the geographic area where seventy percent of the on site survey day trips originated or a 120-mile radius of the beaches under study. The area of influence corresponds roughly to the eastern half of North Carolina. A random sample of telephone households in the area was conducted in the spring of 2003. Of the 1876 households surveyed, 1,187 or 63% reported taking a trip to one or more of the beaches included in this study in 2003. Survey questions gathered information on each respondent's number of trips to each project beach in 2003. The 1,067 survey respondents who answered beach destination questions reported taking 9,002 trips to study area beaches in 2003. These trips were distributed across project area beaches as shown previously in Table O-8.

Based on the telephone survey trip data, a model was estimated to predict annual trips per beach trip-taking household for each beach. North Carolina state government projections of county household populations in the area of influence were used to project the number of households from 2004 through 2059. The number of households is multiplied by the 0.63 fraction of households taking a beach trip to a project beach in 2003 (assumed constant across years) and the number of trips to each beach per beach trip-taking household. For beach i in year t, the baseline predicted number of trips from all households in the area of influence is given by:

$$Baseline \circ \Pr edicted \circ Trips \circ in \circ Year_t \circ \Pr oject \circ Beach_i = \Pr ojected \circ Households \circ in \circ Area \circ of \circ \inf luence * 0.63 * Trips \circ per \circ Beach \circ Trip - taking \circ household \circ to \circ project \circ beach_i \Rightarrow\Rightarrow (7)$$

Estimates of recreation value per recreation trip, or net willingness to pay (WTP) per trip, are calculated for baseline 2003 conditions from the on-site survey data. These estimates are presented in Table O-11.

Table O-11. Baseline 2003/2004 WTP/trip values, Wald Test estimates

Beach	WTP	Std Error
Caswell	$48.82	$3.84
Oak Island	$40.45	$3.07
Holden	$49.71	$3.69
North Topsail Beach	$42.89	$3.97
Surf City	$47.23	$3.03
Topsail Beach	$46.17	$2.66
Pine Knoll Shores	$47.83	$3.28
Salter Path	$47.68	$3.12
Indian Beach	$47.98	$3.17
Emerald Isle	$46.71	$4.13
Atlantic Beach	$38.05	$4.30

Estimates of the annual recreation benefits (2004 year-dollars) of all beach trips taken to each beach in the baseline year are calculated by multiplying the estimated number of beach trips to each beach by the baseline WTP per trip. Annual recreation benefits in future years for each beach are calculated by multiplying estimated annual day trips to each beach (conditional on growth in the household population in the area of influence) by the WTP per trip for each beach (assumed to remain constant in real-dollar terms).

The net present value (NPV) (2004 dollars) of the annual recreation benefits occurring in each future year to each beach is calculated by discounting annual recreation benefits at the FY 2005 interest rate of 0.05375. For each project beach, present worth average annual benefits (PWAAB) are calculated by summing the annual NPV of recreation benefits across all project years and amortizing the accumulated NPV over the 50-year period of analysis. PWAAB are the average annual benefits of recreation expressed in current 2004 dollars, so that the amounts reflect what the recreation benefit due to nourishment is worth today. AAB for each project is calculated by multiplying the PWAAB for each project by the 50-year, 5 3/8% interest and amortization factor (.057981.) For the purpose of calculating AAB, zero benefits are assumed for years the project start year.

The recreation AAB for several alternative project scenarios were estimated. The project scenarios for each beach consider changes to beach widths and how those widths might increase or decrease a beachgoer's willingness to pay additional money for four alternative beach widths.

The four scenarios are:

1) Subtract 50 ft from the width of each beach
2) Add 50 ft to the width of each beach
3) Add 100 ft to the width of each beach
4) Add 150 ft to the width of each beach

Based on the results of the survey data analysis and modeling effort changes in both the estimated numbers of trips made to each beach and the beach-specific WTP per trip

resulting from the changes in beach widths are estimated. NPV, PWAAB, and AAB are re-calculated as outlined above for each beach under each of the four scenarios using the beach-specific estimates of changes in trips and changes in WTP per trip. A "project AAB" for each of the four scenarios for each beach is calculated by subtracting baseline AAB from the scenario AAB for each scenario for each beach. Table O-12 shows a summary of recreation visitors, WTP, NPV, and AAB, truncated from 2012 to 2020, of the with- and without- project conditions for North Topsail and Surf City. A complete set of results can be made available upon request.

Each of the models was used to develop a demand curve of benefits expressed in present worth, 2004 dollars at the then interest rate of 5.375%. These benefits were later updated to 2010 dollars based on the Consumer Price Index ratio of 1.16 and an up dated interest rate of 4.125%. The ratio of 1.16 was obtained through the Federal Reserve Bank of Minneapolis website by inflating 2003 WTP dollars to 2010 WTP dollars, then taking the 2010 WTP dollar amount and dividing by the 2003 WTP dollars. 1.16 was the resulting ratio. Based on survey data, a logit model and linear regression analysis were used to estimate benefits. The average annual net benefits will then be added to the coastal storm damage reduction benefits. Figure O-1 and Figure O-2 show the expected recreation AAB for Surf City and North Topsail Beach, respectively. The with-project condition selected alternative of 1550 plan for each beach would add an additional 65 feet and 73 feet and result in approximately $12,709,000 and $7,796,000 AAB for Surf City and North Topsail Beach, respectively. These recreation benefits for North Topsail Beach apply only to the portion of the town within the selected plan, roughly the southern 1/3 of the town.

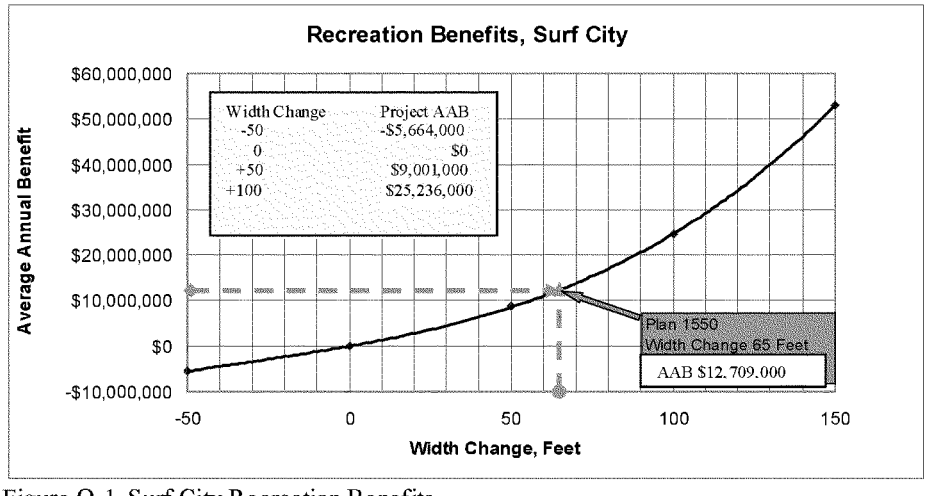


Figure O-1, Surf City Recreation Benefits

Table O-12. Recreation Visitors, WTP, and NPV of the With and Without Project Conditions at North Topsail and Surf City

North Topsail

Trip Estimates

	2004	2009	2014	2019	2024	2029	2034	2039	2044	2049	2054	2059	WTP per Trip Estimates
NC State Gov't projections of households in telephone survey area	1,670,551	1,696,934	1,820,259	1,952,670	2,078,075	2,210,320	2,338,273	2,466,227	2,594,181	2,722,134	2,850,088	2,978,042	
2003 Baseline Trips to this beach	546,609	592,755	635,833	682,086	725,891	772,085	816,780	861,476	906,171	950,866	995,562	1,040,257	$ 42.89
Trips w. -50 width	486,712	525,878	564,096	605,130	643,993	684,976	724,628	764,281	803,934	843,586	883,239	922,892	$ 39.54
Trips w. +50 width	618,375	668,136	716,693	768,827	818,203	870,272	920,651	971,031	1,021,410	1,071,790	1,122,169	1,172,548	$ 50.66
Trips w. +100 width	697,015	753,104	807,836	866,600	922,255	980,946	1,037,732	1,094,518	1,151,304	1,208,091	1,264,877	1,321,663	$ 65.96
Trips w. +150 width	785,655	848,878	910,570	976,807	1,039,540	1,105,694	1,169,702	1,233,710	1,297,718	1,361,725	1,425,733	1,489,741	$ 90.24
						NPV							
Yearly NPV(Baseline WTP)	$ -	$ -	$ 24,558,610.43	$ 20,277,367.80	$ 16,609,473.88	$ 13,597,587.36	$ 11,071,694.85	$ 8,988,018.14	$ 7,276,845.79	$ 5,877,120.13	$ 4,736,148.88	$ 3,808,990.65	
Yearly NPV(WTP w. -50 width)	$ -	$ -	$ 20,088,754.86	$ 16,586,731.24	$ 13,586,422.17	$ 11,122,722.10	$ 9,056,561.42	$ 7,352,129.86	$ 5,952,404.01	$ 4,807,439.16	$ 3,874,133.43	$ 3,115,725.12	
Yearly NPV(WTP w. +50 width)	$ -	$ -	$ 32,697,974.69	$ 26,997,816.55	$ 22,114,288.88	$ 18,104,182.58	$ 14,741,143.40	$ 11,966,881.85	$ 9,688,582.35	$ 7,824,951.08	$ 6,305,832.19	$ 5,071,389.54	
Yearly NPV(WTP w. +100 width)	$ -	$ -	$ 47,985,726.65	$ 39,620,492.01	$ 32,453,695.85	$ 26,568,690.11	$ 21,633,281.09	$ 17,561,929.35	$ 14,218,423.88	$ 11,483,462.42	$ 9,254,088.13	$ 7,442,488.85	
Yearly NPV(WTP w. +150 width)	$ -	$ -	$ 74,003,834.07	$ 61,102,926.25	$ 50,050,256.40	$ 40,974,370.32	$ 33,362,957.20	$ 27,084,097.64	$ 21,927,726.33	$ 17,709,854.72	$ 14,271,702.24	$ 11,477,844.53	

Surf City

Trip Estimates

NC State Gov't projections of households in telephone survey area	1570551.3	1696934.4	1820259.006	1952670.278	2078074.68	2210319.576	2338273.236	2466226.893	2594180.551	2722134.209	2850087.866	2978041.524	
2003 Baseline Trips to this beach	455564.78	492224.3	527996.6686	566404.7791	602780.4309	641140.2827	678255.3882	715370.4937	752485.5991	789600.7046	826715.8101	863830.9156	$ 47.23
Trips w. -50 width	404166.32	436689.8	468426.2021	502500.9726	534772.5937	568804.5502	601732.1972	634659.8442	667587.4911	700515.1381	733442.785	766370.432	$ 45.47
Trips w. +50 width	513499.61	554821.21	595142.8016	638435.3294	679436.9278	722675.0596	764510.1493	806345.2387	848180.3281	890015.4176	931850.507	973685.5964	$ 51.63
Trips w. +100 width	578802.13	625378.66	670828.0102	719626.1142	765841.9477	814578.7383	861734.0592	908889.3801	956044.701	1003200.022	1050355.343	1097510.664	$ 61.36
Trips w. +150 width	652409.27	704909.01	756138.2202	811142.0526	863235.2234	918189.9452	971322.0794	1024474.214	1077626.348	1130778.482	1183930.616	1237082.75	$ 79.29
						NPV							
Yearly NPV(Baseline WTP)	$ -	$ -	$ 22,460,050.70	$ 18,544,644.87	$ 15,190,176.44	$ 12,435,658.86	$ 10,125,606.59	$ 8,219,982.30	$ 6,655,031.48	$ 5,374,913.88	$ 4,331,439.85	$ 3,483,508.30	
Yearly NPV(WTP w. -50 width)	$ -	$ -	$ 19,180,967.79	$ 15,837,196.47	$ 12,972,467.82	$ 10,620,099.45	$ 8,647,306.12	$ 7,019,895.80	$ 5,683,421.91	$ 4,590,196.67	$ 3,699,065.93	$ 2,974,929.19	
Yearly NPV(WTP w. +50 width)	$ -	$ -	$ 27,671,248.26	$ 22,847,387.07	$ 18,714,612.40	$ 15,320,989.62	$ 12,474,957.32	$ 10,127,188.67	$ 8,199,136.80	$ 6,622,005.37	$ 5,336,423.72	$ 4,291,754.47	
Yearly NPV(WTP w. +100 width)	$ -	$ -	$ 37,071,517.34	$ 30,608,930.17	$ 25,072,200.26	$ 20,525,721.39	$ 16,712,856.32	$ 13,567,521.30	$ 10,984,486.10	$ 8,871,583.40	$ 7,149,273.60	$ 5,749,717.13	
Yearly NPV(WTP w. +150 width)	$ -	$ -	$ 53,994,310.11	$ 44,581,613.77	$ 36,517,419.66	$ 29,895,516.70	$ 24,342,115.24	$ 19,760,964.89	$ 15,996,798.85	$ 12,921,376.30	$ 10,412,848.55	$ 8,374,407.96	

***Notes: Total use over the life of the project is presented in 5 year intervals.
Annual dollar values decline over time because the NPV is declining over time.
Change in the number of trips is according to WTP from the Conditional Logit Regression Results

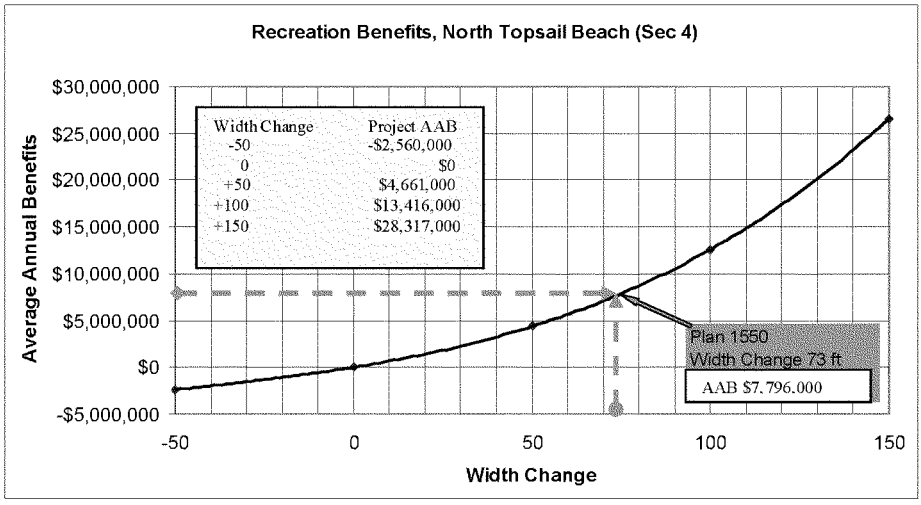


Figure O-2, North Topsail Beach Recreation Benefits

6.0 - PUBLIC BEACH ACCESS AND PARKING REQUIREMENT

The preceding sections focused on the valuation of beach improvement, emphasizing the use of contingent valuation and travel cost methods to determine the recreation value of visitation for Surf City and North Topsail Beach. The following sections will focus on the use of parking space counts, on-site field survey, telephone survey, and aerial photography to meet the objective of developing a method for determining parking space and distribution requirements to support anticipated visitation. Although beach trip demand and beach parking are simultaneously determined theoretically, existing variation in the number of parking spaces across beaches was found not to be a significant determinant of beach demand when other determinants of beach demand were controlled, whereas the index of beach demand was found to have a significant impact on filled parking spaces. As a result, a two-stage model was developed in which an index of beach demand is determined in the first stage, followed by estimation of filled parking spaces as a function of the beach demand index.

6.1 – Parking and Access

The Army Corps of Engineers has several requirements that must be met in order to fully cost share in a shore protection project (see ER 1105-2-100 and ER 1165-2-130). One of these requirements is that the beaches must be available for public use. As described in ER 1165-2-130 (Federal Participation in Shore Protection, paragraph 6.h.) public use implies reasonable access and parking. The Corps' Wilmington District, additionally, has developed more specific minimum parking requirements for participation in shore protection projects within the District's boundaries.

One objective of the recreation study was to predict public access and parking demand. ER1165-2-130 stipulates that in order to qualify for Federal cost sharing of Hurricane and Storm Damage Reduction projects, the local community must, at a minimum, provide public access and parking within a one quarter mile radius of any point of the project. Parking must satisfy the lesser of beach capacity or peak hour demand for that beach community. The peak demand hour had been previously identified as noon on the 4th of July holiday by USACE. The Wilmington District has further established a ten-space minimum for parking lots within one-quarter mile of each required public access point. Total beach visitation and the associated recreation benefit depend on day trip visitors having adequate available public parking. In areas where adequate parking is not provided, the recreation benefits for that portion of the project cannot be counted towards the justification of the project. It is required by guidance that an analysis be conducted to determine the peak hour demand for Surf City and North Topsail Beach. The analysis of the data will be used to determine additional parking needed to meet the Corps' requirements for peak hour demand over the 50-year life of the project.

Another objective of this study was to estimate peak and latent or potential demand of the beaches under study. Latent demand is the number of individuals who would come to the beach if conditions were more conducive to recreation. This demand is modeled from the stated preference of the respondent versus their revealed preference. The recommended methodology and data collected from survey instruments was used to develop a model to calculate the estimated number of trips taken to each beach in 2003 and the additional trips that the respondent would take if the width of the beach were increased. The model was used to predict a decrease in trips with a decrease in beach width, or erosion of the beach. The results for this study focused on the with-project and the without-project conditions in each study area. It was expected that an increase in beach width would generate latent demand for beach recreation, resulting in a future need for additional parking spaces. Econometric models were developed to analyze the data using the procedures in LIMDEP. The models recommended by UNCW were used to compute the number of trips taken to each beach community and the latent demand for those beach communities if the beach width were increased. The number of trips taken to each beach community and the increase in those trips derived from the latent demand was used to develop parking requirements for each beach community. For the purpose of this analysis, parking requirements for a beach are defined as the number of parking spaces that would accommodate all visitors to that beach on a specified percentage (e.g., 70%, 90%, etc.) of peak summer weekend days.

The data for this project was collected separately for Surf City and North Topsail, NC. Therefore, the information and analysis for this report are presented separately for each town.

6.2 Present Conditions

6.2.1. Access

Surf City has 33 public beach access points within the project limits and North Topsail has 22. The access points generally consist of small parking areas and wooden walkways to the beach. There are four regional access parking lots in North Topsail Beach and one vehicle cross-over in Surf City for beach maintenance and emergency access. Tables 12 and 13 list the existing and proposed public access locations. The column titled "Access Points" contains the name of the nearest cross street or other landmark. ER 1165-2-130 states that, "... public use is construed to be effectively limited to within one-quarter mile from available points of public access to any particular shore." Therefore the maximum distance between public access points is one half mile. Through most of the project length the public access sites surpass this definition. However, there are three portions within the project limits that do not meet the access distance requirements. Two of these in North Topsail Beach include a 1000-foot shoreline in the 3600 block of Island Drive and a 900-foot shoreline within the vicinity of Permuda Wynd. In Surf City, a 900-foot shoreline in the 1700 and 1800 blocks of South Shore Drive does not meet the access requirements. The shoreline length currently not meeting the access distance requirements is 2,800 feet: 1,900 feet in North Topsail Beach and 900 feet in Surf City. Additional access points will be necessary to meet the requirements for Federal Cost sharing.

6.2.2 Parking

There are a wide variety of public parking spaces throughout Surf City and North Topsail Beach. These are located at the access sites, on nearby street right-of-ways, and at 4 large parking lots. In 2003 and in 2008, parking space counts were administered on site visits by the Wilmington District and town officials. All right of way areas were considered eligible for parking with the exception of areas that met designated restrictions (e.g. driveways, fire hydrants, intersection, physical barriers). For North Topsail Beach, only the project reaches were included in the count. The combined total from the 2008 count was 1,992 spaces, with 785 at Surf City and 1,207 at North Topsail Beach. These numbers are included in Tables O-13 and O-14.

The Wilmington District requires a minimum of 10 spaces for within a quarter mile of each access point regardless of demand. Criteria for minimum parking requirements was established for Wilmington District projects in North Carolina based on using an average lot size along the shoreline area and determining how many parking spaces could be provided in that lot size (e.g. a 50' x 95' lot size can provide 8 spaces + 1 handicapped space or 10 spaces without a handicapped space.) Where the spacing of the accesses is less than one half mile, having a total sum of 10 parking spaces within one quarter mile of any point in the project provides the 10-space minimum parking requirement. For the project length of 52,150 feet the minimum number of accesses and parking spaces are computed as follows:

$$52{,}150.feet\_x\frac{1.access}{0.5.mile.(2640.feet)} = 19.8.accesses,.approximately.20$$

$$20.accesses\_x\frac{10.spaces}{access} = 200.spaces$$

The combined total of 1,992 spaces exceeds the minimum total of 200 spaces. However, the distribution of parking spaces is uneven with a large amount in the northern and central project reaches and few in the southern project reaches in both Surf City and North Topsail Beach. A total of 37 additional parking spaces are needed in the southern portion of the project limits in Surf City and a minimum of 20 in North Topsail Beach are needed to satisfy the 10-space minimum requirements.

Table O-13. Public Access Locations and Parking Availability Surf City, July 2008.

Access Points	Parking Spaces			Access Points	Parking Spaces		
	Lot	ROW	Total		Lot	ROW	Total
2111 N. Shore	8	0	8	Roland/Central	15	8	23
9th St.	0	10	10	Kinston	15	20	35
2001 N. Shore	9	9	18	High Point	8	3	11
5th St.	9	9	18	Raleigh	6	2	8
1719 N. Shore	5	28	33	Durham	9	8	17
Broadway	43	7	50	Charlotte	20	19	39
Pender	6	40	46	Quarterhorse	0	37	37
Lenior	8	32	40	1140 S. Shore	0	33	33
Jones	2	34	36	Windward	0	35	35
Craven	12	42	54	Oceanair Estates	0	39	39
Mecklenburg	0	11	11	Elizabeth St.	0	6	6
Dolphin	17	34	51	Roberts St.	0	1	1
508 N. Shore	15	5	20	Pirates Cove	0	0	0
Wilmington	10	16	26	Abigail Place	0	4	4
New Bern	12	15	27	Bland Shores	0	2	2
Goldsboro	10	12	22	Hispanola	0	6	6
Greensboro	6	13	19				
Total							785

Table O-14. Public Access Locations and Parking Availability North Topsail Beach, July 2008.

Access Points	Parking Spaces			Access Points	Parking Spaces		
	Lot	ROW	Total		Lot	ROW	Total
Myrtle	32	67	99	14th Ave	0	27	27
2nd Ave	0	39	39	15th Ave	0	34	34
4th Ave	0	32	32	18th Ave	0	41	41
5th Ave	0	19	19	20th Ave	0	13	13
6th Ave	0	23	23	21st Ave	12	51	63
7th Ave	0	15	15	OCBA #4	400	34	434
9th Ave	0	43	43	Chestnut St	12	30	42
10th Ave	0	27	27	Gray St	12	23	35
11th Ave	0	16	16	Green St	6	0	6
12th Ave	0	23	23	Reeves	0	83	83
13th Ave	0	22	22	Sea Shore Dr	6	65	71
Total							1207

Figure O-3, Surf City Public Access Locations and Parking Availability

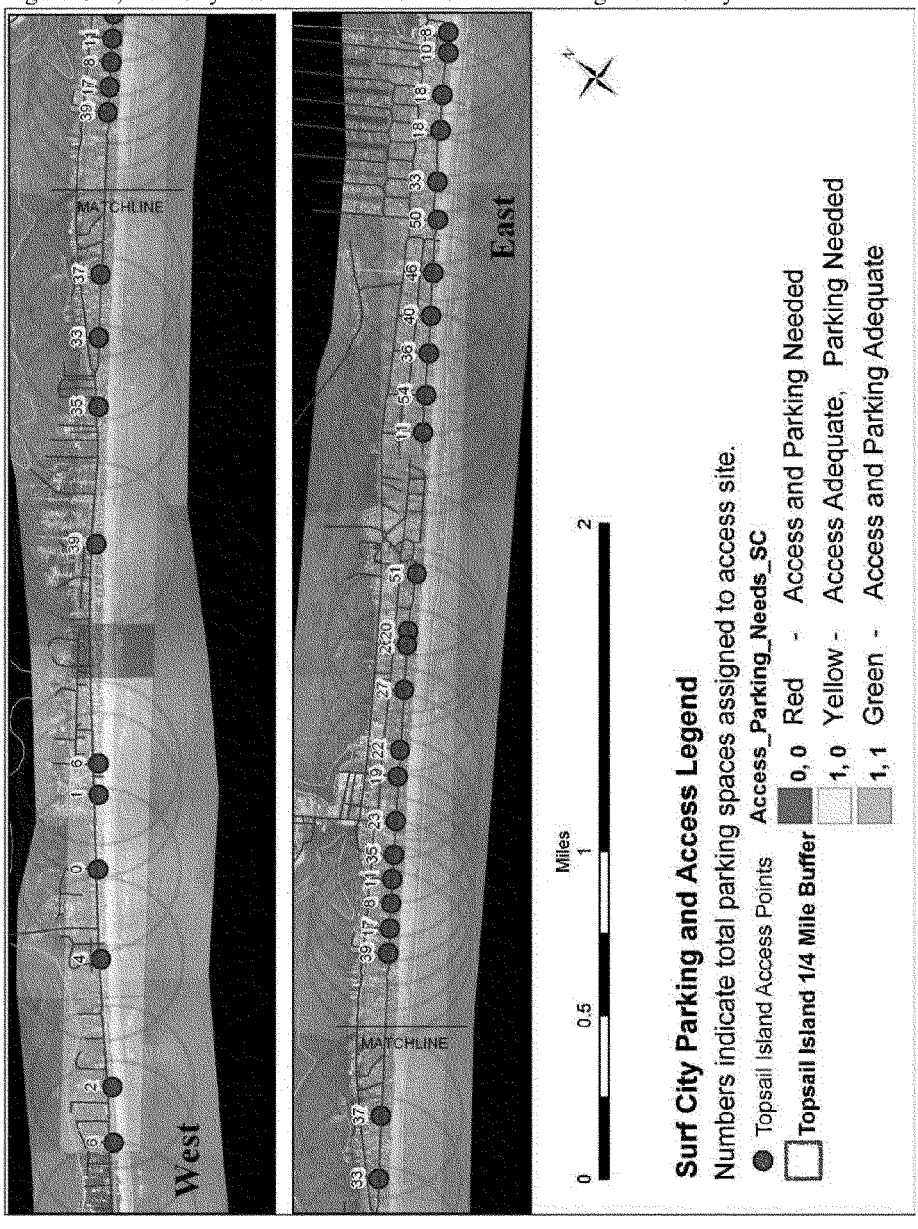
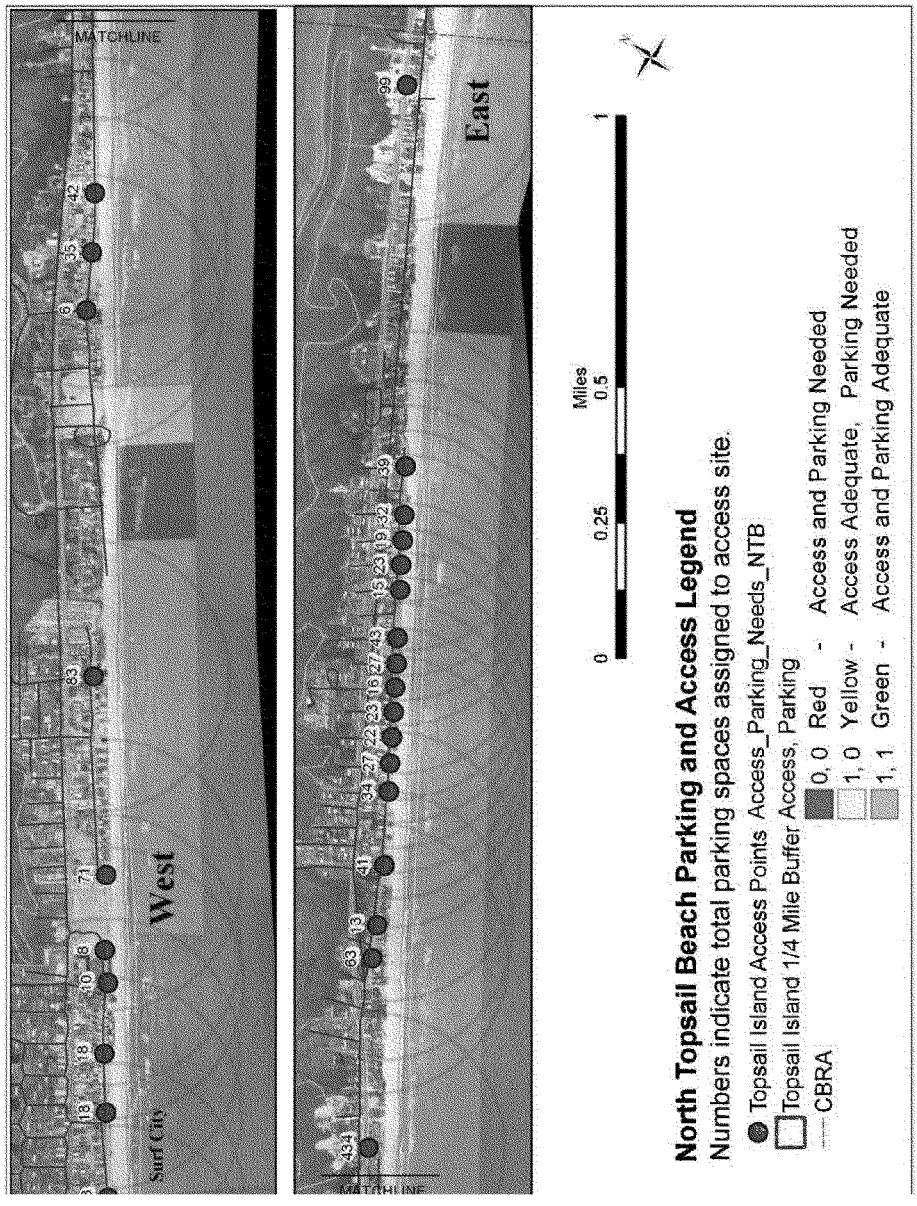


Figure O-4, North Topsail Public Access Locations and Parking Availability



6.2.3 - Map

Maps of the access locations are shown in Figures O-3 and O-4. The access points are labeled with the Access Point designation. The one-quarter mile radius circles centered on each existing and proposed access site show the project areas serviced by the accesses. Color coding illustrates the adequacy of beach access and parking availability for all stretches of beach within the project area.

6.3.0. With Project Condition

The sponsor is in the process of obtaining the additional public access sites and public parking for the project area to meet the definition of a public use shoreline. There will be no placement of material on private-use shores.

All project reaches will be eligible for cost sharing of 65% Federal and 35% non-Federal sponsor once the requirements have been met. These requirements will be affected if more, less, or different access sites are decided upon prior to signing the Project Cooperation Agreement (PCA). Once all access and/or parking sites are obtained, and prior to signing the PCA, the Corps will obtain specific measurements using GIS and or survey data of these sites to make a final determination on project cost sharing. The sponsor will be responsible for ensuring that the access and parking requirements are met throughout the life of the project.

6.4.0 On-Site Parking Lot Data

As part of the on-site filed survey effort in 2003, ancillary data were collected on the number of parking lots, parking spaces (SPACES), and filled parking spaces (FILLEDSP) at the beach, for several times each day, during peak (weekend) days of July and August, 2003. Two holidays (dummy HOLIDAY) were included in the survey effort: the Fourth of July weekend, and the Labor Day weekend. These holidays represent the "peak of the peak" days in terms of beach parking demand. Preliminary tests of significance of time of day dummy variables in the parking model described below indicated that hours could be pooled into three time periods, morning (dummy DMORN), midday (Dummy DMD) and afternoon (dummy DAFTN). The on-site survey of beach recreationist provided an estimate of average number of hours spent on the beach by each party of recreationists for each beach (STAYTIME). The STAYTIME variable provides an index of parking space turnover time. The duration of stay is assumed to affect parking demand. If the duration of stay is usually long, more parking spaces should be provided.

Descriptive statistics for the variables are presented in Table O-15.

Table O-15. Descriptive Statistics for variables in Tobit Regression
Mean Values across all Beaches. N=668

Variable	Mean	Std Dev.	Minimum	Maximum
SPACES	436.47	294.30	75.00	929.00
FILLEDSP	282.86	221.49	2.00	909.00
DMORN	0.38	0.49	0.00	1.00
DAFTN	0.21	0.41	0.00	1.00
STAYTIME	4.34	1.32	0.19	9.50
HOLIDAY	0.53	0.50	0.00	1.00
TRIPINDX	428.96	255.16	146.00	924.00

6.4.1 Tobit Parking Model

A censored regression model, or "Tobit" model, was used to estimate parking space demand for each beach. The dependent variable, $FILLEDSP_{idt}$, is the number of parking spaces that are filled at beach *i,* on day *d,* at hour *h.* When parking lots are full, the dependent variable is "censored," in the sense that some visitors may not be able to find parking spaces, and hence their visits will not be reflected in the value of the dependent variable. In effect the parking needs of these visitors are "censored" from the dependent variable values.

The Tobit regression model estimates an unconditional probability distribution of FILLEDSP, i.e., the number of FILLEDSP that would occur if the number of parking spaces were unconstrained. The resulting probability distributions can be used to estimate parking demand (and potential parking requirements) beyond current parking space capacity.

The independent variables used in the Tobit regression model are: $TRIPINDX_i$, an index of household demand for trips to beach i; $STAYTIME_{id}$, the average length of time in hours that a visitor remained at beach i on day d; DB_i, beach-specific dummy variables that shift the regression intercept, where i indicates beach 00-09 (the dummy for beach 10 is omitted to avoid the dummy variable trap; note that beach 08 is omitted from the entire analysis due to lack of sufficient survey data for beach 8); DMORN and DAFTN, dummy variables capturing time of day effects (if t=9am-11am, DMORN=1, DMORN=0 otherwise; if t=3pm-5pm, DAFTN=1, DAFTN=0 otherwise; and $HOLIDAY_d$, a dummy variable equal to 1 if the day is July 4 or 5, or August 30 or 31, days corresponding to the fourth of July and Labor Day holidays. Note that under this specification, with all dummy variables set to zero, the Tobit regression predicts uncensored FILLEDSP at midday on a non-holiday weekend day on beach 10 (Atlantic Beach, NC). Setting appropriate dummy variables to the value "1" adjusts the regression predictions for alternative time of day or beach destination.

The TRIPINDX variable can be any measure of relative recreation demand across beaches. Recall that TRIPINDX was developed via a separate Poisson regression using telephone survey data in section 4. Trips taken in 2003 by telephone survey household j

to each of the seventeen southeastern North Carolina beaches$_i$, (TRIPS$_{ij}$) are regressed on a list of explanatory variables measuring characteristics of the household and characteristics of the beaches. TRIPINDX$_i$ is formed by summing predicted values of TRIPS$_{ij}$ over the 1,067 households in the sample. The expected number of day trips to beach i, per household per year, denoted ETRIPS, is estimated by dividing TRIPINDX$_i$ by 1,067.

For this analysis the variable SPACES, which gives the existing number of parking spaces at each beach, is used as a censoring variable by the Tobit regression procedure. Each beach, i, has a separate censoring limit, as specified by the SPACESi variable. Each of these variables was used in a censored regression analysis to create a demand curve over a series of years using 2004 as the base year. Along the curve parking requirements will be expressed in percentage of demand met for that increment.

The Tobit regression model (with upper and lower tail censoring) is specified as:

$$Ln(FILLEDSP_{idt}) = \beta_o + \beta_1 DMORN + \beta_2 DAFTN + \beta_3 DB00 + ...\beta_{11} DB09$$
$$+ \beta_{12} STAYTIME_{id} + \beta_{13} HOLIDAY_d + \beta_{14} TRIPINDX_i + e_{idt} \Rightarrow\Rightarrow 8$$

$$\text{If } \ln(FILLEDSP_{idt}) \le 0, \text{ then } \ln(FILLEDSP_{idt}) = 0,$$
$$\text{If } \ln(FILLEDSP_{idt}) \ge \ln(SPACES_i), \text{ then } \ln(FILLEDSP_{idt}) = (SPACES_i),$$

where FILLEDSP, STAYTIME, SPACES, HOLIDAY, DMORN, DAFTN, DB00…DB9, and TRIPINDX are variables defined above, $\beta_0 - \beta_{14}$ are the parameters to be estimated, and e_{idt} is a heteroskedastic error term. The error term is specified as $e_{idt} \sim N(0, \sigma^2.\exp(\alpha.TRIPINDX_i))$, where σ (the standard deviation of the uncensored dependent variable in the absence of heteroskedasticity) and α are the parameters to be estimated. Parameter α allows testing for heteroskedasticity as a function of beach demand index TRIPINDX$_i$; Ho: $\alpha = 0$ is rejected, the null hypothesis of homoskedasticity is rejected in favor of heteroskedasticity as a function of the beach demand index TIPINDX$_i$.

6.4.2. Tobit Parking Model Results

Tobit regression results are presented in Table O-16. The Tobit regression is estimated using LIMDEP.

Table O-16 Tobit Regression Results - Dependent Variable: FILLEDSP,

Explanatory Variables	Coefficient	Std. Error.	t-ratio	P-value	Mean
Constant	4.557***	0.506	9.00	0	1
DMORN	-0.666	0.488	-1.36	0.1727	0.3772
DAFTN	-0.307	0.490	-0.63	0.5311	0.2111
DB00	-0.518	0.567	-0.92	0.3601	0.0329
DB01	0.699	0.512	1.37	0.1723	0.0449
DB02	-0.379	0.527	-0.719	0.4722	0.0404
DB03	0.166	0.595	0.279	0.7803	0.0449
DB04	-0.706	0.564	-1.252	0.2105	0.0404
DB05	-0.101	0.543	-0.186	0.8521	0.0404
DB06	-0.262	0.5577	-0.47	0.6383	0.0389
DB07	-0.946*	0.5378	-1.76	0.0785	0.0404
DB09	-1.271**	0.5544	-2.293	0.0218	0.0434
STAYTIME	0.008	0.0206	0.362	0.7175	4.339
HOLIDAY	0.364***	0.0536	6.78	0	0.5329
TRIPINDX	0.003***	0.00018	12.6	0	428.656
Sigma σ	0.451***	0.0161	28.023	0	----
Alpha α	0.0007***	0.000067	10.992	0	----
Log-likelihood	-623.66				

Notes: ***, **, and * refer to significance at the 1%, 5%, and 10% levels, respectively. The chi-square and overall likelihood ratio statistics are 29.1 and 546.7, respectively. Number of observations =699. Dependent variable: FILLEDSP. D13 is the omitted time of day dummy variable.

A likelihood ratio test indicates that the overall regression is significant at the $p<0.01$ level. The negative coefficient on DMORN and DAFTN indicate that the number of filled spaces is lower in the morning and afternoon, but the effect is not significant for this sample. Beach specific fixed effect dummy variables $DB_{00}...DB_{09}$ vary in sign, reflecting differences in the estimated value of ln(FILLEDSP) at midday across beaches. However, after controlling for other variables in the regression, only beach dummy DB_{09} is statistically significant. STAYTIME has a positive but insignificant effect on ln(FILLEDSP). HOLIDAY has a positive and strongly significant on filled spaces. TRIPINDX, a beach-specific index of recreation demand, is positive and strongly significant. The heteroskedasticity parameter α is positive and strongly significant, indicating that larger values of TRIPINDX increase the variance of ln(FILLEDSP).

With the estimated Tobit coefficients, it is possible to calculate the number of spaces that would be necessary to accommodate all peak (weekend holiday) day beach visitors 60% of the time, 95% of the time, etc. For each beach, ln(FILLEDSP) follows a normal distribution, with a beach-specific, unconditional mean values $\overline{u_i}$ given by the Tobit regression equation (9) (with variables replaced by their mean values):

$$\overline{\mu} = \beta_0 + \beta_1 \text{ DMORN} + \beta_2 \text{ DAFTN} + \beta_3 \text{ DB00} + \ldots + \beta_{11} \text{ DB09} + \beta_{12} \text{ STAYTIME}_{id} + \beta_{13} \text{ HOLIDAY}_d + \beta_{14} \text{ TRIPINDX}_i, \quad (9)$$

and a beach-specific standard deviation SD_i given by:

$$SD_i = (\sigma^2 \cdot \exp[\alpha \cdot \text{TRIPINDX}_i])^{0.5}. \quad (10)$$

The unconditional 90 percentile, for example, of $FILLEDSP_i$ is then given by:

$$FILLEDSP_{i,90\,percentile} = EXP(NORMINV(0.90, \overline{u_i}, SD_i)), \quad (11)$$

where NORMINV is the inverse normal cumulative distribution function.

6.5 PARKING DEMAND DISCUSSION AND CONCLUSION

For each beach, the frequency of FILLEDSP can be graphed against FILLEDSP to determine the number of spaces that would be necessary to accommodate all peak (weekend holiday) day beach visitors 60% of the time, 95% of the time, etc. Figure O-5 shows the estimated frequency of (latent, uncensored) filled parking spaces at North Topsail Beach on peak, summer weekend holidays in base year 2004.

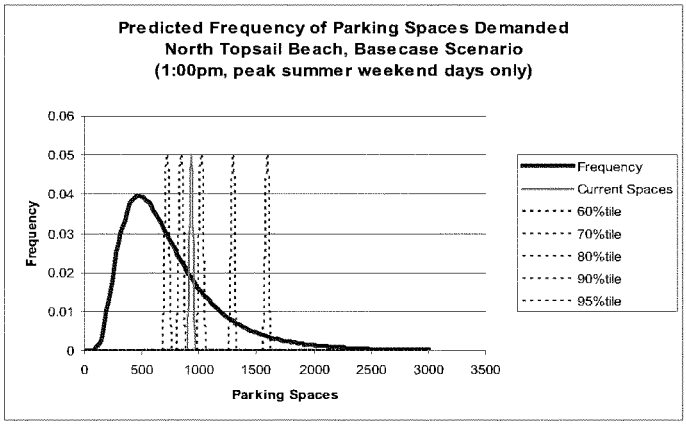


Figure O-5

The current, existing number of parking spaces at North Topsail Beach is 905, indicated by the solid indicator spike, which are used solely to designate particular values of parking spaces. Sixty-three percent of the frequency distribution of FILLEDSP occurs to the left of 905 spaces, suggesting that the existing spaces (summer 2004) fully accommodate all North Topsail Beach visitors on 75% of peak (summer holiday weekend) days. Note that 25% of the frequency distribution of FILLEDSP lies to the right of 905 spaces, indicating that the existing spaces do not accommodate all North Topsail Beach visitors 25% of peak days. Providing additional parking spaces would accommodate additional visitors. The remaining, dashed indicator spikes on the graph mark the numbers of parking spaces that would be required to accommodate all Topsail Beach visitors on 60%, 70%, etc., of peak days. Again, the spikes are used solely to designate particular values of parking spaces.

Similarly 68 percent of the frequency distribution of FILLEDSP for Surf City occurs to the left of 245 spaces, suggesting that the existing spaces (2004) fully accommodate all Surf City visitors on 68% of peak day.

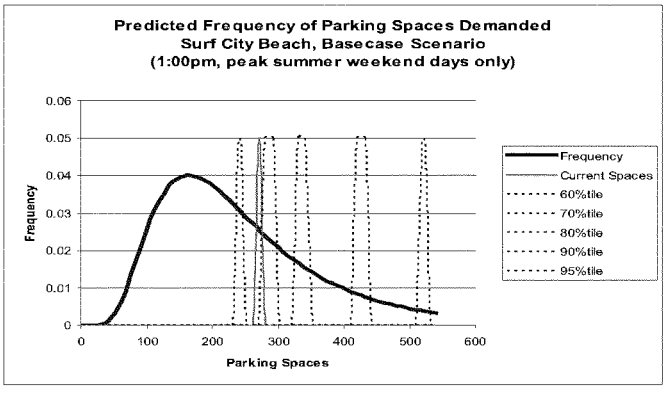


Figure O-6

Furthermore, changes in beach conditions may shift the cumulative frequency distribution of FILLEDSP and the associated number of parking spaces needed to meet a given accommodation policy target. Figure O-7 shows the predicted frequency of FILLEDSP at North Topsail Beach with a 73 ft increase in beach width. The increase in beach width attracts additional beach visitation, which shifts the frequency distribution to the right. As the distribution shifts to the right, the current number of parking spaces accommodates all visitors less frequently. In this example, the current number of spaces (905) would accommodate all North Topsail Beach visitors on only 60% of peak days with a 73 ft increase in beach width. The indicator spikes mark the number of parking spaces that would be required to accommodate parking demand on 60%, 70%, etc., of peak days

In this example, the current number of spaces (905) would accommodate all North Topsail Beach visitors on only 60% of peak days with a 73 ft increase in beach width.

The indicator spikes mark the number of parking spaces that would be required to accommodate parking demand on 60%, 70%, etc., of peak days. The same argument can also be made of Surf City. The current number of spaces (245) would accommodate all Surf City visitors on only 53% of peak days with a 65 ft increase in beach width. See Figure O-8.

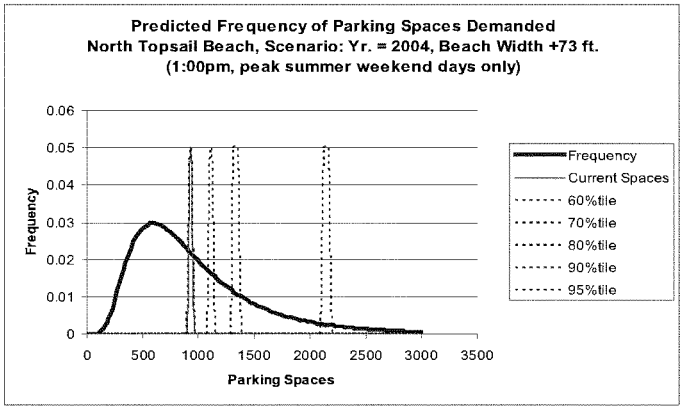


Figure O-7

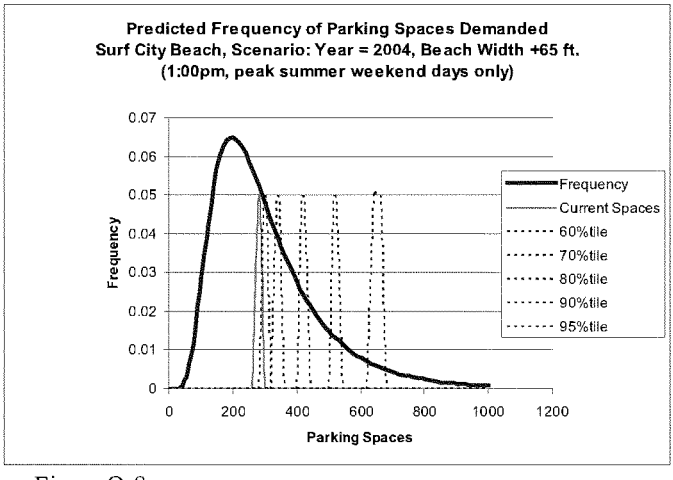


Figure O-8

As state population increases, the number of visitors to North Topsail Beach and Surf City is expected to increase, assuming that the number of trips per household remains roughly constant. Tables O-17 and O-18 show the predicted frequency of filled parking

spaces at Surf City and North Topsail Beach under +65 and +73 beach width conditions from the base year 2004 through 2024, based on projected increases in population of the telephone survey region. Under the assumption that an increase in projected population in the telephone survey region results in a proportional increase in the $TRIPINDX_i$ value for North Topsail Beach and Surf City, the cumulative frequency distribution of FILLEDSP for North Topsail Beach and Surf City shifts to the right. As the curve shifts to the right, the current number of parking spaces accommodates all North Topsail Beach visitors less frequently. It is estimated that by 2008, 707 and 2,403 parking spaces would be required to accommodate peak demand on ninety five percent of peak days for Surf City and North Topsail Beach, respectively. For recreation benefit estimates, however, peak parking demand for North Topsail Beach was only considered for areas within the project reach, or roughly the southern 1/3 of the town. Thus, parking demand for North Topsail Beach was determined to be 801 spaces by multiplying the total number of spaces (2403) by 33%.

Table O-17. Projected Surf City Beach Parking Peak Day Demand, 65 foot width increase.

Year	Pop. Index*	TRIP-INDX	FILLEDSP					
			Mean	Percentile				
				60%	70%	80%	90%	95%
2004	1.000	572	257	296	344	411	525	643
2005	1.015	581	262	302	351	419	537	658
2006	1.031	590	267	308	359	429	549	674
2007	1.047	599	273	315	367	439	562	690
2008	1.064	608	279	322	375	449	576	707
2009	1.080	618	285	329	384	459	590	725
2010	1.097	627	291	336	392	470	604	744
2011	1.112	636	297	343	400	480	618	761
2012	1.127	645	302	350	409	490	632	778
2013	1.143	654	309	357	418	501	646	796
2014	1.159	663	315	365	427	513	661	816
2015	1.175	672	322	373	436	525	677	836
2016	1.192	682	329	381	446	537	694	857
2017	1.209	691	336	390	456	550	711	879
2018	1.226	701	343	399	467	563	729	902
2019	1.243	711	351	408	479	577	748	926
2020	1.261	721	359	417	490	591	767	950
2021	1.276	730	367	426	500	604	784	972
2022	1.291	739	374	435	511	617	802	995
2023	1.307	748	382	444	522	631	820	1019
2024	1.323	757	390	454	534	645	840	1044

Table O-18. Projected North Topsail Beach Parking Peak Day Demand for Entire Town, 73 foot width increase

Year	Pop. Index*	TRIP-INDX	FILLEDSP					
			Mean	Percentile				
				60%	70%	80%	90%	95%
2004	1.000	702	814	944	1107	1334	1726	2137
2005	1.015	713	834	968	1136	1369	1774	2198
2006	1.031	724	855	993	1166	1406	1825	2262
2007	1.047	735	877	1020	1198	1446	1878	2331
2008	1.064	747	900	1047	1231	1488	1935	2403
2009	1.080	758	925	1076	1266	1532	1994	2479
2010	1.097	770	949	1106	1302	1576	2054	2556
2011	1.112	781	972	1133	1335	1617	2110	2628
2012	1.127	791	996	1162	1369	1660	2168	2703
2013	1.143	802	1021	1192	1406	1705	2230	2782
2014	1.159	814	1047	1223	1444	1753	2295	2867
2015	1.175	825	1075	1256	1484	1804	2364	2955
2016	1.192	837	1104	1291	1526	1856	2435	3047
2017	1.209	848	1133	1326	1569	1910	2509	3143
2018	1.226	860	1164	1363	1614	1967	2587	3244
2019	1.243	873	1198	1403	1663	2028	2671	3352
2020	1.261	885	1231	1443	1712	2089	2755	3462
2021	1.276	896	1261	1480	1756	2145	2832	3562
2022	1.291	906	1292	1517	1802	2203	2911	3665
2023	1.307	917	1325	1557	1850	2263	2995	3774
2024	1.323	929	1359	1598	1901	2328	3084	3890

* Telephone Survey Region Population Index (2004 Base Year)

7.0 LIMITATIONS

As in every application of the travel cost method, assumptions and simplifications based on professional judgment have been necessary to use in some aspects of the analysis. Although the focus of this study was on the estimation of recreation benefits and peak parking demand, there are several qualifications to our results and further research would be necessary to address those limitations.

A bias frequently encountered in using onsite surveys is the avidity bias - when avid users are more likely to be included in the sample than occasional users. This is the problem of endogenous stratification and causes bias and inconsistency in the estimates of the parameters (Shaw 1988). Due to time constraints, endogenous stratification due to oversampling of avid users was not considered in the analysis. Not including this analysis could potentially result in an overestimation of benefits.

One important site characteristic that was not considered in this study is beach congestion (i.e., number of persons per unit area), as this can impact the quality of recreational experience. McConnell and Duff (1976) demonstrated that estimates of net benefits may be biased downward if there is excess demand for the recreation site. Ideally, quality differences in the beach sites in demand estimation should be accounted for. Unfortunately, due to limits on the amount of data collected, the effect of congestion on net benefits was not examined. Not properly accounting for congestion issues could also potentially result in an overestimation of benefits.

Finally, overnight users were not considered in the study survey. This group of recreationists was left out of the sample because they were outside the target population, as they would not be expected to utilize public parking. The goal of this study was to develop a method for estimating peak day trip demand for beach parking spaces. Leaving out overnight users from the sample results in an underestimation of benefits.

It should also be noted that because a life-cycle analysis was not conducted on the recreation benefits, the projected recreation benefits are based on the assumption that the difference in beach width in the with- and without project conditions is relatively constant throughout the economic period of analysis. In reality, this difference in width can vary to some degree at various points in the analysis period, particularly immediately after the beach is renourished.

8.0 SUMMARY & CONCLUSIONS

The purpose of this analysis was to improve the recreation benefit analysis for Hurricane and Storm Damage Reduction projects and establish a baseline parking and access requirement and determine future parking needs for Surf City and North Topsail Beach. As previously stated, recreation benefits are included as incidental benefits in the total benefit accounting, but are not included in the formulation of the project with respect to size and scope. However, with respect to Surf City and North Topsail Beach, the project selected alternative is justified on HSDR benefits alone. Therefore, by improving the methodology for calculating recreation benefits more accurately, the added benefit of providing sand for recreation will increase the total net benefit of the selected plan and increases the project's benefit cost ratio.

This study analyzed the demand for beach parking in Surf City and North Topsail Beach using a Tobit regression estimation approach. The study employed data collected through telephone and onsite surveys conducted by the University of North Carolina at Wilmington. The Tobit model provides a framework for estimating peak demand for beach parking spaces. The framework is especially useful for those beaches where current parking capacity constraints parking on peak days.

The analyses show that an increase in beach width will attract additional visitation and will shift the frequency distribution of filled parking spaces (FILLEDSP) to the right. Furthermore an increase in projected population in the telephone survey region increases the trip index value for Surf City and North Topsail Beach, which in turn shifts the predicted frequency distribution of FILLEDSP to the right. It is estimated that by 2008, 707and 801 parking spaces would be required to accommodate peak demand on ninety five percent of peak days for Surf City and North Topsail Beach, respectively, with parking demand for North Topsail Beach projected for only the project reaches of the island (NT4).

REFERENCES

AAA. 2005. Personal communication. American Automobile Association, Heathrow, FL

Bin, O., C. Landry, C. Ellis, H. Vogelsong. 2005. Some Consumer Surplus Estimates for North Carolina Beaches. Department of Economics, East Carolina University. Greenville, NC. (In Press).

Greene, W.H. 2003. Econometric Analysis, 5th Edition, Prentice Hall. Upper Saddle River, New Jersey.

Haab, Timothy C., and Kenneth E. McConnell. 2002. Valuing Environmental and Natural Resources—The Econometrics of Non-Market Valuation. Edward Elgar publishers. Northampton, MA. USA.

LIMDEP. 2002. LIMDEP Version 8.0 Reference Guide and Econometric Modeling Guide Volumes 1 and 2. Econometric Software, Inc. Plainview, NY.

McCollough, B., and Vinod, H. 1999. The Numerical Reliability of Econometric Software. Journal of Economic Literature.

McConnell, K. E. & Duff, Virginia A., 1976. "Estimating net benefits of recreation under conditions of excess demand," Journal of Environmental Economics and Management, Elsevier, vol. 2(3), pages 224-230.

McDonald, John F., and Robert A. Moffitt. 1980. The Uses of Tobit Analysis. *Review of Economics and Statistics*. 62(2):318-321.

NCSD. 2005. Personal communication. North Carolina State Demographics, Raleigh, NC

NCSDC. 2004. Personal communication. North Carolina State Data Center, Raleigh, NC.

NWS. 2005. Personal communication. National Weather Service, 533 Roberts Road, Newport, NC 28570.

Parsons, G.R., M. Massey and T. Tomasi. 1999. Familiar and Favorite Sites in Random Utility Models of Recreation Demand. *Marine Resource Economics*. 14:299-315.

PCMiler. Routing, Mileage and Mapping Software, Version 18. User's Guide. ALK Technologies, Inc., Princeton, NJ. 2005.

Shaw, D. 1988. On-site Samples' Regression: Problems of Non-Negative Integers, Truncation, Endogenous Stratification. Journal of Econometrics 37:211-223.

USACE. 2005. Project data beach widths, lengths, (hurricane season 2002 was nothing significant), parking and access points. In House Data, Wilmington District.

US Army Corps of Engineers. 2005, In House Data, Wilmington District.

US Census Bureau. 2005. Personal Communication. US Census Bureau, 901 Center Park Drive, Suite 106 Charlotte, NC 28217.

---

[i][i] McCullouch and Vinod (1999) have been documented the performance of LIMDEP relative to the National Institute of Standards and Technology, NIST, benchmarks for testing statistical software

[ii][ii] Household income is not included as an independent variable in the binomial probit model because income effects "fall out" of this model specification. However, a varying parameters version of the binomial probit model was also estimated (Haab and McConnel 2002, Chapter 2, pp.48-49). The varying parameters model allows estimation of WTP by household income category. These estimates are available upon request.

Feasibility Report
and
Environmental Impact Statement

on

Coastal Storm Damage Reduction

SURF CITY AND NORTH TOPSAIL BEACH, NORTH CAROLINA

Appendix P

Nonstructural Alternatives

APPENDIX P

NONSTRUCTURAL ALTERNATIVES

1. GENERAL. The nonstructural alternative that would avoid or delay damage due to erosion involves removal of structures from the hazard area. For this alternative, it is assumed that the first row of structures will be removed to avoid loss. As shown on Table P-2, the first cost of this alternative is around $520 million. It would require relocation of 289 structures and demolition of 615 structures. The economic analysis of nonstructural measures was conducted at October 2004 price levels with an FY 2005 interest rate of 5.375%

2. EXISTING CONDITIONS.

2.1. ZONING RESTRICTIONS. Zoning presently requires new structures to be located 60 feet landward of the existing oceanfront vegetation line and 15 feet from the street right-of-way. These regulations preclude future development between the strand and the first roadway in some locations. In some areas septic tanks with drain fields are used and zoning requires these to be within the setback as well.

2.2. AVAILABILITY OF REAL ESTATE. An estimate of vacant lots in each reach that may be available for relocation of structures was made based on review of existing aerial photography from May 2003. Due to the current rate of construction on Topsail Island and uncertainty of lot availability, this alternative was developed assuming only one third of these lots would be available as destinations at the estimated year of project construction.

2.3. DEVELOPMENT. The rate and intensity of new construction implies that any suitable ocean front lot will soon be developed before the shore projection project construction begins. The structure file for the without project condition includes structures assumed to be constructed in the near future on these suitable lots. The analysis of the nonstructural alternative includes both costs and benefits for removal of these potential structures.

3. MEASURES. This alternative involves use of one of three different measures on each structure selected.

3.1. RETREAT. Retreat is the relocation of a structure away from the hazard on the same lot. The ideal situation would be to have relatively deep beachfront lots that would allow the structures to be moved back over time as the coastline eroded. Work would include moving the structure to a newly constructed foundation and may also include replacement of the septic system etc. Costs for this measure are lower than for relocation due to the short distance of the move and the lack of associated real estate costs. Where space allows, retreat will be

considered; however, very few existing lots are deep enough to allow retreat. Approximately 125 structures could be moved back on their existing lots.

3.2. RELOCATION. Where retreat is not an option, this measure proposes relocating the structure to another lot. There are about 741 structures that could be relocated; however, it is estimated that only 164 lots would be available in the project reaches. It was assumed that there were four basic types of structures and that relocation of all of these structures would include new site preparation (utilities, new foundation, driveways etc.) and restoration of the existing site by demolition and removal of the foundation, driveways, septic system and utility connections. No attempt has been made to site each building. The selection of which structures would be relocated and which would be demolished was based on the value of the structures, estimated relocation cost and their proximity to suitable relocation sites. Relocation off the island is not considered practical.

3.3. DEMOLITION. When the estimated cost of relocation was greater than the value of the structure or when real estate is not available for relocation, it was assumed that the structure would be demolished and payments equaling the market value of the structure and lot would be made to the owner. Demolition would include removal and disposal of structures, utility connections, septic system etc. and restoration of the site. This measure would be applied to 615 structures. Costs for this plan include not only property acquisition of the structure and oceanfront lot, but also for demolition costs. Demolition would include removal and disposal of structures, utility connections, septic system etc. and restoration of the site. In this analysis the costs for acquisition of oceanfront lots is the roughly estimated market price of $500,000 per lot. Costs for acquisition of the structure were set to the structure value shown in the structure file.

4 COST. Development of typical cost for the various measures is included in Table P-1. Cost includes construction, real estate, engineering, relocation assistance, construction management and a contingency.

4.1. STRUCTURE MOVE COST. The cost of moving a structure can vary greatly depending on site conditions, structure size, structure relocation type and haul distance. Costs used represent a move of a few blocks. Costs developed for each structure relocation type are as follows:

STRUCTURE RELOCATION TYPE I

These structures are on piles without a closed-in ground floor. They may be one or two story buildings and are typically in the 1500 to 2500 square foot range.

$92,000 / structure

STRUCTURE RELOCATION TYPE II .

These are similar to structure relocation type I; however, the ground floor has been improved. The ground floor may be either utility/ storage space, garage space or heated living space. For the purpose of this comparison, it is assumed that the ground floor at the new site will be developed as garage space with breakaway walls.

$107,000 / structure

STRUCTURE RELOCATION TYPE III

These slab on grade structures are typically the older structures. They may be one or two story, of wood or masonry construction and are typically 1000 to 2000 square feet. Moving cost for these structures is typically more than for structures on piles and in most cases relocation could not be justified.

$133,000 /structure

STRUCTURE RELOCATION TYPE IV .

This includes motels, condominiums and commercial structures. Cost of relocating these will be approximated for each structure using the cost per square foot for structure relocation type III..

4.2. RETREAT COST. For this analysis the cost of retreat was assumed to be the same as for relocation of a similar structure relocation type without the real estate cost.

4.3. DEMOLITION COST. Cost of structural demolition includes removal and disposal of the structure, foundations, paved areas, utilities, and septic systems and grading and planting as needed to restore the site. A cost of $18,000 / structure was used for a typical structure demolition in this analysis.

4.4. REAL ESTATE COST. Land Cost varies based on proximity to water. Although the lot that the structure is being relocated to may be several rows back, the cost of a typical first row lot is used. A typical cost for a 65-foot wide beach front lot would be $500,000.

4.5 TOTAL COST. Total costs presented by reach and by type of structure is shown in Table P-2. The total first cost for this nonstructural plan is estimated to be $520,000,000. This is for practical purposes a present value cost.

5. BENEFITS. As with the beachfill alternatives, benefits were defined as the reduction in storm and erosion damages from the without project condition to the after removal condition. Damages with the nonstructural plan were computed by applying the without project GRANDUC storm and erosion analysis to a modified structure file. The structure file was modified to represent conditions with the nonstructural plan. For demolished or relocated structures, the structure values were set to zero. For the retreat measure the distance from the structure to the seaward reference line was increased. The only residual damages come from the retreated structures, the remaining second or third row structures and from land losses. Benefits estimated from the GRANDUC analysis are estimated to have an effective present value of $135,000,000.

6. TIMING. If this alternative were chosen, the question of whether the first row structures should be relocated or demolished in the base year or as they become threatened by the retreating shoreline would have to be addressed. It would be reasonable to relocate structures as they become threatened; however, by that time, vacant lots may no longer be available on the island. One possibility would be to purchase lots now for a relocation that may not occur for several years. Likewise, structures that would be demolished could be demolished as they become more threatened, allowing several years of use by the current owners. For this analysis, it was assumed that all costs are incurred at the beginning. The present worth of benefits is computed assuming that annual benefits all start in the first project year, not phased in beginning at some future date.

7. PROCUREMENT OPTIONS. The actions that would be taken to achieve this alternative could include purchase of available interior lots by the Government or sponsor and moving of the structures by a Government contract with the property owner retaining possession of the structure and the new lot but giving up ownership of the old lot. A more likely action would involve Government purchase of the beachfront structure and lot, with or without salvage rights, and payment of damages to the property owner in the form of a buy-out. This would be similar to the hazard mitigation buy-outs of homes in inland river floodplains. If the property owner retains salvage rights they would be responsible for locating suitable real estate and relocating the building. If the Government retained salvage rights the Government could surplus the structures as part of the demolition contract.

8. DISCUSSION

Except for where retreat only is the nonstructural measure, implementation of the nonstructural alternative would result in an undeveloped strip between the beach

and the first roadway. This area could be used for parks, day-use parking, or other public uses until the erosion takes the existing land.

Assuming there is no beach or dune nourishment the dune will eventually fail leaving the roadway and the structures beyond the roadway with no protection against storm surge. Although not reflected in the cost of this alternative, there will likely be attempts to repair the dune as it fails and possibly use of sandbags etc. to protect the roadway. This alternative also would result in a reduction in the tax base and growth potential of the community.

This nonstructural alternative does not reduce damages to the second-row structures and does noting to prevent loss of the beach for recreation and habitat.

Overall the nonstructural plan has net present value benefits of -$385,000,000 with a benefit to cost ratio of 0.3 to 1.

Table P-1 Nonstructural costs

STRUCTURE RELOCATION TYPE	DESCRIPTION	CONSTRUCTION COST	E&D (15%)	S&I (15%)	SUBTOTAL	CONTENGENCY (20%)	TOTAL	HOUSING DIFFERENTIAL & MOVING	TOTAL (ROUNDED)
I	RELOCATE BLDG OPEN ON PILES	$ 56,929	$ 8,539	$ 8,539	$ 74,008	$ 14,802	$ 88,810	$ 3,000	$ 92,000
II	RELOCATE CLOSE IN FOR GARAGE	$ 66,757	$ 10,014	$ 10,014	$ 86,785	$ 17,357	$ 104,142	$ 3,000	$ 107,000
III	RELOCATE SLAB ON GRADE	$ 83,447	$ 12,517	$ 12,517	$ 108,481	$ 21,696	$ 130,177	$ 3,000	$ 133,000
I - III	DEMOLITION & DISPOSAL	$ 9600	$ 1,440	$ 1440	$ 12480	$ 2,500	$ 14980	$ 3,000	$ 18,000

1019

Table P-2, Nonstructural Summary

REACH	STRUCTURES				COST				TOTAL
					CONSTRUCTION		ACQUISITION		
	RELOCATIONS	RETREATS	DEMOLITIONS	TOTALS	REMOVAL - RELOCATION OR RETREAT	DEMOLITION	STRUCTURE	LANDS	
27	2	5	7	14	$847,000	$126,000	$589,000	$4,500,000	$6,062,000
28	1	8	3	12	$1,055,000	$54,000	$245,000	$2,000,000	$3,354,000
29	1	0	11	12	$121,000	$198,000	$1,787,000	$6,000,000	$8,106,000
30	4	0	13	17	$484,000	$234,000	$2,158,000	$8,500,000	$11,376,000
31	4	0	14	18	$467,000	$252,000	$1,765,000	$9,000,000	$11,484,000
32	5	0	24	29	$571,000	$432,000	$5,051,000	$14,500,000	$20,554,000
33	8	0	6	14	$951,000	$108,000	$551,000	$7,000,000	$8,610,000
34	6	0	6	12	$709,000	$108,000	$714,000	$6,000,000	$7,531,000
35	6	0	9	15	$726,000	$162,000	$1,014,000	$7,500,000	$9,402,000
36	7	0	6	13	$847,000	$108,000	$757,000	$6,500,000	$8,212,000
37	6	0	11	17	$692,000	$198,000	$1,561,000	$8,500,000	$10,951,000
38	5	0	13	18	$588,000	$234,000	$1,780,000	$9,000,000	$11,602,000
39	2	5	10	17	$860,000	$180,000	$2,446,000	$6,000,000	$9,486,000
40	2	8	9	19	$1,223,000	$162,000	$1,485,000	$5,500,000	$8,370,000
41	4	15	1	20	$2,299,000	$18,000	$120,000	$2,500,000	$4,937,000
42	2	11	1	14	$1,573,000	$18,000	$101,000	$1,500,000	$3,192,000
43	3	3	11	17	$726,000	$198,000	$2,029,000	$7,000,000	$9,953,000
44	2	7	4	13	$1,089,000	$72,000	$444,000	$3,000,000	$4,605,000
45	2	1	17	20	$346,000	$306,000	$3,314,000	$9,500,000	$13,466,000
46	1	0	15	16	$151,000	$270,000	$3,307,000	$8,000,000	$11,728,000

1020

REACH	STRUCTURES				COST				TOTAL
					CONSTRUCTION		ACQUISITION		
	RELOCATIONS	RETREATS	DEMOLITIONS	TOTALS	REMOVAL - RELOCATION OR RETREAT	DEMOLITION	STRUCTURE	LANDS	
47	1	2	19	22	$363,000	$342,000	$2,990,000	$10,000,000	$13,695,000
48	2	3	15	20	$605,000	$270,000	$2,207,000	$8,500,000	$11,582,000
49	3	0	13	16	$329,000	$234,000	$2,229,000	$8,000,000	$10,792,000
50	0	0	12	12	$0	$216,000	$3,412,000	$6,000,000	$9,628,000
51	2	0	6	8	$242,000	$108,000	$777,000	$4,000,000	$5,127,000
52	6	0	16	22	$658,000	$288,000	$2,166,000	$11,000,000	$14,112,000
53	8	0	16	24	$917,000	$288,000	$1,439,000	$12,000,000	$14,644,000
54	5	0	11	16	$605,000	$198,000	$1,338,000	$8,000,000	$10,141,000
55	5	3	6	14	$968,000	$108,000	$552,000	$5,500,000	$7,128,000
56	1	2	16	19	$363,000	$288,000	$1,614,000	$8,500,000	$10,765,000
57	0	1	17	18	$121,000	$306,000	$1,715,000	$8,500,000	$10,642,000
58	1	8	5	14	$1,089,000	$90,000	$504,000	$3,000,000	$4,683,000
59	1	4	6	11	$605,000	$108,000	$611,000	$3,500,000	$4,824,000
60	3	0	11	14	$329,000	$198,000	$909,000	$7,000,000	$8,436,000
61	5	0	6	11	$588,000	$108,000	$488,000	$5,500,000	$6,684,000
62	1	0	19	20	$121,000	$342,000	$3,862,000	$10,000,000	$14,325,000
63	5	0	16	21	$605,000	$288,000	$2,939,000	$10,500,000	$14,332,000
64	3	0	14	17	$363,000	$252,000	$1,763,000	$8,500,000	$10,878,000
65	7	1	14	22	$968,000	$252,000	$923,000	$10,500,000	$12,643,000
66	2	0	16	18	$242,000	$288,000	$1,041,000	$9,000,000	$10,571,000
67	5	0	9	14	$605,000	$162,000	$1,457,000	$7,000,000	$9,224,000
68	2	0	10	12	$242,000	$180,000	$1,040,000	$6,000,000	$7,462,000

1021

REACH	STRUCTURES				COST				TOTAL
					CONSTRUCTION		ACQUISITION		
	RELOCATIONS	RETREATS	DEMOLITIONS	TOTALS	REMOVAL - RELOCATION OR RETREAT	DEMOLITION	STRUCTURE	LANDS	
69	5	6	4	15	$1,314,000	$72,000	$444,000	$4,500,000	$6,330,000
70	3	1	10	14	$450,000	$180,000	$943,000	$6,500,000	$8,073,000
71	0	4	15	19	$484,000	$270,000	$875,000	$7,500,000	$9,129,000
72	2	4	12	18	$692,000	$216,000	$862,000	$7,000,000	$8,770,000
73	1	6	10	17	$847,000	$180,000	$566,000	$5,500,000	$7,093,000
74	0	5	15	20	$588,000	$270,000	$942,000	$7,500,000	$9,300,000
75	0	5	11	16	$605,000	$198,000	$1,881,000	$5,500,000	$8,184,000
76	1	4	8	13	$588,000	$144,000	$1,093,000	$4,500,000	$6,325,000
77	1	2	11	14	$363,000	$198,000	$2,434,000	$6,000,000	$8,995,000
78	1	1	17	19	$242,000	$306,000	$1,982,000	$9,000,000	$11,530,000
106	0	0	5	5	$0	$90,000	$1,289,000	$2,500,000	$3,879,000
107	6	0	7	13	$709,000	$126,000	$655,000	$6,500,000	$7,990,000
108	1	0	8	9	$121,000	$144,000	$1,235,000	$4,500,000	$6,000,000
114	0	0	0	0	$0	$0	$0	$0	$0
115	2	0	18	20	$225,000	$324,000	$2,742,000	$10,000,000	$13,291,000
116	0	0	0	0	$0	$0	$0	$0	$0
TOTALS	**164**	**125**	**615**	**904**	**$34,481,000**	**$11,070,000**	**$85,138,000**	**$389,500,000**	**$520,189,000**

1022

Final Feasibility Report and Environmental Impact Statement

on

Coastal Storm Damage Reduction

SURF CITY AND NORTH TOPSAIL BEACH, NORTH CAROLINA

Appendix Q

Larval Entrainment

(1023)

Appendix Q

Assessment Of Potential Larval Entrainment Mortality Due To Hydraulic Dredging Of Beaufort Inlet

Lawrence R. Settle
NOAA/NOS
National Centers for Coastal Ocean Science
Center for Coastal Fisheries and Habitat Research
101 Pivers Island Road
Beaufort, NC 28516

The larval fish distribution, abundance, seasonality, transport and ingress at Beaufort Inlet has been extensively studied, particularly during the fall-winter period coinciding with the permitted dredging window (see references below). The concentration of fish larvae (all species combined) typically ranges from 0.5 to 5 larvae m^{-3}. The concentration (i.e. abundance) of larvae varies both spatially and temporally over a range of scales. It is therefore important to recognize that not all larvae in the inlet would be vulnerable to entrainment. Larvae are not equally distributed in the inlet as the flow has considerable asymmetry. During flood the bulk of the transport is on the eastern side of the inlet and most larvae enter on that side. Ebb flows containing larvae that were not retained in the estuary are strongest on the west side of the inlet. In addition, many larvae exhibit a vertical migration strategy that facilitates tidal stream transport. That is, larvae are up in the water column during flood and descend to near the bottom during ebb. Such behavior helps to prevent larvae from being flushed back out the inlet.

One can estimate the potential larval entrainment mortality due to hydraulic dredging of Beaufort Inlet using a simple mathematical model that incorporates the following:

C = concentration of larvae
= 0.5 to 5.0 larvae m^{-3}

M = proportion of larvae dying by natural causes every six hours
= 0.0125 (i.e. 5 % d^{-1}) to 0.025 (i.e. 10 % d^{-1})

V = volume of water entrained by dredge (24 h operation)
= 173,299 m^3 d^{-1} (USACE)

$\mathbf{P_s}$ = spring tidal prism
= 1.42 E8 m^3 (Jarrett, 1976)

$\mathbf{P_n}$ = neap tidal prism
= 1.32 E8 m^3 (Logan, 1995)

$\mathbf{P_b}$ = proportion of larvae in the bottom of the water column
= 0.1 to 1.0

$\mathbf{P_c}$ = proportion of larvae in the navigation channel
= 0.1 to 1.0

$\mathbf{P_r}$ = proportion of larvae retained inside to estuary during ebb phase
= 0.1 to 1.0

$\mathbf{E_s}$ = proportion of daily spring tidal volume entrained by dredge
= $V / 2 P_s d^{-1}$
= 0.0006

$\mathbf{E_n}$ = proportion of daily neap tidal volume entrained by dredge
= $V / 2 P_n d^{-1}$
= 0.0007

$\mathbf{L_s}$ = initial number of larvae within a spring tidal prism
= $C * P_s$

$\mathbf{L_n}$ = initial number of larvae within a neap tidal prism
= $C * P_n$

$\mathbf{K_{sf}}$ = number of larvae entrained during a single spring tide flood phase
= $(L_s - (L_s * M * 2)) * P_b * P_c * E_s$

$\mathbf{K_{se}}$ = number of larvae entrained during a single spring tide ebb phase
= $(L_s - (L_s * M * 2) - K_{sf}) * P_b * P_c * P_r * E_s$

$\mathbf{K_{nf}}$ = number of larvae entrained during neap tide flood phase
=$(L_n - (L_n * M * 2)) * P_b * P_c * E_n$

$\mathbf{K_{ne}}$ = number of larvae entrained during neap tide ebb phase
= $(L_n - (L_n * M * 2) - K_{nf}) * P_b * P_c * P_r * E_n$

$\mathbf{K_s}$ = absolute larval entrainment mortality d^{-1} during spring tide
= $(K_{sf} + K_{se}) * 2$

$\mathbf{Z_s}$ = percent larval entrainment mortality d^{-1} during spring tide
= $(K_s/L_s*2)*100$

$\mathbf{K_n}$ = absolute larval entrainment mortality d^{-1} during neap tide
= $(K_{nf} + K_{ne}) * 2$

$\mathbf{Z_n}$ = percent larval entrainment mortality d^{-1} during neap tide
$= (K_n/L_n*2)*100$

Mortality due to entrainment was simulated 10,100 times for each level of natural mortality (i.e. 5% d^{-1} and 10% d^{-1}) during both spring and neap tidal conditions by systematically varying **C**, $\mathbf{P_b}$, $\mathbf{P_c}$, and $\mathbf{P_e}$ over the ranges outlined above using SAS Version 8.2 (SAS Institute Inc., Cary, NC). The results depicting the distribution of outcomes are shown below and include the minimum, maximum and mean impact levels as well as the 10%, 25%, 50% (median), 75% and 90% quantiles.

	Natural mortality 10 % d^{-1}				Natural mortality 5 % d^{-1}			
	$\mathbf{K_s}$ No.	$\mathbf{Z_s}$ %	$\mathbf{K_n}$ No.	$\mathbf{Z_n}$ %	$\mathbf{K_s}$ No.	$\mathbf{Z_s}$ %	$\mathbf{K_n}$ No.	$\mathbf{Z_n}$ %
min	914	0.0006	991	0.0008	925	0.0007	1004	0.0008
max	1660902	0.1170	1801169	0.1365	1682195	0.1185	1824261	0.1382
mean	246426	0.0316	267246	0.0316	249585	0.0320	270672	0.0373
10 %	16282	0.0036	17658	0.0042	16490	0.0037	17884	0.0043
25 %	48845	0.0070	52973	0.0082	49471	0.0071	53651	0.0083
50 %	132906	0.0239	144136	0.0278	134610	0.0242	145984	0.0282
75 %	376763	0.0579	408595	0.0676	381594	0.0587	413833	0.0684
90 %	657882	0.0632	713472	0.0737	666316	0.0640	722619	0.0746

What is quite apparent is that both $\mathbf{Z_s}$ and $\mathbf{Z_n}$ (i.e. the percentage of the daily flux of larvae entrained) are very low regardless of larval concentration and the distribution of larvae within the channel. Under the worst-case scenario where the dredge operates 24 h d^{-1}, all larvae are in the navigation channel, on the bottom, and with poor retention in the estuary following flood stage, the maximum percentage entrained barely exceeds 0.1 % d^{-1}. Most of the simulated scenarios (see the 90 % quantiles) indicate the percent entrainment mortality to be less than 0.06 to 0.07 % d^{-1} with over half falling below 0.03 % d^{-1} (see 50 % quantile). The actual number of larvae entrained however, can range from as few as 914 up to over 1.8 million depending on the initial concentration of larvae within the tidal prism.

This simple analysis of the potential entrainment impacts to larvae could be further refined by stochastically varying the spatial and temporal concentration of larvae and their positions within the water column, but, based on the results presented here, such effort is not required to achieve a useful first approximation of the level of impact to the resource. Because the estimated entrainment mortality, even under the worst-case scenario, is minimal (0.1 % d^{-1}), it seems reasonable to conclude that while any larvae

that are entrained will certainly be killed, it is likely that the impact at the population-level would be insignificant.

References for larval fish distribution, abundance, seasonality, transport and ingress at Beaufort Inlet, North Carolina.

Blanton, J.O., J. Amft, R.A. Luettich, Jr., J.L. Hench and J.H. Churchill. 1999. Tidal and subtidal fluctuations in temperature, salinity and pressure for the winter 1996 larval ingress experiment - Beaufort Inlet, NC. Fish. Oceanogr. 8(Suppl. 2):134-152.

Burke, J.S., J.M. Miller and D.E. Hoss. 1991. Immigration and settlement pattern of *Paralichthys dentatus* and *P. lethostigma* in an estuarine nursery ground, North Carolina, U.S.A. Netherlands J. Sea Res. 27:393-405.

Churchill, J.H., J.O. Blanton, J.L. Hench, R.A. Luettich, Jr. and F.E. Werner. 1999. Flood tide circulation near Beaufort Inlet, North Carolina: implications for larval recruitment. Estuaries 22:1057-1070.

Churchill, J.H., R.B. Forward, R.A. Luettich, Jr., J.L. Hench, W.F. Hettler, Jr., L.B. Crowder and J.O. Blanton. 1999. Circulation and larval fish transport within a tidally dominated estuary. Fish. Oceanogr. 8(Suppl. 2):173-189.

Flores-Coto, C. And S.M. Warlen. 1993. Spawning time, growth, and recruitment of larval spot *Leiostomus xanthurus* into a North Carolina estuary. Fish. Bull. 91:8-22.

Forward, R.B. Jr., K.A Reinsel, D.S. Petrs, R.A. Tankersley, J.H. Churchill, L.B. Crowder, W.F. Hettler, Jr., S.M. Warlen and M.D. Greene. 1999. Transport of fish larvae through a tidal inlet. Fish. Oceanogr. 8(Suppl. 2):153-172.

Hare, J.A., J.A. Quinlan, F.E. Werner, B.O. Blanton, J.J. Govoni, R.B. Forward, L.R. Settle and D.E. Hoss. 1999. Larval transport during winter in the SABRE study area: results of a coupled vertical larval behavior-three-dimensional circulation model. Fish. Oceanogr. 8(Suppl. 2):57-76.

Hettler, W.F., Jr. and D.L. Barker. 1993. Distribution and abundance of larval fishes at two North Carolina inlets. Estuar. Coast. and Shelf Sci. 37:161-179.

Hettler, W.F., Jr. and A.J. Chester. 1990. Temporal distribution of ichthyoplankton near Beaufort Inlet, North Carolina. Mar. Ecol. Prog. Ser. 68:157-168.

Hettler, W.F., Jr. and J.A. Hare. 1998. Abundance and size of larval fishes outside the entrance to Beaufort Inlet, North Carolina. Estuaries 21:476-499.

Hettler, W.F., Jr., D.S. Peters, D.R. Colby and E.H. Laban. 1997. Daily variability in abundance of larval fishes inside Beaufort Inlet. Fish. Bull. 95:477-493.

Hildebrand, S.F. and L.E. Cable. 1930. Development and life history of fourteen teleostean fishes at Beaufort, N.C. Bull. U.S. Bur. Fish. 46:383-488.

Hildebrand, S.F. and L.E. Cable. 1938. Further notes on the development and life history of teleosts at Beaufort, N.C. Bull. U.S. Bur. Fish. 48:505-642.

Jarrett, J.T. 1976. Tidal prism - inlet area relationships, general investigation of tidal inlets. U.S. Army Coastal Engineering Research Center, Fort Belvior, VA and U.S. Army Engineer Waterways Experimental Station, Vicksburg, MS, GITI Rep. 3, 56 p.

Joyeux, J-C. 1998. Spatial and temporal entry patterns of fish larvae into North Carolina estuaries: comparisons among one pelagic and two demseral species. Estuar. Coast. and Shelf Sci. 47:731-752.

Joyeux, J-C. 1999. The abundance of fish larvae in estuaries: within-tide variability at inlet and immigration. Estuaries 22:889-904.

Joyeux, J-C. 2001. The retention of fish larvae in estuaries: among-tide variability at Beaufort Inlet, North Carolina, USA. J. Mar. Biol. Assoc. U.K. 81:857-868.

Judy, M.H. 1982. Catch composition, seasonality of ichthyoplankton from R/V Onslow Bay monthly cruises in Onslow Bay and Newport River estuary, North Carolina, 1972-1974. NOAA Tech. Memo. NMFS-SEFC 46.

Kirby-Smith, W.W. and J.D. Kostlow. 1989. The Newport River Estuarine System. UNC Sea Grant College Publication UNC-SG-89-04.

Klavans, A.S. 1983. Tidal hydrodynamics and sediment transport in Beaufort Inlet, North Carolina. NOAA Tech. Rep. NOS 100.

Lewis, R.M. and M.H. Judy. 1983. The occurrence of spot, *Leiostomus xanthurus*, and Atlantic croaker, *Micropogonias undulatus*, larvae in Onslow Bay and Newport River estuary, North Carolina. Fish. Bull. 81:405-412.

Lewis, R.M. and W.C. Mann. 1971. Occurrence and abundance of larval Atlantic menhaden, *Brevoortia tyrannus*, at two North Carolina inlets with note on associated species. Trans. Am. Fish. Soc. 100:296-301.

Lewis, R.M. and E.P.H. Wilkins. 1971. Abundance of Atlantic menhaden larvae and associated species during a diel collection at Beaufort, North Carolina. Chesapeake Sci. 12:185-187.

Logan, D.G. 1995. Oceanographic processes affecting larval transport in Beaufort Inlet, NC. MS Thesis, North Carolina State University, Raleigh.

Logan, D.G., J.M. Morrison, L.S. Pietrafesa, T.S. Hopkins and J. Churchill. 2000. Physical oceanographic processes affecting inflow/outflow through Beaufort Inlet, North Carolina. J. Coast. Res. 16:1111-1125.

Luettich, R.A., Jr., J.L. Hench, C.W. Fulcher, F.E. Werner, B.O. Blanton and J.H. Churchill. 1999. Baratropic tidal and wind-driven larval transport in the vicinity of a barrier island inlet. Fish. Oceanogr. 8(Suppl. 2):190-209.

Norcross, B.L. and R.F. Shaw. 1984. Oceanic and estuarine transport of fish eggs and larvae: a review. Trans. Am. Fish. Soc. 113:153-165.

Petters, D.S., L.R. Settle and J.D. Fuss. 1994. Larval fish abundance in the vicinity of Beaufort Inlet prior to berm construction: March 1993 - February 1994. Report submitted to USACE Wilmington District.

Petters, D.S., L.R. Settle and J.D. Fuss. 1995. Larval fish abundance in the vicinity of Beaufort Inlet prior to berm construction: October 1994 - April 1995. Report submitted to USACE Wilmington District.

Rice, J.A., J.A. Quinlan, S.W. Nixon, W.F. Hettler, Jr., S.M. Warlen and P.M. Stegmann. 1999. Spawning and transport dynamics of Atlantic menhaden: inferences from characteristics of immigrating larvae and predictions of a hydrodynamic model. Fish. Oceanogr. 8(Suppl. 2):93-110.

Warlen. S.M. and J.S. Burke. 1990. Immigration of fall/winter spawning marine fishes into a North Carolina estuary. Estuaries 13:453-461.

Feasibility Report
and
Final Environmental Impact Statement

on

Coastal Storm Damage Reduction

SURF CITY AND NORTH TOPSAIL BEACH
NORTH CAROLINA

Appendix R -

Hardbottom Survey Reports

Appendix R -

Hardbottom Survey Reports

The following pages contain the reports of surveys in both the offshore borrow areas and in the nearshore of the project area. These surveys and reports were conducted and prepared by consultants under contract to the U.S. Army Corps of Engineers, Wilmington District. Note that due to size, attachment 4 is only being provided electronically, and as a seperate document.

The scanned reports, prefaced by title pages are listed as follows:

1. Attachment 1 – An Assessment of the Availability of Beach Fill Quality Sand Offshore North Topsail Beach and Surf City, NC, HDR Engineering of the Carolinas, with William J. Cleary, PhD., March 2003, 113 pages

2. Attachment 2 – High-Resolution Remote Sensing of Potential Hard Bottom Habitats: Topsail Island, NC July 2006, Greenhorne & O'Mara Inc., and Geodynamics LLC, 75 pages

3. Attachment 3 – High-Resolution 3D Bathymetric Assessment of Potential Hard Bottom Habitats: Topsail Island, Surf City and North Topsail Island, NC January / February 2007, Greenhorne & O'Mara Inc., and Geodynamics LLC, 60 pages

4. Attachment 4 – Surf City / North Topsail Beach, N.C. Shore Protection Project, Hardbottom Resource Confirmation and Characterization Study, Anamar Environmental Consulting, Inc., June 2008, 233 pages.

Feasibility Report
and
Final Environmental Impact Statement

on

Coastal Storm Damage Reduction

SURF CITY AND NORTH TOPSAIL BEACH
NORTH CAROLINA

Appendix R
Attachment 1

An Assessment of the Availability of Beach Fill Quality Sand Offshore North Topsail Beach and Surf City, NC

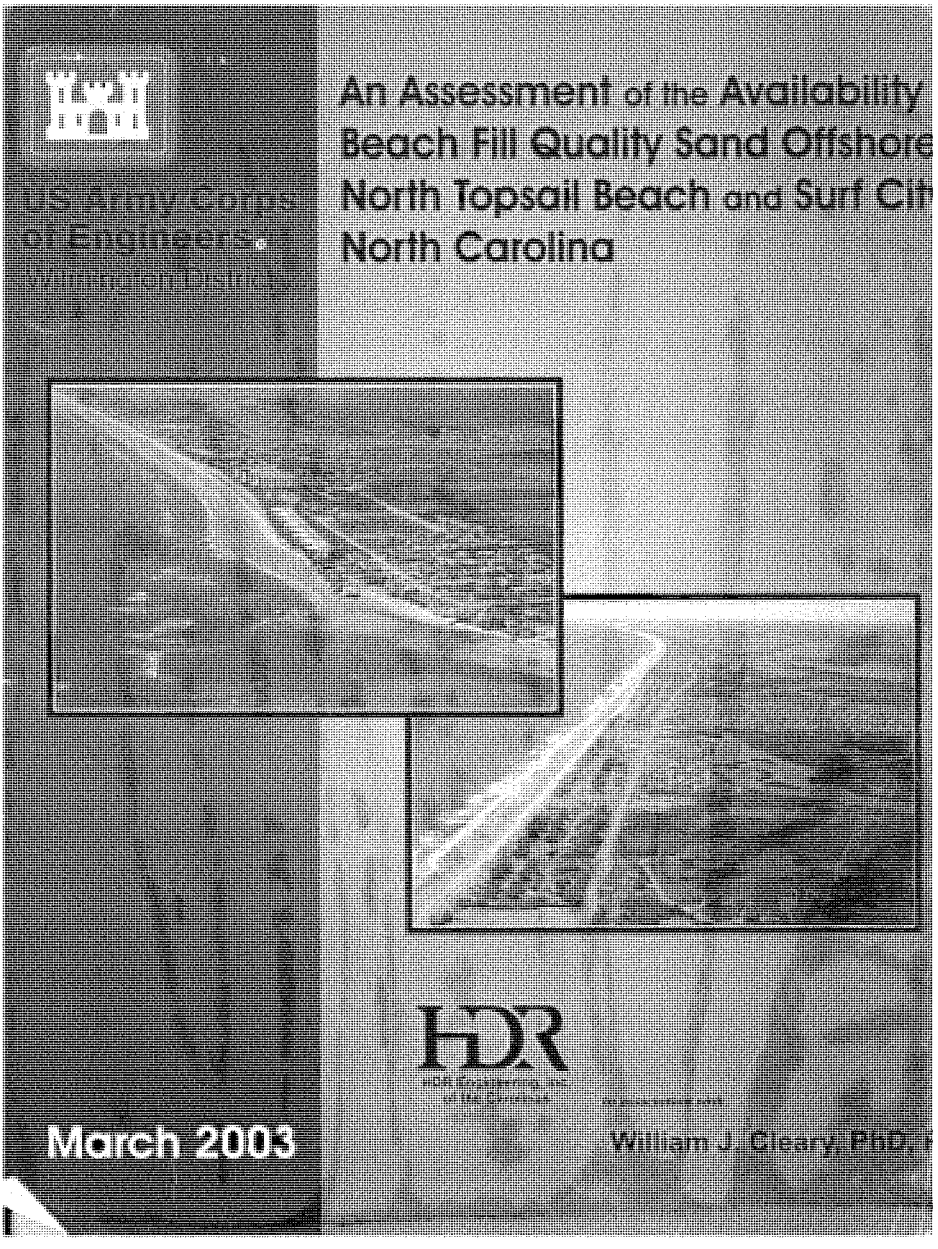

US Army Corps
of Engineers
Wilmington District
An Assessment of the Availability
Beach Fill Quality Sand Offshore
North Topsail Beach and Surf Cit
North Carolina
HDR
March 2003
William J. Cleary, PhD,

TABLE OF CONTENTS

SECTION		PAGE
EXECUTIVE SUMMARY		1
1.0	Background	6
2.0	Methods	8
3.0	Study Sites Setting	10
	3.1 Geologic Controls	10
	3.2 Topsail Island	11
	3.3 North Topsail Beach	12
	3.4 Surf City	13
4.0	Results and Discussions	14
	4.1 Bathymetry and General Nature of Shoreface	14
	4.1.1 Mile Hammocks Bay (Onslow Beach) to Alligator Bay (North Topsail Beach)	14
	4.1.2 Alligator Bay to Surf City's Southern Limit	15
	4.2 Seismic Data	15
	4.2.1 Mile Hammocks Bay (Onslow Beach) to Alligator Bay (North Topsail Beach)	15
	4.2.2 Alligator Bay to Surf City's Southern Limit	16
	4.3 Side Scan-Sonargraph Data	17
	4.3.1 Mile Hammocks Bay (Onslow Beach) to Alligator Bay (North Topsail Beach)	17
	4.3.2 Alligator Bay to Surf City's Southern Limit	18
	4.4 Underlying and Exposed Rock Units	20
	4.4.1 Mile Hammocks Bay (Onslow Beach) to Alligator Bay (North Topsail Beach)	20
	4.4.2 Alligator Bay to Surf City's Southern Limit	22
	4.5 Shoreface Surface Sediments	25
	4.5.1 Mile Hammocks Bay to Alligator Bay	25
	4.5.2 Alligator Bay to Surf City's Southern Limit	26
	4.6 Shoreface Sediment Sequences	28
	4.6.1 Mile Hammocks Bay to Alligator Bay	28
	4.6.2 Alligator Bay to Surf City's Southern Limit	30
	4.7 Sand Resources	32
	4.7.1 Mile Hammocks Bay to Alligator Bay	33
	4.7.2 Alligator Bay to Surf City's Southern Limit	33
5.0	Recommendations for Future Work	37
6.0	References Cited	38

APPENDIX 1

List of Tables

Table 1 Vibracores used in the conduct of the study.

Table 2 Surface sediment samples used in the conduct of the study.

Table 3 Coordinates for recommended seismic surveys of borrow areas I through IV.

List of Figures

Figure 1 Location map of Topsail Island, North Topsail Beach, and Surf City, NC and offshore study area with vibracore, surface sample and dive sites, fathometer and seismic profiles and areas covered by sidescan sonar mosaics.

Figure 2 Map depicting locations of vibracore cross-sections, core and diver surveys.

Figure 3 Map depicting locations of fathometer profiles.

Figure 4 Shore normal fathometer profiles offshore Onslow Beach and New River Inlet.

Figure 5 Shore normal fathometer profiles offshore North Topsail Beach.

Figure 6 Shore normal fathometer profiles offshore North Topsail Beach - Surf City.

Figure 7 Shore normal fathometer profiles offshore Surf City.

Figure 8 Map depicting shoreface relief in vicinity of New River Inlet (after Johnston, 1998).

Figure 9 High-resolution seismic profile (E-08-95) from North Topsail Beach shoreface (after Johnston, 1998).

Figure 10 Side-scan sonargraph mosaic of study area shoreface with fathometer profiles and scarp locations.

Figure 11 Map depicting the distribution of the exposed and underlying Oligocene rock units.

Figure 12 Bottom photographs of dive site 700.

List of Figures (continued)

Figure 13 Cartoon of oyster channel structure and bottom photographs of gravel near exposure.

Figure 14 Photographs of giant oyster valves from dive site 720.

Figure 15 Photographs of giant oyster valves from dive sites 721 and NTP 514.

Figure 16 Bottom photographs of dive site 828 on hardbottom ledge.

Figure 17 Bottom photographs of dive site 810 on moderate to high relief hardbottom.

Figure 18 Bottom photographs of dive site 814 on flat hardbottom surface.

Figure 19 Photographs cobbles and rock slabs from dive sites 504, 508 and 704.

Figure 20 Photographs bored and encrusted cobbles from dive sites 516, 712 and NS 006.

Figure 21 Thin-section photomicrographs of Belgrade limestone.

Figure 22 Thin-section photomicrographs of loose limestone lithoclasts.

Figure 23 Photographs of slabbed limestone cores from dive site TP-116 and TP-14.

Figure 24 Photographs of bored limestone from dive sites SC 100, SC 22 and SC 9.

Figure 25 Bottom photographs of small encrusted scarp and overhang a at dive site VID-1 offshore Surf City.

Figure 26. Bottom photographs of encrusted scarp and overhang and rubble ramp at dive site VID- 1 offshore Surf City.

Figure 27 Photographs of bored limestone cobbles from dive sites SC16, SC 97, SC VC 44 and SDA 9.

Figure 28 Photographs rounded siltstone and limestone gravel from dive sites SDA and SC 10.

Figure 29 Thin-section photomicrographs of limestones from sites SDA, Top 15 and Top 16.

List of Figures (continued)

Figure 30 Thin-section photomicrographs of limestones from sites Top 4, Sc111, SC 95 and SC 105.

Figure 31 Thin-section photomicrographs of limestones and a calcareous siltstone from sites SC 122, SC 89, and SC VC 30.

Figure 32 Thin-section photomicrographs of limestones from sites SC 70, SC 1,and SC 85.

Figure 33 Map depicting surface sediment types and side scan sonar mosaic.

Figure 34 Bottom photographs of sediments and cartoon of hardbottom area (after Johnston, 1998).

Figure 35 Bottom photographs of high-relief scarp at dive site 516.

Figure 36 Bottom photographs of scarp at dive site 505.

Figure 37 Bottom photographs of high relief scarp and oyster gravel at dive site 504.

Figure 38 Bottom photographs of high relief scarp offshore Onslow Beach at dive sites 702-704.

Figure 39 Photographs of surface sediment composed of silt and shelly fine quartz sand from dive sites 835, 812, 827 and NS 017.

Figure 40 Photographs of shelly gravel surface sediment from dive sites 509, 602, 829, 806 and 813.

Figure 41 Photographs of gravel mixtures from dive sites 701, 718, 728, 603, 601, and 834.

Figure 42 Photographs of lithic gravel mixtures from dive sites 511, 515, 507, 513, 510, and 516.

Figure 43 Photographs gravel mixtures from dive sites 703, 720, 810, 721, and 830.

Figure 44 Bottom photographs of thin sediment cover on hardbottom at dive site SC 78.

Figure 45 Bottom photographs of hardbottom ledge with encrusting organisms and sediments at base of scarp at dive site SC 83.

List of Figures (continued)

Figure 46 Bottom photographs of hardbottom scarp with soft corals, macroalgae, and gorgonians at dive site SDA.

Figure 47 Bottom photographs of hardbottom and sand contact and veneer at dive site SC 78.

Figure 48 Photographs of shelly fine quartz sand surface sediment from dive sites SC 3, SC 104, SC 40, and SC 80.

Figure 49 Photographs of gravel surface sediment mixtures from dive sites SC 82, SC 113, TP 4 and SC 22.

Figure 50 Photographs of gravel surface sediment mixtures from dive sites SD 4, SC 84, SC VC 28, and TP 10.

Figure 51 Photographs of gravel surface sediment mixtures from dive sites SC 40, Sc 24, SC 105, and SC 100.

Figure 52 Photographs of fauna and flora encrusted cobbles from dive sites SC 105, SC 9 and SDA12.

Figure 53 Shore normal vibracore cross-section A-A'.

Figure 54 Shore parallel vibracore cross-section B-B'.

Figure 55 Shore parallel vibracore cross-section C-C'.

Figure 56 Shore normal vibracore cross-section D-D'.

Figure 57 Shore normal vibracore cross-section E-E'.

Figure 58 Shore normal vibracore cross-section F-F'.

Figure 59 Shore normal vibracore cross-section G-G'.

Figure 60 Map of shoreface depicting sediment thickness at various sample sites with side scan sonar mosaic, and hardbottom scarps.

Figure 61 Map depicting areas of thickest sediment accumulation and potential target areas for future seismic and coring surveys.

Figure 62 Map depicting areas of thickest sediment accumulation, potential target areas and photographs of representative vibracores.

AN ASSESSMENT OF THE AVAILABILITY OF BEACH FILL QUALITY SAND OFFSHORE NORTH TOPSAIL BEACH AND SURF CITY, NC

EXECUTIVE SUMMARY

The United States Army Corps of Engineers (USACE) Wilmington District office is currently preparing a general evaluation report for storm reduction projects along the Town of North Topsail Beach and Surf City, NC. The focal point of the report is the availability of sufficient quantities of beach fill material for the initial project construction and subsequent maintenance during the next 50 years. The USACE Wilmington District has conducted a number of investigations in the Topsail Island area. McQuarrie (1998) and HDR (2002) provided additional information on the unproven sand resource potential of the area offshore of Topsail Beach. The HDR (2002) indicated several potential existing target areas that may contain significant quantities of beach fill material.

It was speculated that a similar sand resource potential would exist off the remainder of Topsail Island; however, the nature of the sedimentary cover was poorly known. In the interest of locating the most economical and environmentally acceptable borrow sites that could support the proposed projects, information of the availability of beach quality material, or its non-availability, was needed. Therefore, site-specific assessments of each area were necessary. The goal of the investigation was the identification and delineation of suitable borrow sites that contained compatible material for the nourishment projects. An equally important objective was the identification of areas of environmentally sensitive hardbottoms.

The shoreface in the northeastern part of the study area is dominated by a platform-like submarine headland comprised of well-indurated limestone. Fathometer sonargraphs demonstrate that the highly irregular surface is characterized by a series of low- (<1.6 feet [0.48 m]) to high-relief (>6.6 feet [2.0 m]) hardbottom scarps and intervening flat hardbottoms. Reconnaissance level investigations have mapped several linear, shore-normal depressions that were interpreted to channel remnants. These shallow features appear as relatively flat areas where thin sequences of sediments have accumulated. The nature of the shoreface, from Alligator Bay to the Town of Surf City's southern limit, is similar to the shoreface segment off the northeastern part of North Topsail Beach. The most significant difference is the lack of high relief hardbottoms >6.5 feet (>2 m).

The USACE reconnaissance level investigation (ICONS) of the Topsail Island region indicated the shoreface was underlain by limestone and calcareous sandstone of Oligocene age. The uppermost stratigraphic unit mapped from seismic data crops out over most of the northern portion of the study area, and is correlative to the upper Oligocene Belgrade Fm. This unit forms the majority of the limestone platform that controls the bathymetry of the area. The Trent Fm crops out over a significant portion of the Surf City shoreface. A second major stratigraphic unit, the Oligocene River Bend Fm, also underlies a major portion of adjacent Topsail Beach. Vibracores recovered along boomer track lines off Topsail Beach indicated the River Bend Fm consisted of an olive green, fine quartz sand and silt. Vibracores and numerous diver surveys from offshore Surf City indicated that the River Bend Fm extends northward and underlies a significant segment of the Surf City shoreface.

An inspection of the sidescan-sonargraph mosaic indicated that several distinct types and zones of sea-floor morphology occur within the study area. The distinctly different accoustic "signatures" are indicative of lateral changes in the lithology and relief of the underlying stratigraphic units and the nature and thickness of the sediment cover. Interpretation of the data indicated that sediment accumulation is extremely limited particularly in the northern portion of the study area.

The sea floor in the southern portion of the study area consists of isolated, irregular areas of 1- to 2-mile (1.6 to 3.2 km) wide fields of shore-normal to shore-oblique sedimentary features interspersed amongst areas of low relief hardbottoms. Most of the fields of these low relief linear features are discontinuous, while several areas extend as much as 1.2 miles (1.9 km) across the study area. The 2-mile (3.2 km) segment of the sea floor to the southwest is markedly different and characterized by a distinct acoustic nature. An abrupt change occurs from the consistently similar sonar signature of the RCD zone to a 2- to 3-mile (3.2- to 4.8-km) wide area of low reflectivity (light colored) that extends obliquely across the shoreface. An area of mixed sonar returns, indicative of sediment patches within low relief hardbottoms, occurs within the innermost portion of this relatively homogenous area of weak sonar returns. Diver surveys indicated that the surface sediment within this zone of low reflectivity was fine sand underlain by calcareous siltstone.

The subcrop and outcrops within the northeastern part of the study area are composed of two basic Oligocene limestone units (Belgrade and Trent Formations) that are similar in composition. Both units are classified as moldic, sandy limestones. The Belgrade limestone is the most widespread unit and forms the extensive platform off New River Inlet. The limestone exposures provide an immediate source of "new" sediment for the surrounding shoreface. The sediment is a

by-product of the activities of the many boring and encrusting organisms that are found on the hardbottoms.

The subcrop and outcrop units in the area from Alligator Bay to the southern limit of Surf City are composed of rocks that range in composition from a quartz-rich, calcareous-siltstone (River Bend Fm) to very fine grained sandstone to a moldic, sandy limestone (Trent Fm). The siltstone hardbottoms, which were absent on the northern shoreface segment, are composed of poorly consolidated calcite cemented quartz silt. The siltstone is only exposed in two isolated areas offshore Surf City but underlies a major portion of the shoreface. Bio-erosion and wave quarrying of the siltstone adds a significant volume of fine-grained material to the overlying sediment sequences.

The distribution of the major sediment types and their mixtures was difficult to map due to the extremely complex exposure pattern of the hardbottoms. The distribution of the major sediment types is complex and dictated by the spacing, relief, and composition of the rock exposures. Most of the shoreface in the southern part of the study area is blanketed by shelly, fine quartz sand. Gravel size material is abundant and comprised of limestone lithoclasts and molluscan material. The majority of the gravel and gravelly sand is found near or on hardbottoms.

Data indicated that the sediment sequence is thin and consists of units of very fine quartz sands intercalated with gravel mixtures. Mud-rich back barrier sequences were recovered in a number of vibracores. Thickness of the modern sediment package ranged from less than one-half inch (1.0 cm) in hardbottom areas to more than 6.2 feet (1.9 m) in intervening depressions. The sediment cover on the northern part of the study area was generally too thin (0.65 feet [<20 cm]) to core, except in isolated bathymetric lows and in a narrow channel-like feature off New River Inlet. The broad limestone platform off New River Inlet was generally barren of sediment.

Several cores were recovered from the paleo-channel of New River. The ICONS operations also retrieved cores from this feature. The limited data suggested that this very restricted region off New River Inlet is the only area in the northern part of the study area where sand deposits may be preserved. The shoreface in the southern part of the study area was underlain by relatively thin sequences of very fine quartz sands interbedded with sandy gravels. The thickest modern sediment sequences cored 1.6 to 6.4 feet (0.50 to 1.95 m) were recovered from mud-filled paleo-channels. The majority of the individual units present are less than 1.3 feet (0.40 m) thick. Gravel rich units are widespread and comprise major portions of the thin sequences. Gravel rich sequences were typically found in areas where limestone forms the subcrop unit and near exposures (hardbottoms).

Much of the southern portion of the study area is covered by sediment sequences less than ~one foot (30 cm) thick. The area with the thickest deposits of sediment (>3.0 feet [>1.0 m]) is restricted to a small region located within the central portion of the shoreface offshore the southern portion of North Topsail Beach. The sea floor in this area is characterized by linear shore-normal depressions (RCDs). This highly irregular region is underlain by siltstone. A second area where relatively thick sediments are found is located offshore the southern portion of Surf City. Most of the thicker Holocene sequences are comprised of either organic-rich mud or very fine sand units.

The shoreface off the northern portion of North Topsail Beach contained only one potential target area (Area I). The target area is located southwest of the limestone platform off New River Inlet within the remnants of the paleo-channel of New River. The ICONS data suggest as much as 4.5 feet (1.4 m) of bioclastic quartz rich sand may be present along the trace of the ancestral river channel. The volume of material contained in Area I is estimated to be approximately 1.4 million cubic yards (cy) (1.1 million m^3). The prospect of locating significant accumulations of sand in this area is probably very low; nonetheless, the area warrants a detailed investigation.

Approximately 70 percent of the shoreface southwest of Alligator Bay has no potential for significant volumes of compatible beach fill material. However, there are several areas (Areas II through V) where thin (<3 feet [~1.0 m]) sandy sequences may have accumulated. However, the compatibility and continuity of these materials is very questionable.

The irregularly shaped Area II covers approximately 4.8 mi^2 (12.4 km^2) of the shoreface. The thickness of quality beach fill material in Area II is likely to be extremely variable and, at best, probably averages less than 3.0 feet (0.91 m) in thickness. The volume of material contained in Area II is estimated to be approximately 15.0 million cy (11.7 million m^3). The proximity of hardbottoms may restrict the exploitation of sand resources in the narrower regions of Area II. Areas IIa and IIb are the only viable areas within the confines of Area II where there is a possibility of finding beach fill material. Areas IIa (1.5 $mile^2$ [3.9 km^2]) and IIb (0.7 $mile^2$ [1.8 km^2]) comprise approximately 45 percent of Area II. The potential volume of usable sand in these areas is estimated to range from 2.1 to 3.1 million cy (1.6 to 2.4 million m^3) in Areas IIa and IIb, respectively.

Area III, located southwest of Area II, is an 8.4 $mile^2$ (21.8 km^2) area that may contain as much as 2.3 million cy (1.8 million m^3) of questionable quality material. The presence of hardbottoms may also impact the availability and exploitation of sand resources in the narrower regions of

Area III. Area IV, that encompasses 1.6 miles^2 (4.1 km^2) of the shoreface, is located approximately 4.5 miles (7.2 km) offshore Stump Sound. The volume of potentially usable material contained in this region is approximately 0.3 million cy (0.23 million m^3). Area V encompasses approximately 1.1 mi^2 (2.8 km^2) and it is speculated that as much as 1.5 million cy (1.2 million m^3) of material is contained within the target site.

To adequately resolve the stratigraphy of the targeted borrow areas, a detailed geophysical survey utilizing a high quality Chirp system is required. Data from the surveys would be crucial to the detailed mapping of the three-dimensional aspects of the sediment sequences. A detailed coring program should be implemented to ascertain the compatibility of the materials within the target areas. Core data can be used to define the complex three-dimensional aspects of the discontinuous thin sand sequences. The core data can also provide the necessary means of groundtruthing the seismic data in areas where weathered rock units underlie what is interpreted to be a thick sequence of usable material. Additional high-resolution sidescan sonargraph surveys may be necessary to better define the boundaries of selected target sites in hardbottom areas.

1.0 BACKGROUND

The USACE Wilmington District office is currently preparing a general evaluation report for storm reduction projects along North Topsail Beach and Surf City, NC. The purpose of the aforementioned report is to assess the feasibility and interest in constructing beach fill projects that would reduce storm-related damages along this section of the Topsail Island in Pender and Onslow Counties. Alternative scenarios range from protective berms of varying dimensions to project designs that include a berm backed by an artificial dune. The focal point for these projects is the availability of sufficient quantities of beach fill material for the initial project construction and the subsequent maintenance during the next 50 years.

Investigations of the offshore areas of other nearby beaches showed the shoreface to be a very complex region of the inner continental shelf (Thieler, et al., 1995; Marcy and Cleary, 1997; Johnston, 1998; and Cleary and Riggs, 1999). These investigations indicated that each shoreface sector was unique, and could differ significantly in terms of the underlying geologic controls from the immediately adjacent areas. The sand resource potential of the aforementioned areas was also shown to vary from site to site. Data from investigations by Thieler, et al., (1995) and Thieler (1997) suggested the middle and outer portion of the shoreface off Wrightsville Beach provided only a marginal prospect for beach fill sand. An investigation of the shoreface between Bear Island and Onslow Beach indicated that the sand-rich Oligocene Silverdale Fm, that crops out northeast of Onslow Beach had a high resource potential. This extensive potential borrow source lies within the restricted zone offshore the military controlled barriers and could not be exploited. The studies by Meisburger (1979), USACE (1993), Snyder, et al., (1994), and Marcy and Cleary (1997) of the Carolina Beach to Fort Fisher shoreface indicated the offshore areas of this headland shoreline segment contained significant deposits of high quality sand.

The USACE Wilmington District has conducted a number of investigations in the Topsail Island area (USACE 1989 and 1992) primarily within the soundside areas that back New Topsail Inlet. Potential borrow sources identified to-date for the Topsail Beach portion of Topsail Island included portions of the interior bar (flood-tidal delta) and shoals that have formed within the AIWW access channel (Old Topsail Creek). Although significant volumes of high quality beachfill material are available within the interior shoal system, all potential sources within a reasonable distance of Topsail Island will be investigated for evaluation in the study. McQuarrie (1998) and HDR (2002) provided additional information on the unproven sand resource potential of the area offshore of Topsail Beach. A study by HDR (2002) indicated several potential target areas existed on the shoreface that may contain significant quantities of beach fill material. The irregularly shaped potential borrow areas identified contain thin sequences of interbedded sands and gravels. The volume of usable material in the target areas

was estimated to range from ~3.1 million cy (2.4 million cubic meters) to ~ 65.8 million cys (50 million cubic meters). Much of the unproven area lies along a region located ~ four miles (6.4 km) offshore Topsail Beach (see Figure 1).

It was speculated that a similar sand resource potential would exist off the central and northern portion of Topsail Island. However, the nature of the sedimentary cover and underlying rock units in this area was poorly known. In the interest of locating the most economical and environmentally acceptable borrow sites that could support the proposed projects, information of the availability of beach quality material, or its non-availability, in the waters seaward of North Topsail Beach and Surf City was needed. Therefore, a site-specific assessment of the areas was necessary. With this purpose in mind, the USACE Wilmington District Office contracted with HDR Engineering, Inc. of the Carolinas (HDR) and William J. Cleary (WJC) on August 15, 2002, to conduct a study of the area offshore of North Topsail Beach and Surf City utilizing published reports and available unpublished data.

The focus of the investigation was the identification of areas of the shoreface where significant deposits of beachfill quality sand resources were located. The study area included the shoreface within a region that extended from 3.3 miles (5.3 km) north of New River Inlet, off Onslow Beach, southwestward a distance of 20.5 miles (32.8 km) to the southern boundary of the Surf City town limit. The area of investigation (see Figure 1) extended from the outer limit of the active beach (-30 feet [9.1 m]) seaward to a distance of ~5.0 miles (8.0 km).

This report describes the results of the investigation aimed at assessing the availability of offshore beachfill-quality sand resources. The goal of the investigation was the identification and delineation of suitable borrow sites that contained a minimum of 0.50 million yd^3 (0.39 million m^3) of compatible material for the initial construction and subsequent renourishment of erosion mitigation and storm reduction projects. A secondary focal point and equally important objective was the identification of areas of environmentally sensitive hardbottoms.

The report summarizes available vibracore data from the offshore portions of the study area, as well as pertinent information gleaned from fathometer, seismic, and sidescan sonar profiles. SCUBA-based diver mapping and seafloor sampling surveys provided an added dimension and a means of groundtruthing selected sites identified on the sidescan sonar seafloor mosaic.

2.0 METHODS

The database for this study consisted of both published and unpublished geological and geophysical information. Unpublished information and data from the various reports were collected during various periods between September 1994 and July 2002. Some low-resolution seismic data were available for the Topsail Beach area that delineated the general geology and stratigraphy of the inner shelf (Meisburger, 1977 and 1979; and Johnston, 1998). The USACE collected a number of reconnaissance level seismic lines in the Topsail Island area in the mid 1970s as part of the Cape Fear Region Inner Continental Shelf Sediment and Structure Program (ICONS). Three shore-normal and one shore-parallel seismic profiles were obtained off Topsail Island and Onslow Beach during ICONS operations. The profiles, together with limited core data, provided information on the general stratigraphy of the area, but no detailed data on the nature of the upper 5 m of sediment sequence comprising the Topsail Island and Onslow Beach shoreface. The USACE collected five vibracores in the Topsail Island area during the ICONS program (Meisburger, 1979) that were used to identify the major reflectors identified on the seismic profiles. Four of the cores were recovered from the area offshore New River Inlet, and the remaining vibracore was retrieved from the shoreface ~ 4 miles (6.4 km) offshore Surf City.

Geological and geophysical information from Johnston (1998) were incorporated into the database utilized for this study to assist in the delineation of the nature of the geologic framework of the area offshore Surf City and North Topsail Beach. The data consisted of 307 miles (492 km) of sidescan sonargraph track lines and approximately 75 miles (120 km) of seismic profile data. Four shore-parallel seismic profiles were obtained by Johnston (1998) using a UNIBOOM^{TM} sound source. The data from the seismic profiles were utilized to refine the generalized geological framework provided by Meisburger (1979) and Snyder, et al., (1994). Johnston (1998) collected 200 m range side scan-sonargraph data in a 19.4 mi^2 (50 km^2) area of the shoreface off New River Inlet and produced a mosaic of the seafloor that was used to delineate the extensive hardbottoms on the shoreface and map the distribution of the overlying sediment cover. Surveys obtained by divers at 135 locations provided data on the nature of the seafloor and a means of groundtruthing the sidescan-sonar sea floor mosaic.

The bulk of the information utilized in the conduct of this study included geological and geophysical data collected by WJC from the shoreface during various time periods between June 1998 and July 2002 (see Figure 1). The database consisted of approximately 63 miles (101 km of fathometer profiles, 35 vibracores [Table 1], 3 rock cores, and 260 surface samples [Table 2]). Data from an additional 61 SCUBA dive based seafloor mapping exercises and diver logs complimented the geological and geophysical data (see Figure 1). A sidescan sonargraph mosaic of the seafloor was produced for a 69 mi^2 (180 km^2) area of the shoreface that extended from

Mile Hammocks Bay (Onslow Beach) to the southern boundary of Surf City. Bottom photographs and videos of the shoreface sediment types and hardbottom features offshore North Topsail Beach and Surf City provided useful information on the complex sediment distribution and its relationship to areas of hardbottom.

The diver-retrieved vibracores provided an excellent database that could be used in conjunction with the geophysical data from which interpretations of shoreface geology and sediment characteristics could be ascertained. Vibracores were logged, described, and sampled at the top, middle, and bottom of major units for sedimentological analyses. Core logs were used to determine the thickness of the sediment cover, depth to rock and the type of rock when encountered, and to construct a series of vibracore cross-sections (see Figure 2).

Limestone samples that were recovered from the hardbottom areas and from the adjacent seafloor were described in hand sample. Sixteen of these samples were selected for petrologic study. All samples were sent to a commercial lab for impregnation with a blue epoxy and thin-sectioned. A 300-point modal analysis was performed for each thin-section to determine quartz sand and nature of the carbonate content (cement and allochems). Modern borings were tabulated during modal analysis, but were not considered in classification, in order to assess the original lithologic character and abundance of grain types. The classification of the rocks that underlie the area is based on Folk (1980).

In addition to existing NOAA bathymetric data, 16 shore normal fathometer sonargraphs (profiles) were collected using a Lowrance X-15 unit (see Figures 1 and 3 through 7) for use in determining the distribution of major hardbottom scarps. Scarps and unique hardbottom features were marked and way-points recorded utilizing a Differential Global Positioning System (see Figures 3 through 7). Hard copies of the fathometer traces were used to determine the distribution of the major hardbottom areas and intervening low areas. The profiles were also utilized in conjunction with the sidescan sonar data to identify sites for diver mapping surveys and vibracoring operations.

Photographic surveys of approximately 20 sites offshore New River Inlet provided an additional data set for groundtruthing the sidescan sonar data and mapping the surface sediment types. Video-graphic files from four hardbottom areas offshore Surf City were also utilized in the conduct of this study. The extensive data were imported into a Geographic Information System (GIS) software package (ARCVIEW™) for further processing, manipulation, and analyses. A series of maps, cross-sections, and photographic plates were produced from the various data used in the conduct of this study.

3.0 STUDY SITES SETTING

The shape of the North Carolina coastal system (see Figure 1) reflects major differences in the underlying geological framework (Riggs, et al., 1995). Cape Lookout separates the 525-km long North Carolina coastline into two distinct provinces. Each province has a unique geologic framework that results in a wide variety of diverse coastal features such as headlands, barriers, and estuaries. The coastal system in the southern province, from Cape Lookout south to the South Carolina border, is underlain by rock units that range in age from Upper Cretaceous through the Pliocene (Snyder, 1982; Snyder, et al., 1994; Cleary, et al., 1996). Only a thin veneer of Quaternary age sediments was preserved on the shoreface in southeastern NC. The underlying lithologic units are composed of rocks that are associated with the Carolina Platform, which underlies the region between Myrtle Beach, South Carolina and Cape Fear, NC (see Figure 1). This structural platform has risen slightly over geologic time, causing them to be truncated by the migrating shoreface. Consequently, an erosional topography exists along the southern coastal system with widespread exposures of rocks across the shoreface (Riggs, et al., 1995).

3.1 Geologic Controls

A limited sand supply characterizes most of the southern portion of the NC coastal system. Narrow barrier islands and spits that comprise the shoreline system are "perched" on older geologic units that constitute the shoreface (Cleary and Hosier 1987; Riggs, et al., 1995). The barriers consist of a relatively thin layer of sand that occurs on top of a shoreface composed of much older, eroding geologic units (Riggs, et al., 1995; Thieler, et al., 1995). Depending upon the composition and geometry, this underlying rock platform can act as a headland strongly influencing the beach dynamics and overlying sediment composition. Dissecting the underlying rock units is a paleo-drainage system consisting of a series of large-scale river valleys and adjacent inter-stream divides (Riggs, et al., 1995). This drainage network has controlled the development of large-scale topography and formation of a series of non-headland and headland influenced coastal reaches. This drainage system, coupled with the geologic framework, has controlled the availability of sand resources.

Several headland dominated coastal segments, present in the southern province, were developed on topographically high inter-stream features composed of geologically old, semi-indurated sediments and rocks (Morefield, 1978; Crowson, 1980; Riggs et al., 1995; Marcy and Cleary, 1998, Johnston, 1998). Materials associated with these features may crop out on the subaerial beach such as the Quaternary sequences along the Kure Beach-Fort Fisher area in southern New Hanover County. More commonly, the rocks occur as

submarine features where they crop out on the shoreface forming a submarine headland such as the headland along a portion of North Topsail Beach and neighboring Onslow Beach. In this area, Oligocene age limestones form high-relief hardbottoms (Crowson, 1980; Cleary and Hosier, 1987; Riggs, et al., 1995; Cleary, et al., 1996; Johnston, 1998; Cleary, et al., 2000). These rocks extend beneath North Topsail and Onslow Beaches. The offshore portion of the karstic platform has affected the barriers shape, rates of erosion, and sediment supply.

Non-headland shorelines/shorefaces are the most common type along southeastern NC. These shoreline and upper shoreface segments are generally underlain by one of four different kinds of sedimentary materials that include valley-fill, inlet-fill, transgressing, or regressing shoreface sequences (Cleary and Hosier, 1987; Riggs, et al., 1995). The southern portions of North Topsail and Onslow Beaches that flank the New River Submarine Headland are examples of transgressive barrier segments. In these areas, narrow and low barriers are actively migrating across the upper shoreface that is composed of peat and muddy sand. These young units extend from the estuaries, beneath the barrier, and crop out within the surf zone. Segments of North Topsail Beach are characterized by extensive outcrops of mud and peat (Cleary and Hosier, 1979; Riggs, et al 1995; Cleary and Pilkey, 1996; Young, et al., 1999). The common exposures of these units testify to the thin nature of the modern sand prism. The lack of sand in the system is intimately related to the nature of the offshore geology (Cleary, et al., 1999). The Surf City barrier shoreline in general is a coastal segment that is underlain by several centuries old inlet fill sequences.

3.2 Topsail Island

North Topsail Beach and Surf City extends along the northern portions of Topsail Island, the second longest barrier island located within the Onslow Bay compartment. The Island consists of three communities: North Topsail Beach, which comprises the northern 11.7 mile (18.7 km) segment; Surf City, which covers the central 5.5 miles (8.8 km) of the barrier; and Topsail Beach, which extends along the southern 4.5 miles (7.2 km). The Topsail Island is bordered by New River Inlet to the northeast and New Topsail Inlet to the southwest (see Figure 1). The developed portion of the barrier is approximately 21.7 miles (34.7 km) long and averages approximately 918 feet (280 m) in width. The northeast-southwest barrier orientation exposes the island to frequent winter storms. Prior to 1941, the Island was used as a stock grazing range, with no development or access to the mainland. The Island was used as a U.S. Military Reservation between 1941

and 1947. Development began in the early 1950s, several years after the Island's ownership returned to the private sector.

Topsail Island is situated in a severe, or chronic, overwash zone. Storms that occurred on the Island during the period 1944 to 1962, and during the late 1980s, were particularly devastating. Hurricane Hugo (1989) impacted several sections, particularly North Topsail Beach. Hurricane Hazel (1954) and the Ash Wednesday storm (1962) caused significant damage along the entire barrier. During Hurricanes Fran, Bonnie, and Floyd, much of the Island was overtopped, resulting in the formation of massive and extensive washover topography. The northern and southern segments of the Island have been chronically impacted by winter storms since the mid-late 1980s (Cleary, et al., 2000).

3.3 North Topsail Beach

The Town of North Topsail Beach, the northern study site, comprises the northern 19 km section of Topsail Island. New River Inlet forms the northern boundary of the Town. North Topsail Beach is situated in a chronic overwash zone. Storms during the period of 1944 to 1962, and the winter storms during the late 1980s, were particularly devastating (Cleary and Hosier, 1979; Cleary, et al., 2000). North Topsail Beach, even prior to 1996, was considered to be a high-risk zone. Hurricane Bertha (July 1996) eroded a significant portion of the dune field with the exception of an area immediately downdrift of New River Inlet. Washover features were commonplace. The small amount of recovery due to artificial profile manipulation did little to improve the beach conditions before Hurricane Fran struck the area seven weeks later.

During Hurricane Fran, much of the island was inundated resulting in the damage of a large number of homes, most utilities, and almost all of the fronting dunes. The recession of the HWL following Hurricane Fran ranged from ~11 to 20 m. These low values do not adequately portray the complete devastation of the barrier. The extensive exposures of peat and stump forests on the foreshore clearly indicated that major segments of this barrier were poised for an accelerated increase in rollover rates.

Structural damage during Hurricane Floyd was minimal in comparison to Hurricane Fran and, although few homes were severely damaged, much of the infrastructure was destroyed. The lack of destruction was attributable to the fact that the majority of the poorly constructed homes, and those not built to code, were destroyed by the storms of 1996. A minimum of six temporary inlets formed as the barrier was again breached. Some of the breaches reoccupied former inlets opened during Hurricane Fran. In the

aftermath of Hurricane Floyd, the northern portion of North Topsail resembled an extensive flat washover terrace (Cleary and Pilkey, 1996; Young, et al., 1999; and Cleary, et al., 2000).

Several of the breaches that opened during the storm remained opened for several months, testifying to the lack of sand in the system. Numerous winter storms punctuated the intervals between Hurricane Bonnie in 1998 and Hurricanes Dennis and Floyd in 1999. Overwash penetration during Hurricane Floyd was equal to or slightly exceeded that of Hurricane Fran. Since Hurricane Floyd impacted the area in September 1999, a small artificial dune has been reconstructed. Some natural foreshore, as well as backshore recovery, has occurred along the Town's shoreline.

Realignment of the outer bar channel of New River Inlet has promoted significant erosion of the beach and dunes along the extreme northern end of the Island. Since 1997, shoreline retreat has ranged from 45 to 155 feet in the 4,000 feet shoreline reach downdrift of the Inlet. In May 2002, ~300,000 cy (234,000 m^3) of material was placed along the eroding shoreline in an attempt to mitigate the inlet-related erosion.

3.4 Surf City

Surf City occupies the central 8.7 km of Topsail Beach (see Figure 1). The majority of the barrier in this vicinity fronts the relict flood-tidal deltas of Stumpy Inlet that opened and closed several times during the eighteenth and nineteenth centuries. The finger canals were dredged in the mid to late 1960s across the surface of the marsh that caps the coalesced flood tidal deltas.

The average pre-storm (1996) long-term erosion rates for the southern portion of Surf City ranged from 0 to 2 feet/year (ft/yr) (0.61month/year). In contrast, the northern segment of the Town's shoreline was characterized by accretion rates up to >3 ft/y (0.91m) (Benton, et al., 1993). These shoreline change rates do not adequately portray the pre-storm conditions, particularly the nature of the dune line prior to the landfall of Hurricane Bertha. In many places the dunes were low, scattered, and often scarped. Some of the worst structural damage was recorded along segments characterized by long-term accretion. Washover terraces, in the aforementioned segments, extended across much of the low-lying barrier and into some of the finger canals. The southern portion of Surf City was less susceptible to overtopping, and overwash penetration was greatly reduced due to the topographically higher foredune and adjacent dune field. A continuous, relatively low-relief, restored dune currently fronts much of the Town's oceanfront.

4.0 RESULTS AND DISCUSSIONS

4.1 Bathymetry and General Nature of Shoreface

4.1.1 Mile Hammocks Bay (Onslow Beach) to Alligator Bay (North Topsail Beach)

The shoreface in the northern part of the study area (see Figures 1 and 3) is dominated by a platform-like submarine headland comprised of well-indurated limestone. Figure 1 illustrates the extent of this broad shallow platform. Fathometer sonargraphs obtained from this portion of the shoreface show the highly irregular surface is characterized by a series of low- (<1.6 feet [0.48 m]) to high-relief (>6.6 feet [2.0 m]) hardbottom scarps and intervening flat hardbottoms. The scarps trend in a North-Northeast orientation and lie nearly parallel to the present shoreline. Several notable areas of relatively high-relief hardbottoms occur within the area. One such area is located northeast of the inlet offshore Mile-Hammocks Bay on the Onslow Beach portion of the shoreface. This relatively large irregular bathymetric high rises 5 m above the seafloor (see Figures 3 through 5).

A second area of high-relief hardbottoms occurs between Alligator Bay and New River Inlet (see Figure 5). Low-relief limestone scarps are more common south of the Inlet. The scarps generally border relatively flat, low-lying hardbottoms, the most common shoreface feature. Regionally the surface of the karstic platform is marked by small, irregularly shaped depressions, some of which are filled with a variety of sands and gravels (Johnston, 1998, and Cleary and Riggs, 1999).

Reconnaissance level investigations (Johnston, 1998, and Cleary and Riggs, 1999) have also mapped several linear, shore-normal depressions that were interpreted to be either remnants of channels or broad dissolution features. These shallow features trend to the South and Southeast, and are bordered by hardbottoms of variable relief (see Figure 8). On the seafloor, they appear as relatively flat areas of the shoreface where thin sequences of modern and pre-modern sediments have accumulated. Figure 5, line 11 is a sonargraph taken obliquely to the trend of one of the channel-like areas and shows the hummocky nature of the "channel" along the outer 60 percent of the profile. Alligator Bay (see Figure 1) is probably the landward expression of the linear depression mapped offshore North Topsail

Beach that extends beneath the barrier. The significance of these shallow sandy features as potential borrow sites is discussed in a subsequent section of this report.

4.1.2 Alligator Bay to Surf City's Southern Limit

The nature of the shoreface within the southern portion of the study area, from Alligator Bay to Surf City's southern limit, is similar to the shoreface segment off North Topsail Beach. The most significant difference is the lack of high relief hardbottoms >6.5 feet (>2 m) that occur on opposite sides of the area that straddles New River Inlet (see Figure 8). The shoreface off the southern portion of North Topsail Beach and Surf City is characterized by undulating, relatively flat hardbottom platform punctuated by scattered low-relief hardbottom scarps and sediment-filled depressions. Information gleaned from a number of shore-normal fathometer profiles and diver surveys indicated the irregularly spaced, landward facing scarps seldom rise more than 1.0 m (3.3 feet) off the surrounding sea floor (see Figures 6 and 7). The bordering hardbottom surface generally slopes in a seaward direction. Often the depression-like flat areas of the sea floor, between the scarps, are sites where sediment has filled the rock bounded topographic lows.

4.2 Seismic Data

4.2.1 Mile Hammocks Bay (Onslow Beach) to Alligator Bay (North Topsail Beach)

The USACE ICONS of the Topsail Island region of the inner continental shelf indicated the shoreface was underlain by calcareous rich units of Oligocene age. The data of Meisburger (1977 and 1979) provided limited information on sand resources in the area. The stratigraphic geometries of the units underlying the northern portion of the area were investigated by Johnston (1998) in a more detailed study using UNIBOOM™ seismic data. The seismic survey produced images of the upper ~260 feet (80 m) of the shoreface sequence. Figure 9 is a representative shore-parallel profile collected along the inner shoreface offshore North Topsail Beach that depicts the six seismic sequences that were delineated by tracing regional and local unconformities that separated mappable seismic units.

The uppermost stratigraphic unit mapped from seismic data crops out over most of the northern portion of the study area, and was interpreted to be correlative to the upper Oligocene Belgrade Formation (see Figures 9 A-B) exposed inland at the Martin Marietta Belgrade Quarry, ~16 miles (~25 km) inland (Johnston, 1998). This unit forms the majority of the limestone platform that controls the bathymetry of the sea floor in the area (see Figure 8).

Johnston (1998) mapped another unit that crops out on the sea floor in the southernmost portion of the study area that is correlative to the lower Oligocene Trent Formation (O_t). The Trent and Belgrade Formations are compositionally similar (sandy bio-sparrudites) and are separated in the Belgrade Quarry by a highly phosphatized and bored diastem (unconformity ρ) in Figure 9. The location and development of the linear channel-like feature offshore Alligator Bay may be related to the contact between the Trent and Belgrade Fms (see Figure 8).

Johnston (1998) also mapped two types of pre-modern channel structures incised into the Belgrade Formation. The differences between the channels were resolved by diver observation and core data. Type I channels are lined with the Aquitanian age *Crassostrea gigantissima* oysters, as described by Zullo and Harris (1987), and filled with light gray calcite cemented sandstone (designated OM_{pfcf} in Figure 9) . These Tertiary channel structures (OM_{pfcf}) form the core of the bathymetric highs (high relief hardbottoms) as lithified channel features (see Figure 8). A second channel type of Holocene Age (Type II) was identified and mapped off New River Inlet. This feature is traceable over a portion of the shoreface, and core data indicate it is backfilled with unconsolidated sands and estuarine mud (Q_{pfcf} in Figure 9).

4.2.2 Alligator Bay to Surf City's Southern Limit

Although some seismic data are available for the southern portion of the study area, they are low quality and of very limited use in delineating the details of the upper 16.4 feet (5 m) of the shoreface sequences. Data from Johnston (1998) and Snyder (personal communication, 1995) suggest the Trent Fm is the major stratigraphic unit that crops out across much of the Surf City shoreface. Meisburger (1979) reported that the shoreface off Surf City was underlain by Oligocene age units that dipped to the south and southeast. The description of one of the ICONS cores recovered 4.5 miles (7.2 km) offshore Surf City indicated that

the Oligocene unit was composed of a calcareous/quartz sand unit that was capped by a thin sediment veneer.

McQuarrie (1998) demonstrated that the principal stratigraphic unit that underlies much of the Topsail Beach shoreface was the Orb-A Oligocene sequence of Snyder, et al., (1994). Vibracores recovered along boomer track lines indicated the Orb-A unit (River Bend formation) consisted of an olive green, silty, often dolomitic, fine quartz sand and silt. This mid Oligocene sequence was identified as the dominant unit that underlies the thin shoreface sediment sequence off the northern portion of the Topsail Beach shoreface (HDR, 2002). Vibracores and numerous diver surveys provided information on the lithology of the shallow subcrop units that are frequently exposed as hardbottoms offshore Surf City. The data that are discussed in a subsequent section, indicated that the Orb-A silty sand unit is present, as are a variety of limestone and sandstone units.

McQuarrie (1998) also mapped a variety of fluvial channel features on the Topsail Beach shoreface. According to McQuarrie (1998) many of these Quaternary channels are continuous and can be traced across the shoreface off the southern portion of Topsail Island. Subsequent groundtruthing with vibracores in some of these features indicated that the channels were infilled with dark gray estuarine mud (HDR, 2002). Modern analogues of these channels are the small coastal plain, marsh filled estuaries such as Bishop, Kings, Turkey and Virginia Creeks (see Figure 1). It is likely that similar mud-filled paleo-channels occur across the southern portion of the shoreface off Surf City and possibly in isolated areas offshore of Alligator Bay.

4.3 Side Scan-Sonargraph Data

4.3.1 Mile Hammocks Bay (Onslow Beach) to Alligator Bay (North Topsail Beach)

An inspection of the sidescan-sonargraph mosaic indicated that there are several very distinct types and zones of sea-floor morphology that occur within the northern portion of the study area (see Figure 10). The distinctly different accoustic "signatures" are indicative of lateral changes in the lithology and relief of the underlying startigraphic units as well as and the nature and thickness of the sediment cover. The various types of seafloor morphology that were identified by their acoustic signatures were ground truthed using data from diver surveys and

observations. The data indicated that the shoreface in the vicinity of New River Inlet is dominated by low- to moderate-relief 0.65 to 6.5 feet (0.2 to 2.0 m) scarps and associated flat hardbottoms. Much of the North Topsail Beach shoreface is an area of contiguously exposed limestone hardbottoms of variable relief (see Figure 8).

The dark gray and black colored sonar returns imaged on the sea floor mosaic (see Figure 10) depict areas of high acoustic reflectance, such as hardbottom or rippled coarse shell and lithic gravels. The light colored gray to white sonar signals represent areas of low acoustic reflectivity that are usually indicative of unconsolidated materials, such as fine to medium sized sand. Areas dominated by strong acoustic returns (dark) with weaker (white) reflections produces a "pock-marked" appearance, suggesting a hardbottom area with depressions that are filled with shelly coarse sand and gravel. Areas of mixed acoustic returns produce a "patchwork" or "scaly" appearance that represent rock hardbottoms mantled by a rippled veneer of unconsolidated materials that range in size from sand to gravel (see Figure 10). Much of the continually exposed limestone platfom-like hardbottoms in this area are littered with a thin and patchy veneer of coarse gravels derived from the bio-degradation of the limestone.

Interpretation of the data indicated that sediment accumulation is extremely limited and generally restricted to four irregularly shaped, shore normal "linear" features (see Figures 8 and 10). These "channel-like" features contain only a thin sequence of modern sediment. The sediment ponds located offshore Mile Hammocks Bay (Onslow Beach) and Alligator Bay (North Topsail Beach) represent bathymetric lows that are filled with 3.3 feet (< 1 m) of sediment (see Figure 10). Fields of rippled coarse gravel and sand are commonly found in the linear sediment filled depressions (see Figure 10). Frequently, a cap of rippled, fine to medium grained silty, quartz sand mantles the gravel fields.

4.3.2 Alligator Bay to Surf City's Southern Limit

Figure 11 depicts a side scan sonargraph mosaic of the shoreface off the southern portion of North Topsail Beach and Surf City. The different accoustic "signatures" visible on the sea floor mosaic reflect the complex distribution of the principal stratigraphic units that comprise the underlying geologic framework and the nature of the overlying sediment veneer when present. The data used for groundtruthing the sidescan sonar imagery were obtained from 61 SCUBA

diving-based mapping exercises aimed at visually identifying the inferred bottom sediment/rock type and sampling the surficial sediment cover and hardbottoms (see Figure 10). Interpretation of the sea floor mosaic was based on the integration of the accoustic data and the specific sedimentological and lithological characteristics of the various sample sites.

The very dark gray sonar returns depict areas of the shoreface with high acoustic reflectance, such as rock or gravel (see Figure 10). Light gray to white sonar signals represent areas of low acoustic reflectivity indicative of unconsolidated silt to fine sand. Areas dominated by strong acoustic returns (dark) with weaker (white) returns produces a "pock-marked" appearance, suggesting a flat hardbottom area with minor depressions that are filled with shelly coarse sand and gravel. Other portions of the shoreface are characterized by areas of mixed acoustic returns that produces a "patchwork" appearance that represents hardbottoms mantled by a veneer of unconsolidated materials ranging from silt to gravel (see Figure 10).

Interpretation of the side scan sonargraph mosaic indicated that, in general, the sea floor in the southern portion of the study area consists of isolated, irregular areas of 1 to 2 mile (1.6 to 3.2 km) wide fields of shore-normal to shore-oblique sedimentary features interspersed amongst areas of low-relief hardbottoms (see Figure 11). Most of the fields of these low relief linear features are discontinuous, while several areas extend as much as 1.2 miles (2.0 km) across the study area. The channel-like features are similar to the ripple scoured depressions (RSDs) found off Wrightsville Beach and are often floored with rippled coarse shell and lithic gravels, which are imaged on the side scan sonar mosaic as areas of high accoustic reflectivity (Theiler, et al., 1995 and 1998). The immediately adjacent areas that flank the linear (channel-like) depressions (RCDs) are characterized by very fine quartz sand and silt with varying amounts of sand sized shell debris. The presence of these linear depressions on the Topsail Beach shoreface were interpreted to be related to the occurrence of paleo-fluvial channels of varying age (McQuarrie, 1998). The interpretation was based upon analyses of seismic data that indicated the rippled depression features, imaged on side-scan sonargraph profiles, occurred within ancestral fluvial channels.

Scattered areas characterized by high acoustic reflectance and mixed acoustic returns occur in the northeastern portion of the southern segment of the shoreface in a region extending from Alligator Bay southwestward a distance of ~ 2 miles

(3.2 km). Fathometer profiles (see Figures 6 and 7) obtained from this area show the shoreface is characterized by a gently sloping surface, interrupted by a series of 1 to 3 feet (0.30 to 0.91 m) high irregularly spaced scarps. Diver surveys of selected inferred hardbottom sites identified on fathometer profiles indicated that the scarps and scarp backs are composed of moldic limestone of the Trent Fm. A patchy veneer of silty sand and gravel that produces a "pock-marked" or "patchwork" appearance mantles the surface of the flat hardbottom areas.



The morphology and signature of the 2-mile segment of the sea floor to the southwest is markedly different and characterized by a distinct acoustic nature. An abrupt change occurs from the consistently similar sonar signature of the RCD zone to a 2- to 3-mile (3.2- to 4.8-km) wide area of low reflectivity (light colored) that extends obliquely across the shoreface. An area of mixed sonar returns, indicative of sediment patches within low relief hardbottoms, occurs within the innermost portion of this relatively homogeneous area of weak sonar returns. Diver surveys indicated that the surface sediment within the majority of this zone of low reflectivity was a silty, very fine sand underlain by a light tan to olive green, calcareous siltstone.

Sea floor mapping surveys and rocks collected from low lying hardbottoms along the inner shoreface demonstrated the low lying hardbottoms and scarps 1 to 2 feet (0.31 to 0.60) are exposures of the Trent Fm. The southwestern 4 miles of the shoreface, imaged on Figure 10, is an extremely complex area offshore the central portion of Surf City. Diver surveys and fathometer profiles illustrated that numerous saw tooth-like 1 to 2 feet (0.30 to 0.60 m) high limestone scarps occur across much of this shoreface segment. Core data and rock samples collected by divers indicated that Trent Fm limestone underlies much of this area. Some smooth, undulating areas of the sea floor occur within this complex area offshore the northern portion of Surf City. These hummocky and gently sloping areas are mantled by silty sand and underlain by calcareous siltstone (ORB-A).

4.4 Underlying and Exposed Rock Units

4.4.1 Mile Hammocks Bay (Onslow Beach) to Alligator Bay (North Topsail Beach)

A patchy, very thin sediment veneer occurs across much of the shoreface within the northern portion of the study area (see Figures 8 and 11). The surface

sediment layer consists of a mixture of modern and palimpsest material that rests disconformably upon the Oligocene Belgrade limestone that crops out over the majority of the North Topsail Onslow Beach shoreface. The complex surface sediment mosaic originates from the reworking of the underlying stratigraphic units (see Figure 9). The surface sediment unit is easily reworked during storms, exposing hardbottom platforms and low relief scarps in areas where the sediment cover is thin.

The subcrop and outcrops within the study area are composed of two basic Oligocene limestone units (Belgrade and Trent Formations) that are similar in composition. The contact between the Belgrade and Trent Formations lies along the southern margin of Alligator Bay, a broad shallow reentrant, located ~ 5 miles (8.0 km) southwest of New River Inlet (see Figure 9). Both rock units are classified as moldic, sandy limestones and are difficult to distinguish in hand specimens. An upper Oligocene/Lower Miocene channel complex, which contains lithified sandstone, is incised into the Belgrade Fm (see Figures 8 and 9). This unit crops out on the shoreface, forming several major bathymetric features. The structural geometry and composition of the geologic units have dictated the morphology of the hardbottom features in the area (Johnston, 1998).

The Belgrade limestone is the most widespread unit and forms the extensive platform off the mouth of New River Inlet. The low-relief (2.5 feet [0.75 m]) scarps in this area of the shoreface are also composed of this well-indurated, bio-moldic limestone (see Figure 11). The scarps that trend to the north-northeast usually border relatively flat surfaces that slope to the east. The surface of the karstic platform is highly irregular and generally lacks any appreciable sediment cover. The barren limestone surface is often mantled by irregular meadows of macroalgae, particularly on the higher and wider protected areas. The surface is also characterized by numerous fractures of variable and many shallow depressions some of which are partially filled with a variety of sediment (see Figure 12).

The large high relief hardbottoms located northeast and southwest of New River Inlet represent exposures of the Upper Oligocene/Lower Miocene Channel unit. These relatively high (6.6 to 16.4 feet [2 to 5 m]) bathymetric features are composed of very erosion-resistant calcareous sandstones. Both features are characterized by a series of step-like ledges. Johnston (1998) mapped the high relief elliptical-shaped exposure located southwest of New River Inlet and

demonstrated that the feature was an erosional remnant of the lithified channel complex (see Figure 13). The base of the scarp along this hardbottom has been interpreted to coincide with the floor of the channel (Crowson, 1980; Johnston, 1998). The large oyster valves commonly observed on the shoreface (see Figures 13 and 14) and the adjacent beach is derived from the Tertiary channel complex whose floor is lined with the giant oyster (*Crassostrea Gigantissima*).

The limestone exposures in this area provide an immediate source of "new" sediment for the surrounding shoreface that ranges from silt to boulder size material (see Figures 16 and 17). The sediment is a by-product of the activities of the many boring and encrusting organisms that are found on the hardbottoms (see Figures 18 through 20). The large blocks and lithic gravel and sand found at the base of the limestone scarps is derived from the mechanical erosion and bio-degradation of the limestone that forms the scarps (see Figure 19). Bus-sized blocks of encrusted and corroded limestone are commonly found around the margins of the high relief hardbottom located northeast of the inlet. The blocks are separated from the intact hardbottom by a series of variably wide one-meter deep fractures. These collapsed blocks form an irregular ramp or talus at the base of the feature (Johnston, 1998).

The rock units forming the majority of the platfom and the low to moderate relief scarps offshore North Topsail Beach and Onslow Beach are gray to yellowish-brown, Belgrade and Trent Fm. sandy bio-moldic limestone (Johnston, 1998). The majority of the molds are remnant impressions of pelecypods (Pectens) and gastropods (see Figure 9). The moldic pore space represents aragonitic shell material that was leached during various stages of diagenesis. The higher relief features are composed of calcite-cemented sandstone that is characterized by significantly less moldic pore space. The quartz-rich nature of the sandstones probably accounts for the erosion resistant nature of this unit and the high relief of the aforementioned features.

Johnston (1998) conducted a petrologic analysis of 14 samples collected from the rocks comprising the platform. Thin-section modal analyses of limestones from the platform indicated that the terrigenous fraction, composed dominantly of quartz (0.01 in [~ 0.25mm]), comprised ~ 25 percent of the samples examined while the carbonate allochems and cement comprised the remaining portion of the rocks (see Figures 21 and 22). The great variety of cements observed during the thin-section analyses indicated the Belgrade rocks have a very complicated

diagenetic history. The samples analyzed by Johnston (1998) were classified as moldic sandy biosparrudites (Folk, 1962). Figures 22 and 23 illustrate the general characteristics of the Belgrade Formation exposed on the North Topsail Beach – Onslow Beach shoreface (Johnston, 1998).

4.4.2 Alligator Bay to Surf City's Southern Limit

The thickness of the modern sediment cover increases slightly in a southwesterly direction, away from the broad, exposed limestone platform off New River Inlet. The surface sediment sequence in the southern area is similar in composition and texture to the thin sediment sequence found on the northern shoreface segment. Two distinct Oligocene stratigraphic units underlie this region of the study area and occasionally crop out on the shoreface (see Figure 12). The subcrop and outcrop units are composed of stratigraphic units that range in composition from a quartz-rich, calcareous-siltstone to very fine grained sandstone (River Bend Fm) to a moldic, sandy limestone (Trent Fm.) (see Figures 23 and 24).

The Trent limestone forms the numerous low-relief (1 to 3.5 feet [0.30 to 1.06m]) hardbottom scarps offshore the southern portion of North Topsail Beach and Surf City (see Figures 10, 25, and 26). All of the scarps surveyed appear to be landward facing features. The relief of the scarps is highly variable across the shoreface and varies from site to site (see Figures 3, 5 through 7). The barren seaward slope of the limestone hardbottom is hummocky and characterized by numerous irregular fractures and shallow depressions. The surface sediment unit at the base of the larger and more extensive scarps generally contains gravel and cobble size fragments of the units comprising the scarps (see Figures 27 and 28).

The limestone rock unit forming the discontinuous exposures in the southern shoreface segment is similar in color and texture to those found on the northern portion of the shoreface. Generally they are light gray to yellowish-brown, moldic sandy limestones. The majority of the molds are remnant impressions of a variety of pelecypods and gastropods (see Figures 9 and 23). Modal analyses of 20 representative thin-sections of rocks from scarps and flat lying hardbottoms indicate that the terrigenous fraction comprised approximately 25 percent of the samples examined. Subrounded fine grained quartz comprises ~ 99 percent of the terrigenous fraction. The majority of the Trent limestone samples analyzed are classified as moldic, sandy biosparrudites (Folk, 1962). Figures 29 through 32

show the common characteristics of the Trent Formation exposed on the southern segment of the shoreface.

The siltstone hardbottoms, which were absent on the northern shoreface segment, are composed of poorly consolidated calcareous silt (see Figures 31 C through D). The siltstone is only exposed in two isolated areas offshore the central portion of Surf City at the base of limestone scarps that mark the contact between the two units (see Figure 11). However, core data show that the unit is very widespread and underlies major areas of the shoreface off the southern portion of North Topsail Beach and the southern shoreface segment off Surf City (see Figure 11). There is some conjecture as to whether the tan to olive green calcareous siltstone is correlative to the Oligocene River Bend Fm siltstone that crops out over extensive segments of the shoreface from Figure Eight Island to Fort Fisher. McQuarrie (1998) mapped the adjacent Topsail Beach shoreface and assigned the siltstone to the River Bend Fm. However, Harris (2002, personal communication) suggested that the siltstone recovered offshore the central portion of Topsail Island represented a facies of the Trent Fm.

Data from the insoluble residue analysis of 12 siltstone samples from the study area indicated that the quartz silt and sand fraction averaged 72.2 percent by weight of the samples analyzed (Willson, 2002, personal communication). Modal analyses of thin sections of siltstone samples from the Kure Beach shoreface indicated that quartz silt constituted only 17 percent of the dolomite rich samples analyzed (Marcy and Cleary, 1997). In comparison, data from the thin-section analysis of the siltstone offshore Surf City indicated the quartz silt fraction comprised ~ 75 percent of the sample and no dolomite was present. The difference in the percentages of quartz silt between the two sites is a function of the weathering (dissolution) of the carbonate cement (calcite and dolomite) in the siltstone within the study area.

Regardless of the calcareous siltstone's stratigraphic designation, it is an important unit that contributes material to the sediment cover that blankets most of the southern portion of the study area. Bio-erosion and wave quarrying of the siltstone adds a significant volume of fine-grained material to the shoreface sediment sequences. Vibracores that have penetrated the upper 5 feet of the unit show that the siltstone sequence is seldom lithified, commonly bored, and easily disaggregated. The unit's susceptibility to erosion and wave quarrying accounted for the small number of outcrops in the area. The very fine grained and

unconsolidated nature of the unit has resulted in uniform erosion and relatively gently sloping subcrop surfaces that are periodically exposed where the sediment cover is thin. The broad depressions that are underlain by the siltstone are the only sites where beach fill quality sand may be preserved.

4.5 Shoreface Surface Sediments

4.5.1 Mile Hammocks Bay to Alligator Bay

The nature of the surface sediment types and their distribution was initially ascertained through an analysis of sidescan sonargraph profiles, diver surveys and eventually megascopic analyses of 125 surface sediment samples. The distribution of the major sediment types (gravel, sand, and mud) and their mixtures is difficult to map due to the extremely complex exposure pattern of the highly variable relief of the scarps and the flat hardbottom areas. Figure 34 depicts a cartoon and bottom photographs of sediments of a generalized area of the shoreface where scarped and flat hardbottoms are common. Figure 34 conveys the fact that the distribution of the major sediment types is complex and is dictated by the spacing, sea floor relief and the composition of the rock exposures. As a general rule, there is a paucity of sediment 0.16 feet (<5 cm) or no sediment cover on scarp backs. Sediment that temporarily accumulates is eventually transported off the exposed topographic highs by incident waves that periodically re-suspend the sediments and erode the barren surfaces. On scarp backs protected by scattered meadows of macro-algae or in topographic lows proximal to the scarps, gravel-sized lithoclasts are common. Ponded accumulations 3.3 feet (~1 m thick) of sand and silty sand were found only at the base of scarps (see Figure 12), in linear depressions, and in irregular, shallow topographic lows (dissolution features) on scarp backs (Johnston, 1998).

Most of the silt to gravel size sediment in the hardbottom areas results from a combination of bio-erosion (see Figures 32 through 35) and wave quarrying. The moderate- to high-relief hardbottom scarps surveyed were undercut due to a combination of abrasion and bio-erosion. Undercutting at the base of the scarp produced thin overhangs of the hardbottom rocks that extended 3.3 to 4.9 feet (1 to 1.5 m) from the main body of the exposure (see Figure 12). The encrusted and extensively bored rock that comprises the protrusion is structurally weakened, and many eventually collapse forming large talus blocks (cobble to boulder size material) at the base of the scarp (Johnston, 1998).

Johnston (1998) found that most (~70 percent) of the shoreface (see Figure 8) off Onslow Beach and North Topsail Beach, between Mile Hammocks Bay and Alligator Bay, was an area of low - to high-relief hardbottoms with a very thin sediment cover (0.33 feet [< 10 cm]). The sediments sampled at the base of the scarps and on scarp backs contained an average of ~72 percent sand and 28 percent gravel sized material (see Figures 35 through 37). The sediments collected were carbonate-rich (26 percent) and reflected the abundance of gravel size limestone lithoclasts, produced by the mechanical and bioerosion of the submarine exposures. Figures 38 and 39 depict the general nature of the carbonate lithic gravel and sand in this area of the shoreface.

Johnston (1998) mapped several poorly defined, very shallow depressions that extend across portions of the shoreface in the vicinity of New River Inlet (see Figure 8). These features trend to the south and southeast and appear as sandy, relatively flat areas of the sea floor. As previously indicated, Johnston (1998) interpreted these irregular, shallow rock-bound topographic lows to be dissolution features or remnants of paleo-channels. Sediments collected from these shore-normal linear "depressions" consisted of 88 percent sand and 12 percent gravel. The average carbonate content of this suite of samples was 14 percent.

4.5.2 Alligator Bay to Surf City's Southern Limit

The distribution and variability of the surface sediment types (see Figure 53) was ascertained through an integration of data from the analyses of sidescan sonargraph profiles and from diver mapping/sampling surveys. Megascopic examination of the sediment samples collected by divers coupled with diver observations, bottom photographs and videotape footage provided added dimensions for mapping the various types of sediments that comprise the mobile sediment veneer in the southern part of the study area (see Figures 44 through 47). Limestone hardbottom areas are common occurrences and comprise a significant portion of the sea floor. The limestone hardbottoms extend intermittingly from Alligator Bay to the southern limit of Surf City and beyond. The relief and spacing of the limestone scarps/hardbottoms control the distribution of the gravel and sand/silt fractions in a manner identical to that depicted for the North Topsail Beach/Onslow Beach portion of the shoreface (see Figure 34x). Fathometer profiles (see Figures 6 and 7) obtained from the southern shoreface segment illustrate that the scarps are generally low to moderate relief 0.5 to 4 feet (0.15 to

1.2 m) features. There is a general lack of sediment (0.16 feet [<5 cm]) or no sediment cover on the hummocky hardbottom surface that back the scarps. Localized accumulations of silty, very fine to fine, shelly quartz sand were observed to pond at the base of scarps or in small dissolution depressions on scarp backs (see Figures 44 and 46).

The River Bend Fm siltstone, the second important stratigraphic unit in the area, forms the subcrop unit in the flat gently sloping non-hardbottom areas of the shoreface (see Figure 11). The regional outcrop pattern of Trent limestone and the River Bend siltstone coupled with the localized bathymetric highs and lows associated with the hardbottoms control the distribution of the major sediment types. Consequently, mapping the distribution of the major sediment types in this area was difficult due to the extremely complex bathymetry.

Compilation of the data suggested that there are several major types of surface sediment. Most of the shoreface is blanketed by shelly, very fine quartz sand to sandy quartz silt (see Figures 33 and 53 to 59). A significant portion of the silt and very fine quartz component of the surface sediment layer is probably derived from the periodic exposure and erosion of the Oligocene siltstone subcrop unit. The proportion of silt within the surface veneer varies from site to site and across areas of hardbottom. Protected areas generally contain a greater percentage of fine material particularly in the lee of outcrops. Clean fine to medium quartz sand is not an abundant sediment type (see Figures 44 to 46 and 48). It is generally restricted to hardbottom areas where the relief is relatively subdued.

Gravel size material is abundant and is generally comprised of limestone lithoclasts and molluscan material (see Figure 47). The shell material is most commonly fragmented and stained orange brown or gray-black in color. The majority of the gravel and gravelly sand is found near or on hardbottoms and within the linear shore-normal features that contain patchy, rippled coarse material (see Figures 49 to 51). Much of the sediment on the shoreface is related to and a by-product of epifauna (encrusters and grazers) and infauna (borers) activity (see Figures 24 to 28 and 46 to 52).

Isolated pockets of fluidized, black to olive gray mud occur in scattered areas of the shoreface. In areas where the fluidized mud was encountered, the bottom visibility was generally very poor, and, therefore, the relationship of the mud to the surrounding sediment and sea floor could not be determined. Divers reported

that the mud appeared to form a mobile drape over both soft and hardbottom areas alike. It is likely that the ponds of mud are restricted to a localized topographic low and may be derived in part from the reworking of underlying estuarine units that crop out on the sea floor in the immediate area.

4.6 Shoreface Sediment Sequences

Data derived from the analyses of the various suites of vibracores and observations made during diver surveys indicated that the shoreface Holocene sediment sequence is thin and consisted of units of very fine quartz sands intercalated with sandy gravels and gravelly sands (see Figures 2, 53 to 59). Mud-rich back barrier sequences were recovered in a number of vibracores from backfilled paleo-channel features. Thickness of the modern sediment package across the entire study area, seaward of the active beach, ranged from less than one half inch (1.0 cm) in hardbottom areas to more than 6.2 feet (1.9 m) in intervening regions (see Figure 60). Figures 53 to 59 represent a series of shore-parallel and shore-normal vibracore transects that depict the variability of the major sediment types and the thickness of the units that comprise the Holocene shoreface sediment sequence. Inspection of the cross-sections shows that the thickest sequences recovered were either mud or silt rich in nature. The core data clearly indicated that there is a paucity of usable material in the area.

4.6.1 Mile Hammocks Bay to Alligator Bay

Johnston (1998) reported that the Holocene sediment cover on the shoreface in the northern part of the study area was generally too thin (0.65 feet [<20 cm]) to core, except in isolated bathymetric lows and in a narrow channel-like feature off New River Inlet (see Figure 8). With the exception of the gravel-rich accumulations at the base of hardbottom ledges and on some scarp backs, the broad limestone platform off New River Inlet was generally barren of sediment (see Figures. 8, 34, and 60). Only seven cores of variable length were successfully collected from the hardbottom areas in the northern portion of the study area. In all cores, recovered bioclastic-rich, fine to medium quartz sand was the most dominant sediment; abundant gravel lithoclasts were encountered near the bottom of the cored sequence (Johnston, 1998).

Several of the cores were collected from what has been interpreted to be the incised paleo-channel of New River, including cores NT500, NT502, and NRI1 (Johnston, 1998; Cleary and Riggs, 1999). The ICONS operations (Meisberger,

1979) also retrieved four cores from the paleo-channel (C98 - C101) during the mid 1970s. Figure 53 depicts a shore-normal transect of the cores recovered from this channel-like feature. In general, the cores collected by Johnston (1998) penetrated only a short distance before encountering rock or gravel. The short cores consisted of thin 1.3 feet (<40 cm) bioclastic, fine to medium sands, gravel and mud lenses. Core NRI 1 penetrated only 0.72 feet (0.22 m), before encountering a bluish gray fluidized mud that made core extraction difficult. The 0.30 feet (9.5 cm) of NRI 1 consisted of homogeneous fine quartz sand overlying mud. Core NT 500 located further seaward, between C 100 and C 99, recovered 5.2 feet (1.6 m) of inter-bedded sand and gravel. According to the core logs of Meisburger (1979) Core 100 contained 19.2 feet (5.87 m) of fine to medium quartz sand, calcareous sand and sandstone pebbles and calcareous sandstone, while Cores 98 and 99 recovered 0.75 to 4.5 feet (0.22 to 1.4 m) of the same units before encountering limestone.

Cores 98 to 101 from the ICONS operation were not available for inspection to verify the core descriptions of Meisburger (1979). If the descriptions of aforementioned ICONS cores are correct, and Cores 99 to 100 (see Figure 50) contain sand rather than calcareous sandstone, then this area of the shoreface warrants further investigation on a very detailed scale. These limited data suggested that the shoreface off New River Inlet, seaward of the 30 feet (9.1 m) contour, is the only region where significant sand deposits may occur in the northern part of the study area.

The fact that no other portion of the shoreface in this part of the study area is underlain by Holocene age tidal inlet or backbarrier deposits indicated that the recent transgression has eroded all earlier formed coastal lithosomes with the possible exception of those located 4.2 to 4.4 miles (6 to 7 km) off New River Inlet. The thicker sand accumulations south of New River Inlet may represent preserved tidal inlet sand bodies that were preserved during a rapid rise of sea level that quickly raised the depth of the shoreface ravinement. The rapid rise of sea level coupled with channel incision across the limestone platform may have contributed to the preservation of the suspected inlet-related sand bodies. Theiler, et al., (submitted) have identified a tidal inlet facies of considerable extent offshore Wrightsville Beach in an area where backbarrier deposits are generally lacking on the inner shoreface, except in small mud-filled tidal channels. The authors postulated that a rapid rise of sea level occurred ~7.3 ka that contributed to the preservation of the sand deposits by raising the level of ravinement.

4.6.2 Alligator Bay to Surf City's Southern Limit

Vibracore data and information from diver surveys indicated that the shoreface in the southern part of the study area consisted of relatively thin sequences of silty, fine to very fine quartz sands and interbedded with sandy gravels and gravelly sands (see Figures 54 to 59). The thickest modern sediment sequences cored 1.6 to 6.4 feet (0.50 to 1.95 m) were recovered from mud filled paleo-tidal creek channels incised into the underlying Oligocene siltstone unit or from isolated topographic lows that contain remnant sequences of estuarine material (see Figure 60).

McQuarrie (1998) recognized a variety of incised Quaternary fluvial channel features offshore Topsail Beach. McQuarrie (1998) indicated that many of the channels are continuous and could be traced across the Topsail Beach shoreface. HDR (2002) documented that many of the features on the Topsail Beach shoreface were infilled with dark gray-brown, organic estuarine mud. It is highly unlikely that similar channel features found on the Surf City North Topsail shoreface will provide beach fill quality material. The landward portion of some of the shallow channels extends beneath the barrier island and bar built estuary. The small coastal plain, mud-dominated estuaries incised into the mainland between Alligator Bay and Virginia Creek are the modern analogues of the offshore features (see Figures 57 to 58). Remnants of Holocene backbarrier sequences were recovered during coring operations in isolated areas (see Figures 54 to 59). The estuarine sequences generally contained thin, interbeds of mud and silty, shelly sand and occasionally organic rich lenses (peat).

Figures 54 to 59 represent a series of shore-parallel and shore-normal vibracore transects that depict the variability of the sediment type and thickness of the units that comprise the modern shoreface sediment sequence. These data suggest the sediment cover is patchy and extremely thin. The majority of the individual sand units present, as well as other modern sedimentological units (muddy sands and gravel), are less than 1.3 feet (0.40 m) thick. The burrowing activity of organisms commonly obscures the contacts of many of the layers; and hence, many of the units appear to grade into the underlying units. Commonly, the sediment sequences are extensively mottled and a number of cores recovered contain units that were homogenized due to the extensive bioturbation. The burrowing activity of organisms probably contributes to the fine-grained nature of the longer core

sequences recovered in the areas underlain by the siltstone. The burrowing activity of the infauna commonly extends into the underlying weathered calcareous siltstone and weathered limestone (see Figures 55 to 59).

Core logs and vibracore transects (see Figures 54 to 59) illustrate that gravel rich units are widespread and comprise major portions of the thin shoreface sequences. The units contain varying amounts of silt and sand. The shell and lithic gravel units commonly form the basal unit of the modern sediment sequences and are generally capped by 0.32 to 0.82 feet (10 to 25 cm) thick, very fine to fine grain quartz sand units. Megascopic analyses of representative gravel-rich samples indicated that the gravel-rich samples were classified as sandy gravels and gravelly sands. Gravel content comprised as much as 95 percent of some samples (see Figures 51 to 56). Gravel rich sequences were typically found in areas where limestone forms the subcrop unit and near exposures (hardbottoms).

Figure 60, which depicts the thickness of the modern sediment sequence, clearly shows that much of the southern portion of the study area is covered by sediment sequences less than ~1.0 feet (30 cm) thick. The area with the thickest deposits of sediment (> 3.0 feet [>1.0 m]) appears to be restricted to a region located within the central portion of the shoreface offshore the southern portion of North Topsail Beach. The sea floor in this area is characterized by linear shore-normal depressions (RCDs) that contain fields of rippled sand and gravel. This highly irregular region of the shoreface is underlain by the Oligocene siltstone. A second area where relatively thick sediments are found is located offshore the southern portion of Surf City seaward of Topsail Sound (see Figure 60).

Figures 54, 55, and 59, are shore-parallel (B-B' and C-C') and shore-normal (F-F') vibracore transects that depict the variability of the sediment types and thickness of the cored sequences in the aforementioned area offshore North Topsail Beach. Although some relatively thick sediment sequences occur offshore the southern portion of North Topsail Beach, almost all sequences are comprised of either organic mud, very fine sand units or contain gravel beds. Observations from diver surveys have indicated that the upper part of the sediment sequence 1 to 2 feet (0.30 to 0.60 m) in this area contains inter-bedded sand and gravel, and the sequence contains appreciable amounts of very fine sand and silt. Topographic irregularities in the subcrop unit probably dictated where thicker sediment accumulations were preserved. A broad highly irregular area containing thinner sediment sequences 0.98 to 3.3 feet (0.30 to 1.0 m) surrounds

the aforementioned region where sediment thickness exceeds 3.3 feet (1.0 m). Most of the sediment sequences cored also contain very fine sands with occasional muddy material and minor gravel lenses (Figures 54 and 55).

Ponding of sediments against the hardbottom scarps and in depressions between ridges may have produced "thick" (0.91 to 1.2 m [-4feet]) very localized deposits. However, due to the density of sampling sites and the complex nature of the hardbottoms and subcrop units, it was difficult to map the thickness of the modern sediment sequence across the shoreface south of Alligator Bay. The distribution and the relief of the hardbottoms clearly show that the nature of the underlying stratigraphic units determines the resultant seafloor morphology. The lithologic character of the underlying stratigraphic units, Pleistocene sea level oscillations and the Holocene transgression also have played a role in determining the thickness of the modern sediments. Localized relief in hardbottom areas and the depth to the subcrop unit is probably related to a combination of variables, including the resistance to erosion of the various rock type and the resultant paleo-drainage network developed during the various low stands of sea level. Differential erosion of the Trent Fm limestone and River Bend Fm siltstone ultimately dictated the accommodation space that is reflected in the sediment thickness depicted by Figure 60.

4.7 Sand Resources

The primary objective of this investigation was to provide an assessment of the availability beach fill quality material for the construction and maintenance of a storm reduction project along the North Topsail Beach Surf City oceanfront in Pender and Onslow Counties. The basis for the sand resource evaluation was a diverse data set consisting of geological and geophysical information collected during the past decade for investigations pertaining to the nature of the geological framework in this sector of southeastern North Carolina. The assessment was based on the integration of data collected for site-specific studies (Johnston, 1998; and McQuarrie, 1998) or from regional investigations (Meisburger, 1977 and 1979; and Cleary, unpublished data). Data from diver surveys and core descriptions, coupled with the geophysical data, provided the framework for the evaluation of sand resource potential. The principal constraints involved in determining the availability of the sand resources were the location of deposits with respect to 30 feet (9.1 m) isobath, the area extent of the sand sequence, its thickness, sediment compatibility (gravel and mud content), and the proximity of the deposits to environmentally sensitive hardbottoms.

4.7.1 Mile Hammocks Bay to Alligator Bay

Aside from the New River Inlet ebb-tidal delta, which contains as much as 7.0 million cy (5.3 million m^3) of material, the shoreface off the extreme northern portion of North Topsail Beach contained only one potential target area (Area I) where beachfill quality sand may be available in significant quantities (see Figure 61). This target area lies offshore North Topsail Beach on the southwest flank of the broad limestone platform seaward of the New River Inlet. The few cores that have recovered potentially usable material were retrieved along what has been interpreted to be the remnants of the paleo-channel of New River (Johnston, 1998 and Cleary and Riggs, 1999). The vague core descriptions of the ICONS vibracores suggest as much as 4.5 feet (1.4 m) of bioclastic quartz rich sand may be present along the trace of the ancestral river channel (Meisburger, 1979). The exact volume of material (compatible or otherwise) within this potential borrow area was difficult to determine due to the lack of detailed core and high-resolution seismic data. Utilizing an assumed average sediment thickness of 3.0 feet (1.1 m), the volume of material contained in Area I is estimated to be approximately 1.4 million cy (1.1 million m^3). Although the prospect of locating significant accumulations of sand in this area is probably very low, nonetheless, the area warrants more detailed investigations.

4.7.2 Alligator Bay to Surf City's Southern Limit

Compilation of data used in the conduct of this study indicated that the numerous areas of hardbottom (limestone exposures) and the shallow subcrop depths precluded the existence of significant accumulations of usable beach fill material. Given the fact that 40 million cy (31.2 million m^3) of compatible material are needed for the 50-year project, it is very unlikely that the shoreface can provide that volume of material. Approximately 70 percent of the shoreface southwest of Alligator Bay has no potential for significant volumes of compatible beach fill material (see Figure 61). However, there are several areas (Areas II through V) offshore the southern portion of North Topsail Beach and Surf City where thin (<3 feet [~1.0 m]) sandy sequences may have accumulated (see Figure 61). However, the compatibility and continuity of these materials in these areas is very questionable. The core and diver survey data suggested that the potential for finding significant quantities of beach compatible material in these areas is marginal at best (see Figure 62).

The irregularly shaped Area II (see Figure 61) covers approximately 4.8 mi^2 (12.4 km^2) of the shoreface. Area II is bordered by hardbottoms of variable relief and the target area is located in a region of the shoreface where the calcareous siltstone forms the subcrop unit. This irregular shaped depression may represent the remnants of a former drainage system that formed during low stands of sea level (see Figure 25). The thick sediment sequences recovered in cores from this area contained Holocene estuarine units. Most of the sediment sequences comprising the backbarrier facies were muddy in nature. The sequences consisted of a thin sand veneer (0.80 feet [0.25 m]) overlying interbedded dark gray muds and thin sand lenses. Vibracores VC 12, 31, 32, and 37 recovered 5.2 to 6.4 feet (1.4 to 1.6 m) thick sequences of bioturbated, interbedded very fine quartz sand, silt and organic-rich, dark gray mud (see Figures 62). The sediment sequences recovered are underlain by Oligocene siltstone. Core VC 36 was the only core recovered that contained a relatively thick sequence of sand rich material (see Figure 62). The modern sediment (sand) sequence (0.60 feet [0.20 m]) was underlain by ~1.1 m thick sequence of mottled quartz sand and thin muddy sand units. The thicker sand rich units in the cores from this area probably represent small shallow tidal channels or sand rich portions of tidal flats.

The thickness of quality beach fill material in Area II is likely to be extremely variable and, at best, probably averages less than 3 feet in thickness in very restricted areas. Utilizing an assumed average sediment thickness of 3.0 feet (0.91 m), the volume of material contained in Area II is estimated to be approximately 15.0 million cy (11.7 million m^3). A significant portion of this volume of material may contain appreciable amounts of fine material and/or gravel. The proximity of hardbottoms may restrict the exploitation of sand resources in the narrower regions of Area II that are within 1,640 feet (500 m) of "designated" high-relief rock exposures. Areas designated IIa and IIb are the only viable areas within the confines of Area II where there is a good possibility of finding beach fill material. Areas IIa (1.5 $mile^2$ [3.9 km^2]) and IIb (0.7 mi^2 [1.8 km^2]) comprise approximately 45 percent of Area II (see Figure 61). Using liberal estimates of sand thickness (2.0 feet for IIa and 3.0 feet for IIb), the potential volume of usable sand in these areas is estimated to range from 2.1 to 3.1 million cy (1.6 to 2.4 million m^3) for Areas IIa and IIb, respectively. If only 70 percent of the sediment is compatible fill material, the available combined volumes of Areas IIa and IIb (5.1 million cy [4.0 million m^3]) would provide 3.6 million cy (2.8 million m^3), an amount that may be sufficient for the initial construction of a small portion of the

proposed beachfill project. A detailed seismic survey, coupled with a suite of forty well-placed vibracores, should provide the necessary data to evaluate the quality and continuity of the usable material within this area.

Area III, located southwest of Area II, is an 8.4 mi^2 (21.8 km^2) area that may contain as much as 2.3 million cy (1.8 million m^3) of questionable quality material. This area is also underlain by the calcareous siltstone. The volume of potentially usable sand material contained in this area has been based on an assumed average sediment thickness of 2.5 feet (0.76 m). This value was derived from approximately 16 diver surveys and from core logs of vibracores 25 and 01. Vibracore 25 contained ~3.0 feet (0.91 m) of gravelly sand while core 01 recovered only 1.3 feet (0.41 m) of fine quartz sand. The sediment sequence that underlies this area may contain large percentages of silt and very fine sand and gravel. The presence of hardbottoms may also impact the availability and exploitation of sand resources in the narrower regions of Area III (see Figures 61 and 62).

Area IV, located approximately 4.5 miles (7.2 km) offshore Stump Sound, is another area of the shoreface with a marginal sand resource potential. This 1.6 mi^2 (4.1 km^2) area borders the seaward fringes of Area II. The materials within this target area accumulated within what is interpreted to be a shallow depression surrounded by limestone hardbottoms (see Figure 25). Diver surveys in other parts of the area indicated that as much as 3.0 feet (0.91 m) of fine to very fine quartz sand and a basal gravel unit mantled the underlying siltstone. If one assumes that the average sediment thickness in this area is 2.0 feet (0.61 m), the volume of potentially usable material contained in this region is approximately 0.3 million cy (0.23 million m^3).

Area V encompasses approximately 1.1 mi^2 (2.8 km^2) where data are basically non-existent. Only two vibracores have been recovered from sites along the western boundary of the area. Both cores recovered relatively thick estuarine sequences. The surface sand veneer was less than 1.1 feet (0.35 m). Core contained ~4.8 feet (~1.45 m) of interbedded thin units of fine quartz sand and organic rich mud (see Figure 62). The backbarrier units recovered in the core probably represent a potion of tidal flat complex that has been preserved in a shallow depression. The early Holocene sediment package presumably rests on the calcareous siltstone. Assuming the average sediment thickness in this area is approximately 2.0 feet (0.61 m), it is speculated that as much as 1.5 million cy

(1.2 million m^3) of material is contained in the area (see Figures 60 to 62). Only very detailed follow-up geophysical and geological surveys will provide the needed data to trace the sand rich facies of this early Holocene estuarine lithosome.

5.0 RECOMMENDATIONS FOR FUTURE WORK

The next logical step in the evaluation of the sand resource potential in the target areas involves the use of a high quality Chirp system, such as the Edgetech 512i unit. Table 3 lists the corner points for the recommended seismic surveys of Borrow Areas I through IV. The data from the geophysical surveys would be crucial to the detailed mapping of the three-dimensional aspects of the sediment sequence (see Figure 61). Standard Chirp units will not provide the type or quality of data needed to adequately resolve the stratigraphy of the borrow areas for exploitation purposes.

In order to adequately ascertain the compatibility of the materials within the target areas, the USACE should begin the formulation and implementation of a detailed exploratory coring program. This effort can be viewed as a stand-alone operation in all target areas. Data derived from suites of closely spaced cores would provide the information needed to define the complex three-dimensional aspects of the discontinuous thin sandy units and the inter-bedded muddy sand and gravel-rich units. Core data would also provide the necessary means of groundtruthing the Chirp data in areas where degraded (weathered) sandy limestone, calcareous sandstone or siltstone underlie what is interpreted to be a thick sequence of usable material.

The ubiquitous nature of the environmentally sensitive hardbottoms may require additional high-resolution sidescan sonargraph surveys after specific target sites have been identified for dredging operations.

6.0 REFERENCES CITED

Cleary, W.J., 1994, New Topsail Inlet, North Carolina. Migration and barrier realignment: Consequences for beach restoration and erosion control projects. *Union Geographique Internationale, Commission Sur de l'Environment Cotier C, Institute de Geographique,* 16-30.

Cleary, W.J., and Hosier, P.E. 1979. Coastal geomorphology, washover history, and inlet zonation: Cape Lookout to Bird Island, North Carolina, *In:* Leatherman, S.D., (ed)., *Barrier Islands from the Gulf of St. Lawrence to the Gulf of Mexico*: Academic Press, New York, 237-262.

Cleary, W.J., and Hosier, P.E., 1987, Onslow Beach, N.C.: Morphology and Stratigraphy, *Proceedings, Coastal Sediments '87, American Society of Civil Engineers, New Orleans,* 1760-1775.

Cleary, W.J., and Pilkey, O.H., 1968, Sedimentation in Onslow Bay. *In: Guidebook for field excursion, Geological Society of America, Southeastern Section,* Durham, *NC: Southeastern Geology, Special Publication,* 1,1-17.

Cleary, W. J., Rauscher, M.A., McLeod, M.A., Johnston, M.K., and Riggs, S.R., (2001) Beach Nourishment on Hurricane Impacted Barriers in Southeastern North Carolina, USA: Targeting Shoreface and Tidal Inlet Sand Resources, Special Issue # 34, Journal of Coastal Research, p. 232-255.

Cleary, W.J., and Riggs, S.R., 1999, Beach Erosion and Hurricane Protection Plan for Onslow Beach, Camp Lejeune, North Carolina, Comprehensive Geologic Characteristics Report, Final Report US Marine Corps, Camp Lejeune, NC.

Cleary, W.J., and Thayer, P.A., 1973, Petrography of Carbonate Sands on the Carolina Continental Shelf. *Gulf Coast Association Geological Society Transactions,* 23, 288-304.

Cleary, W.J., Riggs, S.R., Marcy, D.C., and Snyder, S.W., 1996. The influence of inherited geological framework upon a hardbottom-dominated shoreface on a high-energy shelf: Onslow Bay, North Carolina, USA. *In:* M. De Batist and P. Jacobs (eds.), *Geology of Siliciclastic Shelf Seas,* Geological Society Special Publication, 117, 249-266.

Cleary, W.J., and Hosier, P.E. 1979. Coastal geomorphology, washover history, and inlet zonation: Cape Lookout to Bird Island, North Carolina, *In:* Leatherman, S.D., (ed)., *Barrier Islands from the Gulf of St. Lawrence to the Gulf of Mexico*: Academic Press, New York, 237-262.

Cleary, W.J., and Hosier, P.E., 1987, Onslow Beach, N.C.: Morphology and Stratigraphy, *Proceedings, Coastal Sediments `87, American Society of Civil Engineers, New Orleans*, 1760-1775.

Cleary, W.J., and Pilkey, O. 1996. Environmental Coastal Geology: Cape Lookout to Cape Fear, NC. In: Cleary, W.J. (ed). *Environmental Coastal Geology: Cape Lookout to Cape Fear, NC Carolina Geological Society Fieldtrip Guidebook.* P 89-128.

Cleary, W. J., McLeod, M.A., Rauscher, M.A., Johnston, M.K., and Riggs ,S.R., 2000, Beach Nourishment on Hurricane Impacted Barriers in Southeastern North Carolina, USA: Targeting Shoreface and Tidal Inlet Sand Resources, Special Issue # 34, Journal of Coastal Research, p. 232-255.

Crowson, R.A., 1980, Nearshore rock exposures and their relationship to modern shelf sedimentation, Onslow Bay, North Carolina. *Unpub. M.S. Thesis, Dept. of Geology, East Carolina Univ.,Greenville*, 128 p.

Folk, R.L., 1980, *Petrology of Sedimentary rocks.* Austin, Texas: Hemphill Publishing Company, 182 p.

Hine, A.C., and Snyder, S.W., 1985, Coastal lithosome preservation: evidence from the shoreface and inner continental shelf off Bogue Banks, North Carolina. *Marine Geology*, 63, 307-330.

HDR Engineering, 2002, An Assessment of the Availability of Beach Fill Quality Sand Offshore Topsail Beach Pender County, NC., 22p. and Figures.

Johnston, M.K., 1998, Inherited geologic framework of the New River submarine headland complex, North Carolina, and its influence on modern sedimentation: unpub. M.S. thesis, Dept. of Earth Sciences, Univ. of North Carolina at Wilmington, Wilmington, NC, 87 p.

Marcy, D.C. and Cleary, W.J., 1997, Influence of inherited geological framework upon a hardbottom dominated shoreface, Fort Fisher submarine headland, Onslow Bay, NC, unpublished final report USACE Wilmington District, 97 p.

McQuarrie, M.E., 1998, Geologic framework and short-term, storm-induced changes in shoreface morphology: Topsail Beach, NC, *Unpub. M.S. Thesis, Dept. of the Environment, Duke Univ., Durham, 105*p.

Meisburger ,E.P., 1977, Sand resources of the inner continental shelf of the Cape Fear region, North Carolina, *U.S. Army Corps of Engineers, Coastal Engineering Research Center, Miscellaneous Report MR77-11,20 p.*

Meisburger, E.P., 1979, Reconnaissance geology of the inner continental shelf, Cape Fear region, North Carolina. *U. S. Army Corps of Engineers, Coastal Engineering Research Center, Technical Report*, TP79-3, 135 p.

Moorefield, T.P., 1978. Geological processes and history of the Fort Fisher coastal area, North Carolina, *M.S. thesis, Department of Geology, East Carolina University, Greenville, North Carolina,* 100 p.

Riggs, S.R., Cleary, W. J., and Snyder, S.W. 1995, Influence of inherited geologic framework on barrier shoreface morphology and dynamics. *Marine Geology*,126, 213-234.

Snyder, S.W., Hoffman, C.W., and Riggs, S.R., 1994, Seismic stratigraphic framework of the inner continental shelf: Mason Inlet to New Inlet, North Carolina. *North Carolina Geological Survey, Bulletin*, 97, 61 p.

Thieler, R.E., 1997, Shoreface sedimentation in southeastern North Carolina: Unpublished Ph.D. Dissertation, Dept. of Geology, Duke University, Durham, NC, 198 p.

Thieler, R.E., Brill, A.L., Cleary, W.J., Hobbs, C. H. III, and Gammisch, R.A. 1995. Geology of the Wrightsville Beach, North Carolina shoreface: Implications for the concept of shoreface profile of equilibrium. *Marine Geology*, 126, 271-287.

Theiler, E.R., Schwab, W.C., Allison, MA., Denny, J.F., and Danforth, W.W., 1998, Sidescan sonar imagery of the shoreface and inner continental shelf off Wrightsville Beach, NC, Dept. of Interior, US Geol. Survey Open File Report 98-596, 3 sheets.

Theiler, E.R., Schwab, W.C., Cleary, W.J., and Pilkey, O.H., submitted, Sea-level stillstand and rapid rise ~7300 years ago: Evidence from the Atlantic Barrier islands. (*Science*)

USACE, 1989, Final Feasibility Report and Environmental Impact Statement, *Hurricane Protection and Beach Erosion Control, West Onslow Beach and New River Inlet, North Carolina (Topsail Beach)*, U.S. Army Corps of Engineers, Wilmington District, 74 p. with supporting documents.

USACE, 1992, Beach Nourishment, *Design Memorandum West Onslow Beach and New River Inlet Topsail Beach, North Carolina*, U.S. Army Corps of Engineers Wilmington District, 7 p. plus appendices.

USACE, 1993, Storm Damage Reduction Project, *Design Memorandum Supplement and Draft Final Environmental Impact Statement, Carolina Beach and Vicinity- Area South Portion, North Carolina (Kure Beach)*, U.S. Army Corps of Engineers, Wilmington District, 2 volumes.

Zullo, V.A., and Harris, W. B., 1987, Sequence stratigraphy, biostratigraphy, and correlation of Eocene through lower Miocene strata in North Carolina. *Cushman Foundation for Foraminiferal Research, Special Publication 24*, pp. 194-214.

Young, R.S., Bush, D.M., Coburn, A.S., Pilkey, O.H. and Cleary, W.J., 1999, Hurricanes Dennis and Floyd: coastal effects and policy implications, *GSA Today*, 9 (12), 2-6.

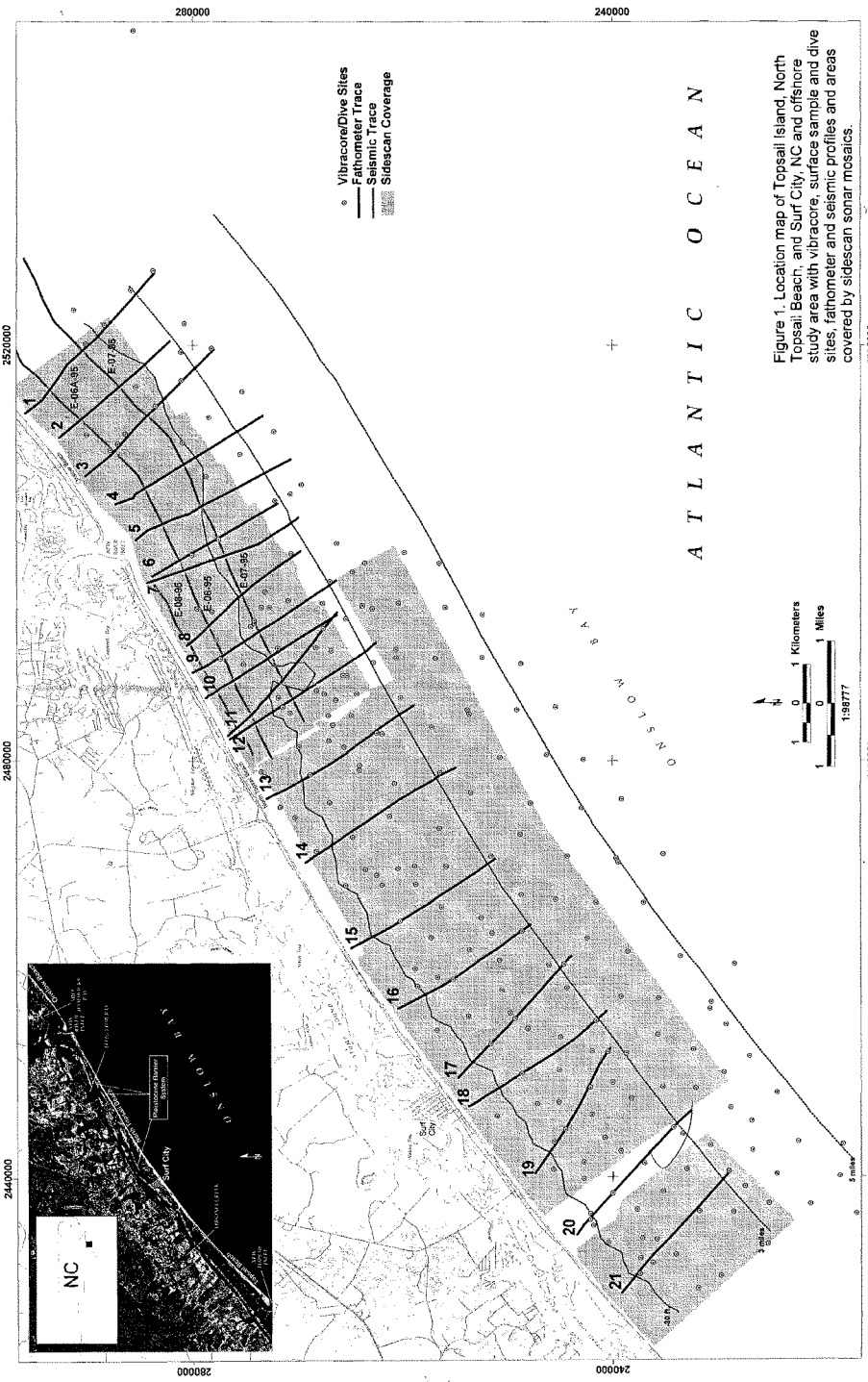


Figure 1. Location map of Topsail Island, North Topsail Beach, and Surf City, NC and offshore study area with vibracore, surface sample and dive sites, fathometer and seismic profiles and areas covered by sidescan sonar mosaics.

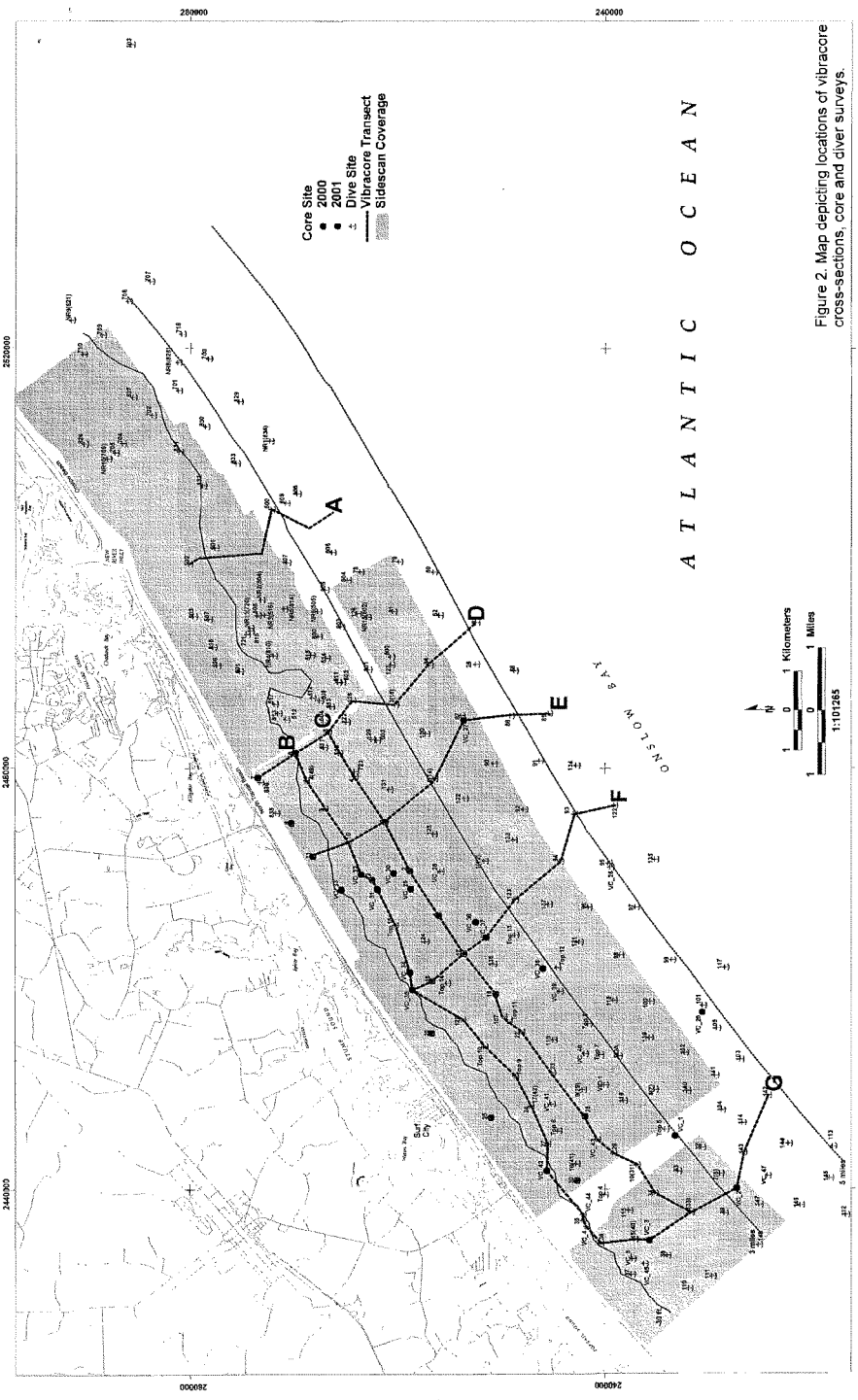


Figure 2. Map depicting locations of vibracore cross-sections, core and diver surveys.

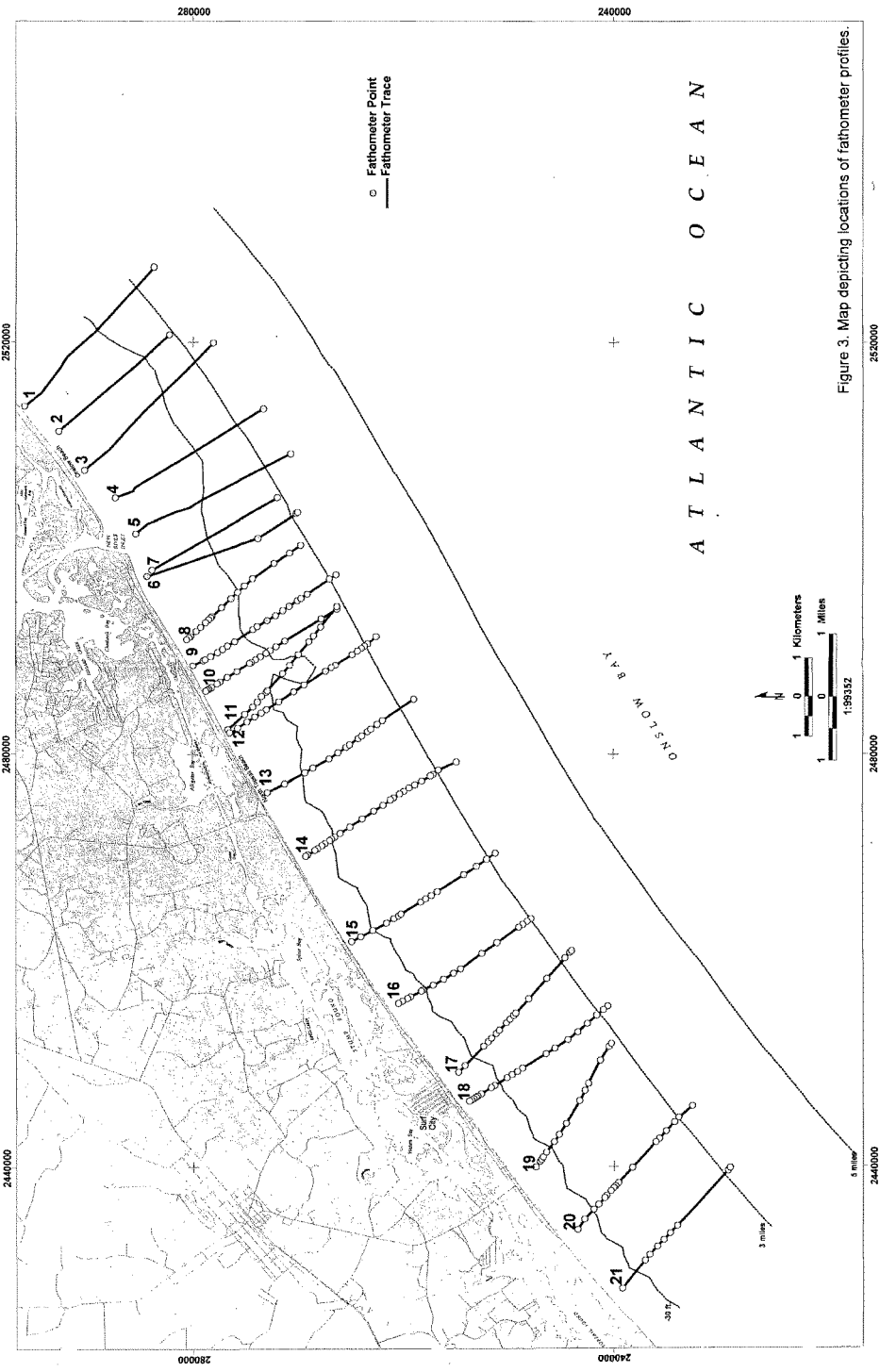
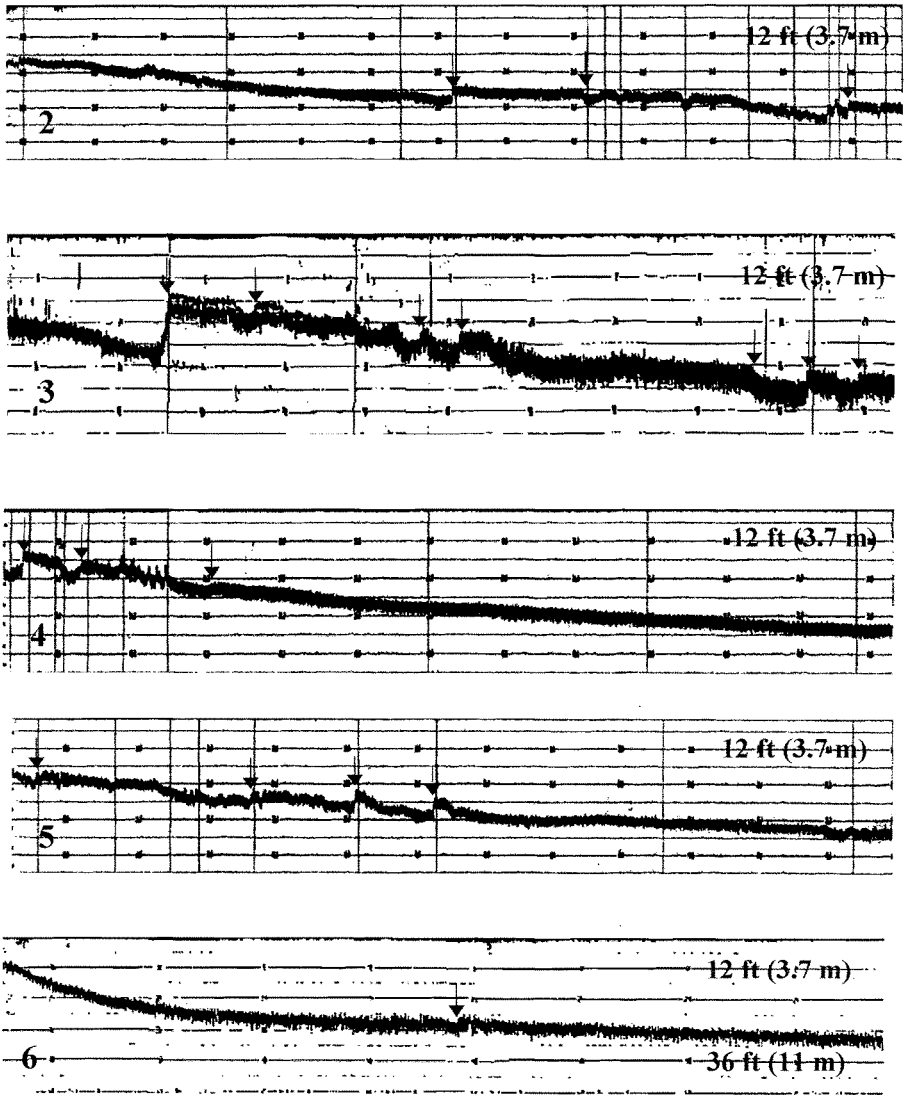
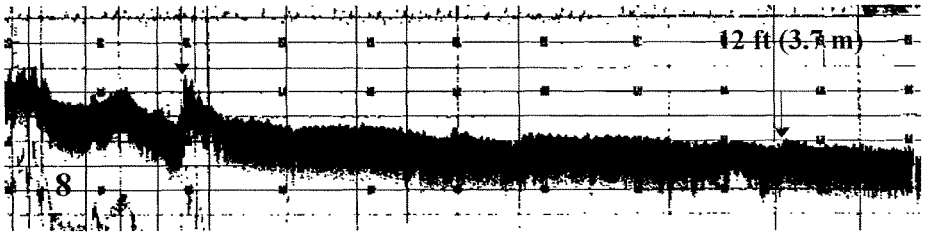
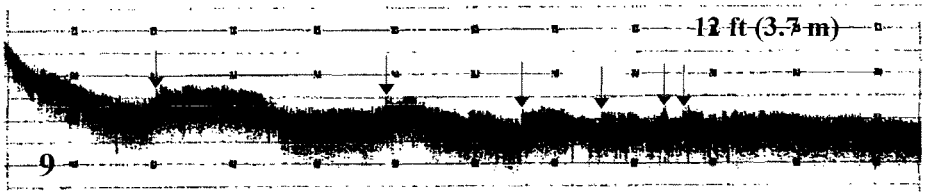
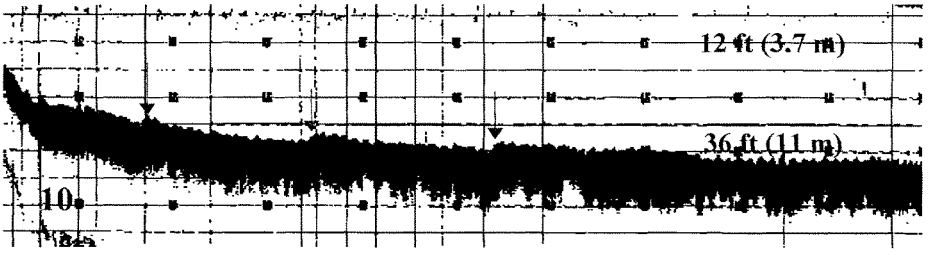


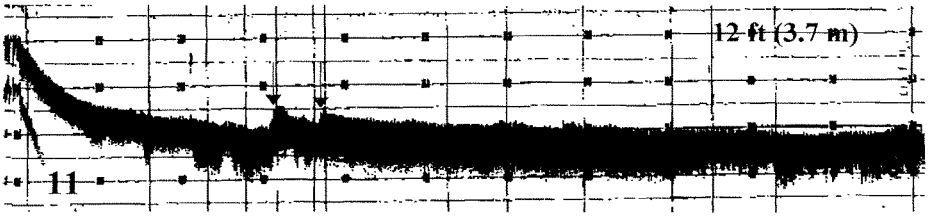
Figure 3. Map depicting locations of fathometer profiles.

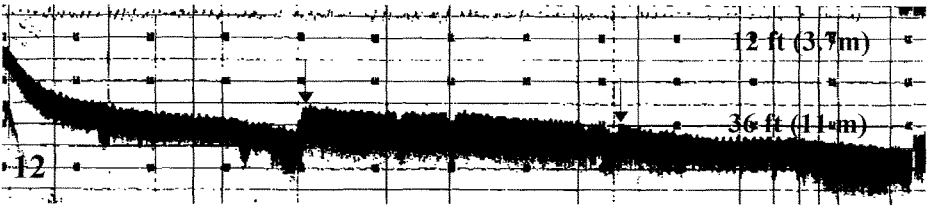

12 ft (3.7 m)
2
12 ft (3.7 m)
3
12 ft (3.7 m)
4
12 ft (3.7 m)
5
12 ft (3.7 m)
6
36 ft (11 m)

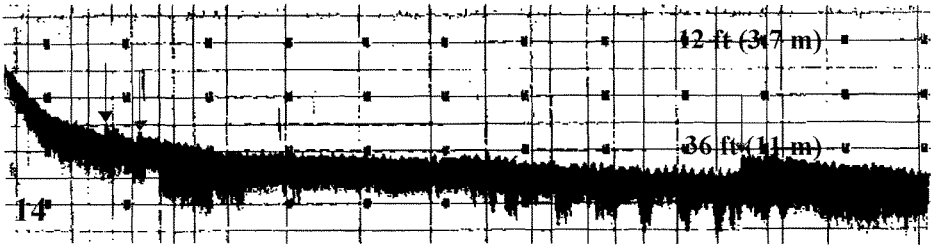

12 ft (3.7 m)
8

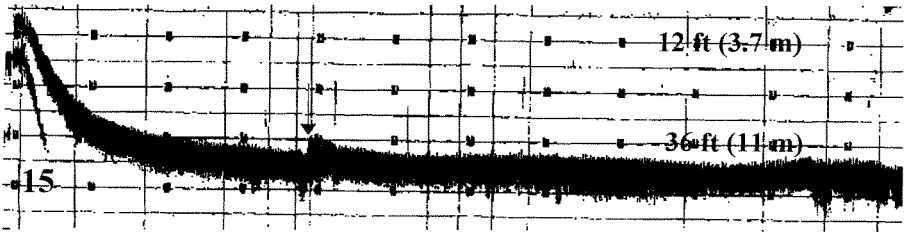

12 ft (3.7 m)
9

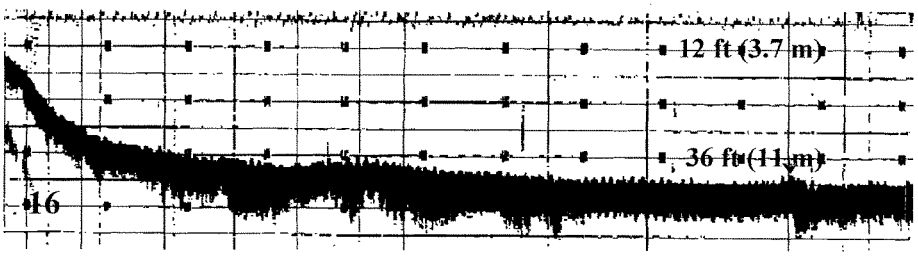

12 ft (3.7 m)
36 ft (11 m)
10

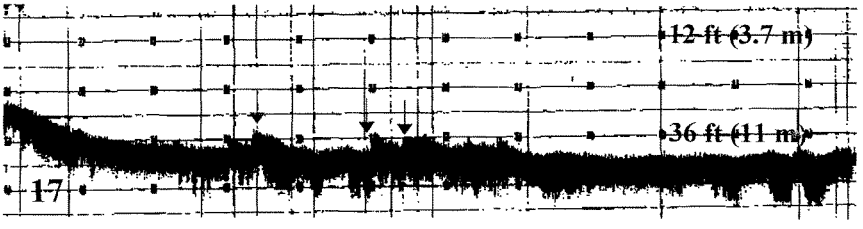

12 ft (3.7 m)
11


12 ft (3.7 m)
36 ft (11 m)
12


12 ft (3.7 m)
36 ft (11 m)
14


12 ft (3.7 m)
36 ft (11 m)
15


12 ft (3.7 m)
36 ft (11 m)
16


12 ft (3.7 m)
36 ft (11 m)
17

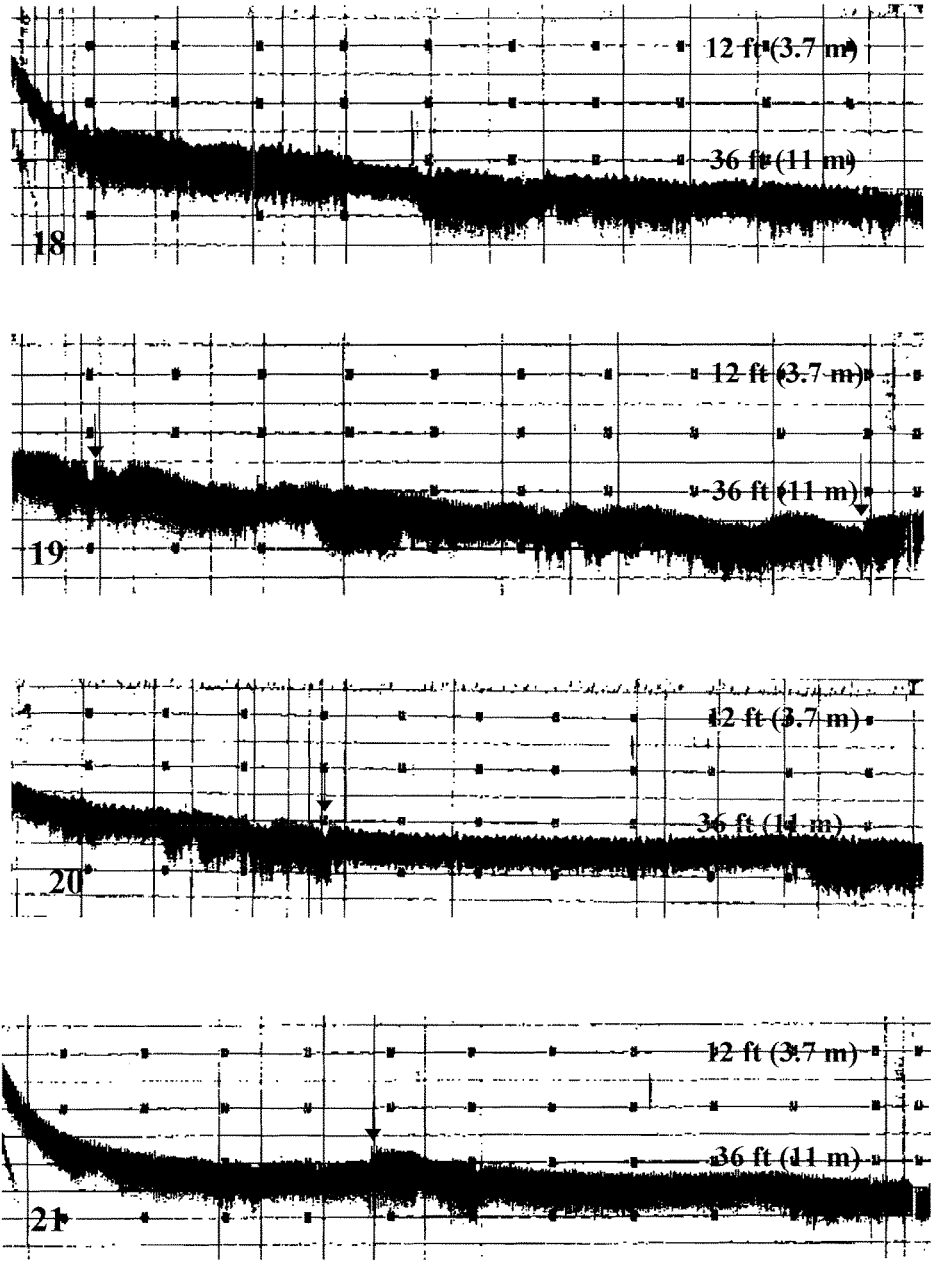


Figure 7. Shore normal fathometer profiles offshore Surf City. See Figure 3 for locations. Red arrows represent limestone hardbottoms (Scarps). Note irregular nature of profiles. Horizontal scale is approximately 3 miles (4.8 kilometers).

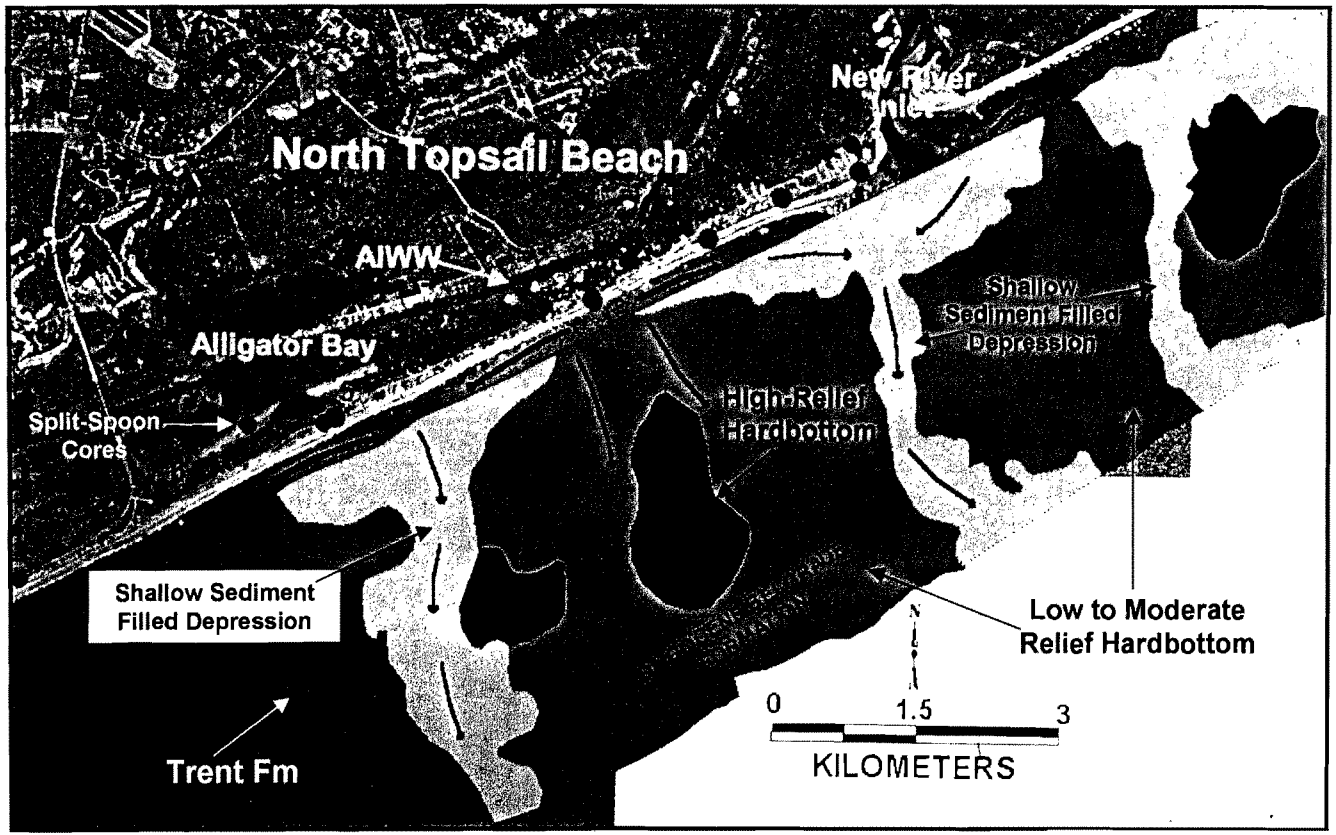


Figure 8. Map depicting nature of shoreface hardbottoms. Photograph (1993) depicts location of split-spoon cores recovered along barrier. Data indicate a saddle in the underlying limestone occurs beneath the barrier in the vicinity of Alligator Bay and the shallow linear depression that extends seaward from the bay (After Johnston, 1998; Cleary, 1999; and Cleary et al 2001).

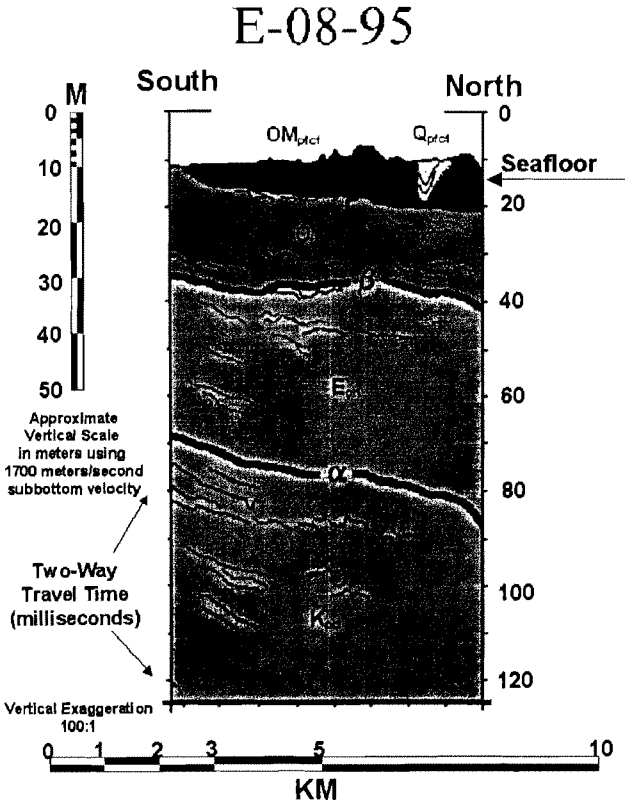
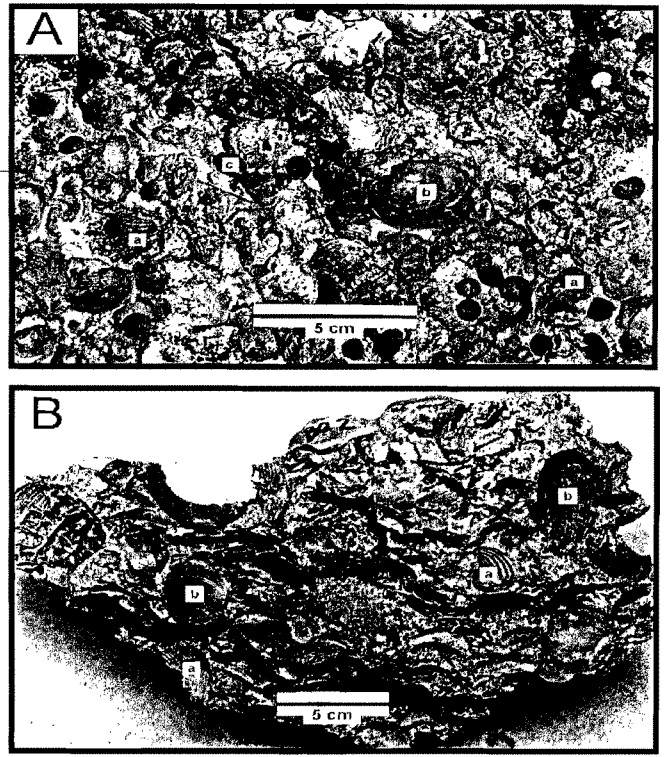


Figure 9. High resolution seismic line offshore North Topsail Beach and photographs of limestone. See Figure 1 for location of seismic line (After Johnston, 1998 and Cleary and Riggs, 1999).



Photographs of clasts of limestone from the Belgrade Formation. **A**. Bored sandy bio-moldic limestone exposure on Onslow Beach shoreface off New River Inlet. **B**. Same rock unit exposed in Belgrade quarry near Jacksonville, NC. The Belgrade Fm underlies much of the northern segment of the study area from Mile Hammocks Bay to Alligator Bay (Modified after Johnston, 1998).

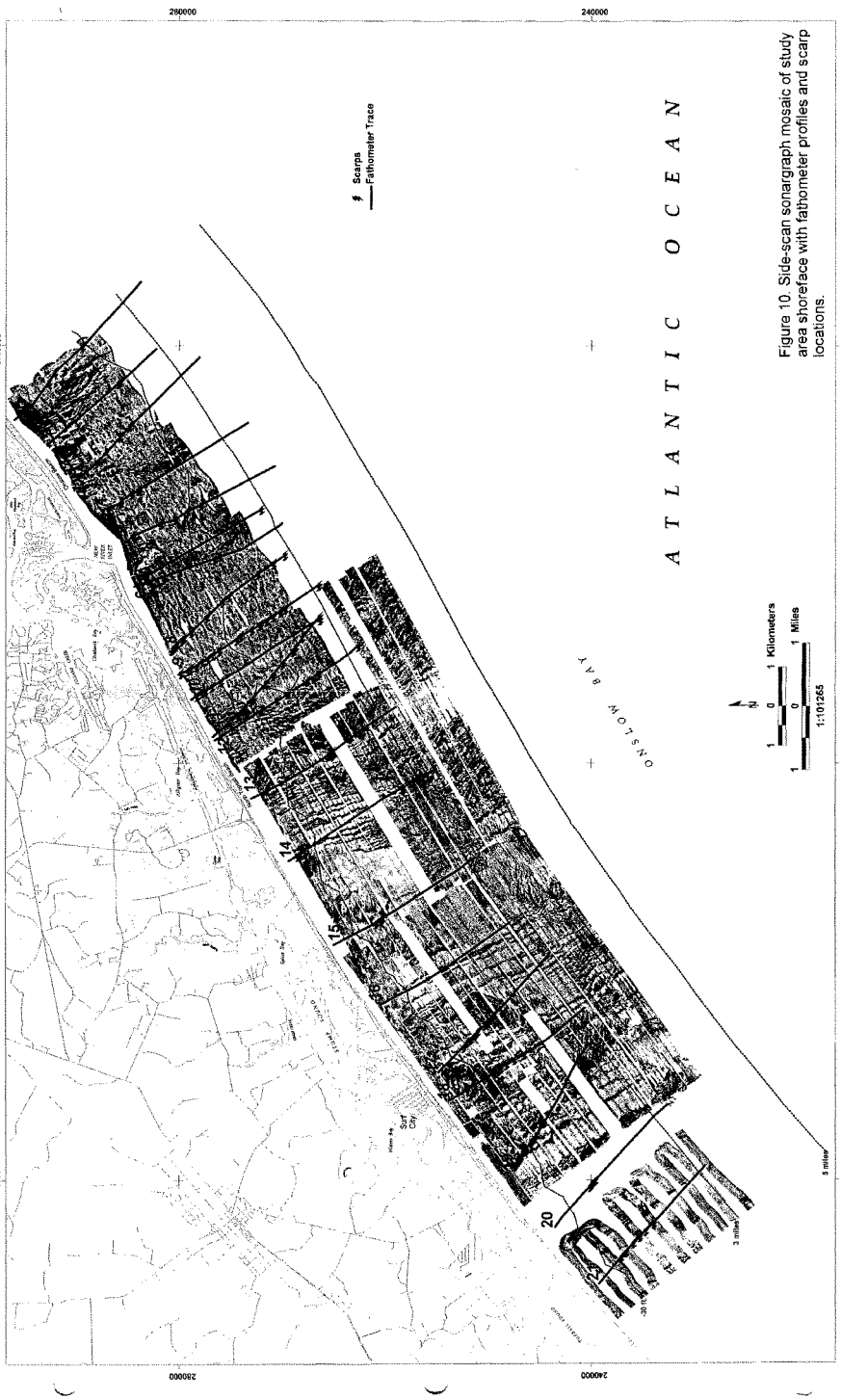
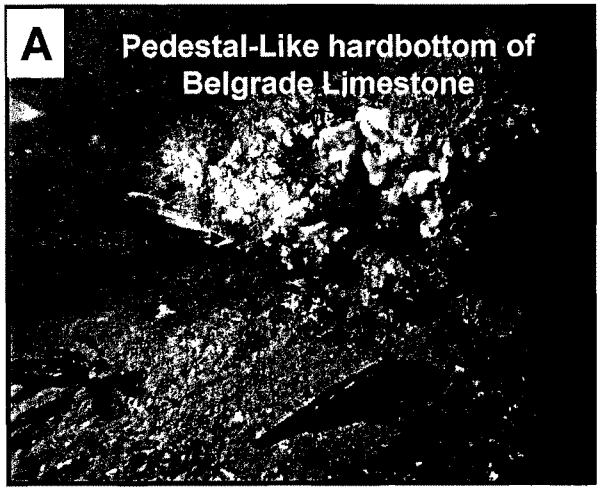


Figure 10. Side-scan sonargraph mosaic of study area shoreface with fathometer profiles and scarp locations.



Figure 11. Map depicting the distribution of the exposed and underlying Oligocene rock units.



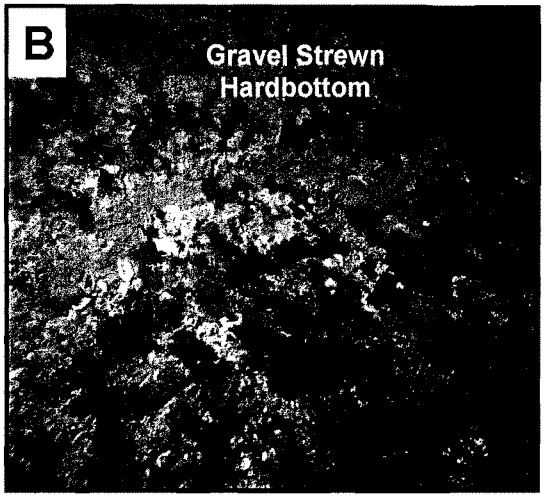




Figure 12. Bottom photographs of hardbottom area at dive site 700 on North Topsail Beach shoreface. **A**. View of a small pedestal-like, heavily encrusted hardbottom. Rock exposure is extensively bored and mantled with a variety of sponges and calcareous algae. Overhang is ~ 1.25 ft high. Thin sand/gravel veneer mantles surrounding area. **B**. Macro algae colonize slightly higher relief areas. Sediment infilled intervening low depressions on limestone surface. **C**. Contact between rippled fine sand and hardbottom. Macro algae colonize the hardbottom surface. Ripple wavelength is ~ 10-12".

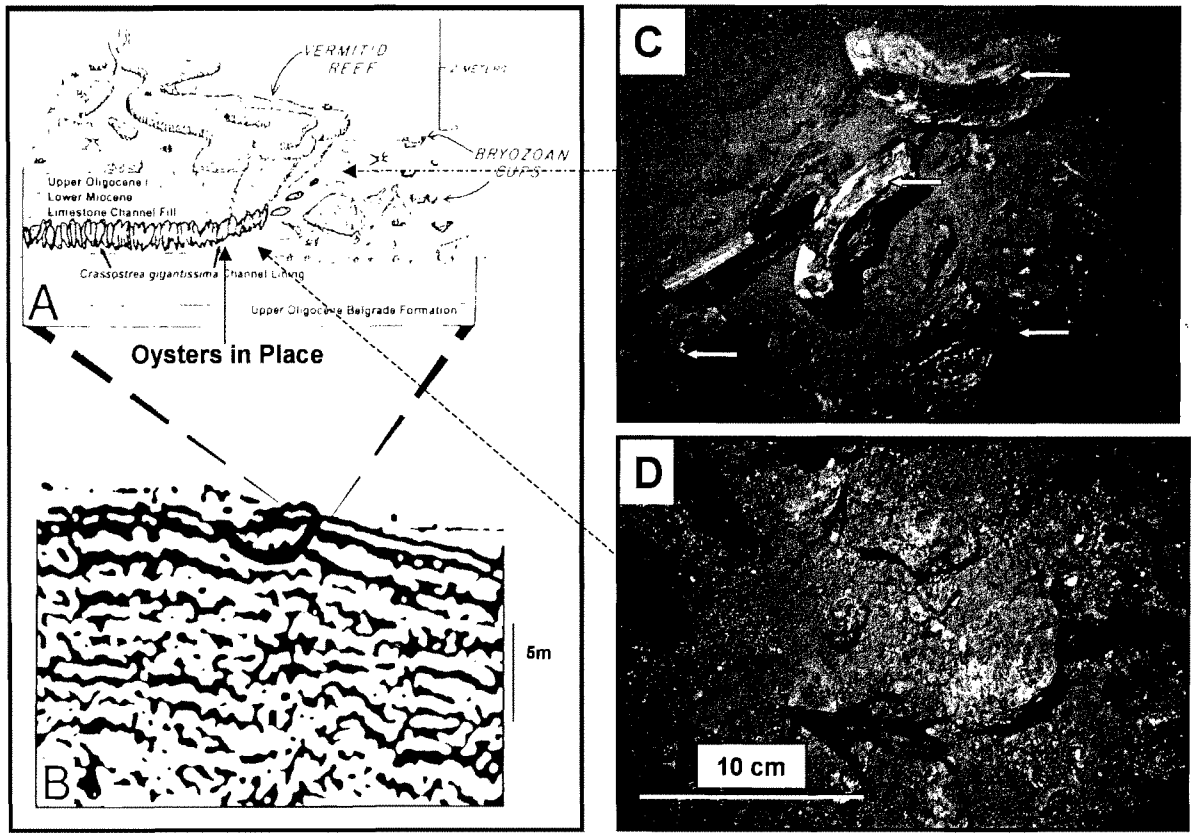
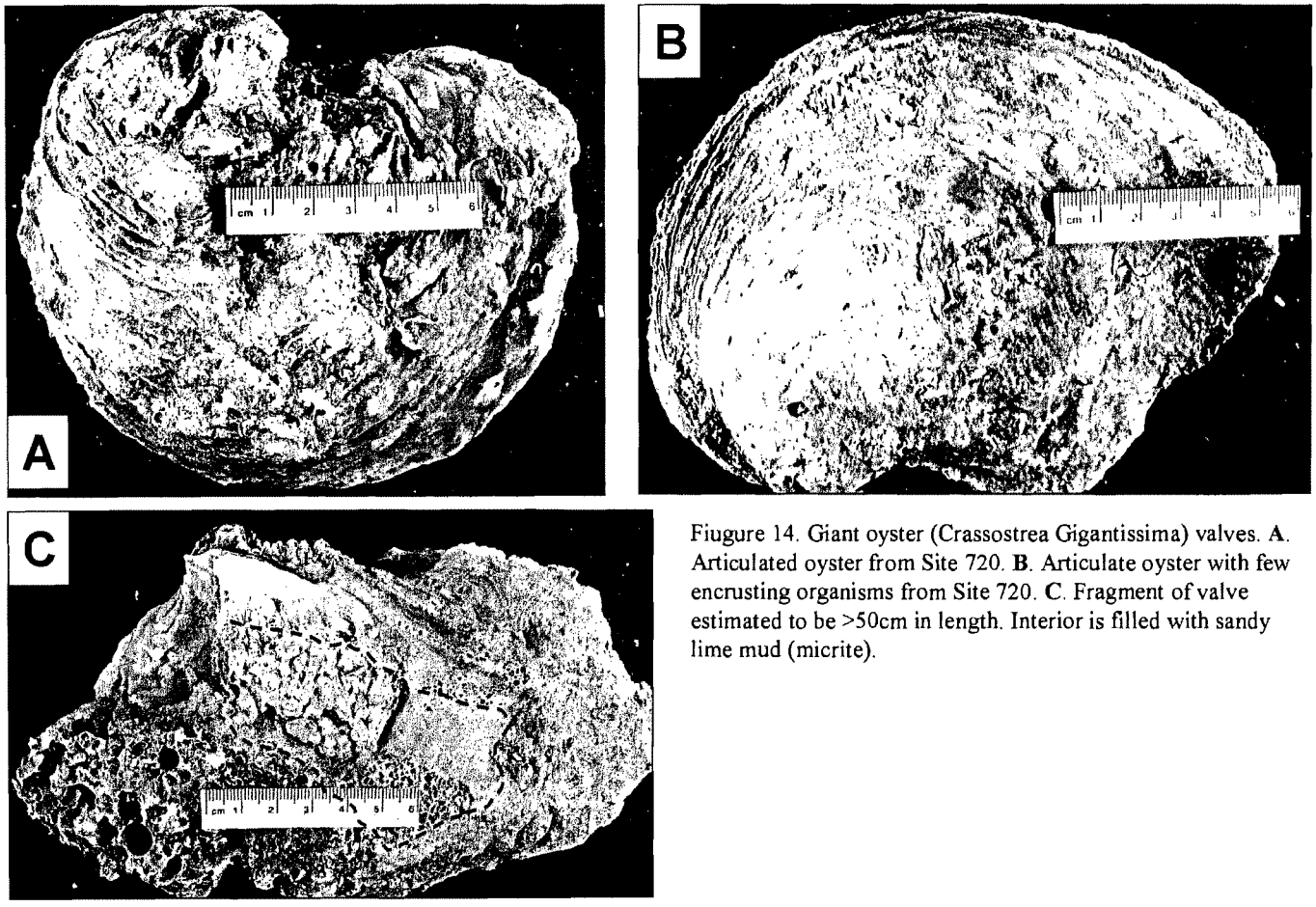


Figure 13. Cross-sectional view of Crassostrea gigantissima channel structure forming moderate relief hardbottom. **A**. exposed channel fill (calcareous cemented sandstone) and giant oysters lining channel bottom (after Crowson,1980). **B**. Enlarged seismic profile section (E-06-95) showing channel structure incised into Belgrade Fm. (A & B modified after Johnston 1998). **C**. Scattered oyster valves at Site 504. **D**. Algal encrusted rubble at base of scarp at site 516.



Fiugure 14. Giant oyster (Crassostrea Gigantissima) valves. **A**. Articulated oyster from Site 720. **B**. Articulate oyster with few encrusting organisms from Site 720. **C**. Fragment of valve estimated to be >50cm in length. Interior is filled with sandy lime mud (micrite).

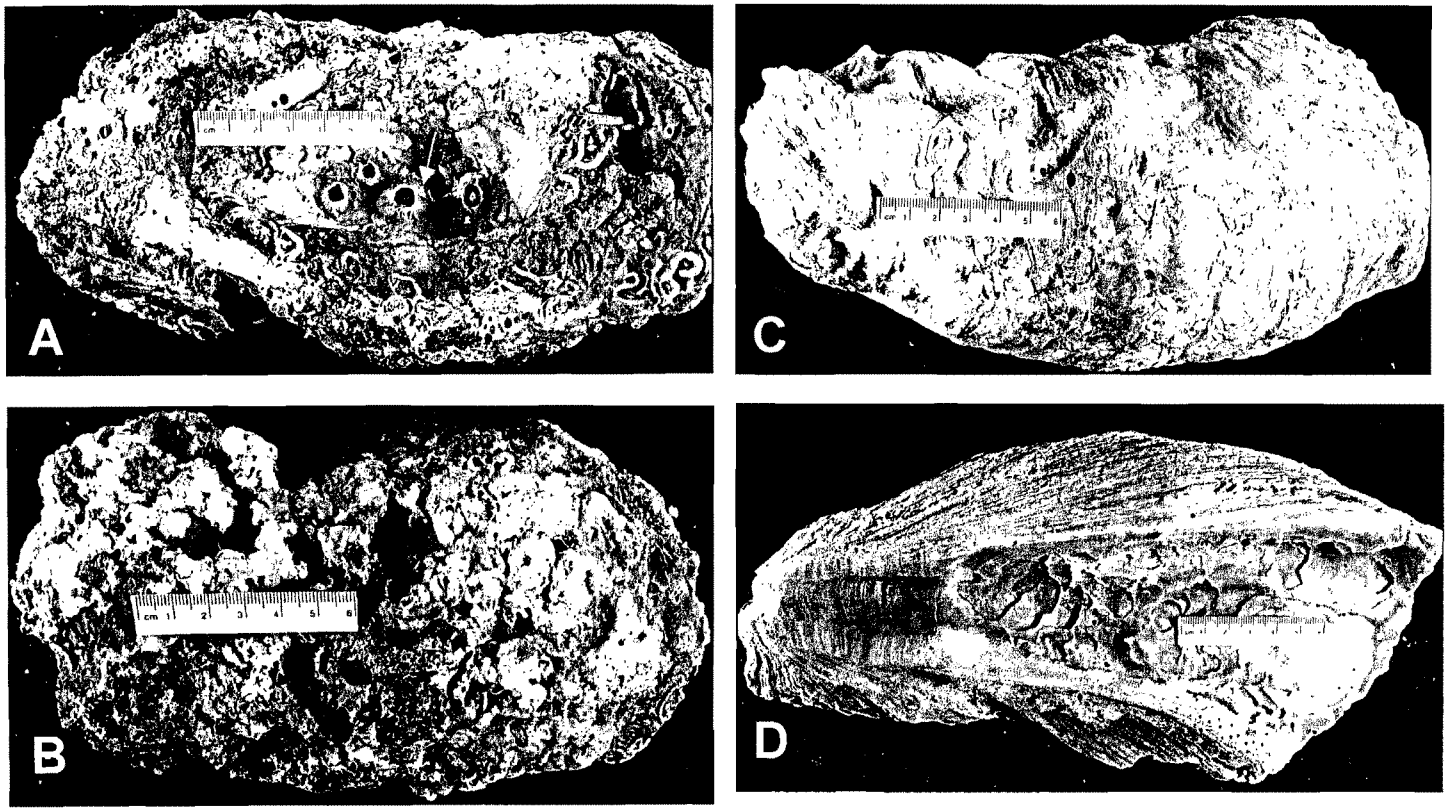


Figure15. Giant oyster (Crassostrea Gigantissima) valves. **A**. Encrusted disarticulated oyster valve from Site 721 offshore North Topsail Beach (interior view). **B**. Bored and encrusted disarticulated oyster valve from Site 721 (top view) **C**. Large fragment of disarticulated valve of oyster estimated to be ~75cm in length from Site NTP 5014. D. Interior view of valve pictured in "C". Most encrusting organisms have been worn off due during landward transport of clast.

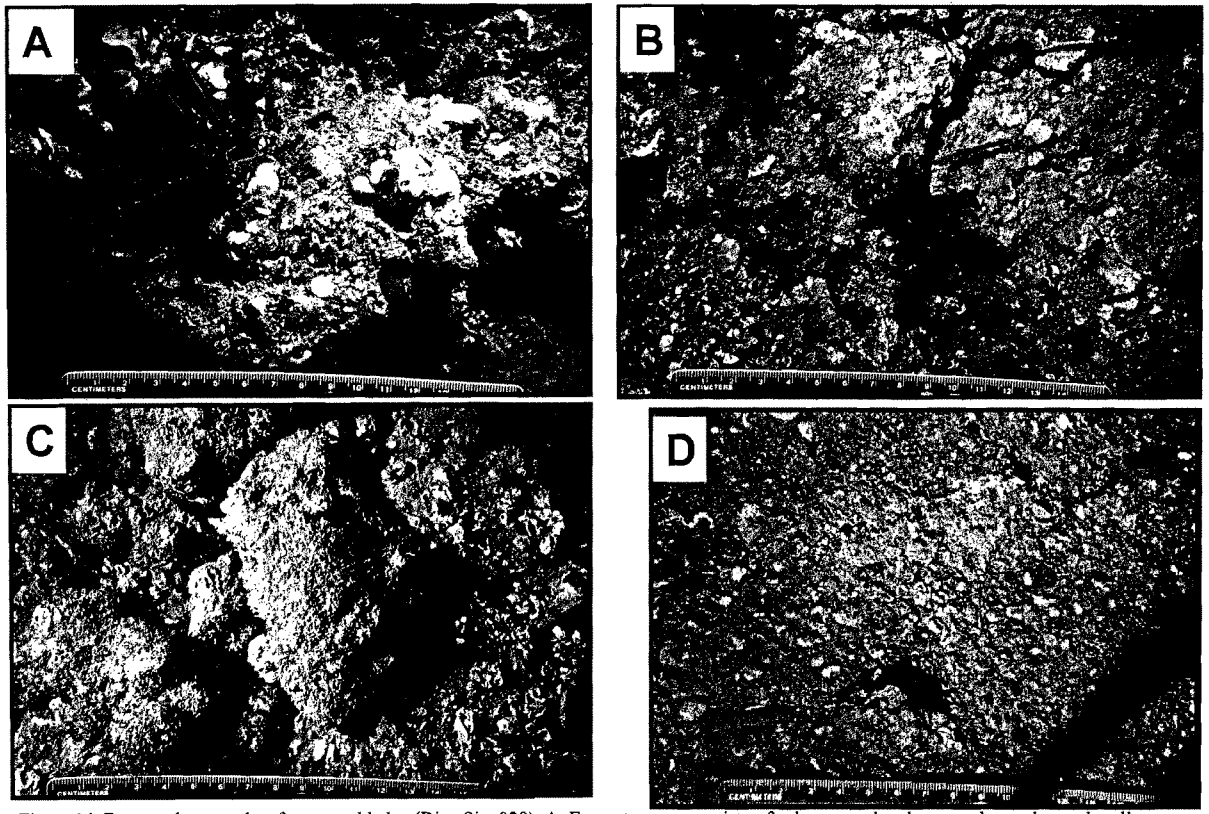


Figure 16. Bottom photographs of encrusted ledge (Dive Site 828). **A**. Encrusters are a variety of calcareous alga, bryozoa, barnacles, and molluscs. Sponges and macro alga also colonize the higher portions of the hardbottom ledges and scarps. Small overhang is visible in lower right where sand abuts the rock. **B**. Thin veneer of silty very fine sand and gravel overlies the lower portions of the hardbottom and rubble ramp. **C**. Thin silt veneer on eencrusted rubble that typically forms ramp at scarp base. **D**. A poorly-sorted, silty to sandy gravel forms a variably thick sequence of sediment between ledges. Scale is 15 cm in length.

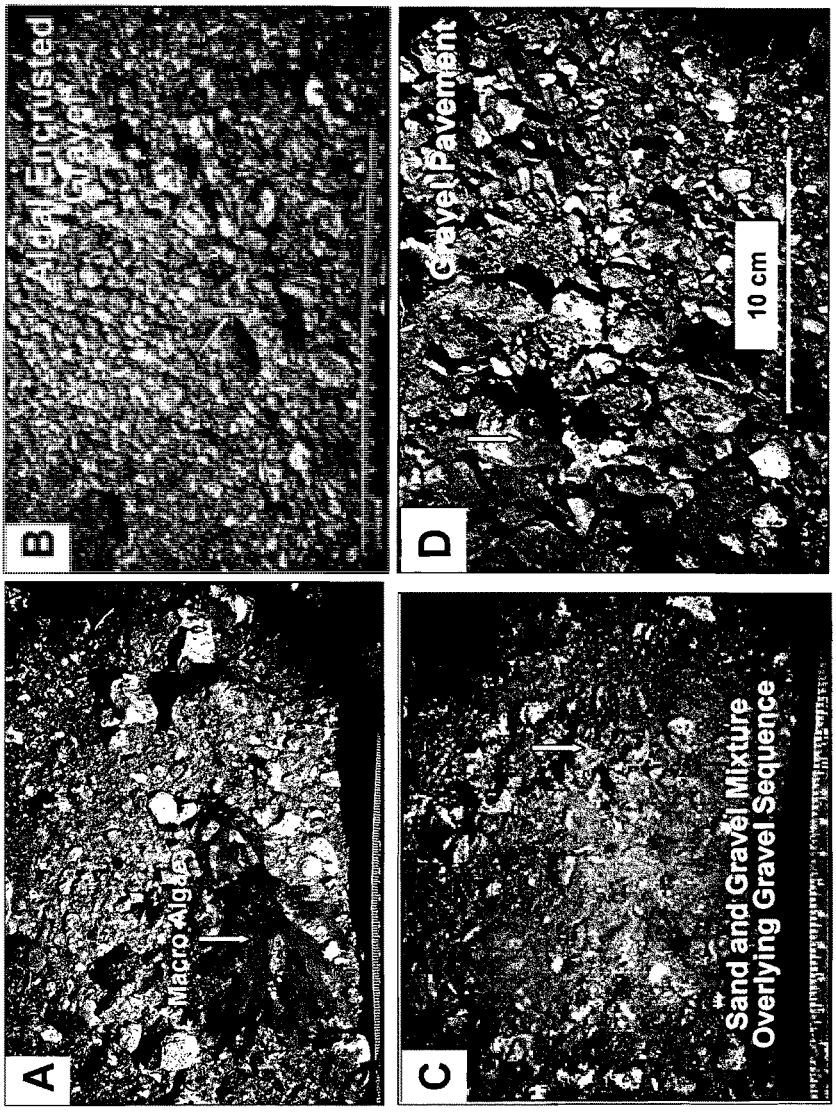


Figure 17. Bottom photographs of Dive Site 810 on North Topsail Beach shoreface in an area of moderate to high relief hardbottoms (>6 ft). **A**. Sand and gravel mixture overlying rock surface. **B**. Gravel lag produced by bioerosion, **C**. Sandy gravel mixture at protected scarp base. **D**. Gravel-sized material on a scarp back. Sandier sediment is usually located closer to scarp. A significant portion of the coarse gravel is coated with a thin crust of calcareous algae (arrows in **B**, **C** and **D**). Scale is 15 cm in length. Bar scale in **D** equals 5cm.

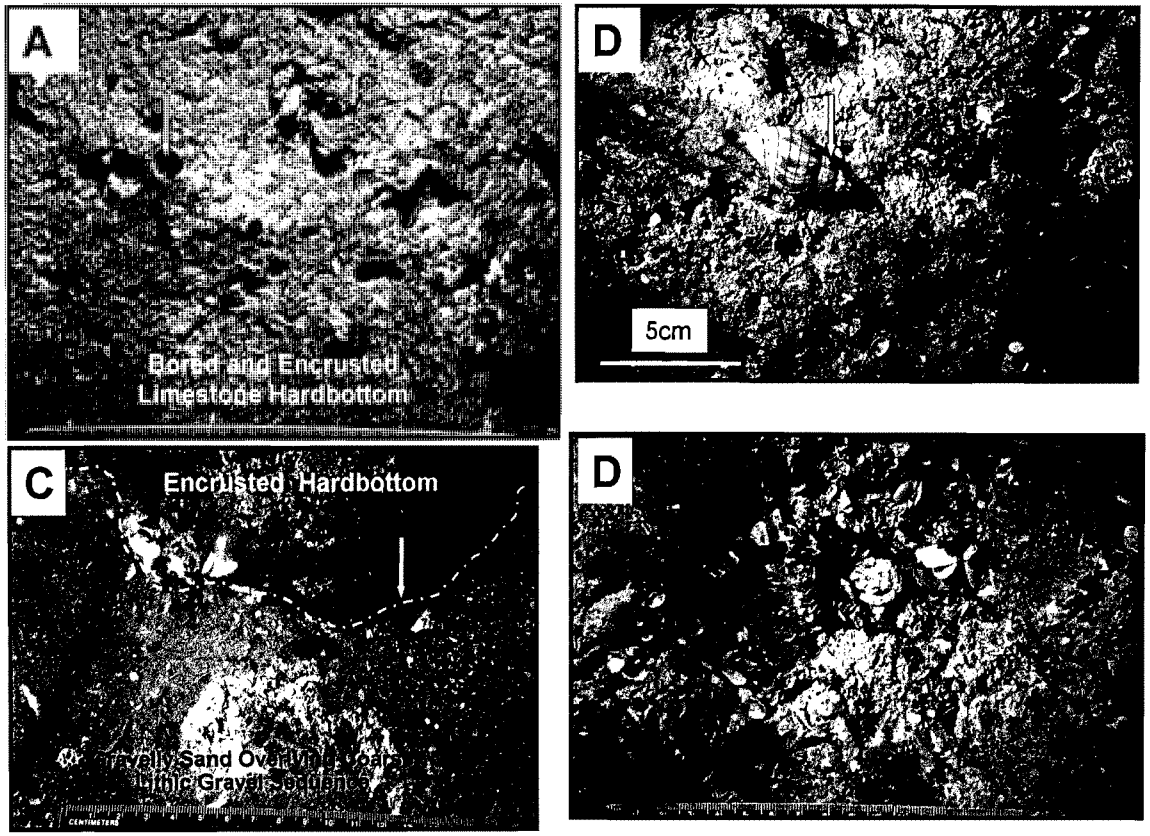


Figure 18. Bottom photographs at dive Site 814 on flat irregular hardbottom. Scale is 15 cm in length. **A**. Bored algal encrusted limestone platform. **B**. Low relief bored and encrusted ledge and contact between rock and sand veneer (lower right). Note grazing gastropod. **C**. Low relief limestone ledge and contact between gravelly, silty sand. Note macro algae. Sandy sediment fills low relief solution depression. **D**. Macro algae and black shell gravel lag deposit on low relief ledge.

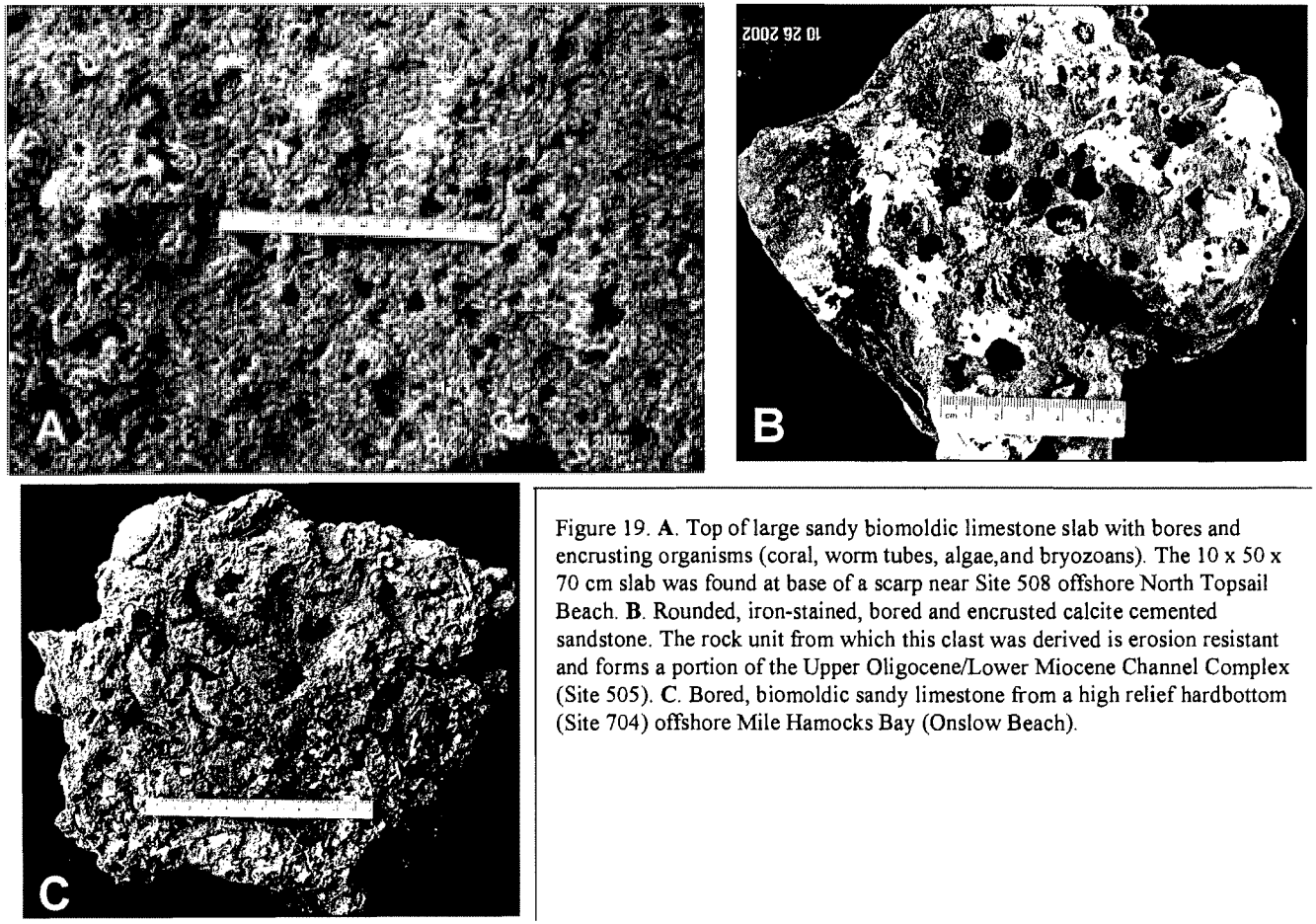
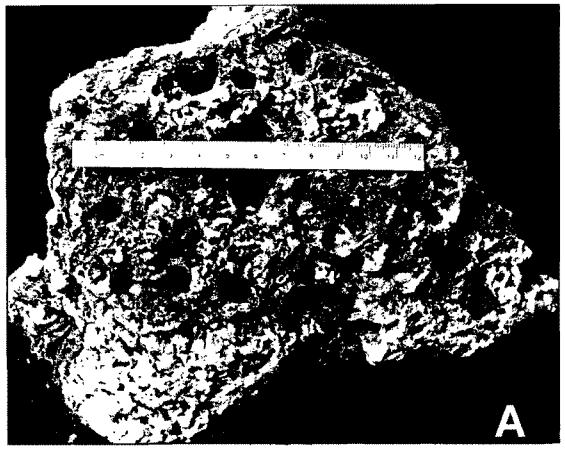
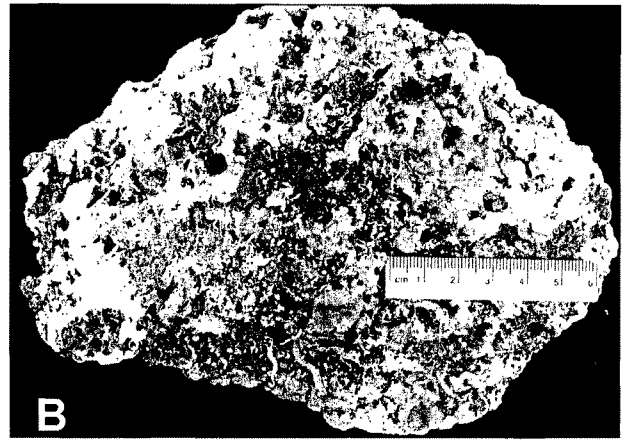


Figure 19. **A**. Top of large sandy biomoldic limestone slab with bores and encrusting organisms (coral, worm tubes, algae,and bryozoans). The 10 x 50 x 70 cm slab was found at base of a scarp near Site 508 offshore North Topsail Beach. **B**. Rounded, iron-stained, bored and encrusted calcite cemented sandstone. The rock unit from which this clast was derived is erosion resistant and forms a portion of the Upper Oligocene/Lower Miocene Channel Complex (Site 505). **C**. Bored, biomoldic sandy limestone from a high relief hardbottom (Site 704) offshore Mile Hamocks Bay (Onslow Beach).





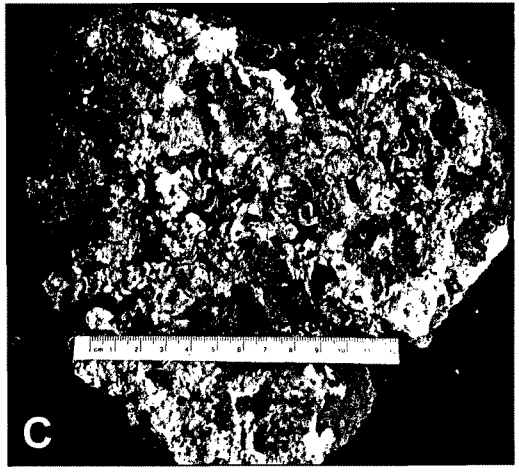


Figure20. Bored and encrusted limestone fragments. **A**. Bored and algal encrusted limestone fragment from debris at base of small overhang in vicinity of Site 516 offshore North Topsail Beach. **B**. Algal and worm tube encrusted surface of sandy limestone at Site 712 near base of High relief scarp offshore North Topsail Beach. **C**. Top of bored and encrusted sandy limestone at base of small overhang at Site NS 006 offshore Alligator Bay.

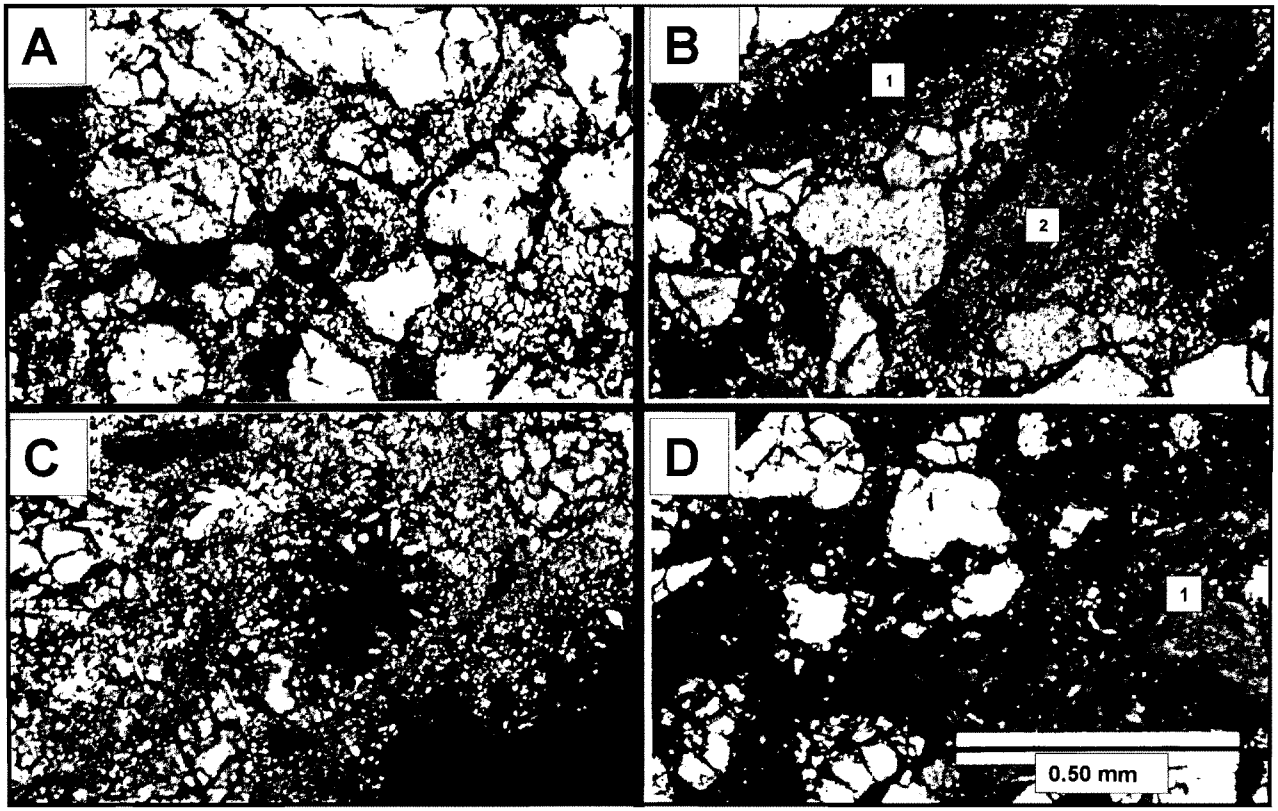


Figure 21. Photomicrographs of Belgrade Limestone from the North Topsail Beach shoreface (modified after Johnston, 1998). Red color is a stain used to enhance the identification of constituents. Plain light. **A**. Equant calcite cemented quartz . **B**. Pelcypod mold formed by dissolution of shell material (1) calcite cement lines mold. Large allochem is bryozoan fragment (2). **C**. Moldic pore space lined with bladed calcite. Equant calcite cement is dominant variety. **D**. Phosphatized sandy limestone. (After Johnston 1998).

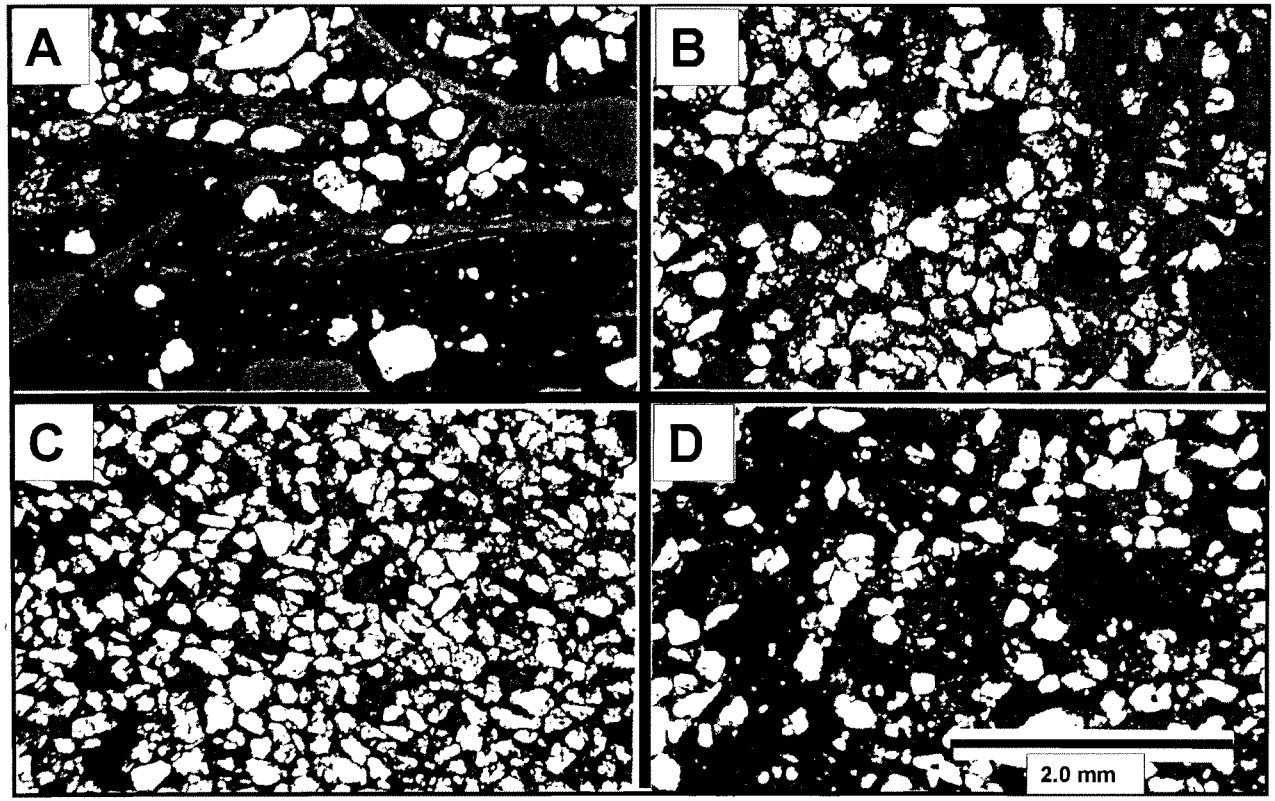


Figure 22. Photomicrographs of loose lithoclasts from shoreface platform (after Johnston, 1998). **A**. Sandy moldic biomicrudite with abundant molds. Blue background is from dye in impregnating medium. **B**. Sandy moldic biosparrudite. Note segregation of bio moldic pores (dissolved shells). **C**. Quartz rich calcite cemented sandstone. Clast was likely derived from high relief hardbottom composed of Upper Oligocene/Lower Miocene channel structure. **D**. Phosphatized sandy limestone. Scale bars refers to A-D. (Modified after Johnston, 1998).

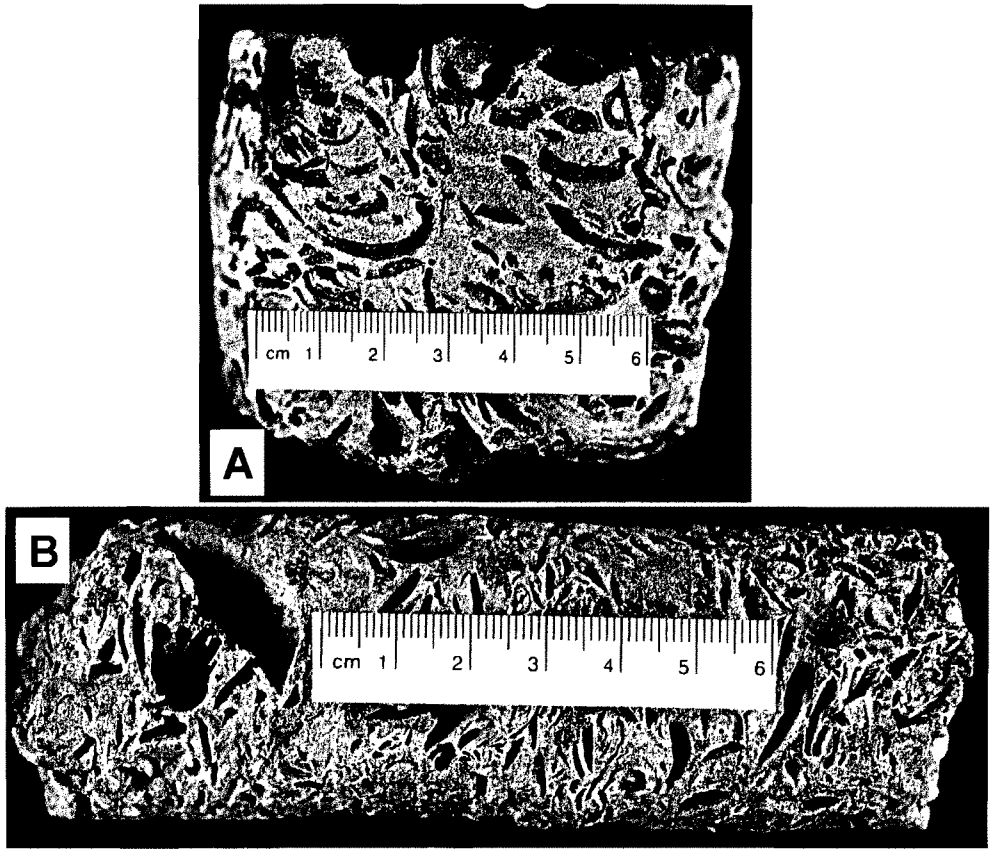


Figure 23. Slabbed cores of Trent Fm (?) arenaceous moldic limestone. Most aragonite bearing shell material has been dissolved leaving voids. **A**. TP-116. **B**. TP-14. Sandy pelecypod-moldic limestone is the dominant rock unit that underlies most of the the shoreface in the southern portion of the study area.

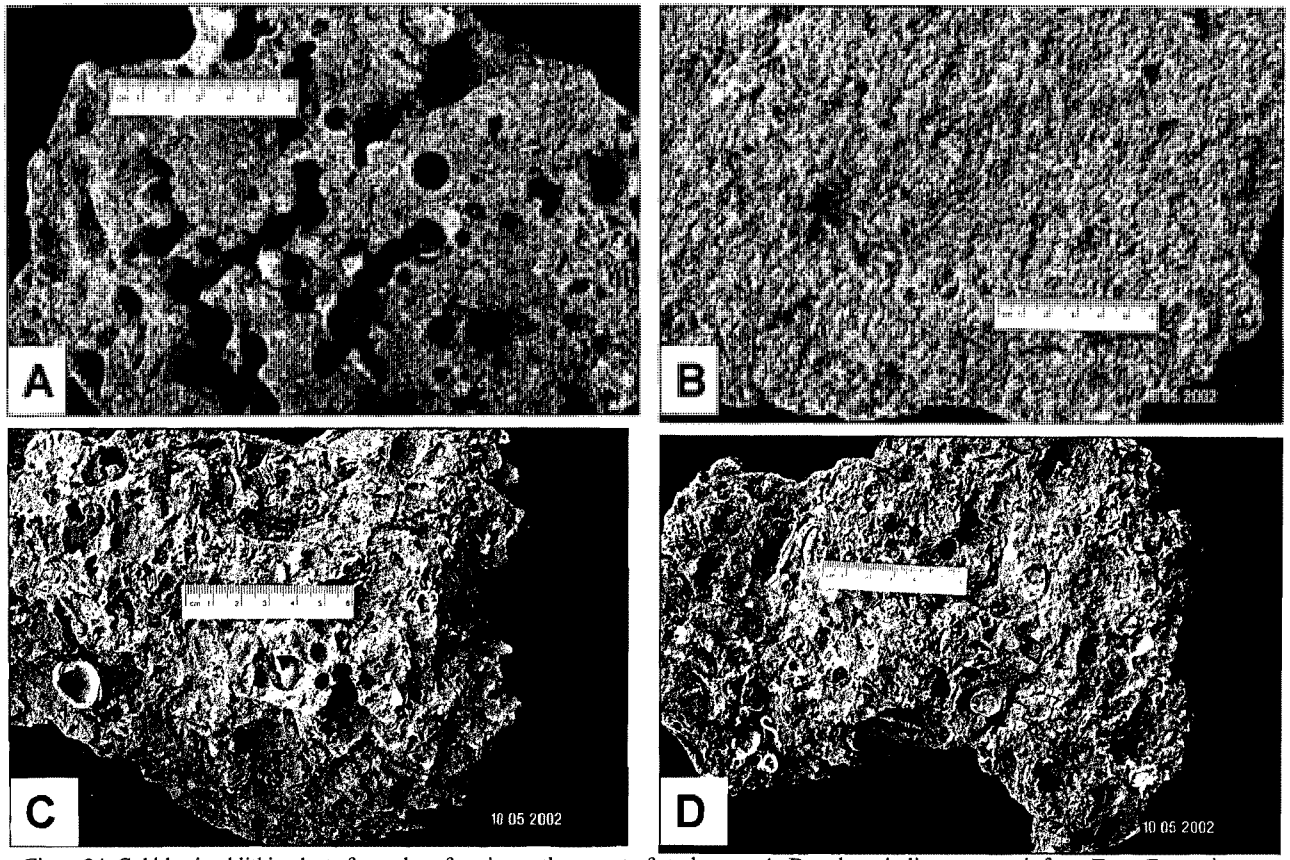


Figure24. Cobble sized lithic clasts from shoreface in southern part of study area. **A**. Bored sandy limestone unit from Trent Formation (SC 100). **B**. Large cobble sized slab of bored limestone near hardbottom scarp (Site 22) . **C**. Top of slightly encrusted, bored moldic limestone slab (SC 9). **D**. Bottom of same slab pictured in "C" (SC 9).

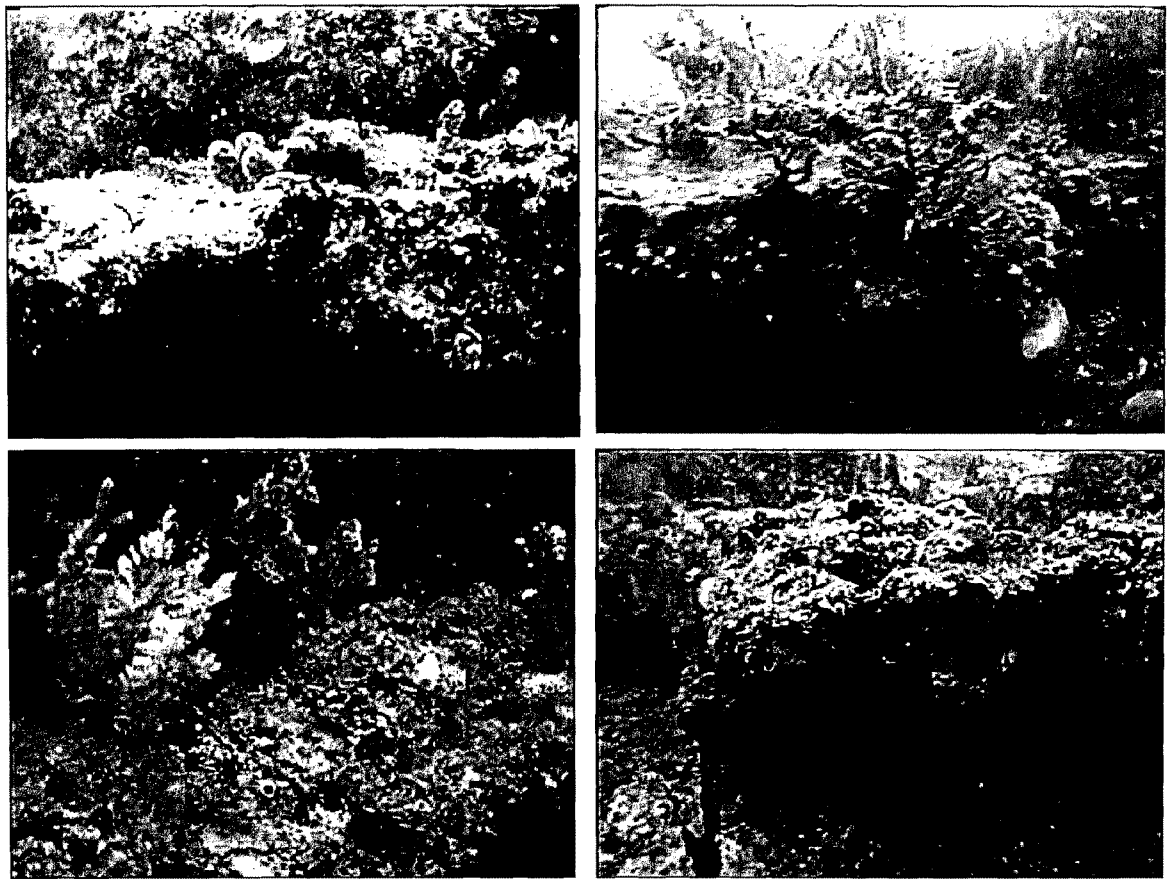


Figure 25. Hardbottom ledge offshore Surf City at Site VID 1. **A.** - **D**. Algal and epifauna encrusted limestone ledge with gravel mixture at base of scarp. Step-like ledges are encrusted with a variety of organisms. Small overhangs occur at rear of each step.

Figure 26. Hardbottom scarp and overhang at Site VID 1 offshore Surf City. A. Poorly sorted angular blocks at base of scarp. B. Sand/gravel mixture at base of corroded limestone scarp. C. Highly bored and corroded limestone scarp face with gravel/sand mixture at base. D. Encrusted overhang with macro algae and sponges. Future collapse of overhang will produce rubble ramp seen in "A".

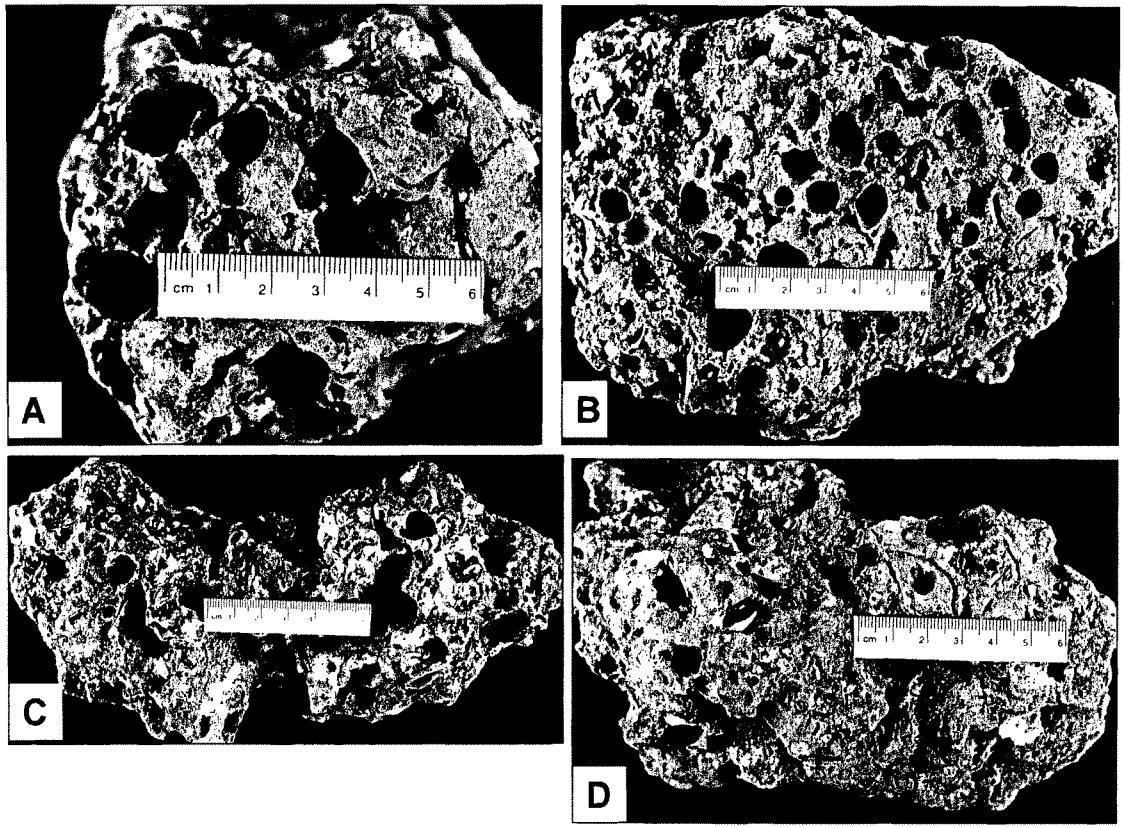


Figure 27. Cobble sized clasts of bored limestone from gravel-rich areas of the shoreface in the southern part of the study area. Cobbles are derived from various units of the Trent Formation (?) **A**. Rounded cobble of bored, quartz sand-rich limestone (SC 16 [4]). **B**. Highly bored limestone. Note some bores are filled with mud and silt from overlying thin veneer of surface sediment (SC 97). **C**. Elongated, encrusted cobble of bored limestone (SC VC 44). **D**. Cobble size clast derived from adjacent overhang (SDA 9).

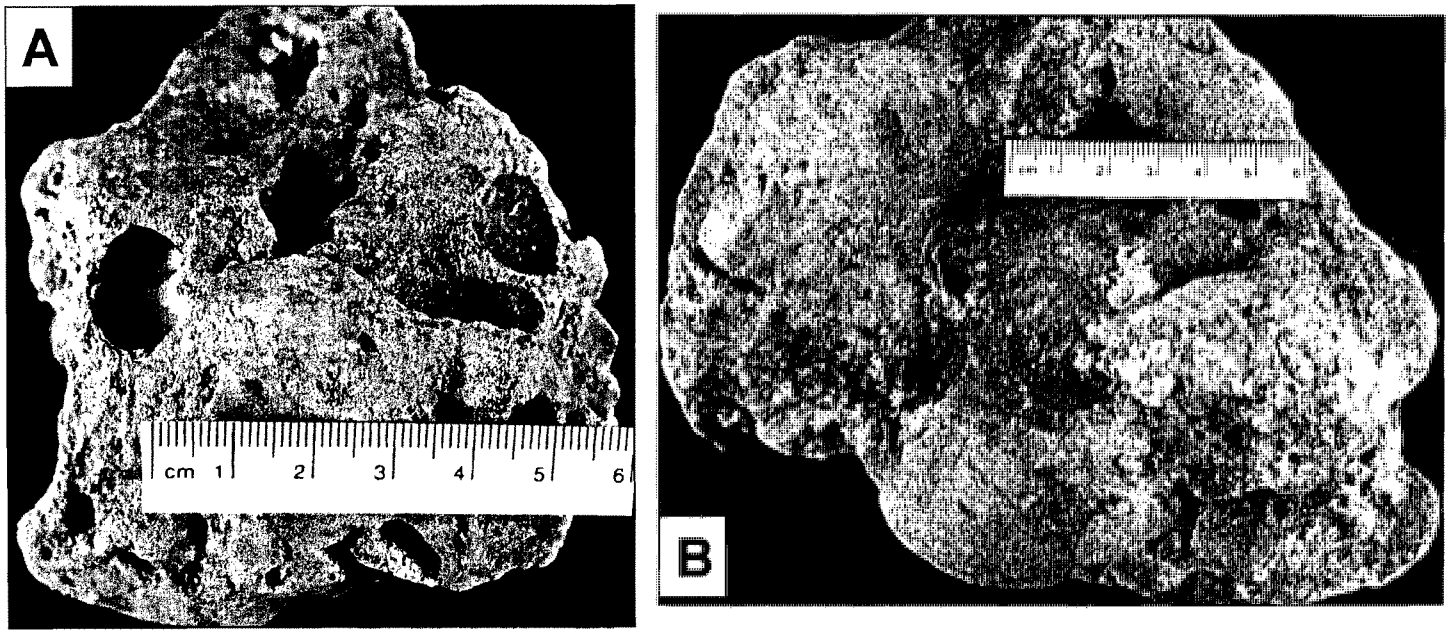


Figure 28. Rounded cobble size clasts from the dominant stratigraphic units that underlie the shoreface in the southern part of the study area. **A**. Bored clast of the Oligocene River Bend Fm. The olive green dolosilt clast is very friable and easily disaggregated with transport (SD 7 19). Most of the silt found in the surface sediment veneer is derived from the erosion of the siltstone. **B**. Rounded cobble of quartz bearing limestone from the Trent Formation (?). The Trent Fm forms the majority of the hardbottoms off Surf City and the southern part of North Topsail Beach (SC 10).

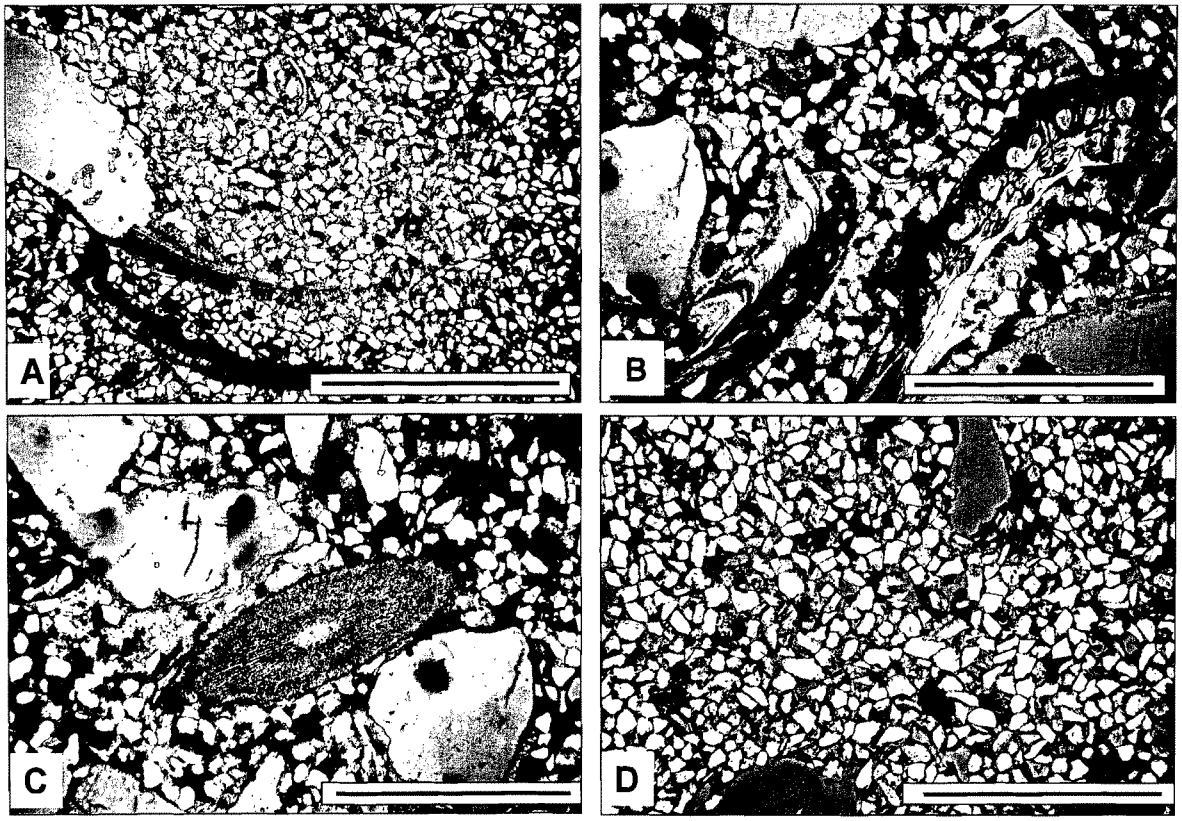


Figure 29. Thin-section photomicrographs of rocks from the southern segment of the shoreface. Scale bar =2.25mm. **A**. Sandy moldic Ls showing molds of dissolved shell material (Site SDA) in recrystallized micrite. **B**. Hollow wall barnacle in microcrystalline calcite cement (Top 15). **C**. Biomoldic sandy limestone with recrystallized echinoid fragment. Dark brown areas represent micritized allochems and partially altered micrite cement (Top 15). **D**. Sandy biomoldic limestone. Molds represent dissolved shell material. Dark brown opaque grains are micritized allochems set in a variety of cement (Top 6).

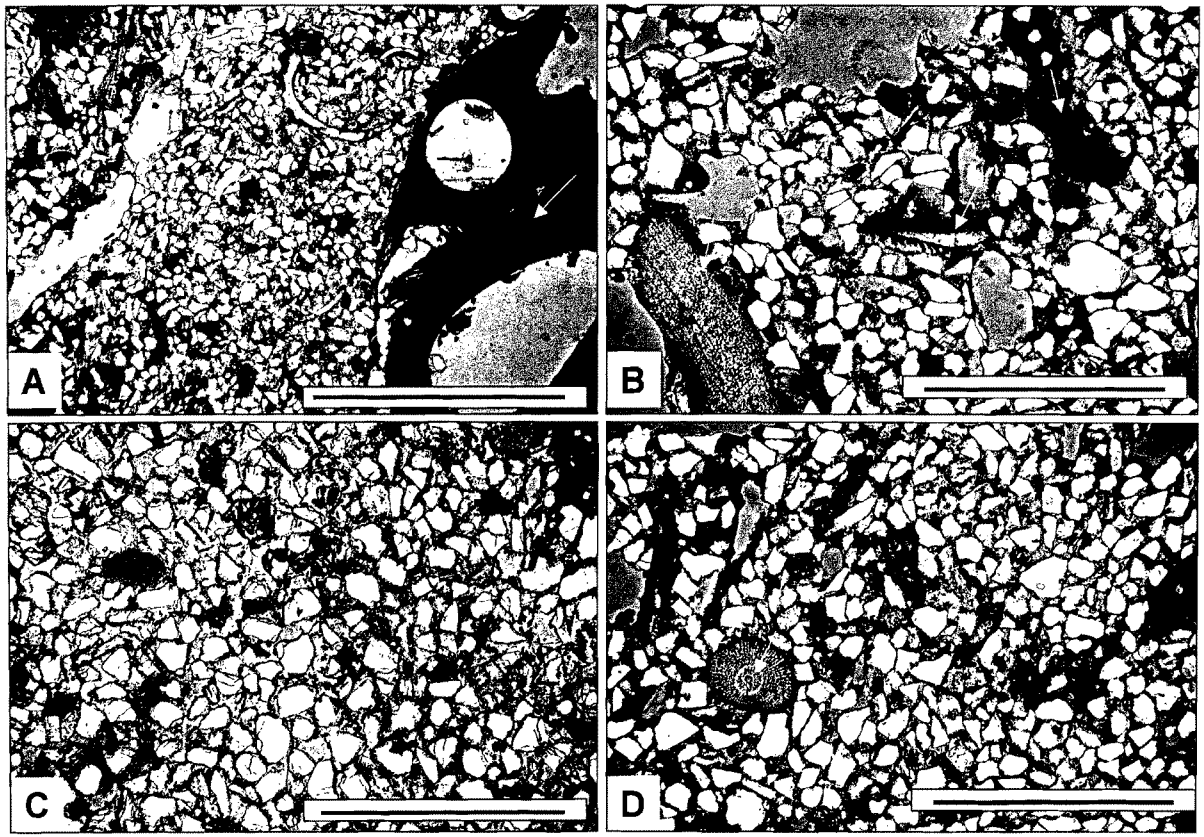


Figure30. Thin-section photomicrographs of rocks from the southern segment of the shoreface. Scale bar = 2.25mm. **A**. Sand- silt rich biomoldic Ls. Quartz and allochems set in recrystallized micrite cement, a variety of calcite cement has filled molds and pores. Opaque grains are mixture of micritized allochems (peloids) and phosphatized shells. Large opaque areas (arrow) are worm tubes (Top 4). **B**. Sandy biomoldic Ls. Angular -subrounded fine quartz sand, phosphatized and micritized allochems set in partially recrystallized micrite cement (SC 111). **C**. Poorly cemented calcareous sandstone with small molds of shell. A variety of calcite cement types are present. Some phosphate (opaque grains) are present (SC 95). **D**. Sandy biomoldic Ls. Micritized and phosphatized pelecypod grains, recrystallized echinoid plate and fine quartz sand are set in an aggraded micrite and phosphate matrix (SC 105).

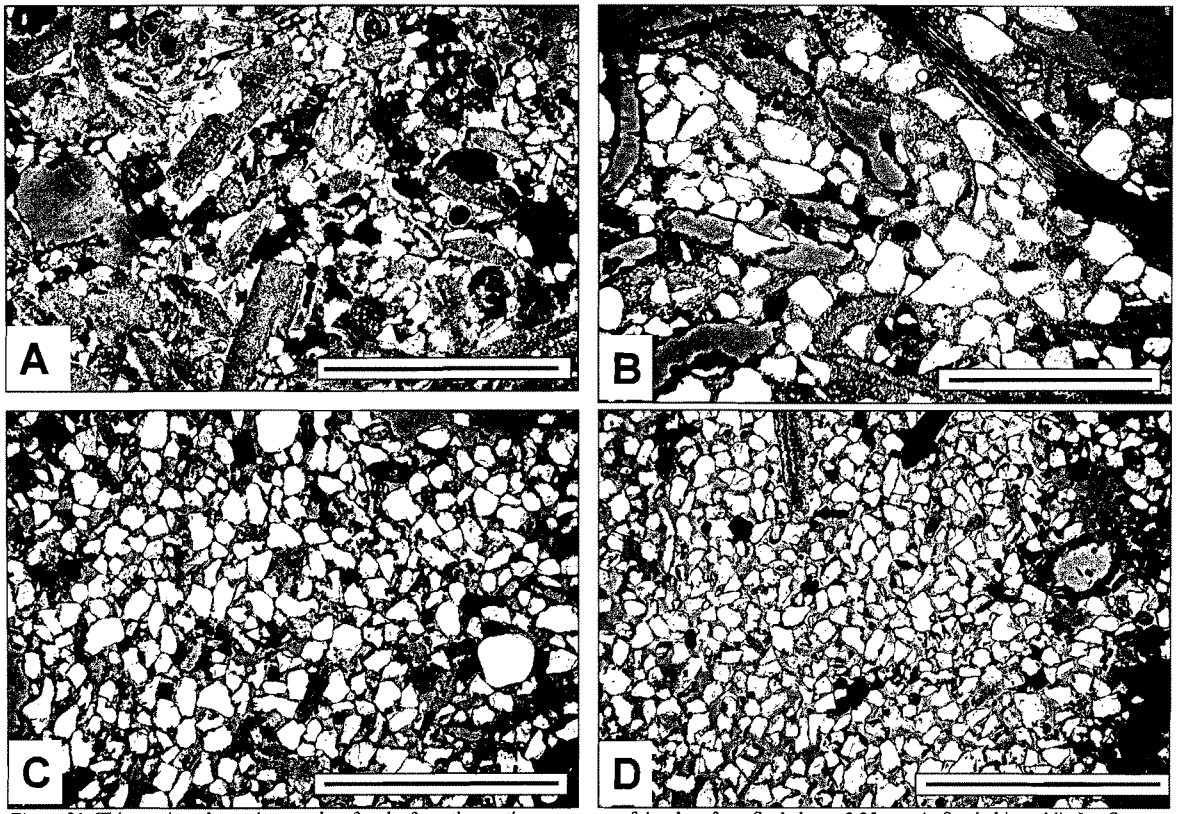


Figure 31. Thin-section photomicrographs of rocks from the southern segment of the shoreface. Scale bar = 2.25mm. **A**. Sandy biomoldic Ls. Quartz and allochems (echinoid plates and molluscan fragments) set in sparry calcite cement, clusters of calcite overgrowths on original grains are abundant (SC 122). **B**. Sandy biomoldic Ls. Angular - subrounded fine quartz sand and shells are set in recrystallized cement. Molds and pores are infilled with a variety of calcite cement types. (SC 89). **C**. – **D**. Severely weathered calcareous siltstone (Lower River Bend unit ?). Angular very fine quartz sand and silt with minor amounts of micritized shells and recrystallized echinoid plates with traces of calcite cement (SC VC 30).

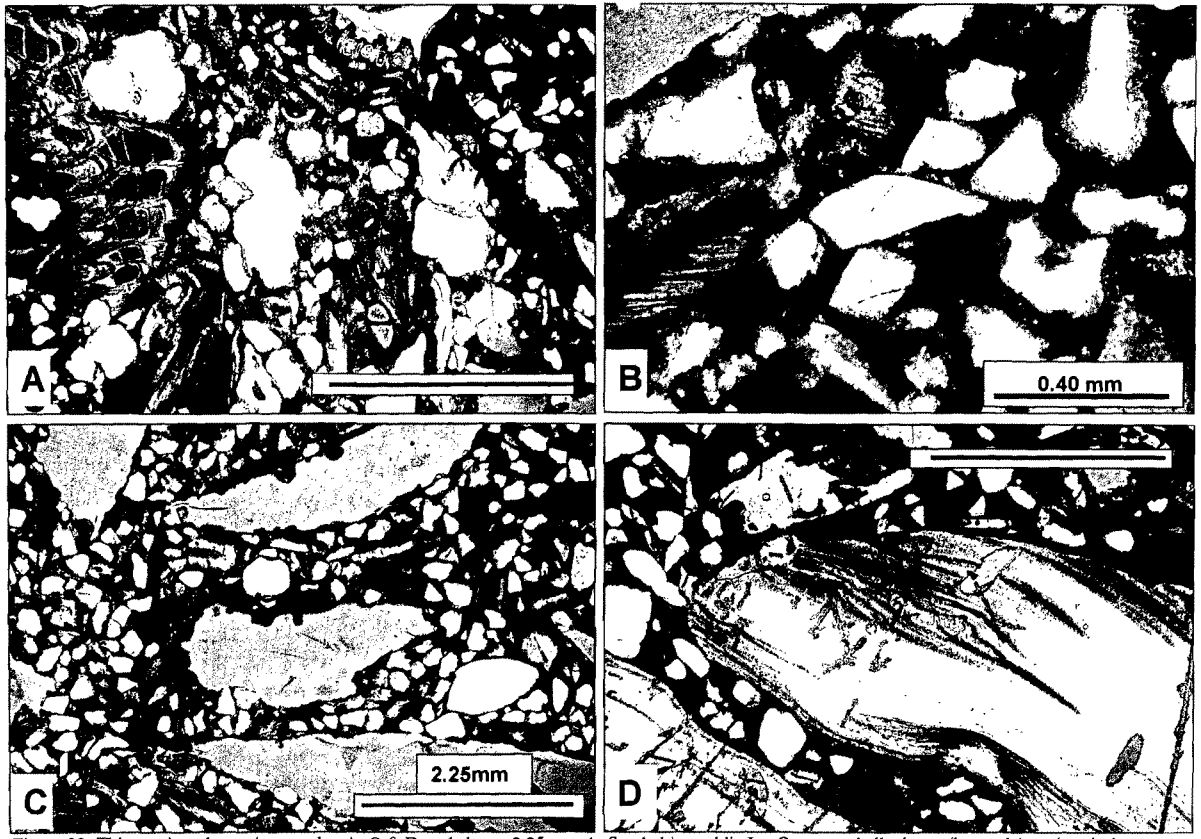
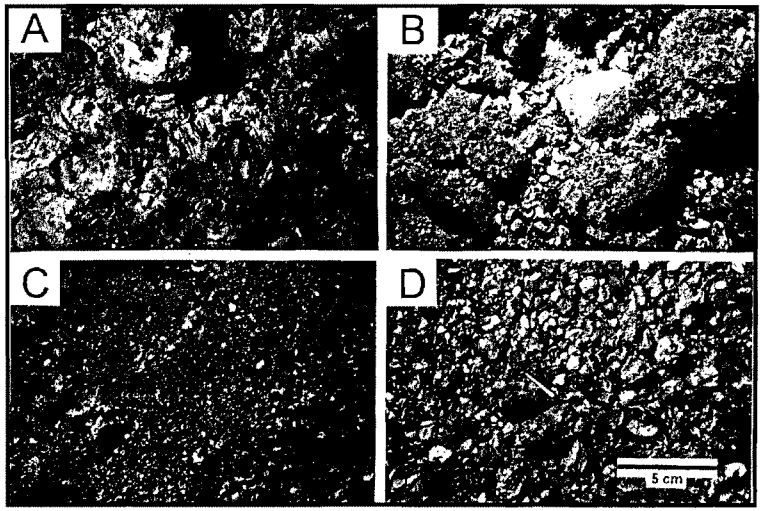


Figure 32. Thin-section photomicrographs. A, C & D scale bar = 2.25mm. **A**. Sandy bio moldic Ls. Quartz and allochems (barnacle) set in micrite cement (SC 79). **B**. Sandy biomoldic Ls. Angular fine quartz sand and recrystallized allochems are set in partially recrystallized micrite cement (SC 81). **C**. Sandy moldic Ls. with molds of dissolved shell material and fine quartz sand set in micrite matrix. Some phosphate (opaque grains) are present (SC 81). **D**. Sandy biomoldic Ls. Large bored and partially altered allochem (pelecypod) and fine quartz sand set in micrite and phosphate matrix (SC 85).



Figure 33. Map depicting surface sediment types and side scan sonar mosaic.



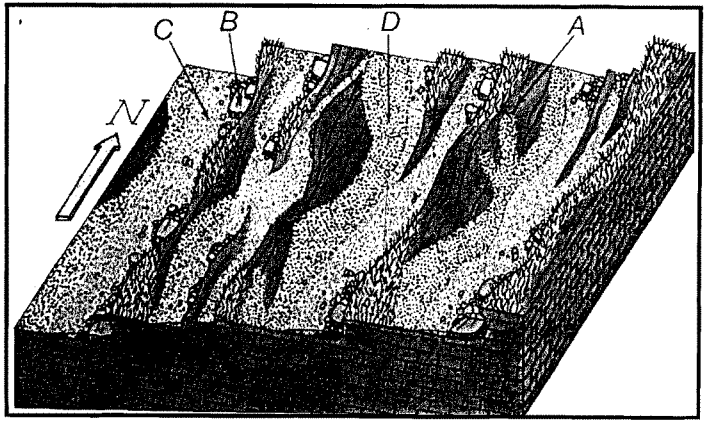


Figure 34. Bottom photographs of sediments and cartoon illustrating the general nature of step-like hardbottom features of shoreface off North Topsail Beach - Onslow Beach. **A**. East sloping scarp backs are generally barren of sediment near scarp edge. **B**. Poorly sorted rubble at base of scarp (talus ramp) is by-product of bio-erosion and mechanical erosion (undercutting) of overhangs. **C**. Poorly sorted sand mixture accumulates at base of scarp and grades into lithic gravels. **D**. Patches of lithic gravel accumulates on scarp backs. Distribution and thickness of sediment types is a function of scarp spacing, relief and composition of hardbottoms. Meadows of macroalgae are scattered across barren surfaces (modified after Johnston, 1998).

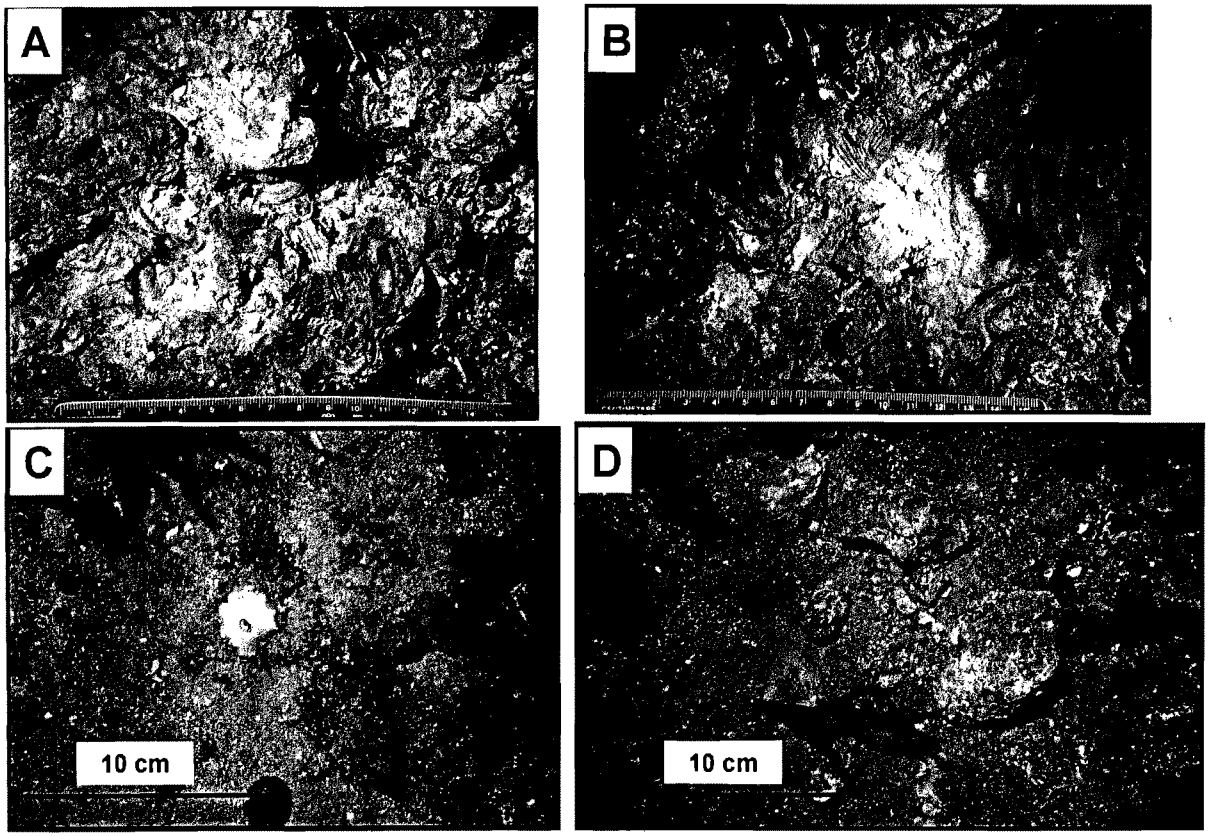


Figure 35. Bottom photographs of Dive Site 516 on high relief (>6 ft) hardbottom scarp on North Topsail Beach shoreface. **A**. Algal encrusted surface of bio moldic limestone in a sheltered area. **B**. Macro algae on lower portion of encrusted scarp face. **C**. Sand covered basal portion of scarp. A large variety of sponges and macro algae cover the karstic platform surface. **D**. Algal encrusted gravel and sand mixture at base of scarp. Scale in **A** and **B** are 15 cm in length. Scale bars in **C** and **D** are 5cm.

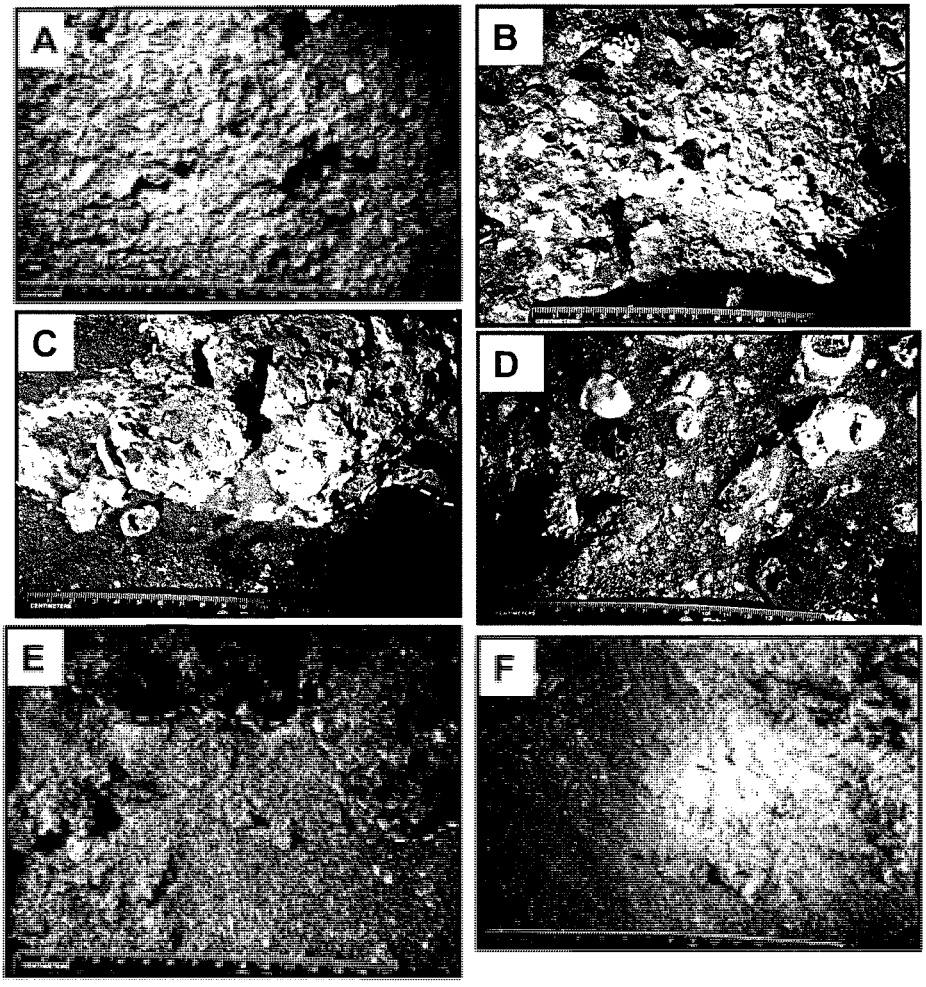


Figure 36. Bottom photographs of Dive Site 505 on North Topsail Beach shoreface in area of moderate relief hardbottom ledges. **A**. Irregular barren surface of moldic limestone ledge. **B**. Bored and encrusted limestone surface. **C**. Contact of mobile fine sand and irregular hardbottom **D**. Poorly sorted sand and gravel mixture away from base of scarp. **E**. Contact between gravelly sand and algal encrusted hardbottom scarp. **F**. Subdued, rippled fine sand field at base of scarp. A thin layer of very fine silt drapes the fine sand ripples. Scales are 15 cm in length.

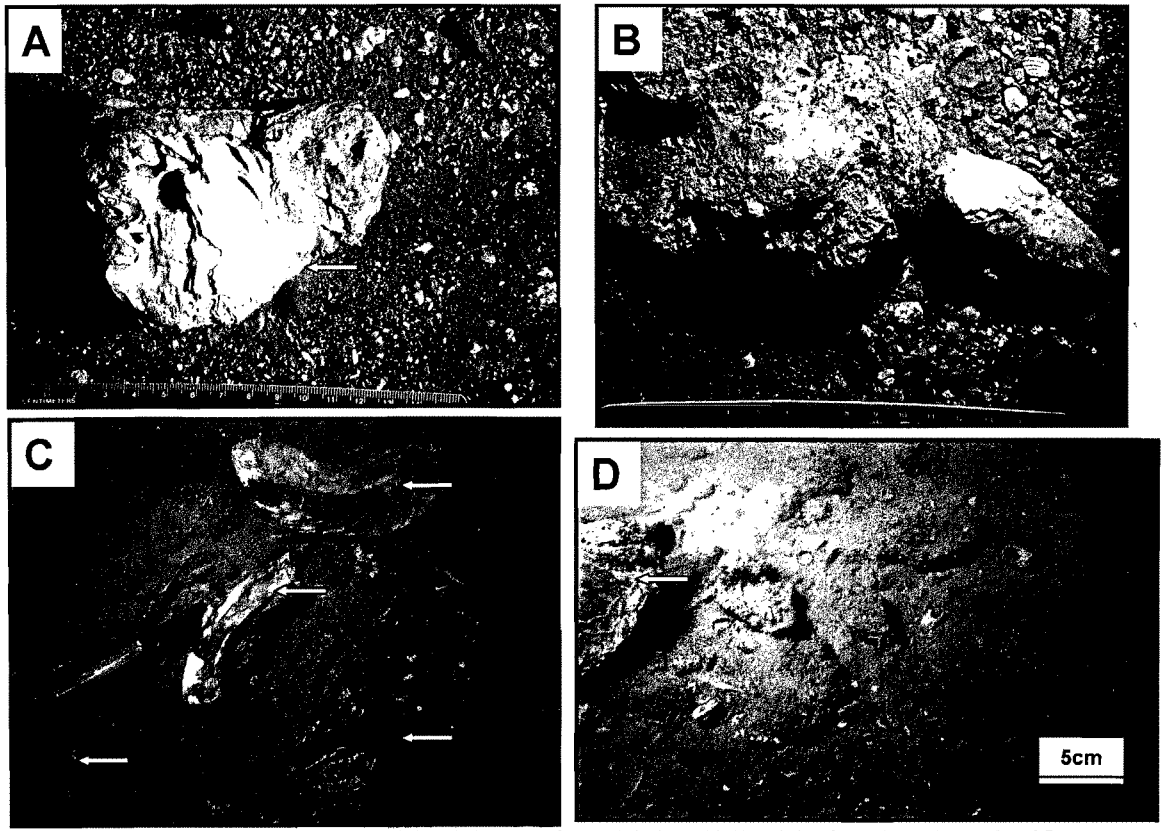


Figure 37. Bottom photographs at dive Site 504 on North Topsail Beach shoreface. Scale in A and B is 15 cm in length. **A.** Abraded lower valve of *Crassostrea gigantissima* (Oyster) and sand/ gravel mixture on limestone platform. **B.** Contact between limestone exposure (hardbottom) and silty fine sand veneer. Large white elongated cobble is fragment of oyster. **C.** In-place *Crassostrea gigantissima* Oyster Reef. Cobbles of *Crassostrea gigantissima* (arrows) are abundant in the vicinity of the lower Miocene channel structures. Divisions on crowbar are 10 cm in length. **D.** Mud draped oyster shell fragments litter the platform area. The sediment veneer in the area is generally less than 10-15 cm. Dissolution related depressions in the area are filled by modern sediment. Scale bar is ~ 5cm in length.

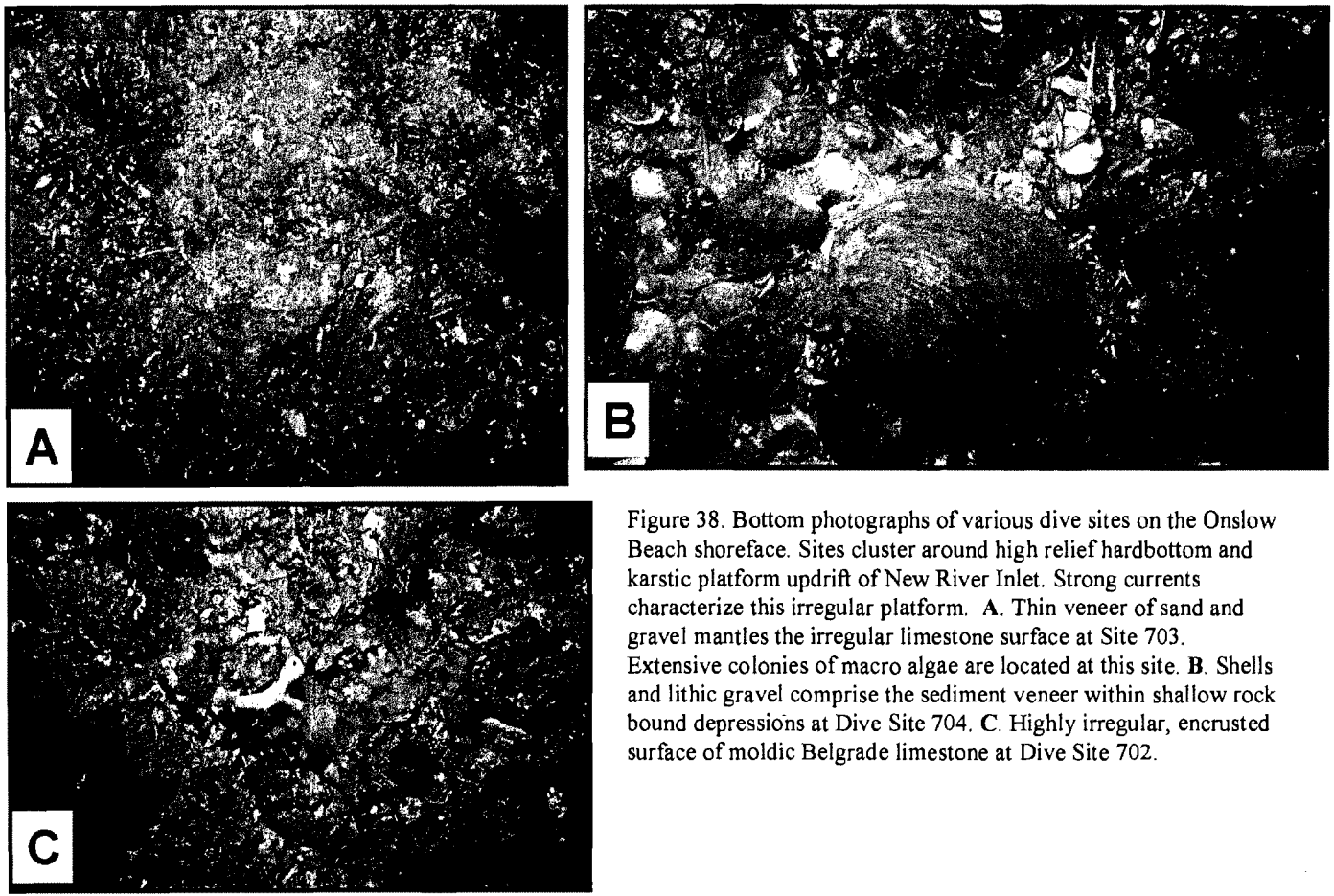


Figure 38. Bottom photographs of various dive sites on the Onslow Beach shoreface. Sites cluster around high relief hardbottom and karstic platform updrift of New River Inlet. Strong currents characterize this irregular platform. **A**. Thin veneer of sand and gravel mantles the irregular limestone surface at Site 703. Extensive colonies of macro algae are located at this site. **B**. Shells and lithic gravel comprise the sediment veneer within shallow rock bound depressions at Dive Site 704. **C**. Highly irregular, encrusted surface of moldic Belgrade limestone at Dive Site 702.

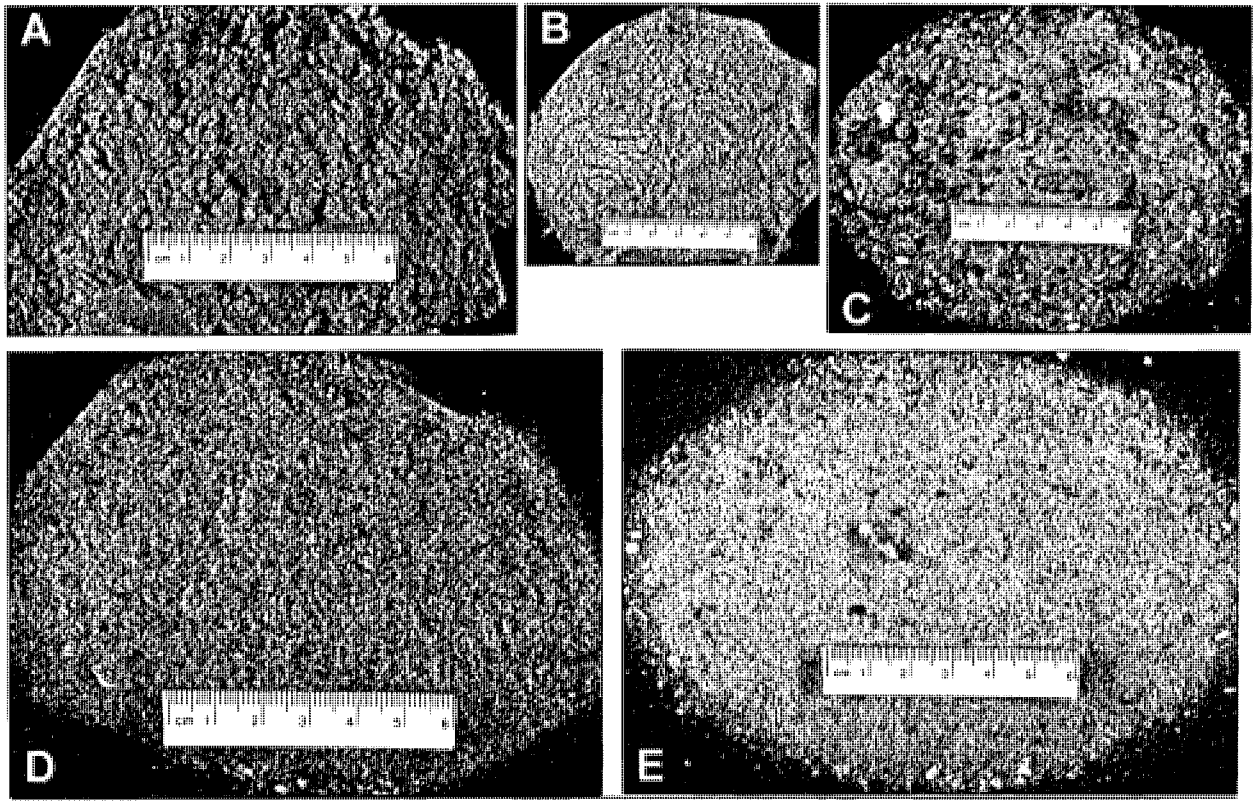


Figure 39. Silt and very fine shelly quartz sand surface sediments. **A**. Calcareous quartz silt offshore Alligator Bay inner shoreface (Site 835). **B**. Very fine quartz sand and silt withjin linear depression off shore Alligator Bay (Site 812). **C**. Black shell rich fine quartz sand offshore Alligator Bay (linear depression). Shells reworked from paleo channel. **D**. Orange brown fine quartz sand with minor shell material near hardbottom offshore Onslow Beach (Site 827). **E**. Clean fine quartz sand with minor shell material. Near ancestral channel of New River (Site NS 017).

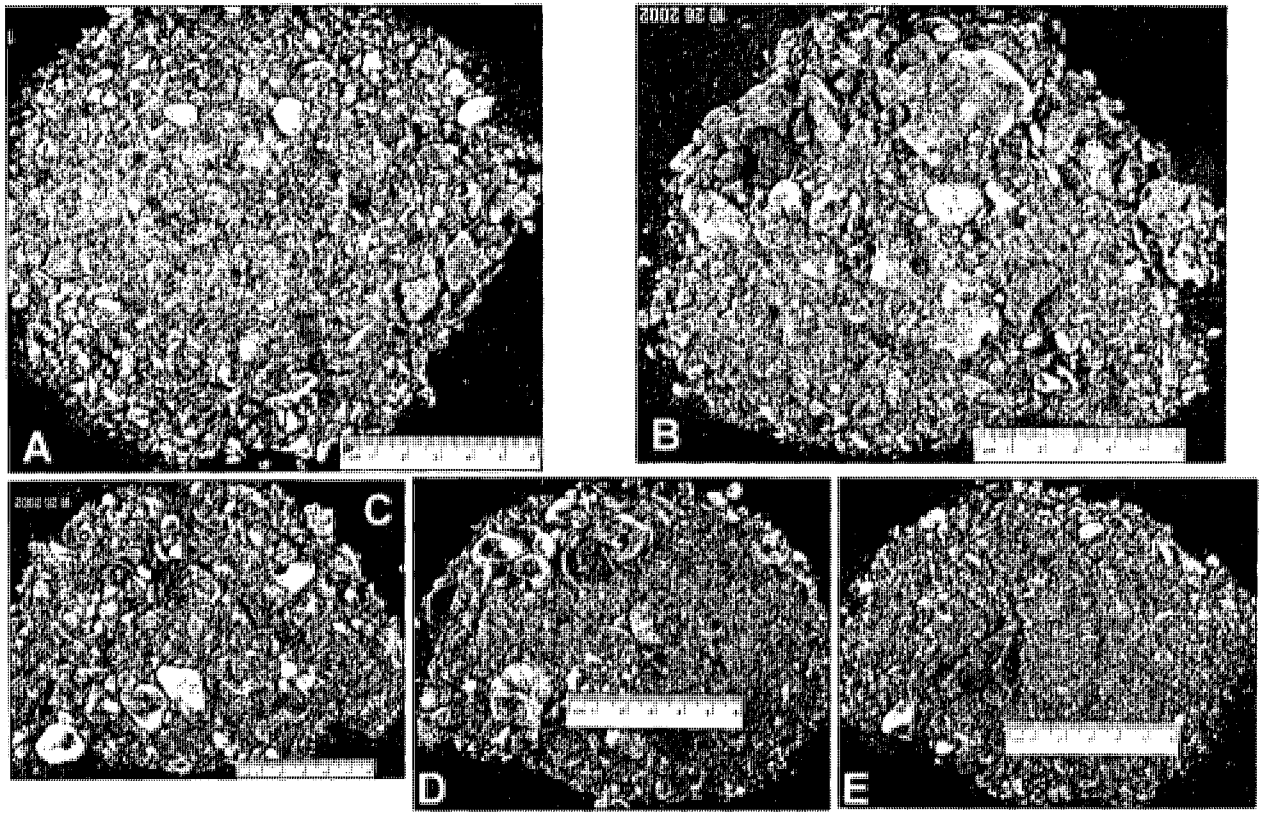


Figure 40. Sandy gravel and gravelly sand surface sediments. **A**. Sandy, lithic and shell gravel near high relief hardbottom (Site 509). **B**. Poorly sorted sandy lithic gravel offshore Alligator Bay (Site 602). **C**. Sandy algal, shell-rich lithic gravel on limestone platform off New River Inlet (Site 829). **D**. Gravel rich quartz sand offshore North Topsail Beach (Site 806). **E**. Gravelly, lithic sand near high relief scarp off Alligator Bay (Site 813).

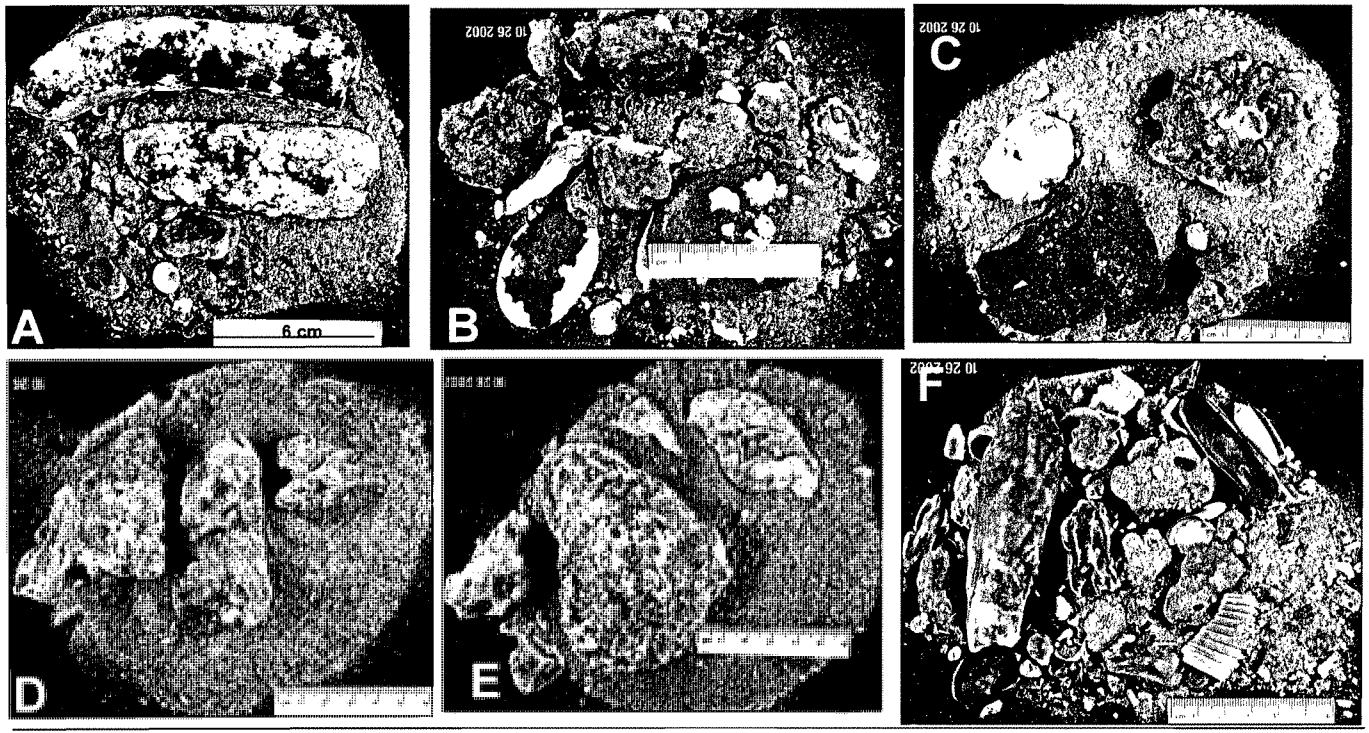


Figure 41. Gravelly sand and sand gravel mixtures. A. Orange brown quartz sand with lithic and shell gravel material. Large brown black fragments are encrusted bones from Site 701 offshore Onslow Beach (Site701). B. Poorly sorted sand/gravel mixture from Site 718 near outer platform offshore Onslow Beach. Quartz cobbles are derived from units farther offshore. C. Gravelly quartz and lithic sand mixture from Site 728 offshore Onslow Beach. Large black gravel is fragmented phosphatized sandy limestone clast. D. Fine quartz sand with subrouded moldic limestone fragments from Site 603 offshore Alligator Bay. E. Quartz sand and limestone gravel from Site 601on inner shoreface offshore North Topsail Beach.E. Sandy gravel mixture from outer platform offshore New River Inlet (Site 834). Black and gray oyster shells are derived from reworking of Holocene age backbarrier deposits.

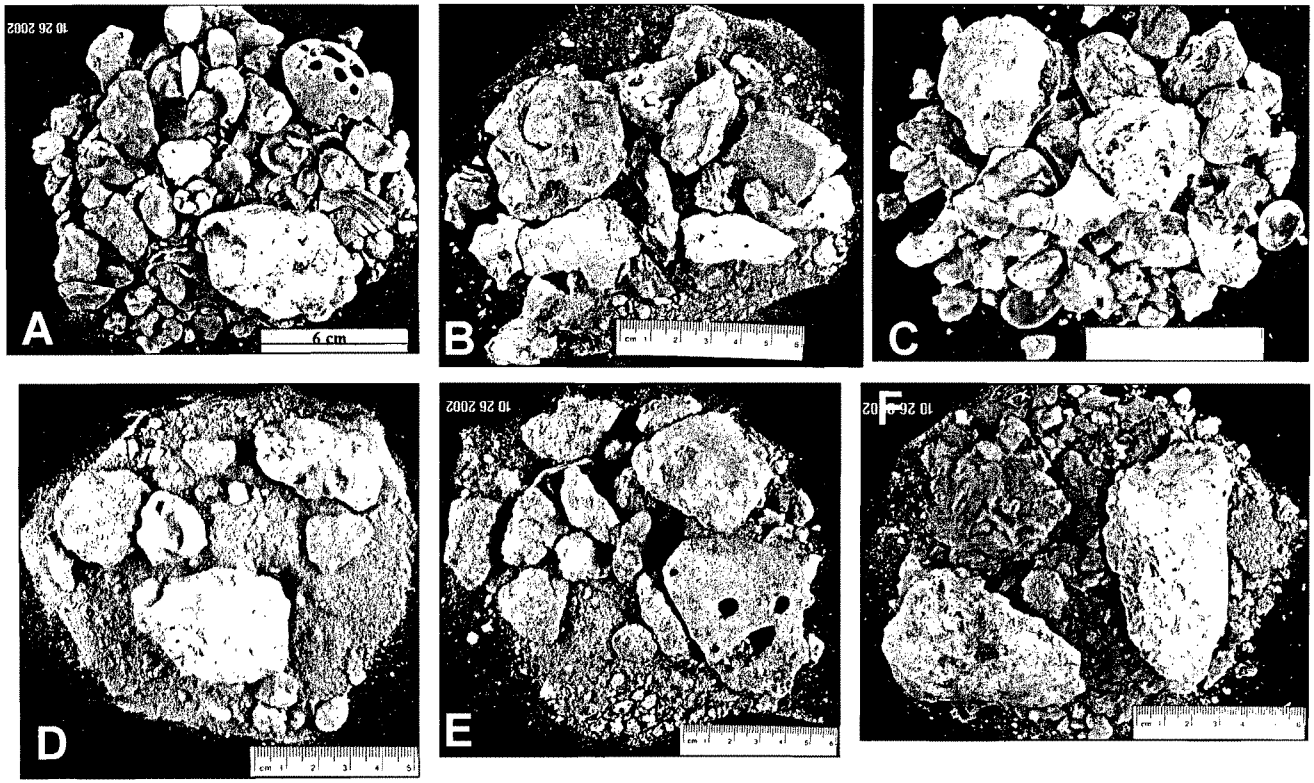


Figure 42. Lithic gravels, silt and sand rich gravel. **A**. Sandy subrounded to rounded limestone gravel (Site 511). **B**. Poorly sorted silt/sand rich angular lithic gravel near scarp (Site 515) offshore North Topsail Beach. **C**. Lithic and shell gravel on inner shoreface offshore North Topsail Beach (Site 507). **D**. Weathering residuum at base of small scarp. Fine material is calcareous mud (Site 513) offshore Alligator Bay. **E**. Weathering residuum near scarp. Fine material is lithic, quartz sand (Site 510) offshore Alligator Bay. **F**. Poorly sorted angular gravel mixture from gravel ramp at Site 516 near high relief hardbottom offshore North Topsail Beach.

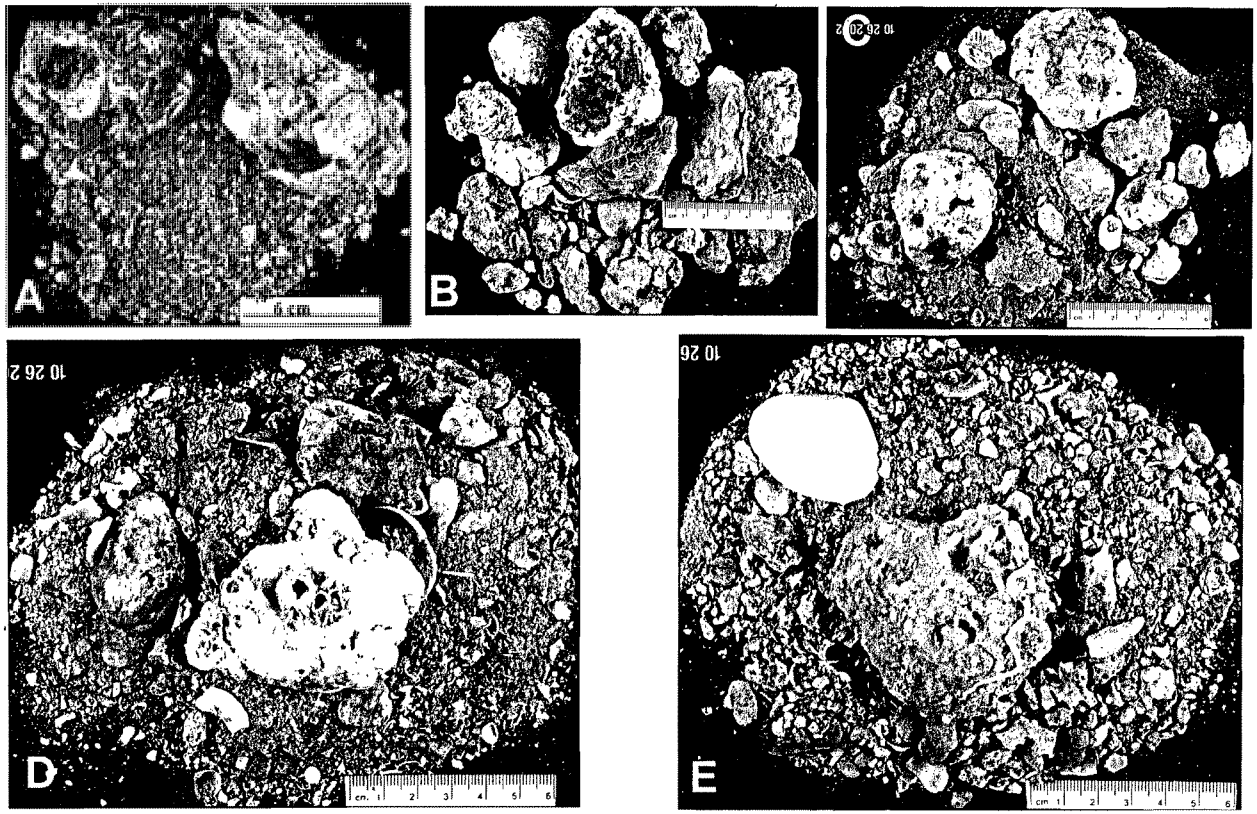


Figure 43. Lithic gravel and sandy gravel. A. Poorly sorted limestone gravel from platform near high relief scarp offshore Onslow Beach (Site 703). B. Subrounded lithic gravel on scarp back offshore North Topsail Beach (Site 720). C. Poorly sorted gravel/sand mixture. Some clasts are encrusted with calcareous algae (Site 810). D. Sandy lithic gravel from Site 721 near scarp. Gravels are bored and encrusted. E. Sandy poorly sorted gravel mixture from Site 830 offshore New River Inlet.

Figure 44. Bottom photos of hardbottom area with thin sand veneer off Surf City (Site SC 78). **A.** - **C**. Thin rippled sand veneer overlying limestone exposure. Gorgonians and epifauna are partially buried by mobile sand cover. **D**. Thin sand veneer with bored limestone protruding above sediment cover.

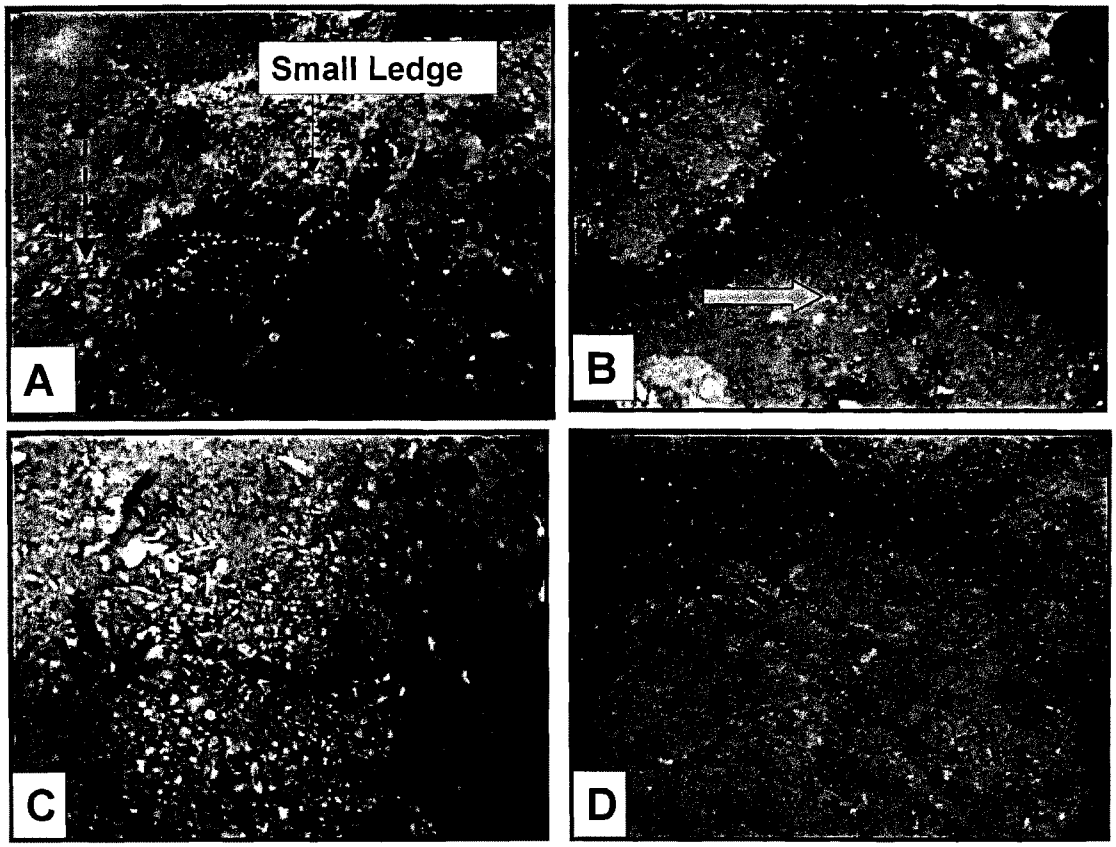


Figure 45. Small encrusted limestone scarp offshore Surf City (Site SDA). **A**. Macro algae and silt layer mantle ledge with poorly sorted gravel/sand mixture at base. **B**. Gravel/sand mixture at base of step like scarp. **C**. Buried macro algae at base of scarp. **D**. Rubble ramp at base of scarp. Silt to garvel size material infilled void spaces in ramp feature.

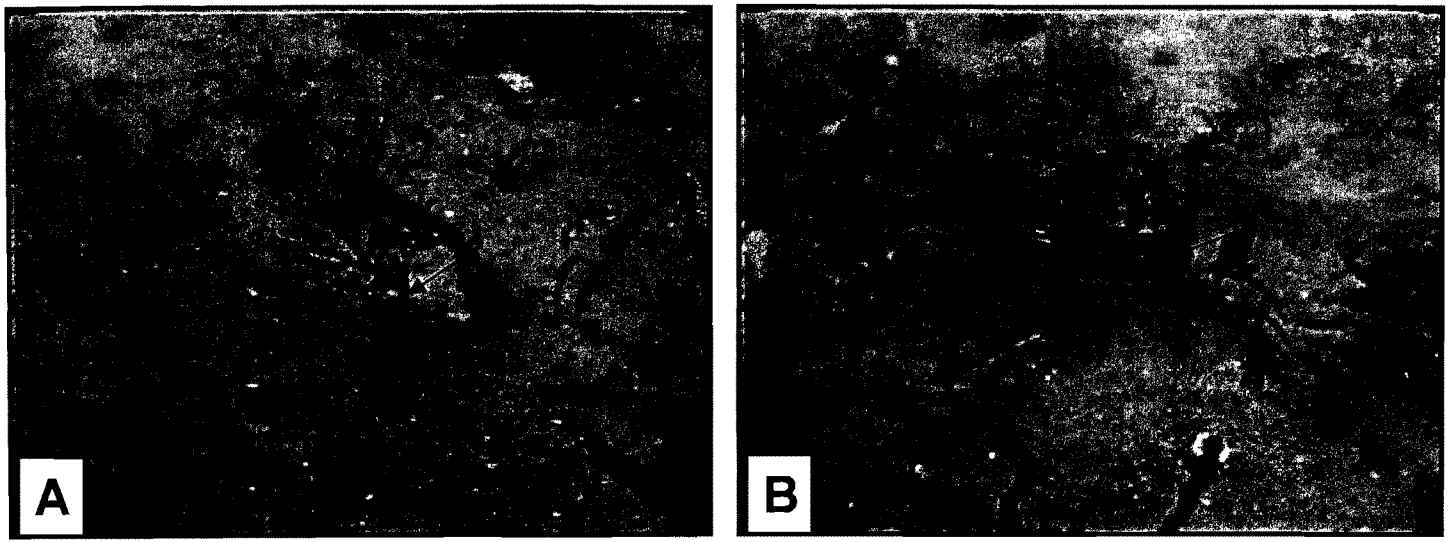


Figure 46. Thin sediment cover overlying limestone hardbottom at Site SC 83 offshore Surf City. **A**. Epifauna and macro algae meadows on limestone scarp back mantled with thin rippled sand veneer. **B**. Macro algae partially buried by a mobile silty fine-medium sand veneer.

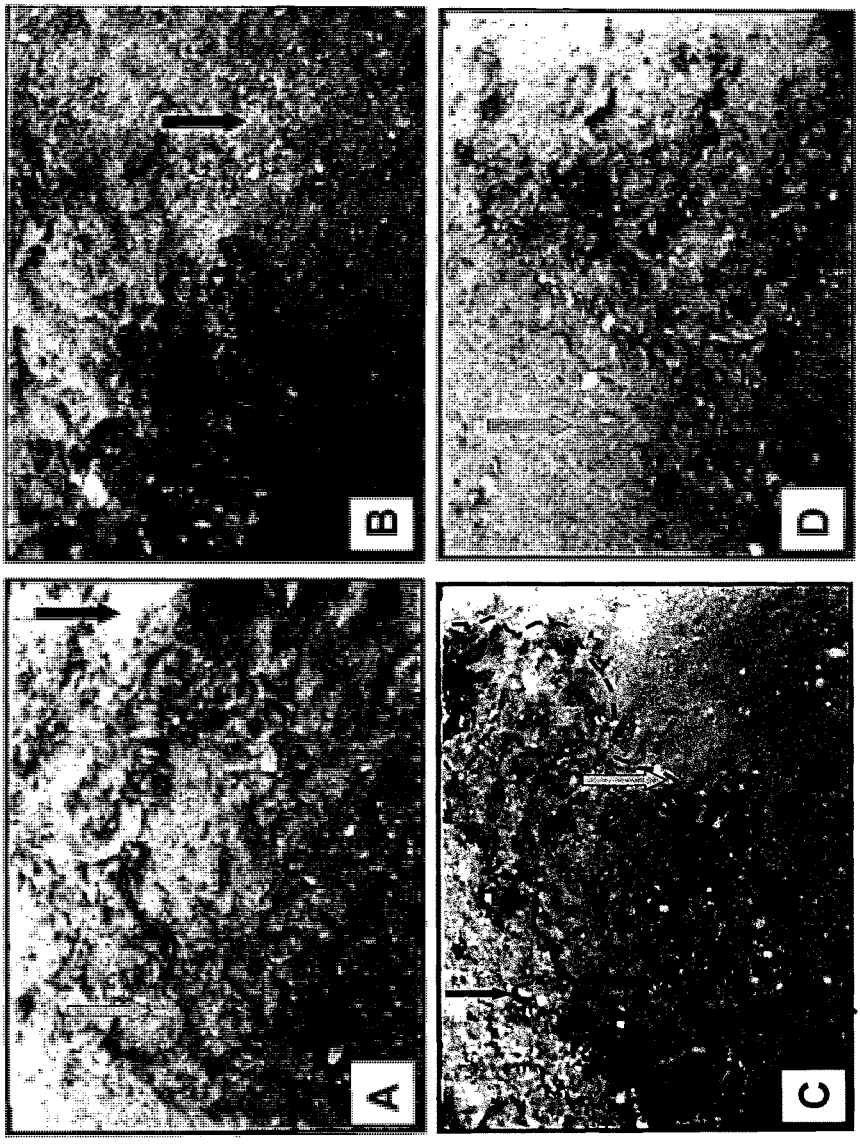


Figure 47. Hardbottom area offshore Surf City (Site 78). **A**. Thin layer of very fine sand (black arrow) overlying corroded limestone surface (white arrow). **B**. Gravel rich sand mixture overlying limestone. **C**. Bored (arrow) low relief limestone exposure and contact of surficial sand unit. **D**. Step-like limestone exposure covered with thin veneer of very fine sand.

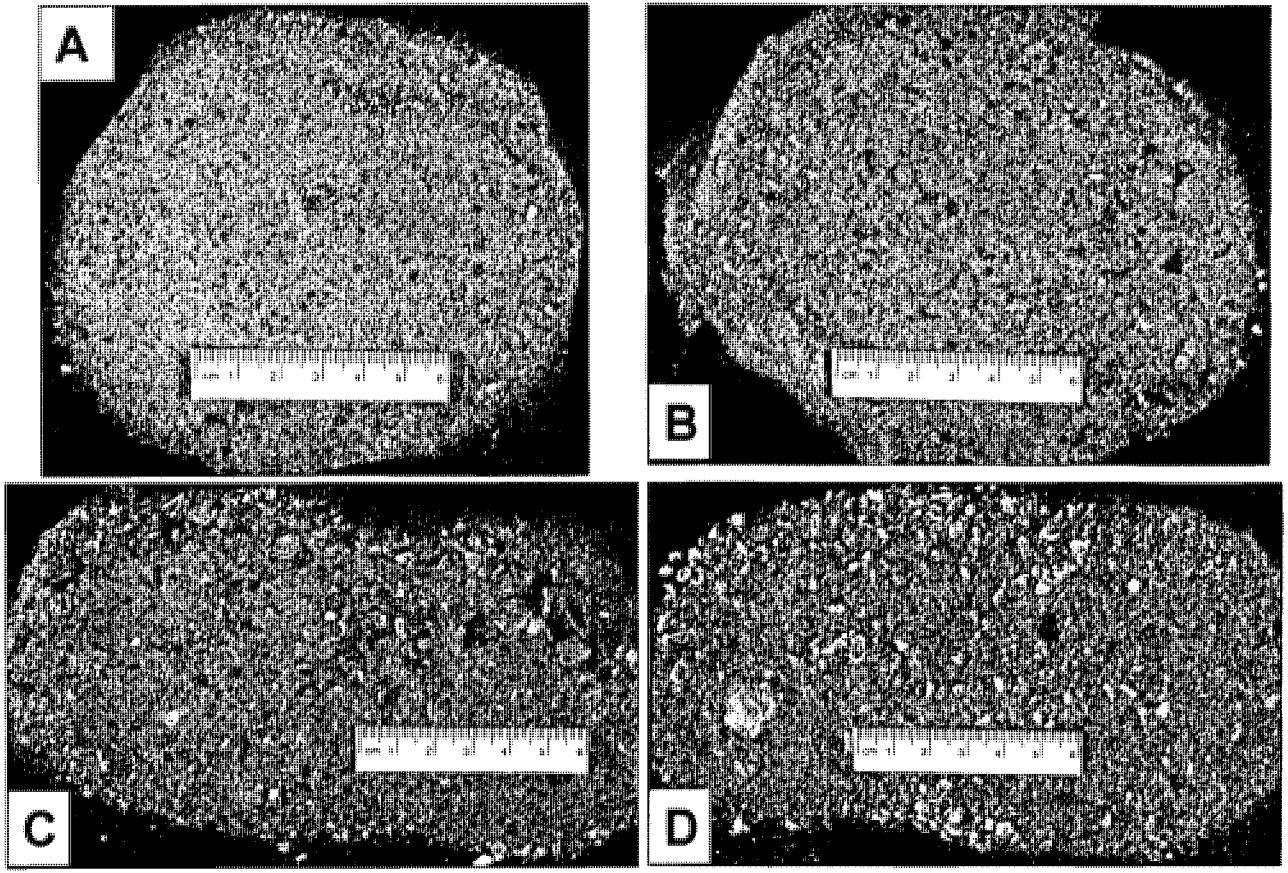


Figure 48. Shelly, fine to medium quartz sands from the shoreface in the southern part of the study area. The carbonate content is usually less than 15 % but can be higher near hardbottoms **A**. (SC3). **B**. (SC 104). **C**. (SC 40). **D**. (SC 80).

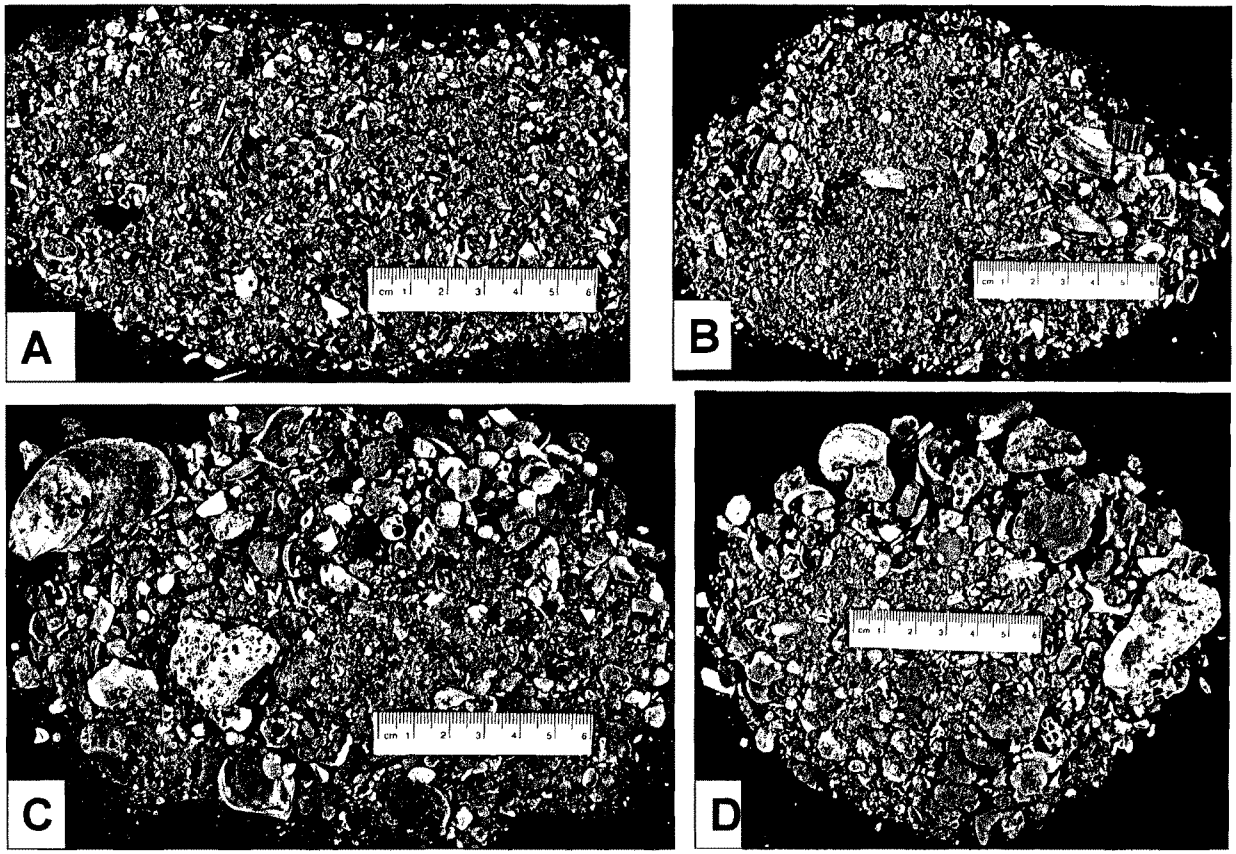


Figure 49. Sandy gravel and gravelly sand from the southern segment of the shoreface. **A**. (SC 82) and **B**. (SC113) are typical of the patches of rippled coarse sand and gravelly sand found near hardbottoms **C**. (TP 4) and **D**. (SC 22) are typical coarse sand and fine gravel. **C.** and **D.** contain 10-15 % coarse silt.

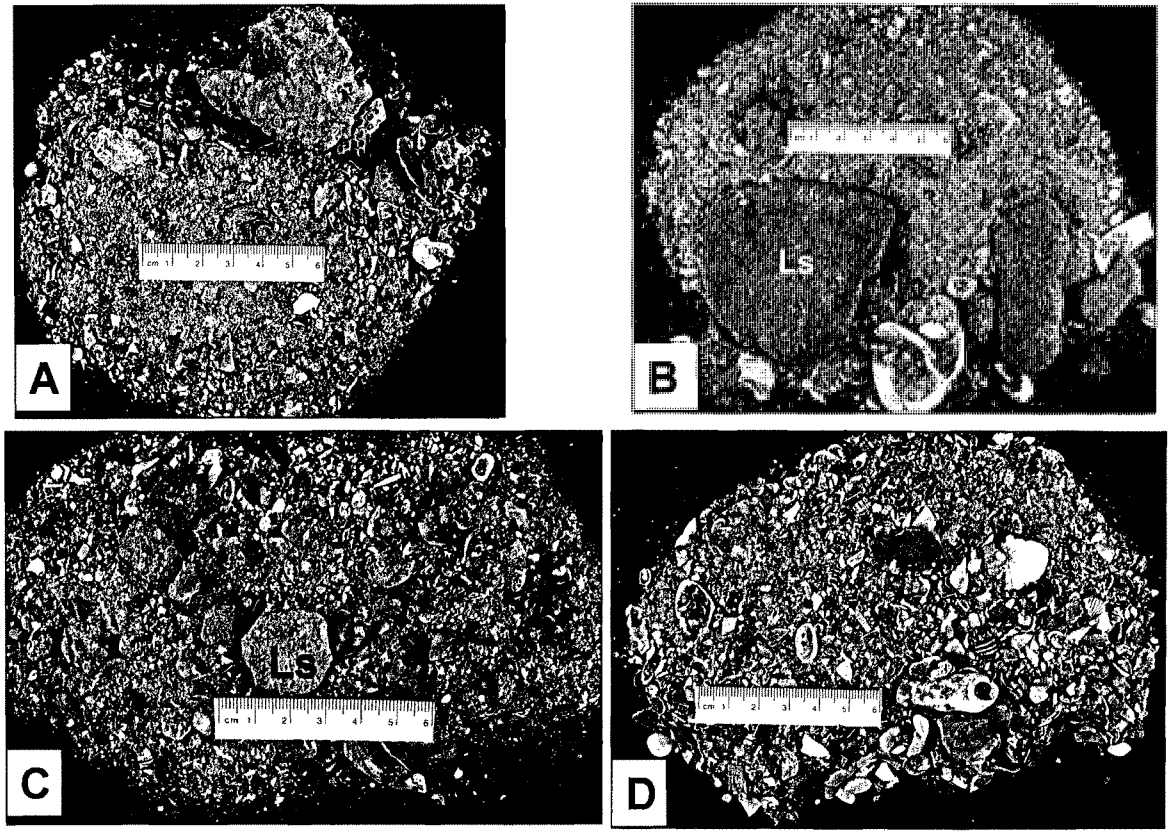


Figure 50. Gravel rich sand from the southern segment of the shoreface. **A. – D.** The composition of the gravel fraction varies from site to site depending upon the nature of the underlying substrate. Arenaceous and moldic limestone lithic fragments constitute a range of sizes. The black and gray shell material reflects reworked backbarrier channel deposits. **A**. SD 4 (49). **B**. SC 84. **C**. SC-VC 28. **D**. TP 10.

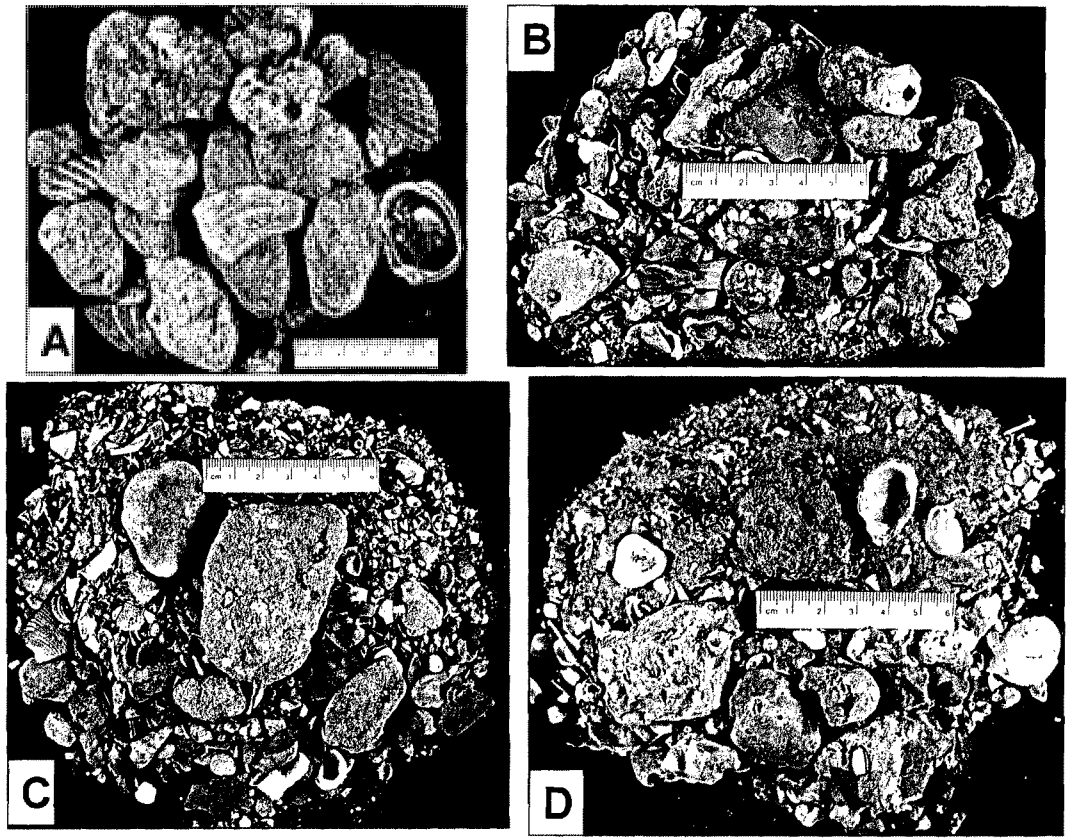


Figure 51. Gravel and sand/gravel mixtures from the shoreface surface sediment veneer in the southern part of the study area. **A**. Cobble size rounded fragments of Tertiary limestone and blackened shells. Shell material is derived from reworked backbarrier units (SC 40). **B**. Mixture of sandy shell and lithic gravel (SC 24). **C**. Poorly sorted sandy gravel. Note abundant black and gray shell fragments. Most large fragments are rounded (SC 105). **D**. Sand-rich lithic gravel (SC 100).

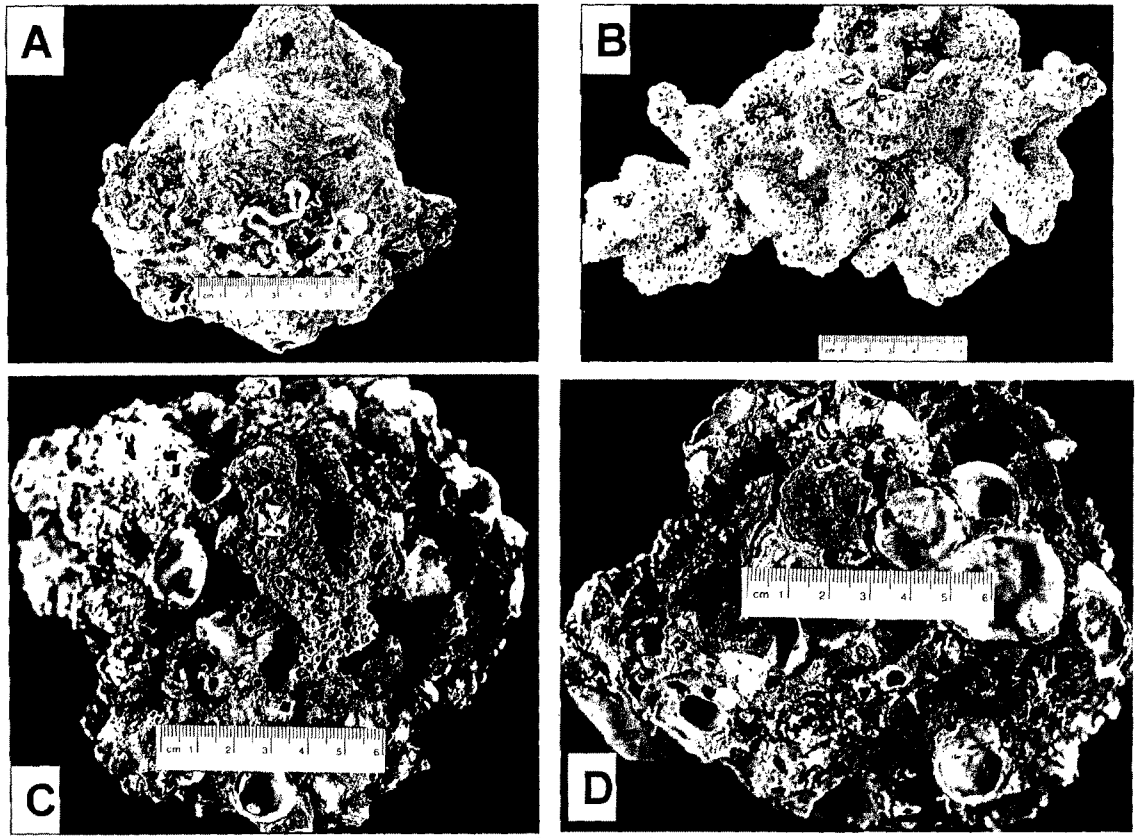


Figure 52. Hardbottom fauna and flora. **A**. (SC105) A variety of mollusks and worm tubes are commonly found encrusting large cobbles and surfaces. **B**. (SC 9 [29]) A variety of species of corals are typically found on the higher relief hardbottoms and on some cobbles in areas were sedimentation rates are low. **C**. (SDA 12) Cobble encrusted with molluscs, worm tubes, algae, and coral. **D**. (SDA 12) Bottom surface of cobble pictured in **C**. Note articulated mollusks and barnacles. Limestone fragment is extensively bored.

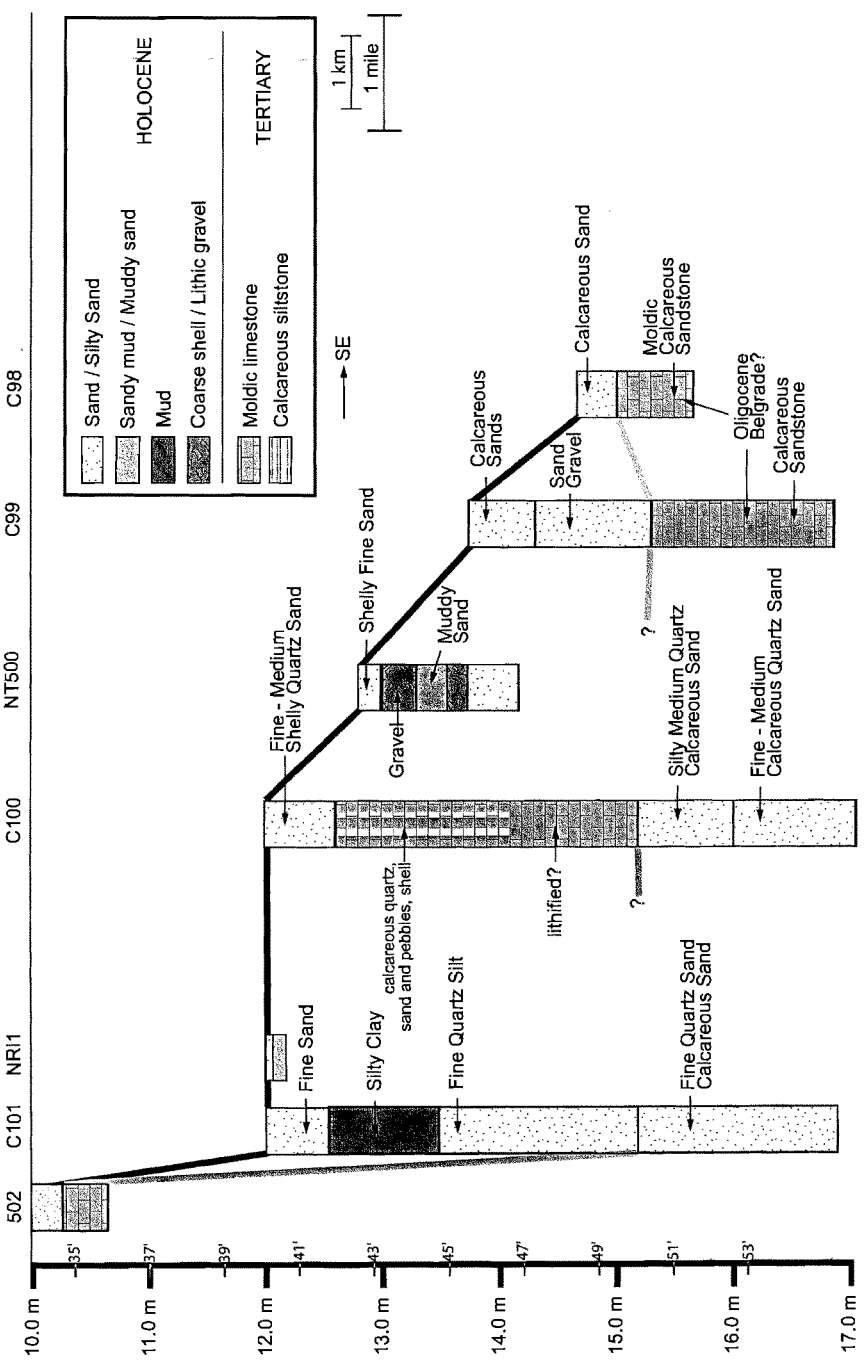


Figure 53. Shore-normal vibracore cross-section A-A'.

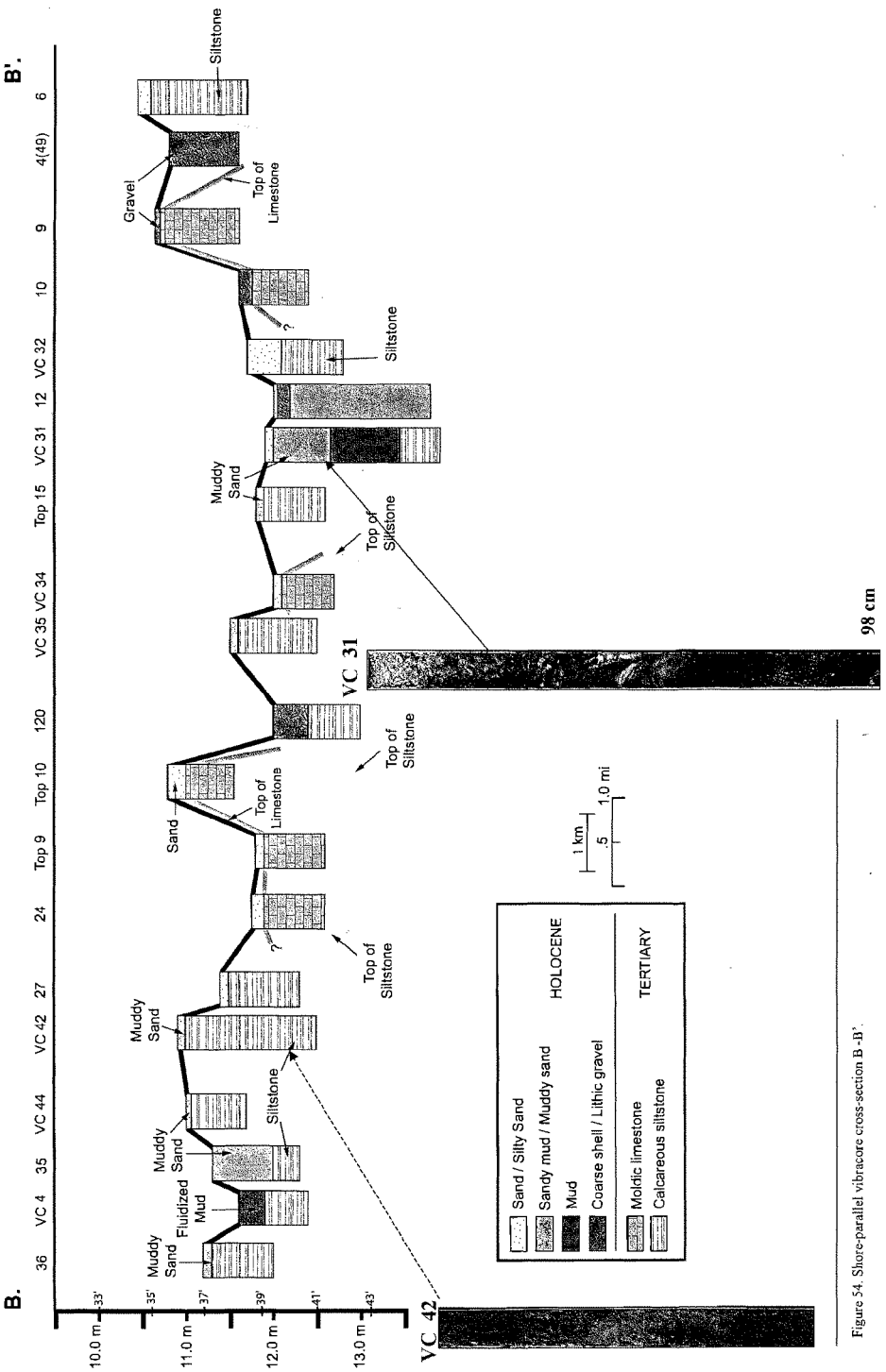


Figure 54. Shore-parallel vibracore cross-section B-B'.

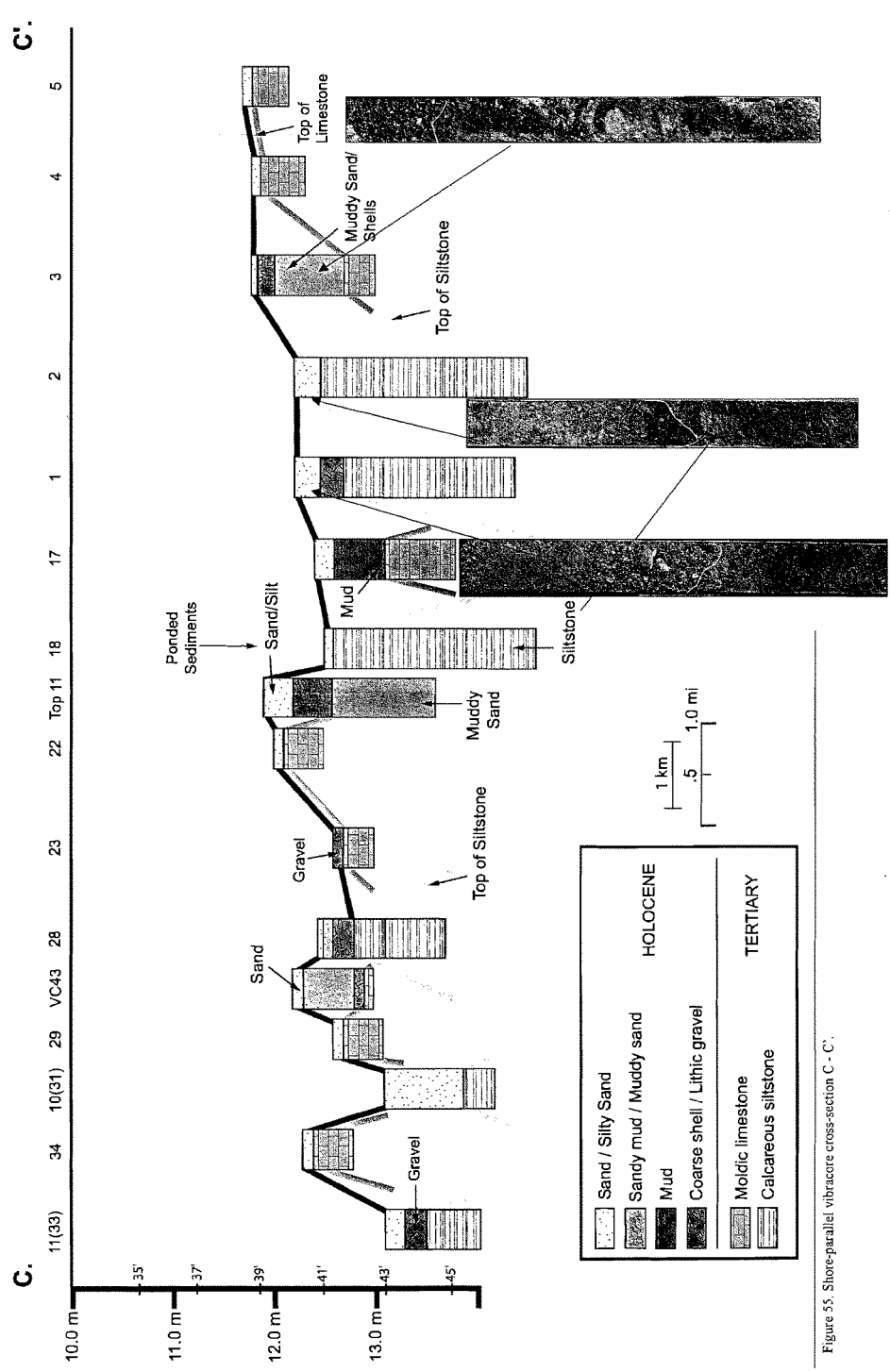


Figure 55. Shore-parallel vibracore cross-section C - C'.

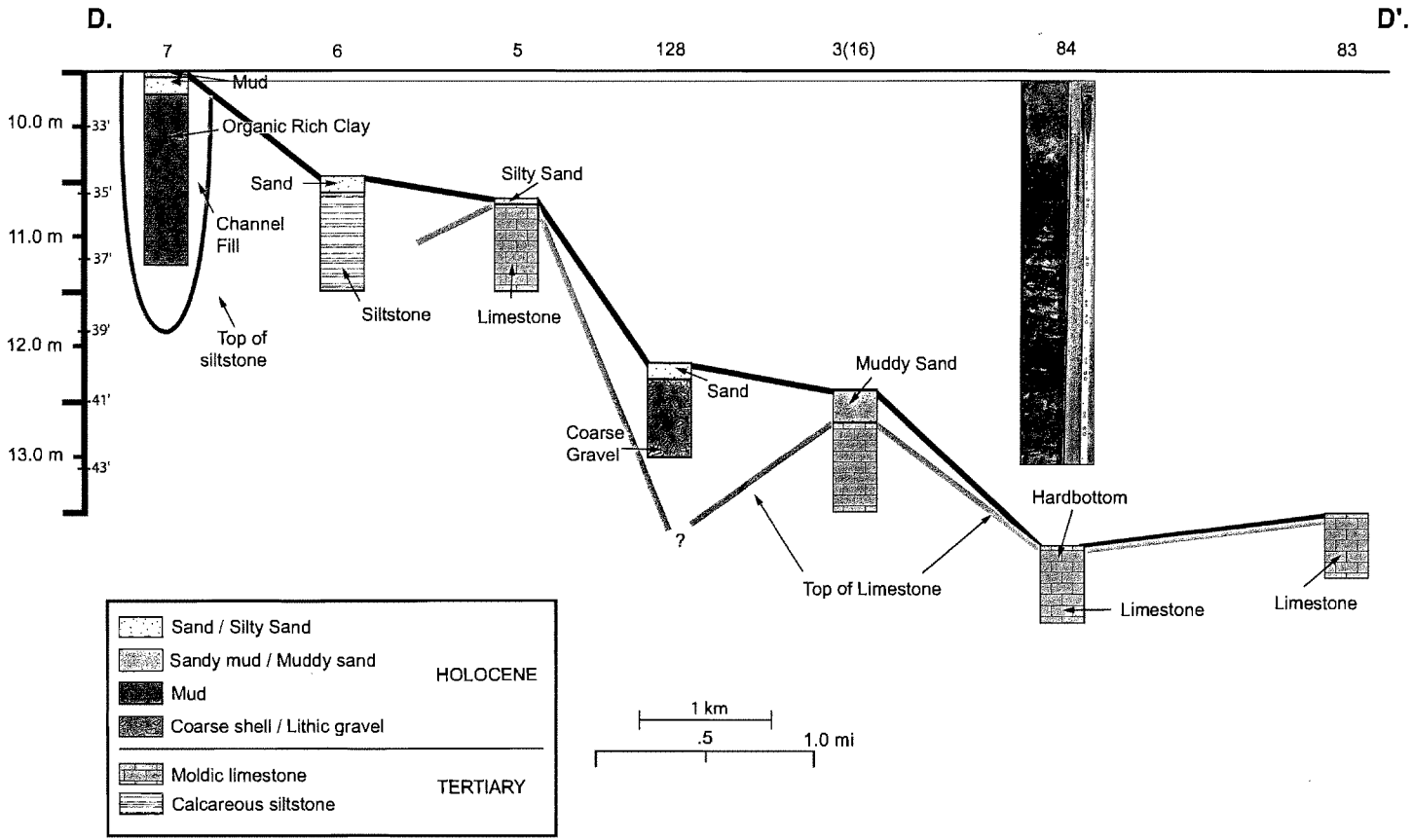


Figure 56. Shore-normal vibracore cross-section D - D'.

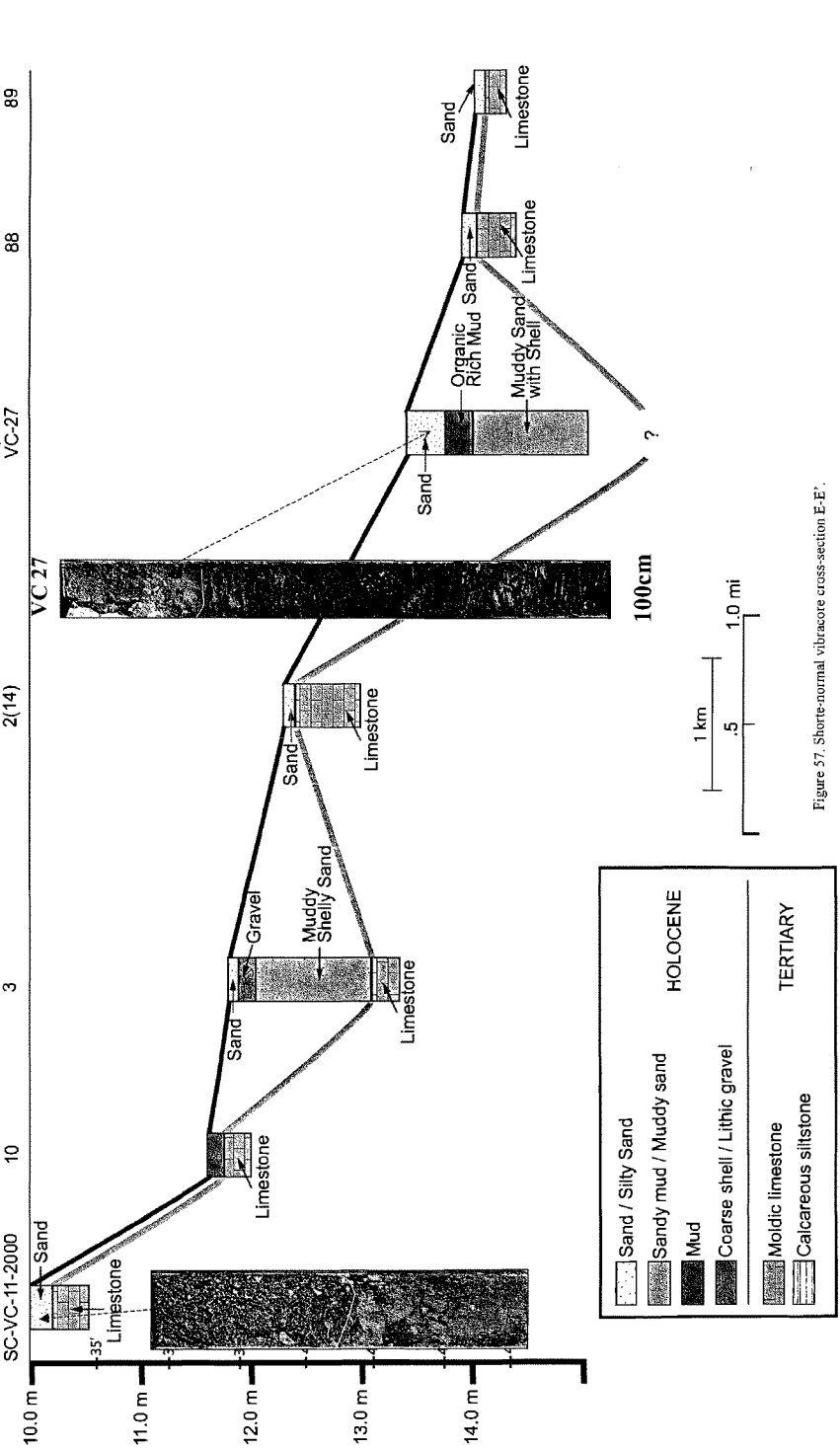


Figure 57. Shorte-normal vibracore cross-section E-E'.

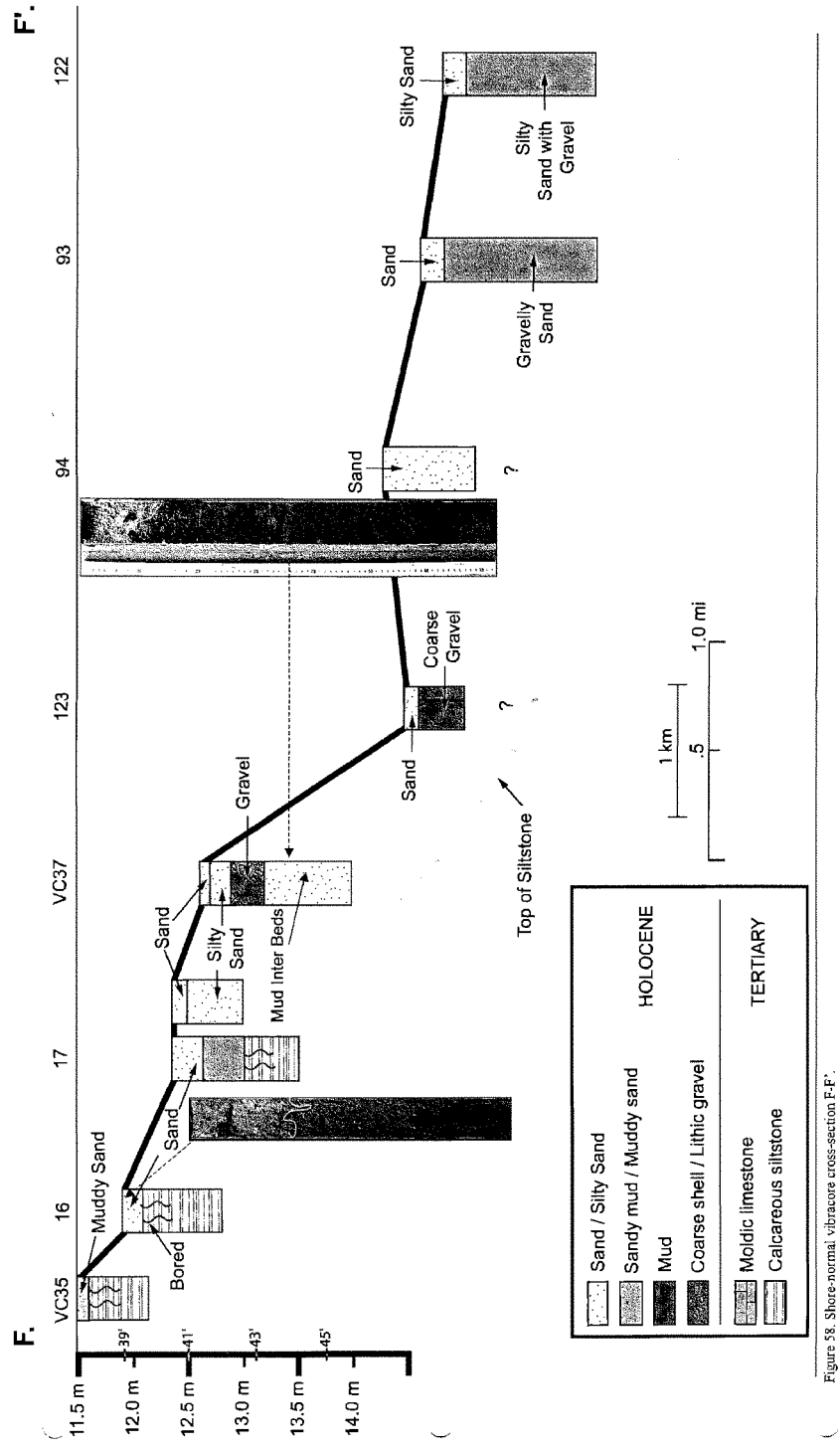


Figure 58. Shore-normal vibracore cross-section F-F'.

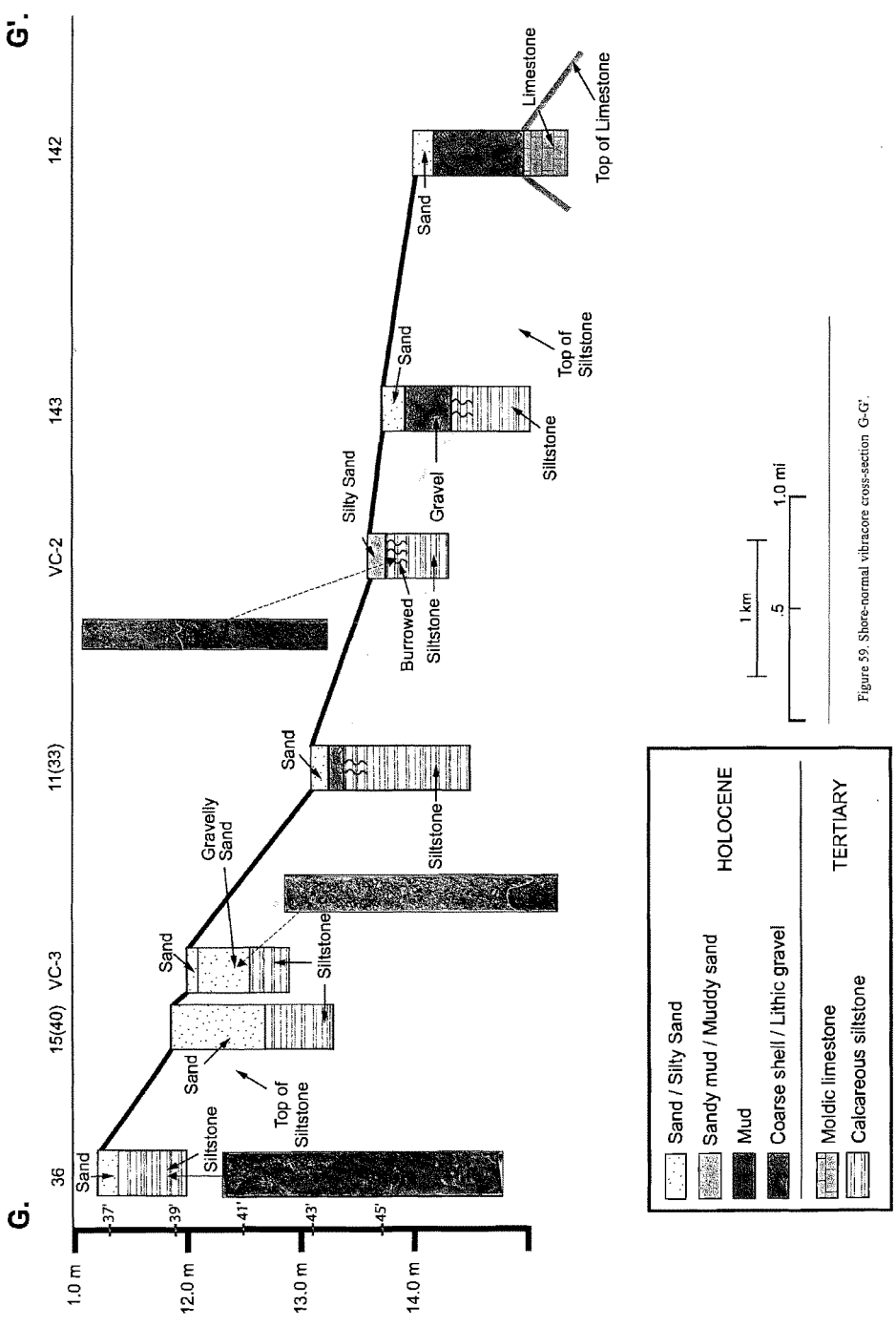


Figure 59. Shore-normal vibracore cross-section G-G'.



Figure 60. Map of shoreface depicting sediment thickness at various sample sites with side scan sonar mosaic, and hardbottom scarps.

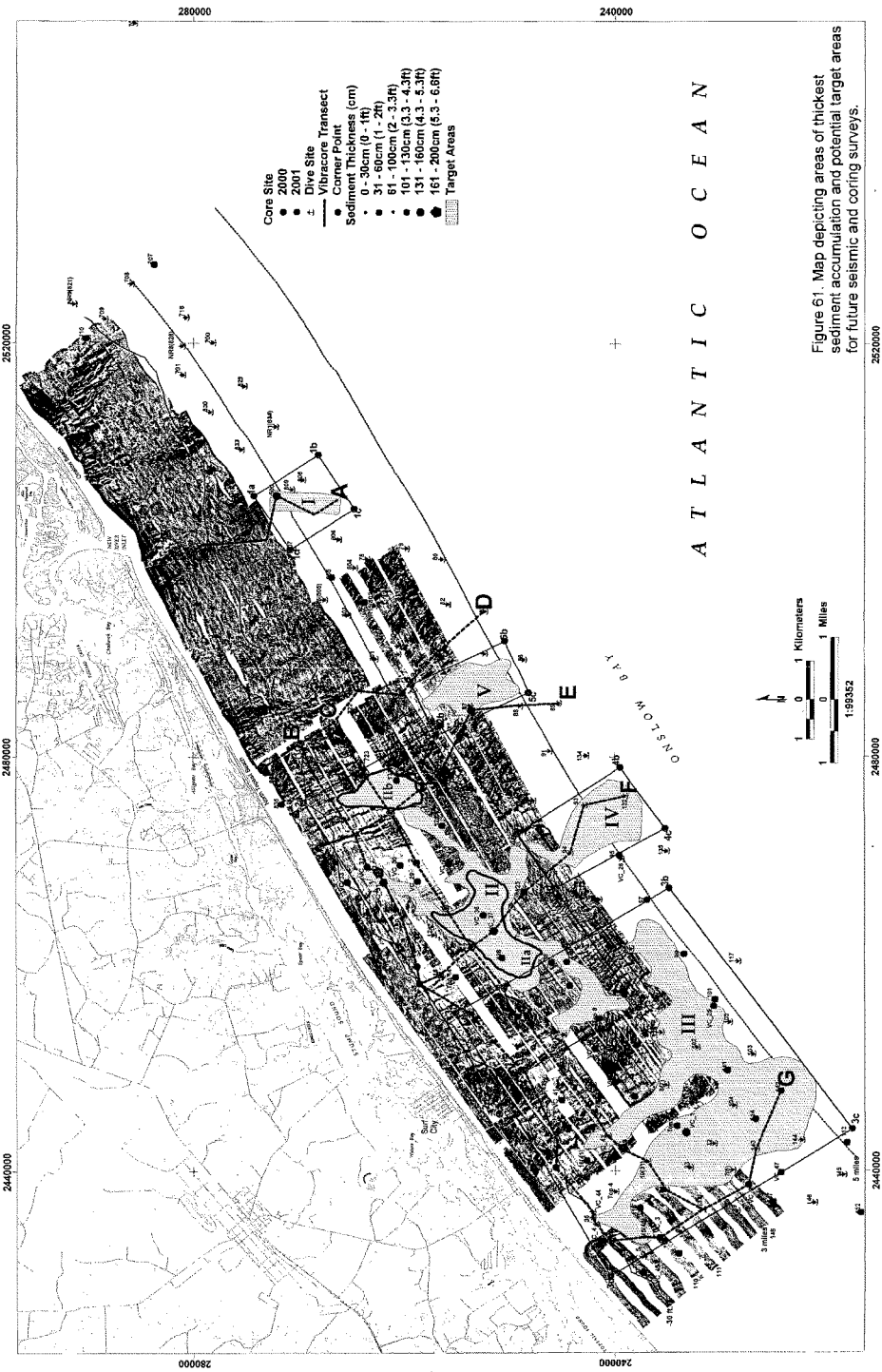


Figure 61. Map depicting areas of thickest sediment accumulation and potential target areas for future seismic and coring surveys.

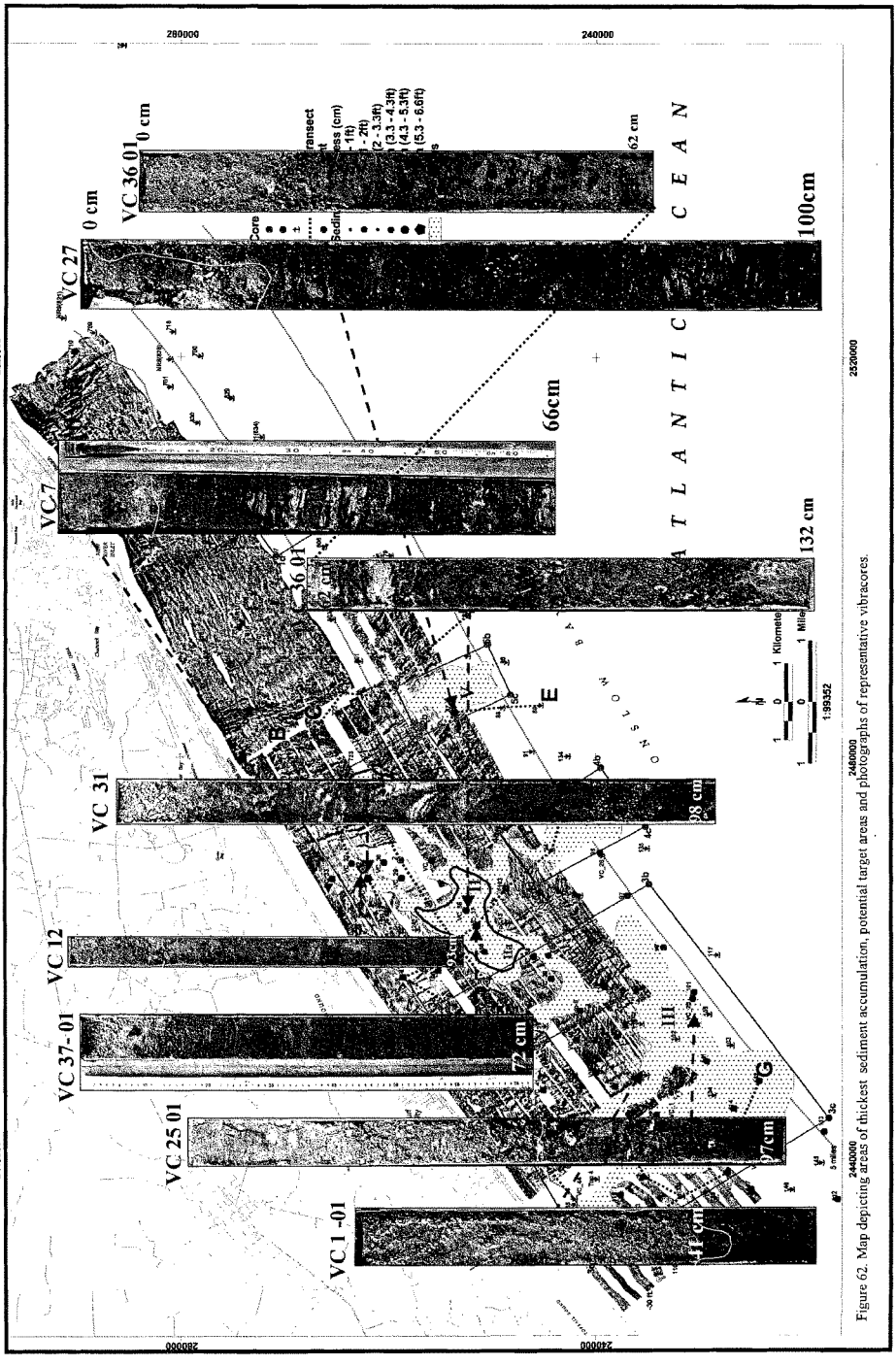


Figure 62. Map depicting areas of thickest sediment accumulation, potential target areas and photographs of representative vibracores.

Core	Date Retrieved	Latitude	Longitude	Length (meters)
1	8/23/2000	34.444	-77.456	1.9
2	8/23/2000	34.451	-77.441	1.7
3	8/23/2000	34.457	-77.425	1.6
6	8/23/2000	34.481	-77.403	0.93
7	8/23/2000	34.491	-77.411	1.67
8	8/23/2000	34.482	-77.425	1.64
11	8/23/2000	34.477	-77.436	0.35
12	8/23/2000	34.461	-77.444	1.66
16	10/11/2000	34.446	-77.477	1.2
17	10/11/2000	34.437	-77.468	1.17
18	10/11/2000	34.429	-77.481	1.63
20	10/11/2000	34.446	-77.494	0.5
25	10/11/2000	34.431	-77.521	0.24
28	10/11/2000	34.406	-77.521	0.76
30	10/11/2000	34.408	-77.542	0.27
VC-1	5/23/2001	34.382	-77.528	1.43
VC-2	5/23/2001	34.366	-77.545	0.49
VC-25	6/20/2001	34.374	-77.488	0.98
VC-27	6/20/2001	34.436	-77.393	1.47
VC-29	6/20/2001	34.451	-77.447	1.3
VC-3	5/23/2001	34.389	-77.561	0.62
VC-30	6/20/2001	34.455	-77.442	1.63
VC-31	6/20/2001	34.460	-77.447	1.59
VC-32	6/20/2001	34.464	-77.442	2.03
VC-33	6/20/2001	34.469	-77.447	1.52
VC34	6/20/2001	34.451	-77.474	2.02
VC-35	6/20/2001	34.451	-77.480	0.92
VC-36	6/20/2001	34.434	-77.458	1.32
VC-37	6/20/2001	34.431	-77.463	1.38
VC-38	6/21/2001	34.416	-77.474	1.34
VC-42	6/21/2001	34.416	-77.539	1.32
500	9/9/1994	34.486	-77.324	1.6
502	9/9/1994	34.508	-77.341	0.85
512	9/12/1994	34.483	-77.392	0.75

Table 1. Vibracores used in conduct of study.

Sample	Latitude	Longitude	Date Retrieved	Sample	Latitude	Longitude	Date Retrieved
4	34.465	-77.411	8/23/2000	125	34.444	-77.429	8/6/2002
5	34.472	-77.396	8/23/2000	126	34.464	-77.358	9/18/2002
9	34.473	-77.421	8/23/2000	127	34.455	-77.375	9/18/2002
10	34.467	-77.432	8/23/2000	128	34.465	-77.386	9/18/2002
22	34.422	-77.494	10/11/2000	129	34.460	-77.399	9/18/2002
23	34.414	-77.507	10/11/2000	130	34.446	-77.397	9/18/2002
24	34.420	-77.518	10/11/2000	131	34.456	-77.415	9/18/2002
29	34.398	-77.533	10/11/2000	132	34.436	-77.418	9/18/2002
33	34.381	-77.539	5/14/2001	133	34.423	-77.432	9/18/2002
35	34.407	-77.555	5/14/2001	134	34.406	-77.408	9/18/2002
36	34.402	-77.562	5/14/2001	135	34.386	-77.439	9/18/2002
37	34.394	-77.573	5/14/2001	137	34.414	-77.453	9/18/2002
38	34.384	-77.567	5/14/2001	138	34.429	-77.472	10/2/2002
39	34.369	-77.553	5/14/2001	139	34.388	-77.496	9/18/2002
78	34.463	-77.344	6/12/2001	140	34.378	-77.514	9/18/2002
79	34.452	-77.341	6/12/2001	141	34.371	-77.509	10/3/2002
80	34.443	-77.345	6/12/2001	142	34.357	-77.515	10/3/2002
81	34.454	-77.357	6/12/2001	143	34.364	-77.534	10/3/2002
82	34.442	-77.359	6/12/2001	144	34.352	-77.531	10/3/2002
83	34.432	-77.361	6/12/2001	145	34.341	-77.542	10/3/2002
84	34.445	-77.375	6/12/2001	146	34.349	-77.551	10/3/2002
85	34.433	-77.375	6/12/2001	147	34.360	-77.551	10/3/2002
86	34.422	-77.377	6/12/2001	148	34.360	-77.564	10/3/2002
87	34.437	-77.392	6/12/2001	1(12)	34.431	-77.439	7/19/2000
88	34.424	-77.392	6/12/2001	10(31)	34.392	-77.537	7/19/2000
89	34.413	-77.391	8/22/2001	11(33)	34.378	-77.553	7/19/2000
90	34.428	-77.407	8/22/2001	15(40)	34.393	-77.561	7/19/2000
91	34.416	-77.406	8/22/2001	16(41)	34.408	-77.537	7/19/2000
92	34.420	-77.422	8/22/2001	17(42)	34.420	-77.518	7/19/2000
93	34.407	-77.424	6/12/2001	2(14)	34.444	-77.412	7/19/2000
94	34.411	-77.439	8/22/2001	3(16)	34.454	-77.388	7/19/2000
95	34.398	-77.440	6/12/2001	4(49)	34.478	-77.412	7/19/2000
96	34.404	-77.454	8/22/2001	7(5)	34.370	-77.540	7/19/2000
97	34.391	-77.454	6/12/2001	8(7)	34.387	-77.513	7/19/2000
98	34.396	-77.470	8/22/2001	9(29)	34.406	-77.513	7/19/2000
99	34.382	-77.471	6/12/2001	SDA	34.396	-77.502	7/19/2000
100	34.388	-77.485	8/22/2001	Top 10	34.432	-77.498	7/27/1998
101	34.374	-77.486	6/12/2001	Top 11	34.425	-77.491	7/27/1998
102	34.379	-77.501	8/22/2001	Top 12	34.412	-77.473	7/27/1998
103	34.364	-77.504	6/12/2001	Top 13	34.423	-77.463	7/27/1998
104	34.369	-77.520	8/22/2001	Top 14	34.442	-77.478	7/27/1998
105	34.370	-77.494	8/22/2001	Top 15	34.455	-77.459	7/27/1998
107	34.427	-77.489	8/22/2001	Top 4	34.401	-77.547	7/27/1998
110	34.379	-77.577	8/6/2002	Top 5	34.384	-77.526	7/27/1998
111	34.372	-77.574	8/6/2002	Top 6	34.413	-77.526	7/27/1998
112	34.337	-77.554	8/6/2002	Top 7	34.401	-77.502	7/27/1998
113	34.340	-77.532	8/6/2002	Top 8	34.404	-77.492	7/27/1998
114	34.364	-77.524	8/6/2002	Top 9	34.424	-77.508	7/27/1998
115	34.394	-77.552	8/6/2002	VC_26	34.398	-77.441	5/20/2001
116	34.395	-77.516	8/6/2002	VC_28	34.443	-77.442	5/20/2001
117	34.368	-77.474	8/6/2002	VC_39	34.412	-77.481	6/21/2001
118	34.398	-77.484	8/6/2002	VC_4	34.406	-77.557	5/23/2001
119	34.414	-77.497	8/6/2002	VC_40	34.405	-77.501	6/21/2001
120	34.438	-77.490	8/6/2002	VC_41	34.414	-77.517	6/21/2001
121	34.406	-77.465	8/6/2002	VC_43	34.402	-77.529	6/21/2001
122	34.397	-77.421	8/6/2002	VC_44	34.407	-77.553	6/21/2001
123	34.423	-77.451	8/6/2002	VC_45	34.390	-77.569	6/21/2001
124	34.447	-77.464	8/6/2002	VC_47	34.357	-77.541	6/21/2001

Table 2. Surface samples used in conduct of study.

Sample	Latitude	Longitude	Date Retrieved	Sample	Latitude	Longitude	Date Retrieved
VC_5	34.394	-77.567	5/23/2001	805	34.472	-77.350	6/4/1996
501	34.501	-77.336	9/9/1994	806	34.470	-77.338	6/4/1996
503	34.507	-77.358	9/9/1994	807	34.482	-77.341	6/5/1996
506	34.501	-77.374	9/9/1994	808	34.479	-77.319	6/5/1996
507	34.503	-77.359	9/9/1994	809	34.482	-77.322	6/5/1996
508	34.490	-77.358	9/9/1994	811	34.469	-77.380	6/5/1996
509	34.474	-77.386	9/9/1994	812	34.476	-77.385	6/5/1996
510	34.469	-77.403	9/12/1994	813	34.485	-77.390	6/5/1996
511	34.473	-77.401	9/12/1994	815	34.492	-77.363	6/5/1996
513	34.471	-77.388	9/12/1994	816	34.502	-77.368	6/5/1996
514	34.472	-77.372	9/12/1994	826	34.535	-77.302	6/6/1996
515	34.476	-77.371	9/12/1994	827	34.522	-77.287	6/6/1996
517	34.486	-77.387	9/12/1994	829	34.494	-77.289	6/7/1996
600	34.474	-77.365	NA	830	34.503	-77.297	6/7/1996
601	34.495	-77.376	NA	831	34.510	-77.305	6/7/1996
602	34.468	-77.380	NA	832	34.504	-77.316	6/7/1996
603	34.459	-77.399	NA	833	34.495	-77.309	6/7/1996
604	34.473	-77.393	NA	835	34.486	-77.422	6/7/1996
700	34.502	-77.275	8/31/1995	836	34.490	-77.412	6/7/1996
701	34.510	-77.285	8/31/1995	NR1(834)	34.486	-77.302	6/24/1996
702	34.517	-77.293	8/31/1995	NR2(504)	34.489	-77.353	6/24/1996
703	34.521	-77.173	8/31/1995	NR3(516)	34.488	-77.358	6/24/1996
704	34.525	-77.302	8/31/1995	NR4(810)	34.486	-77.371	6/24/1996
705	34.527	-77.305	8/31/1995	NR5(814)	34.483	-77.356	6/24/1996
707	34.517	-77.250	8/31/1995	NR6(505)	34.474	-77.357	6/24/1996
708	34.523	-77.256	8/31/1995	NR7	NA	NA	6/24/1996
709	34.530	-77.267	8/31/1995	NR8(828)	34.510	-77.276	6/25/1996
710	34.535	-77.273	8/31/1995	NR9(821)	34.538	-77.262	6/25/1996
718	34.509	-77.267	9/1/1995	NR10(706)	34.529	-77.307	6/25/1996
719	34.486	-77.324	9/1/1995	NR11(720)	34.492	-77.362	6/25/1996
721	34.493	-77.364	9/1/1995	NR12(810)	34.486	-77.371	6/25/1996
722	34.467	-77.393	9/1/1995	NR13	NA	NA	6/25/1996
723	34.465	-77.409	9/1/1995	NR14(834)	34.486	-77.302	8/6/1996
800	34.455	-77.372	6/4/1996	NR15(802)	34.461	-77.359	8/6/1996
801	34.461	-77.376	6/4/1996	NR16	NA	NA	8/6/1996
803	34.468	-77.362	6/4/1996	VID 1	34.400	-77.511	9/18/2002
804	34.466	-77.347	6/4/1996				

Table 2 (continued). Surface sampes used in conduct of study.

Corner Point	X	Y
1a	2505011.58000	274287.78312
1b	2509003.90742	268163.18993
1c	2503809.34504	264760.63815
1d	2499907.75234	270862.54767
2a	2475680.29831	269531.46941
2b	2483061.71851	256544.60980
2c	2456033.51069	237785.81259
2d	2448097.09648	251882.66020
3a	2455508.96953	255130.28245
3b	2467501.26325	234862.60475
3c	2444428.37065	217540.40270
3d	2430332.16574	240473.03456
4a	2472721.79341	249289.29331
4b	2478996.28451	239540.94232
4c	2473206.51804	235232.27890
4d	2467497.53901	245653.85855
5a	2486913.45354	259333.86490
5b	2491249.04611	250474.17575
5c	2486186.36659	248265.98574
5d	2482039.27805	257044.88746

Table 3. Coordinates for recommended seismic surveys of Borrow Areas I - IV.

Feasibility Report
and
Final Environmental Impact Statement

on

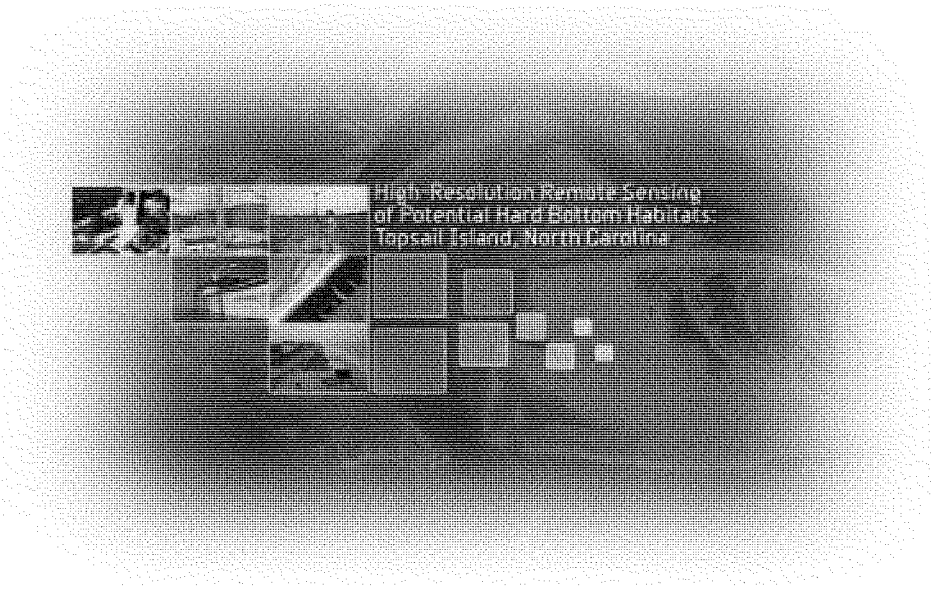
Coastal Storm Damage Reduction

SURF CITY AND NORTH TOPSAIL BEACH
NORTH CAROLINA

Appendix R
Attachment 2

High-Resolution Remote Sensing of Potential Hard Bottom Habitats: Topsail Island, NC

High-Resolution Remote Sensing of Potential Hard Bottom Habitats: Topsail Island, NC July 2006



Survey Report

Project No. DACW54-02-D-0006, Delivery Order 0035, Nearshore Hardbottom Sidescan Survey, Topsail Island, NC
G&O Project Number 146046.T35.6480.GEO

Submitted by:

GREENHORNE & O'MARA
CONSULTING ENGINEERS

With Subconsultant:

geodynamics
COMPLEX COASTAL CHANGE MADE CLEAR

TABLE OF CONTENTS

TABLE OF CONTENTS ii

Executive Summary 1

Survey Preparation 1

Survey Area 1

RTK-GPS Survey Control & Multibeam Calibration 2

RTK-GPS Network Adjustment & Site Calibration 3

Multibeam Echosounder Calibration Report 8

Data Processing Routines & QA/QC Information 14

Introduction 14

Bathymetry Processing 14

Side-Scan Processing 15

Typical Side-Scan Artifacts 16

Potential Hardbottom Identification 20

Topsail Island Remote Sensing Workflow Diagram 22

Topsail Island Remote Sensing QA/QC Workflow Diagram 22

Graphical Summary of Deliverables 23

Appendix A – Official USACE Scope of Work 30

Appendix B - Benchmark Descriptions 34

Appendix C– Field Notes, Daily GPS Quality & Copy of Field Book 41

Appendix D - *R/V 4-Points* Setup & Instrument Accuracies 47

Appendix E – QTC Report 53

Executive Summary

Geodynamics LLC was contracted on June 30th by the USACE Wilmington District through Greenhorne & O'Mara Inc. to perform a detailed side-scan sonar survey between New Topsail Inlet, NC and the Surf City, NC boarder. This high-resolution survey is phase one of a two phase effort to located and quantify potential hard bottom habitats by the US Army Corps of Engineers Wilmington District for future renourishment efforts in the region. To better assess hard bottom locations, provide increased positioning accuracy for the side-scan mosaic and to increase productivity for phase two, Geodynamics provided multibeam bathymetry acquisition and processing at no cost to the project.

The July 17-18 side-scan and multibeam surveys of the Topsail Island shoreface employed a Klein 3000 digital side-scan sonar and a Simrad EM3002 shallow water multibeam sonar system to collect spatially dense seafloor imagery and bathymetric data for the assessment of nearshore hard bottom habitats as described in the official Scope of Work (Appendix A). The dual frequency side-scan system runs at both 100 and 500 kHz nominal. In order to maximize the resolution of the system we brought the swath widths to 100m-150m (range of 50m-75m) and a pixel resolution of 4096. The multibeam system runs at 300 kHz and is compensated for motion and heading with an Applanix POS MV 320 v4 inertial navigation system. The EM3002 produces a swath of sonar approximately 4 times the water depth and collects approximately 400 soundings per square meter. Sound velocity was calculated using an Odom Digibar Pro sound velocity meter.

Tidal corrections and positioning information were acquired using a site calibrated Trimble 5700 Real-Time Kinematic GPS (RTK-GPS) system integrated with the POS MV 320 through a Pacific Crest PDL radio modem. The RTK-GPS system uses a land-based station coupled with a 25-watt radio and a Maxrad 5 dB high-gain antenna to broadcast the computed real-time horizontal and vertical corrections at 10 Hz to the survey rovers (hydro/topo survey platforms). To compute centimeter-scale position and elevation information, determine the relationship between WGS-84 and local grid coordinates, and to evaluate the local geoid-spheroid separation, we first performed a detailed network adjustment and site calibration. Information on the site calibration can be found in the corresponding section of this final report and published accuracies on each of the systems can be found in Appendix D.

Survey Preparation

Survey Area

Topsail Island, located approximately 20 miles northeast of Wilmington and separates Lee Island to the south and Onslow Beach to the north. The Topsail Island nearshore survey was comprised of 6 planned survey lines spaced 320' (100m) in depths ranging from ~5' MLLW to ~30' MLLW. The distance between survey lines was calculated in separate zones of relatively equal depths using 4

times the water depth for multibeam and 394' swaths (120m) for side-scan as indicated on the NOAA digital nautical chart 11541_4.kap. The total area of the survey encompassed 3.2 square miles

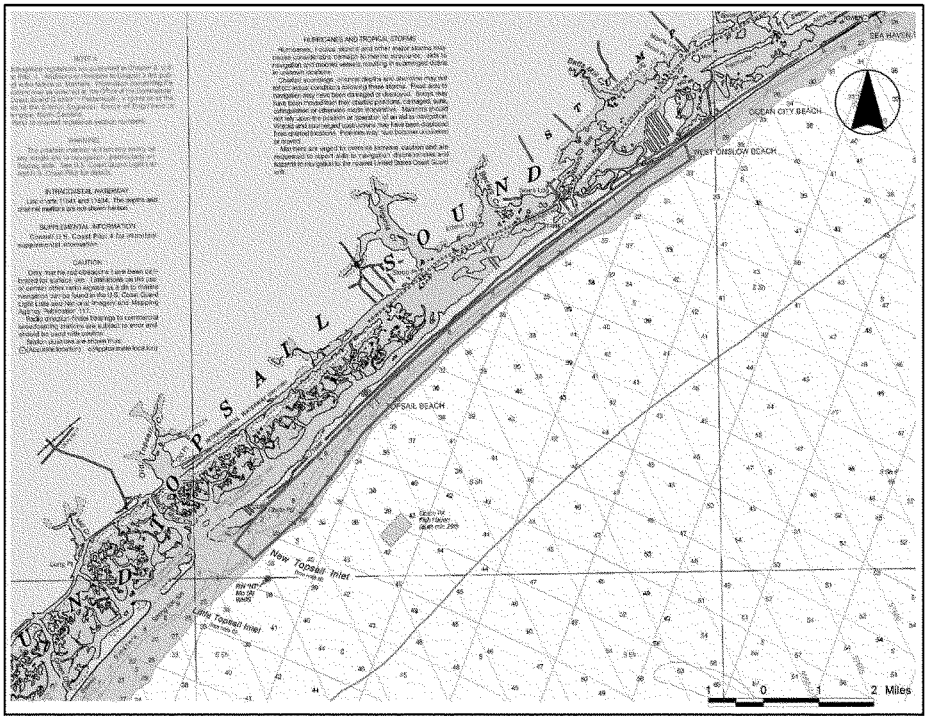


Figure 1. Topsail Island side-scan survey planning map illustrating the proposed survey extents.

RTK-GPS Survey Control & Multibeam Calibration

Introduction & Purpose

The most common problem in accurately measuring the seafloor with any sonar-based system, especially in and around a tidal inlet, is the calculation of the tidal elevation offset. Commonly a tide staff or gauge is deployed in one location near the survey site and is used to calculate the tides for the entire survey area. However, it is widely understood that non-linear tidal phenomena, phase lags and tidal gradients can drastically influence the tidal elevation spatially across a tidal inlet and therefore the use of a single point measurement is often unreliable.

To avoid these potential tidal elevation errors which can translate into significant departures from the true bottom depth, we use geodetic Global Positioning Systems (GPS) with real-time kinematic (RTK) baseline processing that is integrated with the multibeam and inertial navigation instruments. The motion

and Geoid 03 compensated positions and orthometric elevations of the RTK-GPS data stream are tagged with each sonar ping. In effect, the RTK-GPS mounted on the hydrographic survey vessel acts as a roving tide gauge collecting the most accurate tidal measurements throughout the survey area.

Multibeam swath sonar systems combine a complex array of instruments, consisting of the transducer, motion sensor, gyrocompass, and geodetic GPS system. Standards developed by the International Hydrographic Organization (IHO), USACE Standards for Hydrographic Surveys, and the NOS Hydrographic Surveys Specifications and Deliverables for shallow water (<30 m) hydrography (IHO 1987; USACE 2003; NOS 2003) are used as the protocol for calibration. Proper alignment of these instruments with one another and with the vessel's reference frame is critical to achieve the high-accuracy required in the SOW. Calculation of the horizontal and vertical offsets between each of the instruments is followed by a series of sea-based measurements known as the patch test.

The patch test is performed to calculate several residual biases influenced by the dynamics of the survey vessel and the alignment of the instruments. Results of the patch test, documented in the following sections, are used to calculate a pitch, roll and heading offset and positioning time delay or navigation latency. Additional calibration measures are performed in the field including comparison of nadir depths with a lead line and frequent sound velocity profiles. The results of these daily field checks can be found in the html metadata file accompanying the final soundings.

To keep bathymetric accuracy the highest for phase one of this project we have kept the soundings in NAVD 88 until we can assess the best way to make this translation. Prior to phase 2 of multibeam acquisition we will need to model the difference in orthometric height between the North American Vertical Datum of 1988 (NAVD 88) and the National Geodetic Vertical Datum of 1929 (NGVD 29) for each benchmark used in the site calibration. This can be completed with VERTCON 2.0 a datum transformation model considered accurate at the 2 cm (one sigma) level. According to studies by Milbert (1999), higher accuracy is particularly noticeable in the eastern United States but there will be some level of inaccuracy that we will attempt to quantify.

RTK-GPS Network Adjustment & Site Calibration

There are many environmental and operator-based influences that can affect the accuracy of RTK-GPS and the resultant baseline solutions (Bilker 2001; Trimble Navigation Limited 1998; Magellan Corporation 2001). Although RTK-GPS is an emerging tool among hydrographers, little attention has been given to an accuracy standard for this methodology—especially in the field of coastal mapping and monitoring (Morton et al., 1993). In an effort to limit operator error and to quantify daily environmental error, we have developed an internal standards protocol for RTK error estimation based on thresholds developed by the California Department of Transportation and the US Army Corps of Engineers (USACE) Topographic Accuracy Standards (CALTRANS 2002; USACE 1994).

The first step in our protocol is to determine an appropriate land-based GPS station that will provide the most accurate corrections and range to the outer limits of the survey area. We chose to use a location that that provided both exceptional range and benchmark quality that was situated on a circa 1940's rocket observation platform called "Tower 3".

The second step in our RTK-GPS protocol is to perform a detailed GPS site calibration prior to the collection of any hydrographic survey data. The site calibration is used to determine the basestation quality relative to the local network of NGS and NOS survey control and to analyze any potential spatial separations between the local geoid heights (GEOID 03) and ellipsoidal values (WGS-84) that may influence the resulting orthometric elevations. The calibration entails selecting the control to be used for the RTK-GPS basestation receiver and radio broadcast system and then checking at least three known geodetic benchmarks of exceptional horizontal and vertical quality within and even outside the survey boundaries. The benchmarks are occupied in "site calibration mode" over 300 epochs or approximately 3 to 5 minutes.

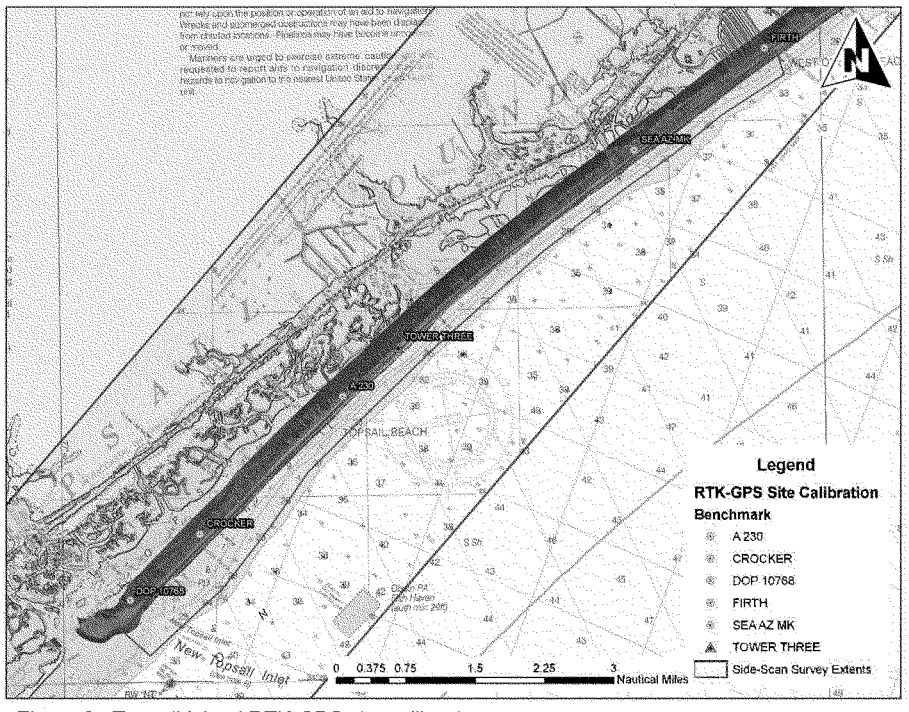


Figure 2. Topsail Island RTK-GPS site calibration map.

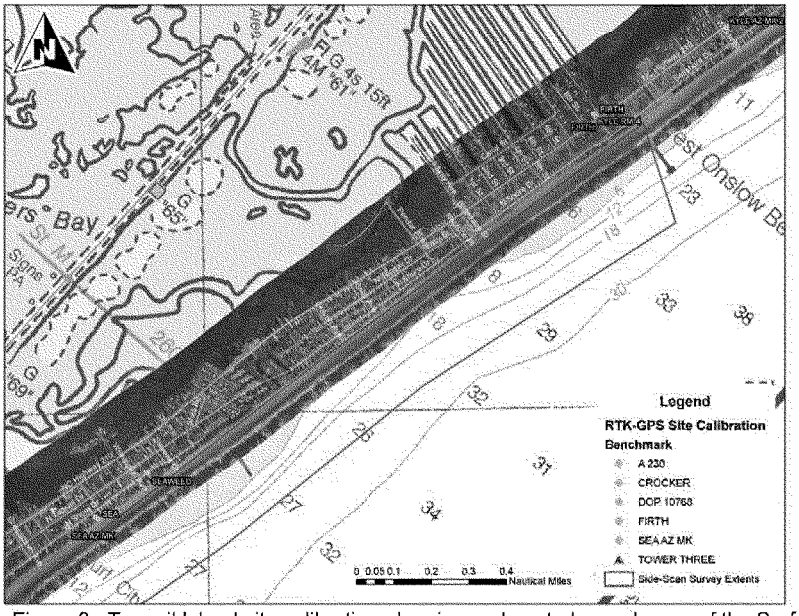


Figure 3. Topsail Island site calibration planning and control search map of the Surf City area.

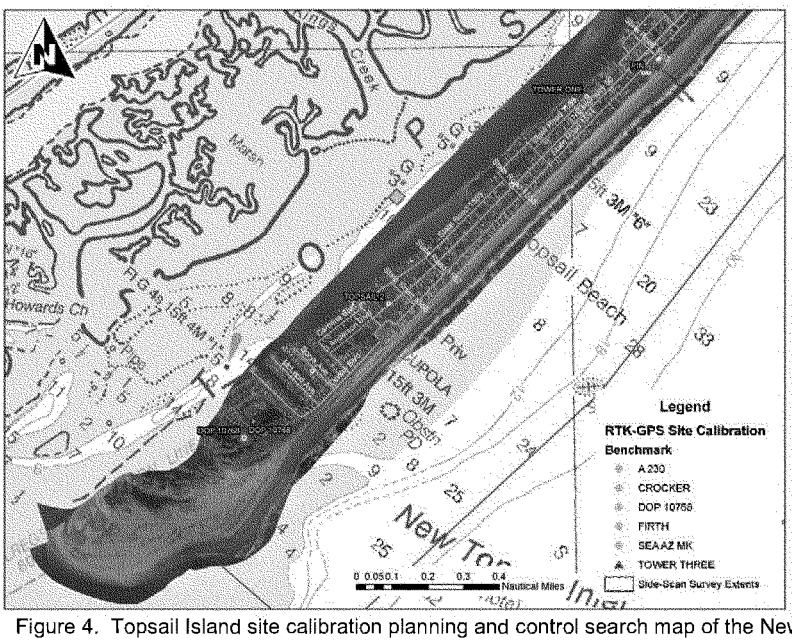


Figure 4. Topsail Island site calibration planning and control search map of the New Topsail Inlet area.

geodynamics
COMPLEX COASTAL CHANGE MADE CLEAR

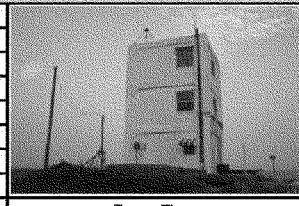
RTK-GPS Pre-Survey Site Calibration

General

Date	6/10/2005 & 6/11/2006
Project	USACE Topsail Island Side Scan - phase 1
Surveyor(s)	Freeman / Bernstein
Equipment	Trimble 5700 Basestation, Trimmark III 25 watt RTK Radio, Maxrad 5dB gain Antenna, Zepher Geodetic base antenna, Trimble 5700 RTK rover, Zepher antenna
Weather	Sunny, Few Clouds, 84 F, ESE Wind 10-15 kts, humid
Units	Meters
Notes	Day 1 of site cal-initail Benchmark scouting and base feasibilty of using a tower. Basestation set on top of Tower 3. Permission granted by owner John Gresham (910-328-4471). Tower stairs are in tack and benchmark is accessible. No power on site. Day 2 of site cal-basestation setup, accuracy checks and range checks.
Coordinate System	NC State Plane, NAD83 (horiz), NAVD88 (vert)

Basestation Information

Designation	Tower Three 1947
PID	EA0695
Agency	CGS
Horiz Order	2
Vert Order	2
N	72282.902
E	738983.122
Z	15.434



Tower Three



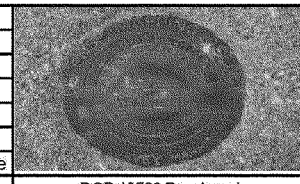
Tower Three - looking NE

Benchmark Checks

Designation	DOP 10768
PID	AI0899
Agency	NCGS
Horiz Order	1
Vert Order	3

	Recorded	Published	Difference
N	67222.286	67222.119	-0.167
E	733619.27	733619.291	0.021
Z	2.341	2.31	-0.031

Notes	Benchmark is it the south end of Topsail Island behind cottage # 2125 A

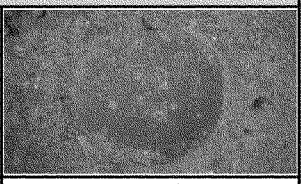


DOP 10786 Benchmark



DOP 10768 BM Check

Benchmark Checks (cont.)			
Designation	CROCKER		
PID	AI0831		
Agency	NCGS		
Horiz Order	1		
Vert Order	3		
	Recorded	Published	Difference
N	68542.204	68542.046	-0.158
E	735010.538	735010.571	0.033
Z	1.351	1.33	-0.021
Notes	Benchmark is at intersection of Crocker and S. Anderson		

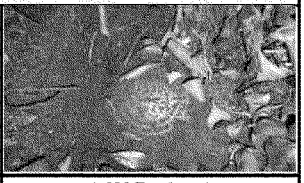


Crocker Benchmark



Crocker BM Check

Designation	A 230		
PID	EA0696		
Agency	CGS		
Horiz Order	1		
Vert Order	2		
	Recorded	Published	Difference
N	71298.722	71298.606	-0.116
E	737877.39	737877.413	0.023
Z	3.460	3.480	0.02
Notes	Benchmark is located in shrubs at 715 Shore Drive about 0.54 miles south of Catherine Drive.		

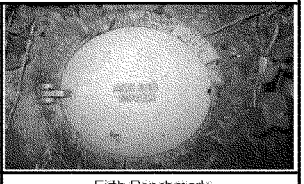


A 230 Benchmark

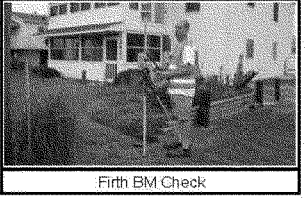


A 230 BM Check

Designation	FIRTH		
PID	AI0904		
Agency	NGS		
Horiz Order	1		
Vert Order	3		
	Recorded	Published	Difference
N	78267.573	78267.452	-0.121
E	746327.18	746327.233	0.053
Z	1.234	1.20	-0.03
Notes	Benchmark is on NW side of W 9th St. North of Surf City.		

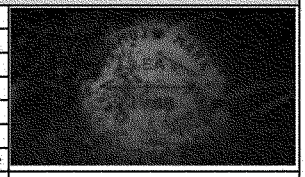


Firth Benchmark



Firth BM Check

Benchmark Checks (cont.)			
Designation	SEA AZ MK		
PID	AI0866		
Agency	NCGS		
Horiz Order	1		
Vert Order	3		
	Recorded	Published	Difference
N	76227.279	76227.107	-0.172
E	743713.279	743713.317	0.038
Z	2.605	2.57	-0.035
Notes	Benchmark is located on the N side of house at 313 N. Shore Dr.		



Sea AZ MK Benchmark



Sea AZ MK MB Check

Multibeam Echosounder Calibration Report

Calibration Date:	June 24, 2006
Ship	
Vessel	RV 4-Points
Echosounder System	EM3002
Positioning System	POS MV (tightly coupled)-RTK GPS
Attitude System	POS MV
Sound Velocity Probe	Odem Digibar Pro (profiler) / Valeport Mini SVS (at head)

Annual		
Installation	x	
System change	x	
Periodic/QC		
Other		

Calibration type: Multibeam Sonar

The following calibration report documents procedures used to measure and adjust sensor biases and offsets for multibeam echosounder systems. This report has been adopted and modified from NOAA. Calibration must be conducted A) prior to CY survey data acquisition B) after installation of echosounder, position and vessel attitude equipment C) after changes to equipment installation or acquisition systems D) whenever the Hydrographer suspects incorrect calibration results. The Hydrographer shall periodically demonstrate that calibration correctors are valid for appropriate vessels and that data quality meets survey requirements. In the event the Hydrographer

determines these correctors are no longer valid, or any part of the echosounder system configuration is changed or damaged, the Hydrographer must conduct new system calibrations.

Multibeam echosounder calibrations must be designed carefully and individually in consideration of systems, vessel, location, environmental conditions and survey requirements. The calibration procedure should determine or verify system offsets and calibration correctors (residual system biases) for draft (static and dynamic), horizontal position control (DGPS), navigation timing error, heading, roll, and pitch. Standard calibration patch test procedures are described in *Field Procedures for the Calibration of Multibeam Echo-sounding Systems*, by André Godin (Documented in Chapter 17 of the Caris HIPS/SIPS 6.0 User Manual, 2006). Additional information is provided in *POS/MV Model 320 Ver 4 System Manual* (10/2003), Appendix F, Patch Test, and the NOAA Field Procedures Manual (FPM, 2003). The patch test method only corrects very basic alignment biases. These procedures are used to measure static navigation timing error, transducer pitch offset, transducer roll offset, and transducer azimuth offset (yaw). Dynamic and reference frame biases can be investigated using a reference surface.

Pre-calibration Survey Information

Reference Frame Survey

RV 4-Points was surveyed by the National Geodetic Survey on February 15, 2006 for precise centerline and instrument locations. Steve Breidenbach performed the survey with a Trimble 5603 total Station.

(IMU, Ref Pt., and XY of CG are all co-aligned and attitude and position is valid at the sensor. The values below are entered in POSview software.)

Reference to IMU Lever Arm

X(m)	Y (m)	Z (m)
0	0	0

Reference to Pri. GPS

X(m)	Y (m)	Z (m)
1.849	-1.061	-1.724

IMU frame w.r.t. Reference frame

X(deg)	Y (deg)	Z (deg)
0	0	0

Reference to Sensor Lever Arm

X(m)	Y (m)	Z (m)
-0.097	-2.130	0.849

Reference to CG

X(m)	Y (m)	Z (m)
0	0	0.313

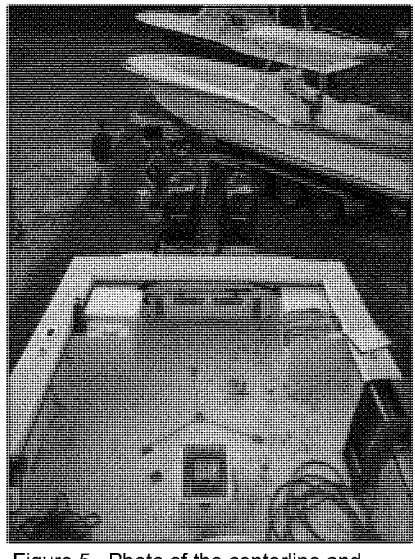


Figure 5. Photo of the centerline and instrument survey by NGS.

Reference to Vessel (Pt of validation for attitude and nav)

X(m)	Y (m)	Z (m)
-0.097	-2.130	0.849

__X__Measurements verified for this calibration.
_____Drawing and table attached.
_____Drawing and table included with project report

POS MV Configuration File: 4_points_022806_*_____

Notes: _NGS vessel survey results were put in POSview and GAMS calibration was done on February 28, 2006___.

Calibration Area

Site Description

This patch survey was conducted in the Port of Morehead City's turning basin near Beaufort Inlet, North Carolina (N34 41 39.16 W076 40 07.53). This site was selected for its particular bottom features, such small scale ripple fields, sand waves (wavelength: ±5m, amplitude: ±0.15m), deep flat areas, and high slopes.

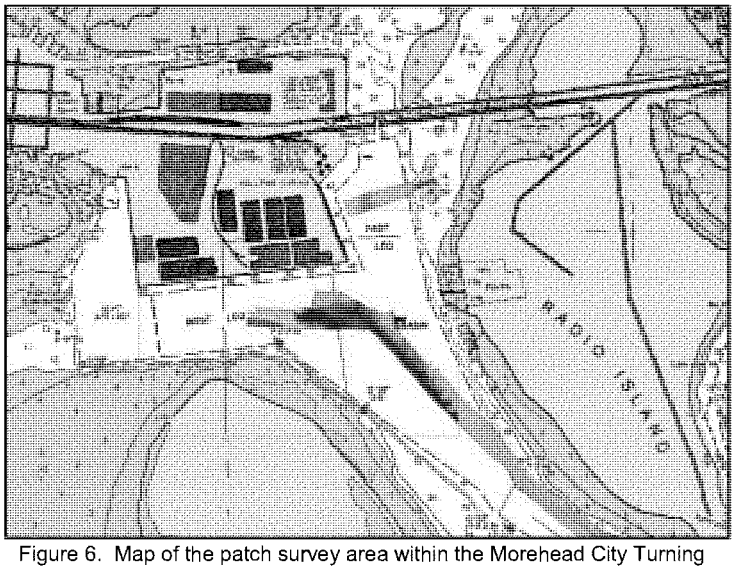


Figure 6. Map of the patch survey area within the Morehead City Turning Basin.

Survey Procedure

Vessel biases were determined through a patch test survey procedure. Data was acquired and analyzed in Kongsberg SIS package. The latency test was performed first by surveying the same survey line in the same direction at 2

different vessel speeds. The latency test was done twice to verify initial results. The pitch test was done second by surveying the same survey line in opposite directions at the same speed and evaluating the sloped portion of the survey line. The roll test was performed next by surveying the same survey line in opposite directions at the same speed and evaluating the deep flat portion of the survey line. The roll test was done twice to verify initial results. The yaw test was performed next by surveying 2 adjacent survey lines in the same direction, with similar speeds, with enough overlapping coverage such that the outer beams from each swath overlap (±40%).

Calibration Lines

Hypack Line	Line File	Az.	Spd	Correction			
				Pitch	Roll	Yaw	Latency
1	0000_20060301_163731_4points.all	57°	3.3kts				X
1	0001_20060301_164249_4points.all	57°	7.1kts				X
1	0002_20060301_165502_4points.all	237°	3.2kts				X
1	0003_20060301_165938_4points.all	237°	7.0kts				X
1	0002_20060301_155849_4points.all	237°	7.0kts	X			
1	0003_20060301_160222_4points.all	57°	7.0kts	X			
1	0000_20060301_172142_4points.all	57°	7.0kts		X		
1	0001_20060301_172427_4points.all	237°	7.0kts		X		
1	0000_20060301_183521_4points.all	237°	7.0kts		X		
1	0001_20060301_183741_4points.all	57°	7.0kts		X		
8	0001_20060301_191059_4points.all	280°	7.0kts			X	
7	0002_20060301_191957_4points.all	100°	7.0kts			X	

Sound Velocity Correction

Measure water sound velocity (SV) prior to survey operations in the immediate vicinity of the calibration site. Conduct SV observations as often as necessary to monitor changing conditions and acquire a SV observation at the conclusion of calibration proceedings. If SV measurements are measured at the transducer face, monitor surface SV for changes and record surface SV with profile measurements.

Sound Velocity Measurements

Time	Max Depth	Surface SV	Change Observed	Position	
				Latitude	Longitude
14:52:00	15.5m	1490.2		34 42.9705	76 41.6239
Continuous SV at head			<4 m/s throughout entire calibration		

Data Acquisition and Processing Guidelines

Initially, calibration measurement offsets should be set to zero in vessel configuration files. Static and dynamic draft offsets, inertial measurement unit (IMU) lever arm offsets, and vessel reference frame offsets must be entered in appropriate software applications prior to bias analysis. Perform minimal cleaning to eliminate gross flyers from sounding data.

Navigation Timing Error (NTE)

Measure NTE correction through examination of a profile of the center beams from lines run in the same direction at maximum and minimum vessel speeds. NTE is best observed in shallow water.

Transducer Pitch Offset (TPO)

Apply NTE correction. Measure TPO correction through examination of a profile of the center beams from lines run up and down a bounded slope or across a conspicuous feature. Acquire data on lines oriented in opposite directions, at the same vessel speed. TPO is best observed in deep water.

Transducer Roll Offset (TRO)

Apply NTE and TPO corrections. Measure the TRO correction through examination of roll on the outer beams across parallel overlapping lines. TRO is best observed over flat terrain in deep water. An additional check for TRO adjustment can be performed by running two lines parallel to a sloped surface.

Transducer Azimuth Offset (TAO or yaw)

Apply NTE, TPO and TRO corrections. Measure TAO correction through examination of a conspicuous topographic feature observed on the outer beams of lines run in opposite directions.

Patch Test Results and Correctors

Evaluator	NTE (sec)	TPO (deg)	TAO (deg)	TRO (deg)
Bernstein/Hohing	0.00	0.00	0.00	-0.65
Final Values	0.00	0.00	0.00	-0.65

Corrections Calculated in:	
Caris	
ISIS (BathyPro)	
Other	SIS

NOTE: TRO bias of -0.65 was put in SIS software.

Evaluator: Dave Bernstein
Reviewed by: Dave Bernstein
Accepted by: Dave Bernstein
Date accepted: June 25, 2006

Graphical Examples of Calibration Acceptance

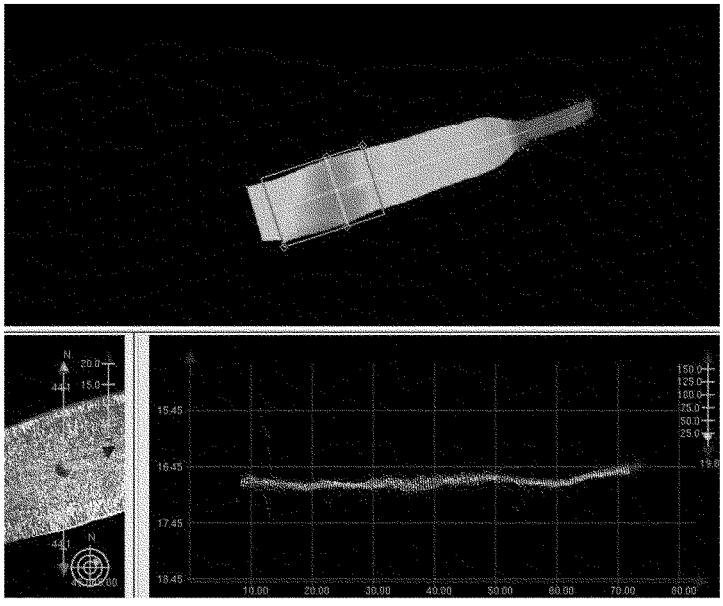


Figure 7. Caris screen grab illustrating acceptance of roll calibration.

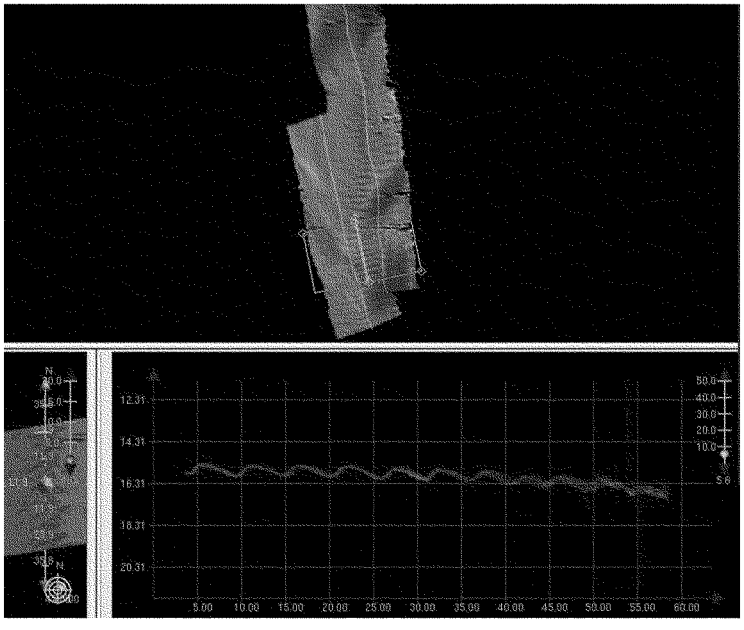


Figure 8. Caris screen grab illustrating acceptance of yaw calibration.

Data Processing Routines & QA/QC Information

Introduction

Processing high-density multibeam bathymetry and backscatter data requires a multitude of processing routines and data quality analyses. The following section will detail all aspects of data post-processing for the Beaufort Inlet multibeam surveys. Also presented in this section is detailed QA/QC information and analysis generated throughout the various processing procedures.

Bathymetry Processing

The multibeam collects swath widths approximately 4 times the water depth. The portions of swath, mainly in the outer beams, that exhibit areas of inconsistent data are clipped and not included in the final digital file. Sounding track lines are generally parallel to each other and parallel to the seafloor contour. Sinuous lines and data acquired during turns are not included in the final processed data. To meet the accuracy and resolution standards for measured depths specified in the USACE Hydrographic Surveying Manual and the NOS Hydrographic Surveys, Specifications and Deliverables Manual, measured echosounder depths were corrected for all departures from true depths attributable to the method of sounding or to faults in the measuring apparatus. These corrections are subdivided into four categories, and are listed below in the sequence in which they were applied to the data.

1. Instrument error corrections: included to account for the sources of error related to the sounding equipment itself.

2. Vessel offsets: added to the observed soundings to account for the depth of the echosounder below the water surface, positioning of the motion reference unit, and GPS antenna.

3. Velocity of sound correctors: applied to the soundings to compensate for the fact that echosounders may only display depths based on an assumed sound velocity profile while the true velocity may vary in time and space.

4. Heave, pitch, roll, heading and navigation latency corrections: applied to the multibeam soundings to correct for the effect of vessel motion caused by waves and swells, the error in the vessel's heading, and the time delay from the moment the position is measured until the data is received by the GPS receiver.

Multibeam Data Processing Steps in CARIS HIPS software:

The EM3002 sonar system has a unique arrangement of data flow. Most settings that influence the data are put in before and during a survey and therefore are not a factor in data processing (these include vessel offsets, lever arms, vessel biases, timing biases, and survey sound velocity). Vessel attitude is also processed real-time during a survey.

Post-processing of multibeam data consist of attitude and navigation editing, merging, swath editing, area-based editing, and exporting of final data.

1. Attitude & Navigation Editing: Errors or gaps in attitude and navigation information causing errors in soundings are edited.

2. Merging: Computing and integrating the GPS tide in the sounding data. Additional sound velocity corrections are made if needed in this phase. Draft changes for datum conversions are made here as well.

3. Total Propagated Error (TPE) is calculated

4. Swath- and beam-based filters and TPE (IHO standards) filters are applied.

5. Swath Editing: Swaths are edited for erroneous data if needed

6. Base or CUBE Surface is created for area- and CUBE-based editing.

7. Area-based editing using the subset editor to edit/check erroneous data only within the desired subset.

8. CUBE filtering (if needed)

9. Recompute TPE

10. Recompute CUBE and/or base surface

11. Final export of base surface to XYZ decimated soundings (1m).

NOTE: Bathy is delivered in NAVD 88 until we determine if phase 2 will require the NGVD 29 vertical datum. Also, bathy data maybe adjusted in phase 2 once we get some overlapping coverage to determine slight offsets that may need to be applied for roll due to the towing of the side-scan sonar.

Side-Scan Processing

1. Side scan is replayed (ISIS) and slant range corrected. Areas that have lost bottom track data are manually digitized to replace lost altitude data.

2. Appropriate image corrections are determine in ISIS and defined for the mosaic procedure.

- A threshold of 4 was used for all files incorporated in the mosaic. This means the 8 bit or 16 bit data is shifted by 4 bits to correct the histogram when the data is played for mosaic.

- A "STANDARD: TVG correction with a Pixel to Pixel Balance correction was applied to all files in the mosaic. This correction implemented a 4% darkness and a 10% decay rate.

3. The data is then mosaiced using ISIS to play back the data and Delphmap Mosaic to create the mosaic file.

All of the mosaic setting and corrections are applied in Delph Mosaic.
- layback = 4.5m
- X shift = 4.3m
- set data resolution 50 cm for channels 1-2 15cm for channels 3-4
- cover up for overlapping lines
- fill gaps between pings
- use course made good for heading (heading not as useful due to unknown declinations to the klein mag compass)

During this stage, the depth, delay, and duration settings are altered for each file played back in order to provide adjacent lines with specific coverage (overlap) in ISIS.

4. The mosaic in Triton DDS_VIF format is then exported to Geo-Tiff file format with associated .world file.

Typical Side-Scan Artifacts

Feature Accuracy Information: Side-scan sonar artifact information has been synthesized from the Handbook of Seafloor Sonar Imagery, Blondel & Murton, Geoff Shipton at Triton Imaging, and from out past experience with these data.

The Klein 3000 is a digital side-scan sonar system capable of producing digital image maps of the seafloor from reflected sound waves or acoustic backscatter from the seafloor. These images are created by transmitting a series of sound pulses and recording their echoes from the seafloor as the survey vessel moves across a set course. The sound source and receivers are built into a "tow fish" that moves through the water at varying depths and distances from the survey vessel dependent on the water depth. The returned signal is then recorded by shipboard computers with an amplitude range of 0-255 with strong returns recorded as higher values and weak returns recorded as lower values. The darkness or brightness of a side-scan mosaic is a function of the gradient or slope of the seafloor, surface roughness, and the sediment characteristics such as texture which can all be interpreted by a marine geologist.

The main advantage of side-scan sonar over the backscatter product generated from multibeam sonar is the greater coverage that can be achieved (ex. in 10m of water = 40m for multibeam and up to 300m (although this dataset uses a swath width of 120m for higher detail) with side-scan) and a more detailed image of the seafloor. However, side-scan data tends to be much noisier and contains far more artifacts than multibeam. Below are some of the major artifacts to be expected in any side-scan mosaic.

Heave & Motion Artifacts: In a perfect scenario side-scan would be collected in flat calm conditions with zero boat motion that would translate into the towed vehicle. In addition, towing a side-scan into shallow water creates additional heave artifacts due to the short tow. Flat calm conditions rarely happen in an oceanic environment and really never happen when approaching the nearshore environments where waves begin to propagate. Heave artifacts are caused by changes in pitch due to tugging on the vehicle line. At the point where the fish moves through the horizontal (Pitch = 0) the sonar beam strikes the bottom at a right angle and the return path is directly along the axis, which gives a good return. Either side of the zero pitch point the returns become weaker. The effect on the record is banding in the across track direction. Aside from slight pitch corrections made in the processing software (ISIS in this case) there is nothing that can be done to correct for the fact that the point where the return comes from moves fore and aft as the pitch changes. Roll, Pitch, Yaw can all be taken into account in post processing to some reasonable level; however, the towfish based altimeter and flux gate compass are not to the standard of those used for compensating bathymetric data.

Running Parallel to a Slope Artifacts: Depending on how steep the slope is you will see a stronger return on the uphill slope and a weaker return on the downhill slope. How much this affects the image will depend on two things; how steep the slope and how reflective the seafloor. The slope could, in some cases, decrease the grazing angle sufficiently that the sound simply bounces off completely and hardly anything gets back. This angle varies with different bottom types. The artifact that can be generated in this scenario, provided there is a highly reflective bottom (which we see in several areas at Topsail) is a two toned effect on the area of interest. There are a few independent gain settings for each sonar channel that can help; however, applying different gain settings for each opposing line becomes a bit black magic and hence we don't typically tweak these settings beyond a certain point.

Sea Surface Reflection Artifacts: In shallow water applications such as the Topsail Island project side-scan sonar imagery can be corrupted by multiple reflections from the sea surface. The first reflection is formed when the sonar beam reflects once from the seafloor and once from the sea surface. This artifact can manifest itself as bright lines parallel to the sonar track, at a distance from the sonar track roughly equivalent to the water depth. If the swath is wide enough subsequent multiples will also be present as equidistant bright lines parallel to the first reflections. They primarily occur in areas with flat and smooth sedimentary features or from white capping of waves on the surface. A few of these artifacts can be seen in the inshore side-scan line at Topsail.

Water Column Artifacts: Artifacts related to the propagation of the acoustic pulse in the water column from the sensor to the seafloor and back can be attributed to two sources. The first are variations in the structure of water column due to density variations, salinity variations and temperature variations. Depending on the depth, a certain amount of thermocline layers will modulate the

depth and angle at which the acoustic rays propagate. These artifacts are generally at the far range of the swath and look similar to linear bedforms. The second artifact that can be produced from speed of sound variations are derived from the presence of bubbles in the water. This may come from the wake of the survey vessel or from cavitation caused by the ships propellers. High-frequency systems such as the Klein 3000 are sensitive to bubbles and cause the sonar beams to become partially dispersed and partially reflected before they reach the seafloor. The artifact that can be created in this case is random data gaps at all ranges. In the Topsail data there is no indication that thermoclines are playing a role in artifact generation (sound velocity measurements for multibeam do not indicate any presence of thermoclines); however, prop wash may be the cause for some random gaps in across track data.

Radiometric Artifacts: The most frequent cause of systematic radiometric artifacts reside in the acquisition system itself. Connections between the cable and topside computers, broken points in cable, faulty grounds, etc. Another cause is interference between other acoustical systems. Although we turn off our shipboard singlebeam sonar since this is a known point of origin for artifact we are running the Simrad EM3002 multibeam sonar simultaneously which might create a small level of cross-talk. We have never seen this in the data per say but there are some slight noise artifacts on the edges of some swaths that might be attributed to cross-talk between the two systems. Another possible radiometric artifact is the rapid attenuation of the backscattered signal when the sonar platform goes up or down too rapidly or an abrupt change in seafloor depth. This change is usually too localized and rapid to be corrected with the normal time-varying gain (TVG).

Geometric Artifacts: Side-scan data can become distorted by the variations in the horizontal and vertical movement of the towfish such as those created by motion; however, variations in the survey vessel speed, if not taken into account properly, can cause distortion in the along-track direction. If the platform speed assumed during processing is higher than the actual value the swath lines will be positioned too far away from each other, and the image will be stretched along-track. Conversely, if the platform speed is lower, the swath lines will be positioned too close to each other, and the image will be compressed along-track. Discrepancies between matching seafloor morphology will be the result. Since we collected multibeam sonar simultaneously we were able to use the cm-scale positioning from the RTK-GPS to align each successive swath.

Examples of Known Artifacts in Topsail Side-Scan Data

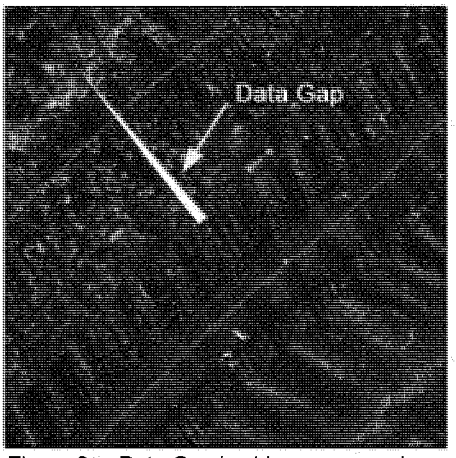


Figure 9a. Data Gap in side-scan record.

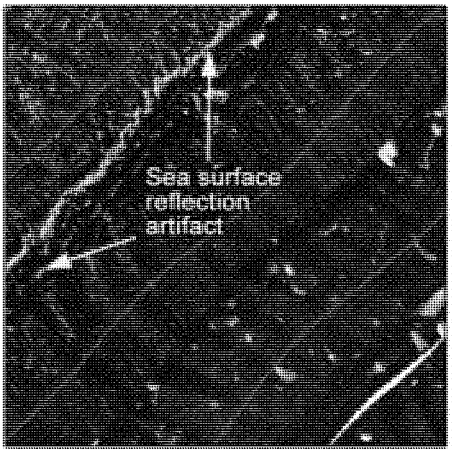


Figure 9b. Sea surface reflection artifact.

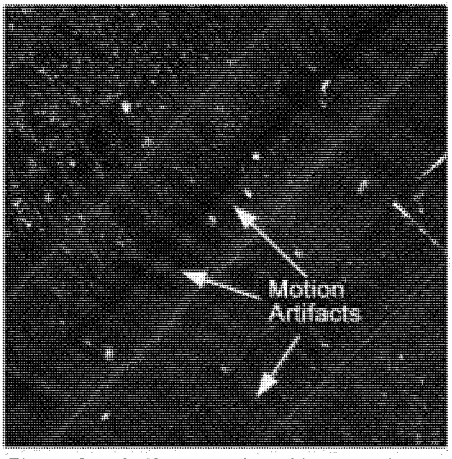


Figure 9c. Artifacts produced by vessel-towfish motion.

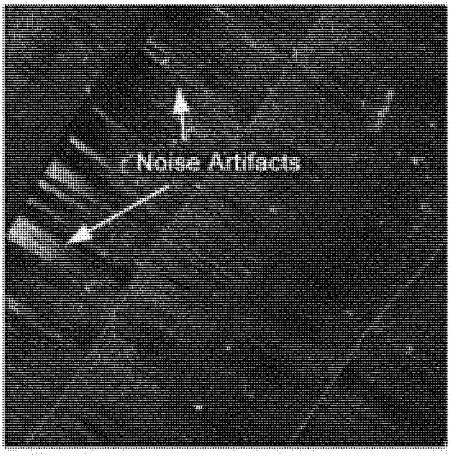


Figure 9d. Noise artifacts.

Potential Hardbottom Identification

To facilitate maximum efficiency in identifying hardbottom regions for phase 2 of the project we completed a QTC analysis of the backscatter which fell outside of the official SOW. Data from this analysis is provided on the accompanying DVD and the Quester Tangent report is provided in Appendix E. Preliminary results of the QTC unsupervised classification show several classes that exist on areas of known artifact. However, visual inspection of the data shows that QTC Class 4 correlates to our interpretation of potential hardbottom regions.

In order to synthesize these data into a structure to identify potential hardbottom regions and to eliminate much of the noise present in these data we manually digitized the areas that we feel have the most potential of being hardbottom. To provide a more quantitative digitization we used both the QTC Class 4 data and some preliminary analysis completed in Triton SeaClass software.

Between the three preliminary analyses it appears that most all of the potential hardbottom regions exist starting approximately 800 ft offshore (2004 wet/dry line) to the end of the survey which is approximately 1800 ft offshore (2004 wet/dry line). There are a few areas on the inshore seam, from approximately 300 ft to 800 ft from the 2004 wet/dry line, that exhibit a differing signature from the surrounding seafloor. It is thought that these areas are likely artifact since we have compared the overlapping multibeam backscatter and there are no correlations that can be made between the two. However, closer inspection may be required during phase two in an effort to eliminate these zones as possible hardbottom.

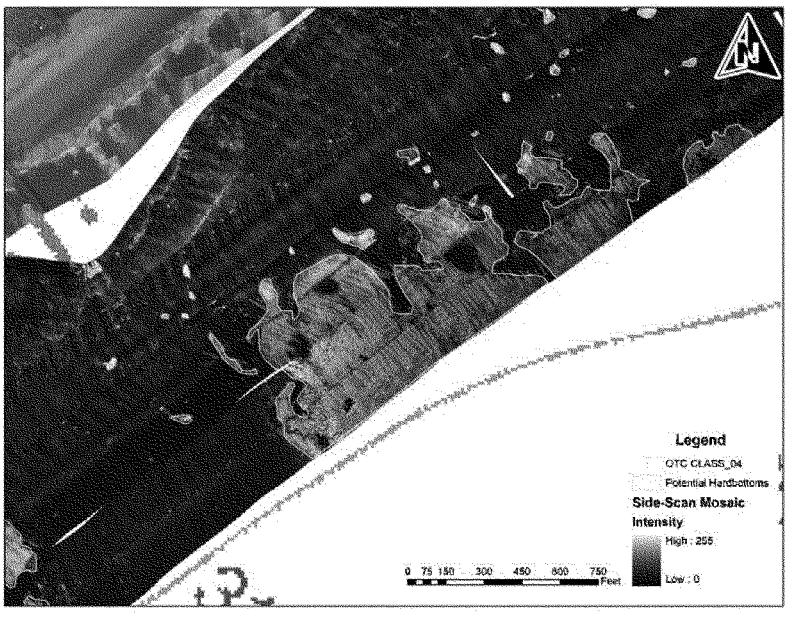


Figure 10. Map illustrating potential hardbottom areas.

Topsail Island Remote Sensing Workflow Diagram

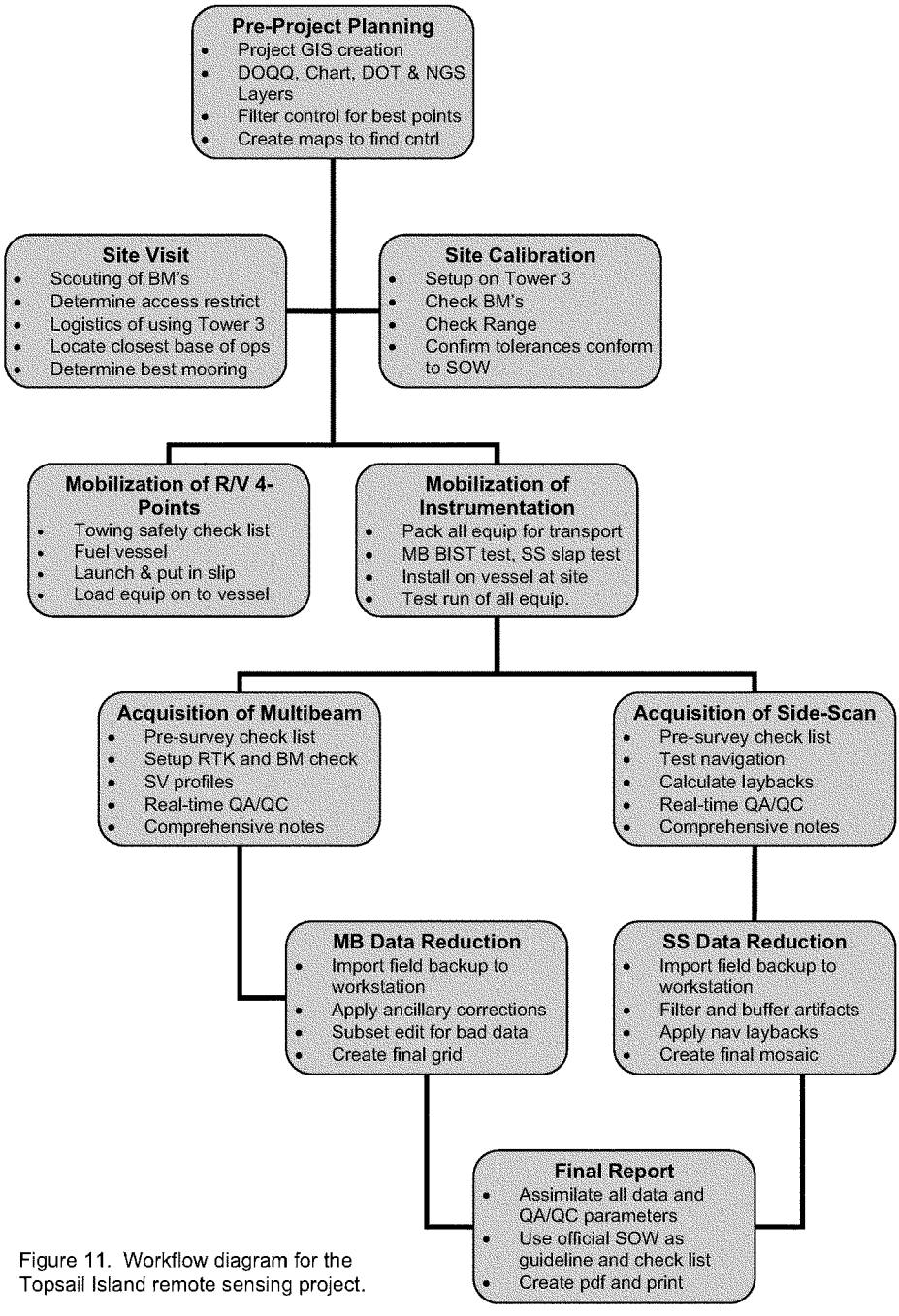


Figure 11. Workflow diagram for the Topsail Island remote sensing project.

Topsail Island Remote Sensing QA/QC Workflow Diagram

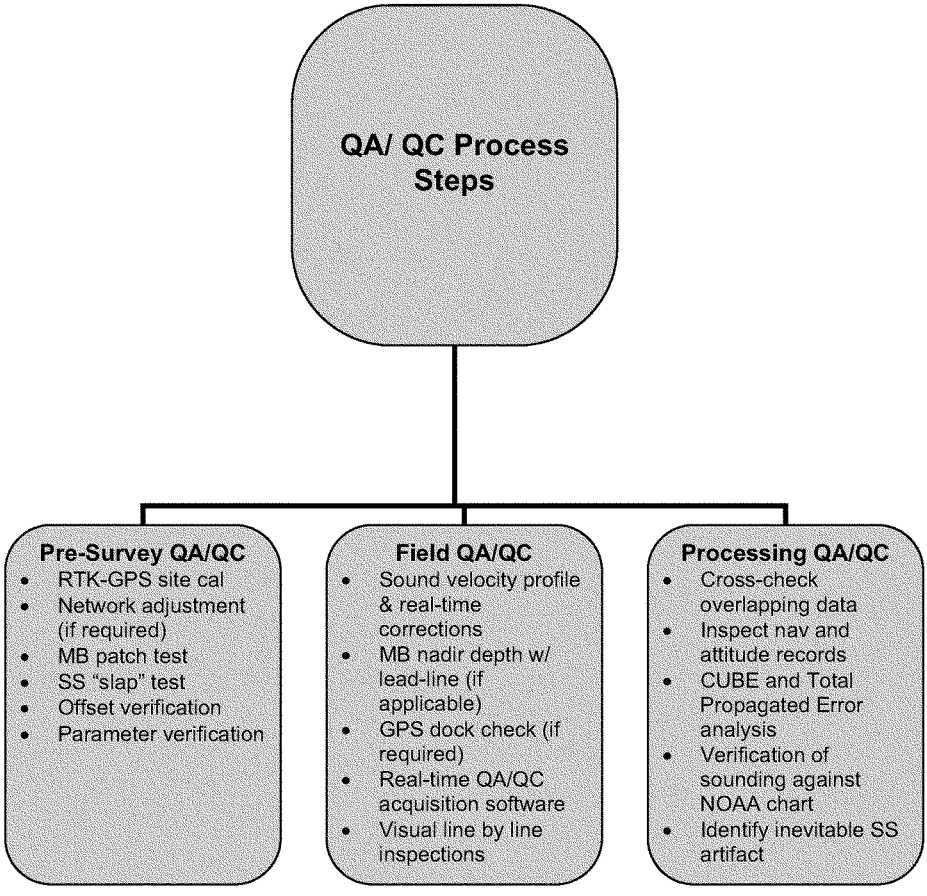


Figure 12. QA/QA Workflow diagram for the Topsail Island remote sensing project.

Graphical Summary of Deliverables

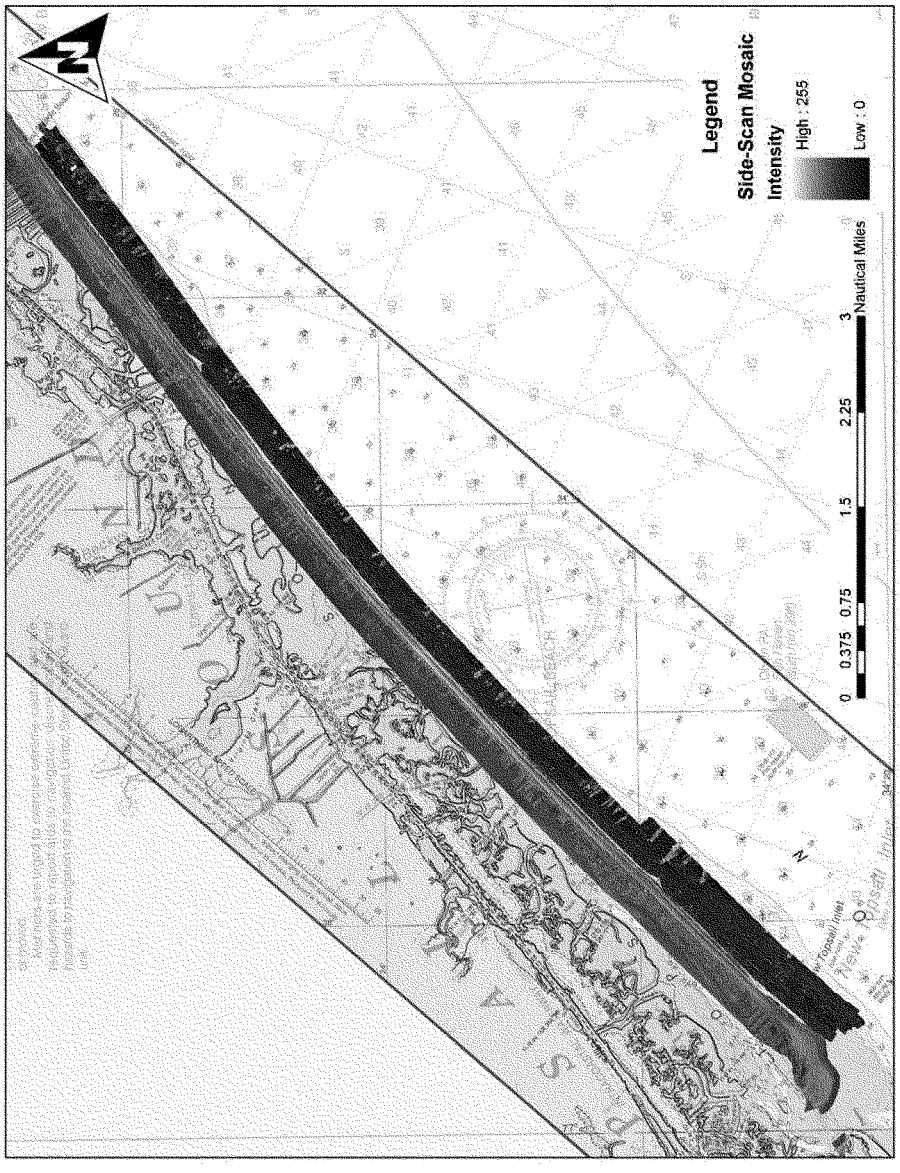


Figure 13. Side-scan sonar mosaic.

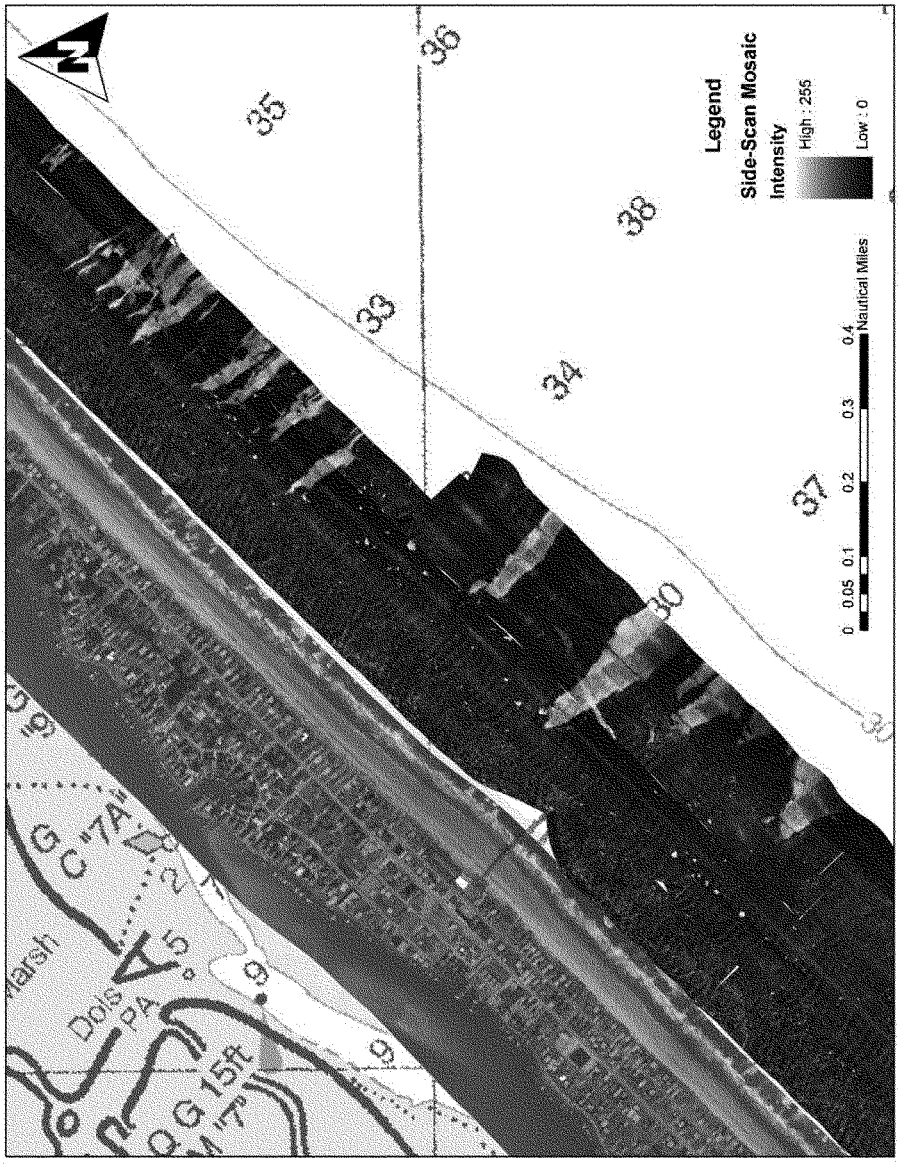


Figure 14. Close-up view of the side-scan sonar mosaic in the south portion of the survey area.

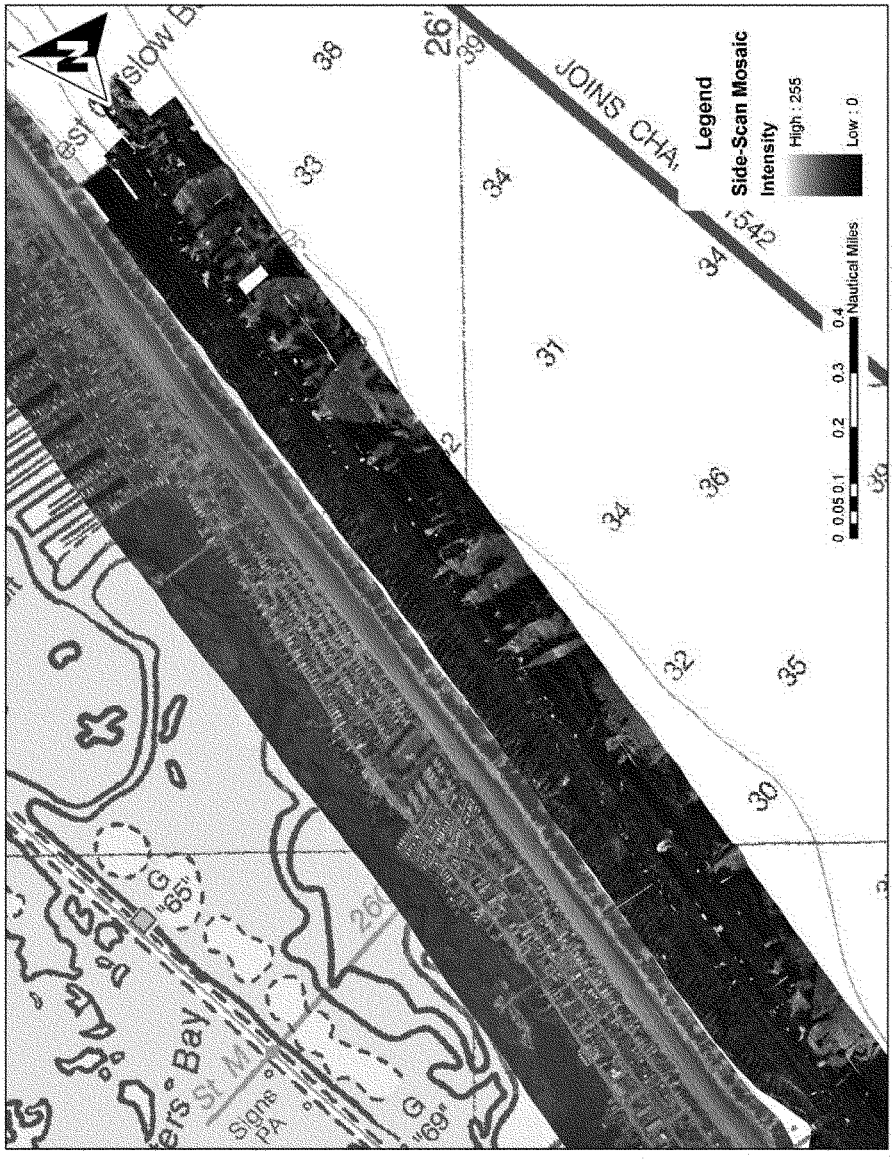


Figure 15. Close-up view of the side-scan sonar mosaic in the north portion of the survey area.

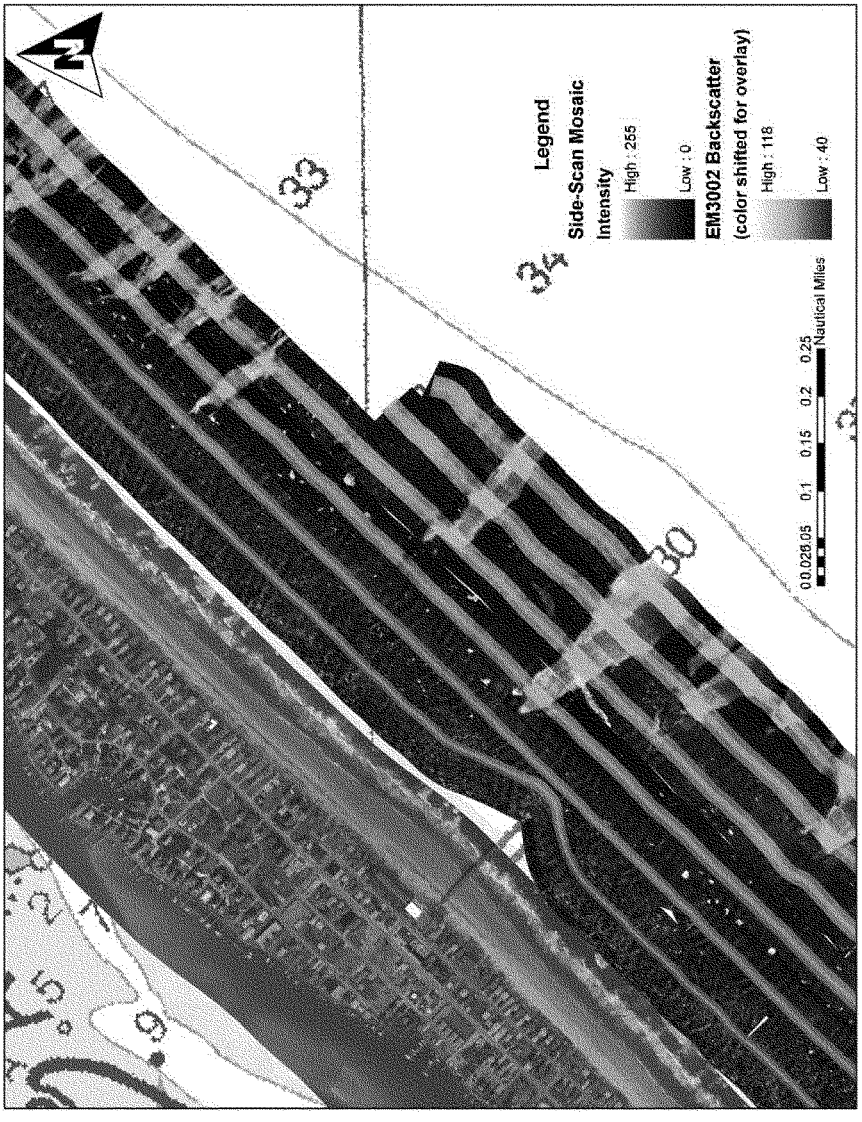


Figure 16. Side-scan sonar mosaic overlaid with EM3002 backscatter data. Alignment of features between datasets illustrates excellent positioning calculation for the side-scan mosaic.

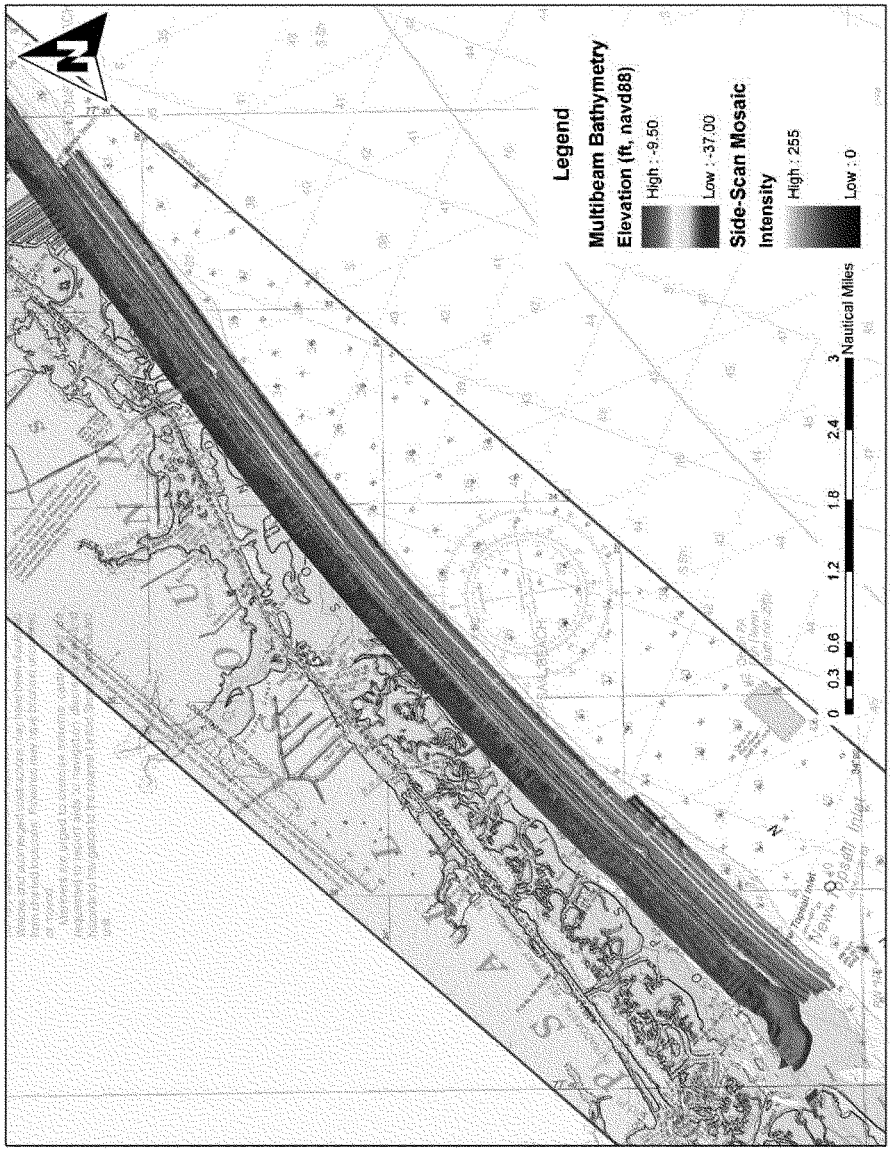


Figure 17. EM3002 Multibeam bathymetry.

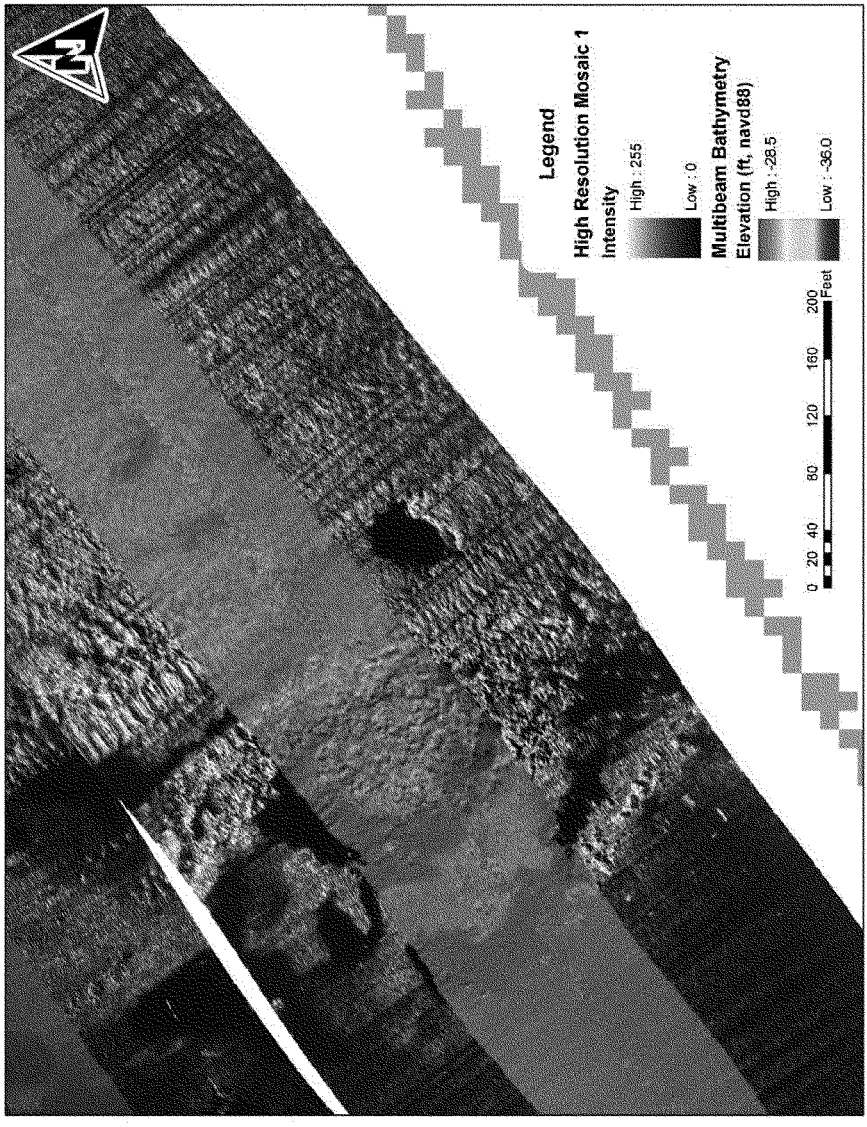


Figure 18. Rendered bathymetry overlaid on high-resolution side-scan sonar imagery. Map illustrates a low-relief hardbottom and sediment interface.

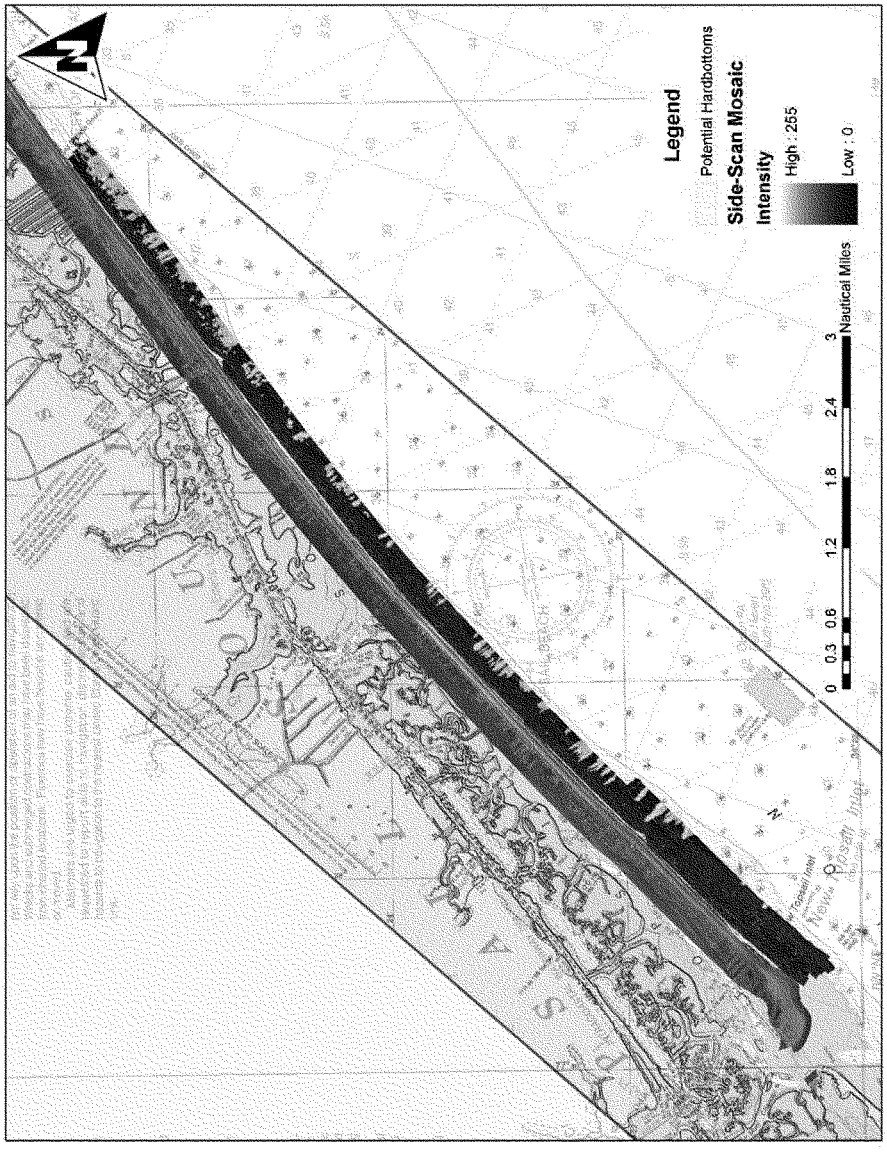


Figure 19. Side-scan sonar mosaic overlaid with polygon shapefile of potential hardbottom areas.

Appendix A – Official USACE Scope of Work

SCOPE OF WORK
NEARSHORE HARD BOTTOM SIDESCAN SURVEY
TOPSAIL ISLAND, NORTH CAROLINA

1. General. The Contractor shall acquire Sidescan Sonar Data along Topsail Island, North Carolina for the purposes of identifying and mapping potential Hard Bottom Areas. The longshore limits of the data collection extend form New Topsail Inlet to the Surf City/North Topsail town line as identified on the Government furnished map. The offshore limits shall extend from the mean low water contour to the -25 feet NGVD 1929 contour as identified on the Government furnished map.

2. Survey Control. All horizontal and vertical control used for this survey shall be from the North Carolina or a Federal Agency Network and be of third order accuracy or better. All control loops must be tied to at least two or more control points. The Contractor shall furnish a list of all points used to the Government. All work shall be relative to NAD 1983 North Carolina State Plane Feet in the horizontal plane and NGVD 1929 in the vertical plane. The Government will provide control information for previously established Control Points along the length of the project area.

3. Clearances. The Contractor shall acquire all Clearances necessary to obtain the required data. All discussions for access to private or public property or restricted waters or airspace must be included in the required weekly status report with name of person, address, and telephone number.

4. Required Deliverables. The Contractor is required to deliver Side Scan Mosaic Raster Data Sets, Shapefiles, Metadata Records, a Weekly Status Reports, and a Final Written Report.

4.1 Side Scan Mosaic Raster Data Sets. The Contractor shall deliver Georeferenced Mosaics of the Raster Data sets from the Side Scan Survey. The Raster Data sets shall depict the backscatter information used to map the potential hard bottom areas in the project area. The Raster Data Sets shall be in a format compatible with ESRI ArcView/ArcInfo Version 9.0.

4.2 Shapefiles. The Contractor shall deliver Polygon Shapefiles defining the potential hard bottom areas within the project area. The Shapefiles shall be in a format compatible with ESRI ArcView/ArcInfo Version 9.0.

4.3 Metadata Record. An FGDC compliant metadata record for each spatial data deliverable shall be created using ESRI ArcView/ArcInfo ArcCatalog version 9.0. Appropriate information shall be entered in all required fields. The Contractor shall attach the appropriate metadata record to each spatial data file using ArcCatalog so that no importing or formatting of the metadata record is required by the Government.

5. Weekly Status Report. **The Contractor is required to submit a Weekly Status Report each week, beginning on the Task Order Award Date, until all deliverables are received and accepted by the Government**. The Weekly Status Report shall be delivered via e-mail no later than 8:00 AM each Monday and shall document the Contractor's progress from the previous Monday through the previous Sunday. The status report shall itemize each scope item with percent of work complete and an estimated date of completion. The report shall also include the number and type of field crews working, a description of any problems and/or delays encountered, and any photographs of the site and/or significant site features (such as outlet structures, retaining walls, escarpments, etc.) and/or specialized data collection activities.

6. Final Written Report. A written report summarizing all data collection activities shall be submitted as a Portable Document File (PDF) and in bound hardcopy. The following items shall be included in the survey report:

- Written description of workflow to complete task order (start to finish) including flowchart diagram and detailed description of QA/QC process
- Dates and times of each data collection activity
- Atmospheric Conditions for each day of data collection activity
- All Horizontal and Vertical Control used including monument name, establishing agency, date established, description, and published horizontal and vertical values
- TBM descriptions with vertical values
- Copy of all field notes
- Complete and detailed list of all survey equipment used including copy of last factory calibration report
- Metadata Record as described in 4.3 above
- Photographs of the site and any significant features or data collection techniques used

7. Quality Control. If work is found to be in error, incomplete, illegible or unsatisfactory after assignment is completed, the Contractor shall be liable for all cost in connection with correcting such errors. Corrective work may be performed by Government personnel or Contractor personnel at the discretion of the Contracting Officer. In any event, the Contractor shall be responsible for all costs incurred for correction of such errors, including salaries, automotive expenses, equipment rental, supervision, and any other costs in connection therewith. All data and deliverables shall be reviewed for the following:

- Required coverage of the project limits
- Capture of all required features
- Required accuracies
- Required horizontal and vertical datum
- Adherence to the delivery order requirements

8. Technical POC. All technical questions concerning work under this task order shall be directed to Jim Jacaruso at (910) 251-4064.

9. Completion Date. All work required under this task order shall be **completed and delivered no later than 14 calendar days from the Task Order Award Date.**

This schedule is subject to adjustment by the Contracting Officer in writing.

10. Deliver To. All work shall be delivered to:

U. S. Army Corps of Engineers
Wilmington District
Attn: Jim Jacaruso, TS-EE
69 Darlington Avenue
PO Box 1890
Wilmington, NC 28402-1890

Appendix B - Benchmark Descriptions

NGS Mark Designated Tower Three (1947)

DESIGNATION: TOWER THREE (used for survey control basestation)
PID: AEA0695
STATE/COUNTY: NC/PENDER
USGS QUAD: HOLLY RIDGE (1997)

Current Survey Control:
NAD 83(1986): 34 23 35.96043(N) 077 35 34.60089(W) ADJUSTED
NAVD 88: 15.434 (meters) 50.64 (feet)

LAPLACE CORR: -2.78 (seconds) DEFLEC99
GEOID HEIGHT: -37.37 (meters) GEOID03
DYNAMIC HT: 15.419 (meters) 50.59 (feet) COMP
MODELED GRAV: 979,654.0 (mgal) NAVD 88
HORZ ORDER: SECOND
VERT ORDER: SECOND CLASS 0

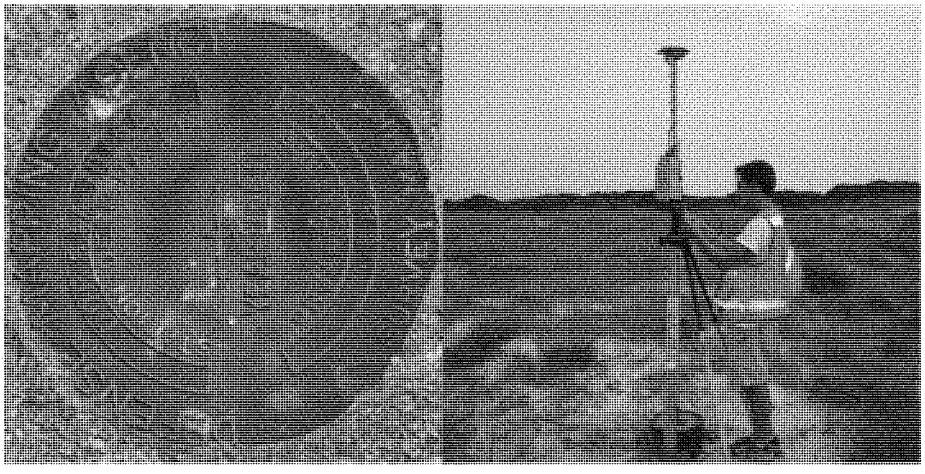


DMA Mark Designated DOP 10768 (1981)

DESIGNATION: DOP 10768
PID: AI0899
STATE/COUNTY: NC/PENDER
USGS QUAD: HAMSTEAD (1970)

Current Survey Control:
NAD 83(1986): 34 20 54.15165(N) 077 39 07.26281(W) ADJUSTED
NAVD 88: 2.31 (meters) 7.6 (feet) ADJUSTED

LAPLACE CORR: -3.37 (seconds) DEFLEC99
GEOID HEIGHT: -37.32 (meters) GEOID03
DYNAMIC HT: n/a (meters) n/a (feet) COMP
MODELED GRAV: n/a (mgal) NAVD 88
HORZ ORDER: FIRST
VERT ORDER: THIRD

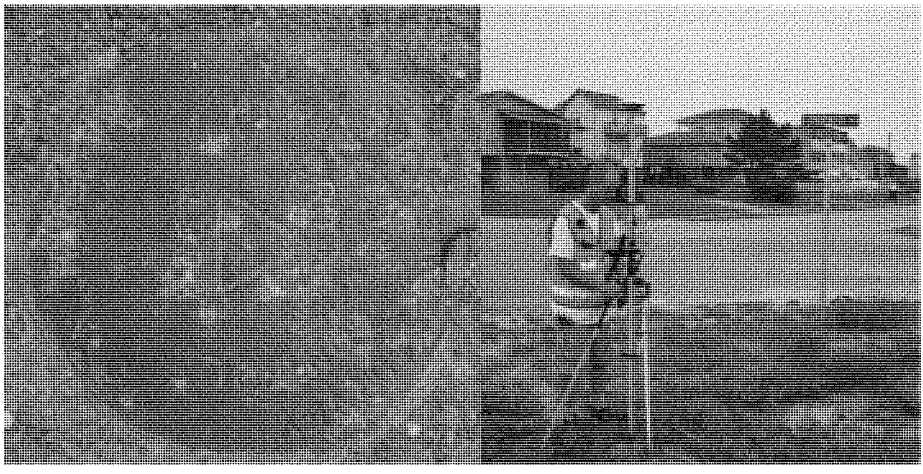


NCGS Mark Designated Crocker (1988)

DESIGNATION: CROCKER
PID: AI0831
STATE/COUNTY: NC/PENDER
USGS QUAD: HAMSTEAD (1970)

Current Survey Control:
NAD 83(1986): 34 21 36.36724(N) 077 38 12.12062(W) ADJUSTED
NAVD 88: 1.33 (meters) 4.4 (feet) ADJUSTED

LAPLACE CORR: -3.41 (seconds) DEFLEC99
GEOID HEIGHT: -37.34 (meters) GEOID03
DYNAMIC HT: n/a (meters) n/a (feet) COMP
MODELED GRAV: n/a (mgal) NAVD 88
HORZ ORDER: FIRST
VERT ORDER: THIRD



CGS Mark Designated A 230 (1947)

DESIGNATION: A 230
PID: EA0696
STATE/COUNTY: NC/PENDER
USGS QUAD: HOLLY RIDGE (1997)

Current Survey Control:
NAD 83(1986): 34 23 04.52612(N) 077 36 18.42596(W) ADJUSTED
NAVD 88: 3.480 (meters) 11.42 (feet) ADJUSTED

LAPLACE CORR: -2.97 (seconds) DEFLEC99
GEOID HEIGHT: -37.36 (meters) GEOID03
DYNAMIC HT: 3.476 (meters) 11.40 (feet) COMP
MODELED GRAV: 979,654.2 (mgal) NAVD 88
HORZ ORDER: FIRST
VERT ORDER: SECOND CLASS 0

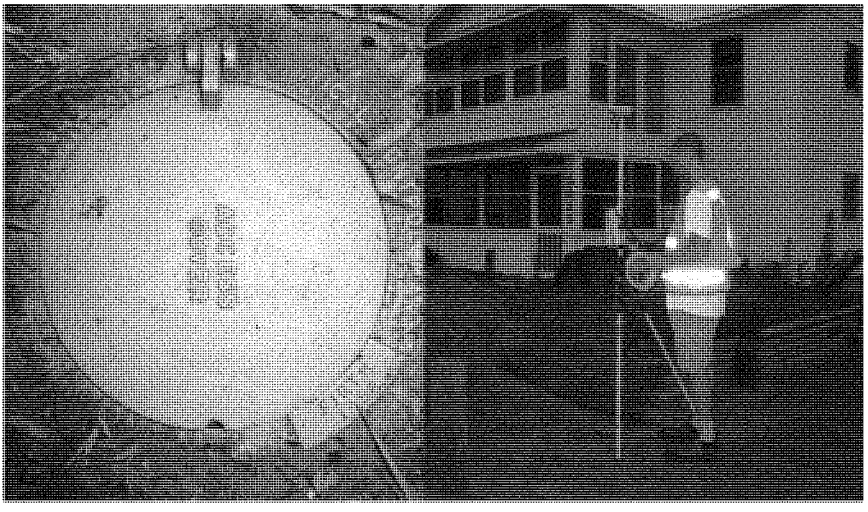


NGS Mark Designated Firth (1988)

DESIGNATION: FIRTH
PID: AI0904
STATE/COUNTY: NC/PENDER
USGS QUAD: HOLLY RIDGE (1997)

Current Survey Control:
NAD 83(1986): 34 26 46.68504(N) 077 30 43.60383(W) ADJUSTED
NAVD 88: 1.20 (meters) 3.9 (feet) ADJUSTED

LAPLACE CORR: -1.31 (seconds) DEFLEC99
GEOID HEIGHT: -37.40 (meters) GEOID03
DYNAMIC HT: n/a (meters) n/a (feet) COMP
MODELED GRAV: n/a (mgal) NAVD 88
HORZ ORDER: FIRST
VERT ORDER: THIRD



NCGS Mark Designated Sea AZ MK (1988)

DESIGNATION: SEA AZ MK
PID: AI0866
STATE/COUNTY: NC/PENDER
USGS QUAD: HOLLY RIDGE (1997)

Current Survey Control:
NAD 83(1986): 34 25 41.73477(N) 077 32 27.16683(W) ADJUSTED
NAVD 88: 2.57 (meters) 8.4 (feet) ADJUSTED

LAPLACE CORR: -1.79 (seconds) DEFLEC99
GEOID HEIGHT: -37.40 (meters) GEOID03
DYNAMIC HT: n/a (meters) n/a (feet) COMP
MODELED GRAV: n/a (mgal) NAVD 88
HORZ ORDER: FIRST
VERT ORDER: THIRD



Appendix C– Field Notes, Daily GPS Quality & Copy of Field Book

geodynamics
COMPLEX COASTAL CHANGE MADE CLEAR

Multibeam Daily Operation Proceedures & Checklist

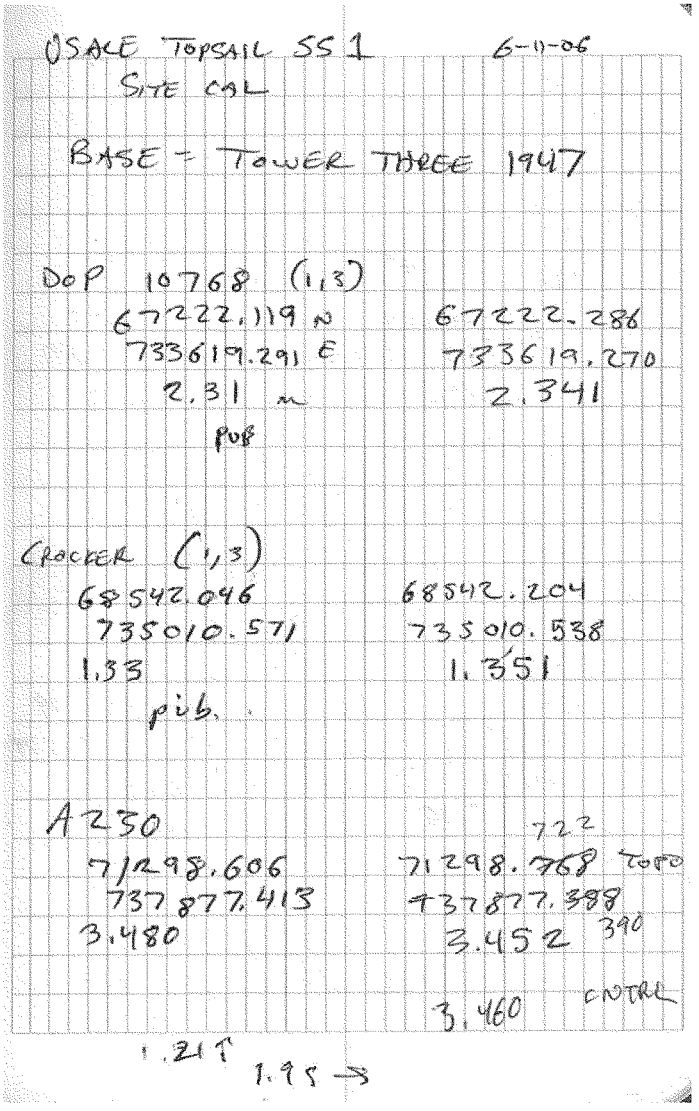
Pre-Survey Operations	Complete	Notes		
		Latitude (Northing)	Longitude (Easting)	Elev.
Perform Survey GPS Check	X	n/a	n/a	Δ0.017m
Power up POS MV	X			
Power up UPS	X			
Power up EM3002 PU	X			
Power up Acquisition PC	X			
Power up Navigation PC	X			
Power up Trimble GPS	X			
Perform BIST (head in water)	X			
Survey Operations		**Latitude (Northing)**	**Longitude (Easting)**	**Value**
Input Initial SV cast in SIS Runtime	X	34 20 42.48	077 38 46.45	1542.0
SV Cast #1	X	34 20 42.48	077 38 46.45	1542.0
SV Cast #2	X	34 23 49.52	077 34 57.73	1542.6
SV Cast #3	X	34 26 27.46	077 30 47.34	1543.7
SV Cast #4				
SV Cast #5				
SV Cast #6				
SV Cast #7				
SV Cast #8				
Vessel Draft Check (waterline to ducer)				0.53m

General Survey Notes	
Project	USACE Topsail SS1
Survey Area	Southern 11miles of Topsail nearshore
Sea State	2' SSE swell, glassy (am), surface wind chop by 2 pm
Wind	N 5 kts to variable (am), SE 10kts by 2pm)
Air Temperature	75 F(am), 91 F (pm)
Sea Temperature	
Tides	L: 8:55 am H: 2:54pm EST
Survey Features & Navigational Aids	N/A
Comments	- NAV from POS into ISIS for Side Scan at 19200 intermitten. Used Hypack NMEA out at 9600 for SS NAV. Can't split to auto helm. Get powered splitter operational. - Tide too low for acqusition in the nearshore first thing in am. Starting on mid lines - Trawling activity in Northern reach of survey bounds. Look for trawl scars in data - Water clarity excellent for this region. No New river water in place? - Check for new version of ISIS for Neuse River project. Improved bottom track?

Line Name	MS/CL	Direction	Notes
0	MS	NE	HP 7 7:04 am EST Start line
1	MS	NE	cont - SS swath at 90m
2	MS	NE	cont
3	MS	NE	cont
4	MS	NE	cont
5	MS	SW	HP 9 (spacing 100m)- start 9:10am EST
6	MS	SW	cont - SS swath at 135m
7	MS	SW	cont
8	MS	SW	cont
9	MS	NE	HP 11 (spacing 100m) - start 11:10am
10	MS	NE	HP 11 cont - SS swath at 135m
11	MS	NE	HP 11 cont
12	MS	NE	HP 11 cont
13	MS	SW	HP 5 - inshore line (same swath 135m)
14	MS	SW	HP 5
15	MS	SW	HP 5
16	MS	SW	HP 5
17	MS	NE	HP 13
18	MS	SW	HP 15
End Survey Day 6:50pm			
Side Scan Operation Notes			
23.5 ft length on tow line from block			
Position is 4.3m to STBD of Ships NAV PT			

Comments:
- We got a 3:40am start
- Setup basestation by 4:15am
- After another "slap test" of side-scan we left the dock at ~ 4:35am
- Made it to the New Topsail Inlet crossing at AIWW by 5:15am and out the inlet by 5:30am
- On the first line by 5:45am but having nav problems since ISIS won't take the string at 19200
- Finally were able to split nav from Hypack at 9600 but can't use auto helm. :(
- First line by 6:50am

Acquisition comments:
- Inshore lines have slight artifacts due to shallow water and possible aeration of water in surfzone
- Mid water lines looking a little cleaner
- Imaging old pilings from piers. very cool.
- Very distinct returns on possible hard bottoms in NorthEastern section of survey area. Low relief in bathy.
- Getting quite hot in cabin by 11am. Call Danny M. @ new AC unit.
- Using a 100m range on the inshore lines and ~ 120m on the outside. Overlap looking great.
- Slight seabreeze kicking up around 3pm. Data still looking good though.....
- Finished acquisition by ~ 6pm. Headed back to dock.
- Layback calculations and geometry in field book.


USACE TOPSAIL SS 1 6-11-06
SITE CAL

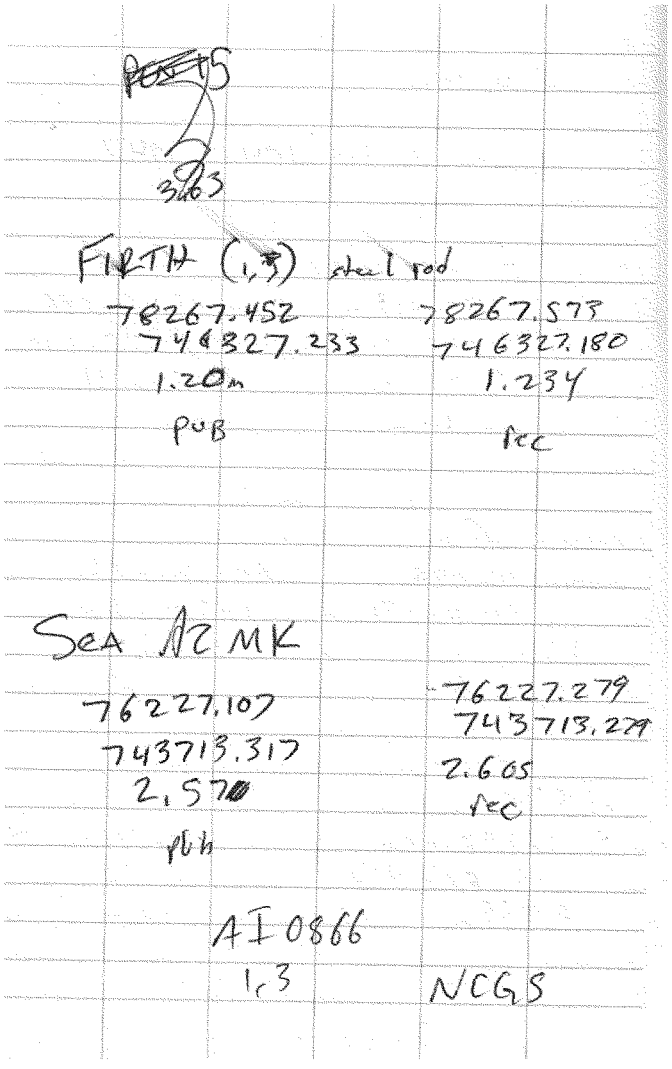
BASE = TOWER THREE 1947

DOP 10768 (1,3)
67222.119 N 67222.286
733619.291 E 733619.270
2.31 m 2.341
POB

CROCKER (1,3)
68542.046 68542.204
735010.571 735010.538
1.33 1.351
pob

A230
71298.606 71298.768 722 TOPO
737877.413 737877.388
3.480 3.452 390
3.460 CNTRL

1.21 ↑
1.95 →


3263
FIRTH (1,3) steel rod
78267.452
746327.233
1.20m
PUB
78267.575
746327.180
1.234
rec
SEA ATC MK
76227.107
743713.317
2.570
pbh
76227.279
743713.279
2.605
rec
AI0866
1,3
NCGS

USACE Topsail Side Scan

July 17, 2006

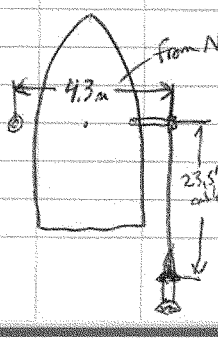
Mobilization

- left PKS ~ 12:15pm after USACE estimate
- Got boat in water + slip ~ 2:00pm
- Set up base on Tower 3
  - checked mark ~ 1.3cm!
- Set side scan + tested MB at Dock
- Turned off base and charge batteries for Survey

July 18, 2006

- left dock at 4:00am
- for survey notes see digital survey log!

Side Scan Measurements



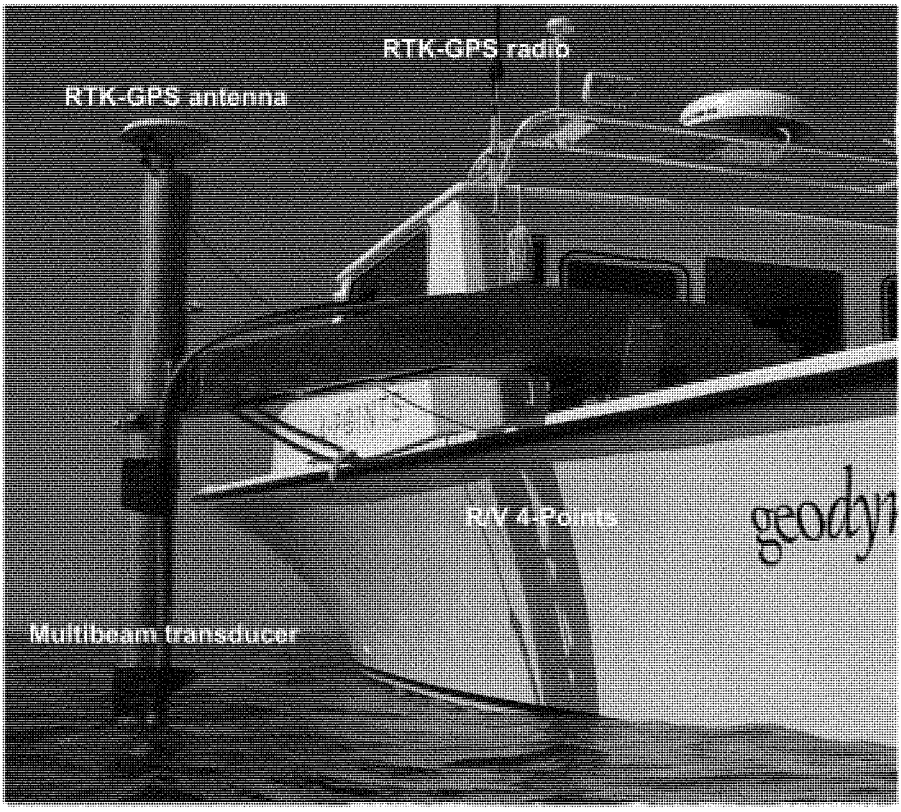
Cable out from block to fish = approx. 23.5'

Logbook calc would come to: 12.5 m roughly

Seems more like 6 in data

Appendix D - *R/V 4-Points* Setup & Instrument Accuracies

Multibeam Deployment



Side-Scan Deployment





Survey Instruments & Published Accuracies

Survey Vessel

The research vessel *4-Points* is a custom fiberglass survey boat designed specifically for shallow water sonar and acoustical operations. The vessel is 25' long with a 10' beam; the bottom tapers from a deep "Carolina" style Vee to a relatively flat-bottomed stern that provides a shallow draft of approximately 1.2'. Twin 140 four-stroke engines, hung on a stainless steel bracket, power the vessel. All electronics and generators are grounded to the sea via a bottom mounted bonding plate to eliminate all electrical noise. The transducer mount was engineered and designed at the University of North Carolina at Chapel Hill's Institute of Marine Science specifically for multibeam and ADCP surveys (Hench, et. al, 2000 "A portable retractable ADCP boom-mount for small boats". *Estuaries*, 23 (3): 392-399.). The mount was designed to keep the transducer below any potential bow wave and to also house the motion sensor directly over the transducer. Side-scan instrumentation is deployed, towed and retrieved from custom davit on starboard side.

Side-Scan Sonar Equipment

- **Klein 3000 side-scan sonar towfish**
  - Frequency: 132 kHz and 445 kHz
  - Transmission pulse: tone burst selectable from 25-400 usec. Independent pulse for each frequency
  - Beams: horz-100 kHz 7 degrees, horz-500 kHz 21 degrees, vertical-40 degrees
  - Range: 100 kHz to 450m, 500 kHz to 150m
  - Multiplexer: T1, 1.5 MB/sec
  - Note: There are no calibration reports associated with side-scan

Multibeam Equipment

- **Simrad EM 3002 multibeam sonar transducer**
  - Multi-Frequency: in 300 kHz band
  - Max ping rate: 40 Hz
  - No. of beams/ping: 254 Roll and Pitch stabilized
  - Beam width: 1.5^{o} x 1.5^{o}
  - Beam spacing: 0.9^{o}
  - Depth range from sonar head: 1 to 150 m
  - Depth resolution: 1 cm
  - Depth accuracy: 5 cm RMS
  - Range sampling rate: 15 kHz
  - Bottom detection by phase or amplitude. Seabed imaging & classification with backscatter (sidescan-like) output.
  - Full swath width accuracy to the latest IHO standard

- **POS MV 320 v4 Main Specifications (with RTK Corrections)**

- Roll, Pitch accuracy: 0.02° (1 sigma with GPS or DGPS) 0.01° (1 sigma with RTK)
- Heave Accuracy: 5 cm or 5% (whichever is greater) for periods of 20 seconds or less
- Heading Accuracy: 0.02° (1 sigma) with 2 m antenna baseline, 0.01 (1sigma) with 4 m baseline
- Position Accuracy: 0.5 - 2 m (1 sigma) depending on quality of differential corrections 0.02 - 0.10 m (RTK) with input
- Velocity Accuracy: 0.03 m/s horizontal

- **Trimble 5700 dual frequency GPS system & RTK-Basestation**
  - Instrument used for positioning and tidal corrections
  - High precision L1 and L2 measurements
  - 24 channels L1 C/A code, L1/L2 full cycle carrier
  - Extremely low latency (20 milliseconds)
  - RTK-GPS accuracy depends on conditions such as multipath, obstructions, satellite geometry, atmospheric parameters and basestation control quality.
    - Published horizontal accuracy: 10 mm + 1ppm RMS
    - Published vertical accuracy: 20 mm + 1ppm RMS

- **Odom Hydrographics Digibar Pro sound velocity probe**
  - Sampling rate: 10 Hz
  - Depth accuracy: > 31 cm
  - Velocity accuracy: +/- 0.3 m/sec

Computers & Software

- Rack mounted multibeam acquisition PC
  - 3.0 GHz Intel Pentium 4 processors with 800 MHz system bus
  - 1 GB of RAM
  - Triton Elics International (TEI) Isis version 6.2 acquisition software
  - CARIS HIPS/SIPS processing software

- Rack mounted Simrad multibeam power unit
  - EM3002 controller and power modulator

- (3) Fujitsu pentop navigation PC
  - Hypack Max.

- (4) Dell high-end GIS processing workstations
  - Arcview 3.3, ArcGIS 9.1, Surfer 8.0, Trimble Geomatics Office, Matlab 12, TEI Bathypro and DelphMap, CARIS

Backup field & processing computers and instrumentation

- (2) Dell laptops

- (3) Fujitsu pentop
- (5) Maxtor 250 – 300 gigabyte external backup drive

Appendix E – QTC Report

Quester Tangent

SIDESCAN SEABED CLASSIFICATION

Processing of Klein 3000 data

Prepared for Geodynamics LLC
SC75-840C
Issue Date: July 28, 2006



DATE	REVISION	DESCRIPTION
06.07.28	R00	Original Issue

COPYRIGHT

The QTC SIDEVIEW and QTC CLAMS and surrounding acoustic seabed classification technology is the sole property of Quester Tangent.

DISCLAIMER

Quester Tangent makes no representation or warranties with respect to the contents of this document and specifically disclaims any implied warranties of merchantability or fitness for any particular purpose. Further Quester Tangent Corporation reserves the right to revise this publication and to make changes to it from time to time without obligation of Quester Tangent Corporation to notify any person or organization of such revisions or changes.

Quester Tangent
Marine Technology Centre
201-9865 West Saanich Road
Sidney, B.C., Canada V8L 5Y8
Tel: 1-250-656-6677
Fax: 1-250-655-4696
www.questertangent.com

Table of Contents

Executive Summary 3

Introduction 4

Processing the Data 5

Sidescan Data Quality 8

Classification Results 13

Discussion and Recommendations 17

Selected Reading 18

APPENDIX A Format of Seabed File 19

List of Figures

Figure 1: Towfish heading and yaw rate in a line of Topsail data set 10

Figure 2: Towfish pitch and roll in a line of the Topsail data set 10

Figure 3. : Backscatter Mosaic of "Topsail" survey area. (source: Geodynamics Group) 13

Figure 4: Acoustic Classes Overlaid on Bathymetry 14

Figure 5 Interpolated classified point data set. 14

Figure 6: The results of automatic classification showing only Class 5 which is interpreted as reef. 15

Figure 7: Class 5 interpreted as reef only. The purple class (Class 5) correlates with the reef class seen on the sidescan sonar mosaic. Please see Figure 3 for location of this area. 16

List of Tables

Table 1: Cleaning tools. 5

Table 2. Survey lines in Topsail data set 11

Table 3: Cleaning parameters. 12

EXECUTIVE SUMMARY

Quester Tangent received approximately 5 GB of Klein 3000 XTF data acquired on July 18, 2006 by Geodynamics LLC from the Topsail, NC area. The data are from the first survey of a 2-phase project. The data were processed in QTC SIDEVIEW, automated seabed classification for sidescan sonar imagery. Although the overall results were less than satisfactory due to the challenges of acquiring sidescan data in a shallow water, very dynamic environment, some specific classes such as reef areas were well demarcated. Specific issues relating to original data quality and recommendations for improvement are outlined in the report.

INTRODUCTION

The following report describes the classification of a set of sidescan data using QTC SIDEVIEW. The original data were acquired using a Klein 3000 sidescan and provided to Quester Tangent on 2 DVDs in XTF format.

It is well known that the statistical characteristics of a sonar backscatter image depend on the bottom type. Even to a novice user, the texture differences between images of rocks, sand, and mud are readily apparent. Differences between silt and clay are less obvious. Statistical processing can capture many of the pertinent details of the interaction between the sound and the bottom and of its vertical relief. Multivariate statistics can then isolate those details that are rich in information about the bottom, producing features that contain the information necessary for accurate and reliable bottom classifications.

Image-based seabed classification is the segmentation of seabeds into discrete classes based on the characteristics of acoustic backscatter throughout a region. Segmentation is a valid and useful survey tool, even though it does not independently identify geophysical types. Dividing the seabed into classes is useful because seabed characteristics are relatively constant throughout a class and distinct from the characteristics of other classes. Therefore, the amount of ground truth that needs to be collected, visually or mechanically, is dramatically reduced. The strategy of identifying classes with a few samples and confidently extrapolating those characteristics throughout the acoustic classes is both scientifically valid and very cost effective.

The Quester Tangent approach to automated classification involves the data first being transformed into a format readable by QTC SIDEVIEW software. Both automatic and manual data quality assessment is performed throughout the process including the reformatting stage. Image patches or rectangles are placed on only the most suitable data. Features capturing the subtleties of image intensity and texture are generated. A statistical analysis helps to further refine the information to the point where classification can occur. Classification of the bottom that gave rise to these features is done by an automated clustering method that adapts to the characteristics of the multibeam or sidescan data set. Each cluster represents a bottom type, which can be identified based on ground truth; for example, photographs, grain-size analysis, or other local data. If the bottom type is known before classification, data from the areas of known sediment type can be used to build a catalogue, which would then be used to classify subsequent or archived data. This is called supervised classification. The alternative, unsupervised classification, forms the data into logical clusters that can then be identified based on ground truth. The effectiveness of unsupervised classification in uncovering practical and valuable information from the acoustic data has been demonstrated in many projects. This clustering technology, with its ability to easily perform supervised and unsupervised classification, forms part of QTC SIDEVIEW.

PROCESSING THE DATA

Loading Data

Backscatter images from a wide variety of sidescan systems can be loaded with position and ancillary data. Validation and quality control are important considerations. Backscatter data points can be flawed for various reasons, including tow fish and vessel motion, and interference from another sonar source. The data are cleaned to ensure the highest quality data available are presented to the classification. Data designated as not usable are captured in a mask. The mask is used to exclude regions of poor quality from further processing. QTC SIDEVIEW gives the user several cleaning options (Table 1).

Name	Function
Preserve Bottom Edits	The altitude line in the sidescan images may be edited. This function saves those edits.
Water Column Offset (m)	The water column must always be masked. This tool allows a specified distance from the altitude pick into the image to be masked.
Angle	The image can be masked using the sonar depression angle. The angle values are as follows: zero degrees is in the horizontal plane with the sonar and ninety degrees is directly below the sonar
Range (m)	Parts of the image can be excluded using absolute or percent range. All data greater than the specified range value will be masked.
Surface Echo (m)	The sidescan image may display some along track banding which does not represent the seafloor. This may be a result of surface echo. This tool allows for masking of this banding.
Preserve Border Edits	A tool is provided to edit the border in the sidescan images. This function saves those edits.
Despeckle	The program facilitates removal of speckle during feature generation. Despeckle level allows the user to choose the size of the median filter kernel (low, medium or high) used in the despeckle algorithm during feature generation.

Table 1: Cleaning tools.

Placing Rectangles

The seabed in the image is divided into rectangular patches. Patch placement depends on data quality through use of the mask. The mask and the user-selected patch sizing determine the number of patches per side (to port and to starboard). A class assignment will be generated for each patch.

Generate Features

A large number of features are extracted from the backscatter amplitudes in each rectangular patch of each image. QTC SIDEVIEW is able to use many features because Principal Components Analysis (PCA), in the next processing step, will select those combinations of features best suited to each data set.

For bottom classification, features are extracted from both backscatter image data and depth data using the following algorithms:

Basic Statistics: Mean, standard deviation, and higher-order moments are indicative of acoustic impedance changes and interface roughness

Quantile and Histogram: These measure the distribution of backscattered information intensities at low resolution.

Power Spectra: Fast Fourier Transforms (FFTs) are used to find power spectra, which describe statistical characteristics on many resolution scales.

Ratios based on Power Spectra (Pace): Ratios of log-normalised power in various frequency bands provide good discrimination for classifying images.

Grey-Level Co-occurrence Matrices: Grey-Level Co-occurrence Matrices (GLCMs) describe the amplitude changes over selected distances and directions in the image patch, and are widely used to assess texture.

Fractal Dimension: Fractal dimension is a sensitive measure of the distribution and structure of both backscatter and depth variations.

These features have been selected to capture as many useful aspects of the data as possible. As QTC SIDEVIEW was developed, the selection of features was frequently examined to determine which features were providing useful discrimination and to determine if any algorithm consistently produced redundant features. One interesting result from these studies was that mean intensity was rarely the sole determining feature in the overall classification process. It is combinations of intensity and texture that seem to drive classifications.

Multivariate Statistical Analysis

A major strength of QTC SIDEVIEW processing is the incorporation of multivariate statistical techniques as they permit the use of many features. Experience has shown that some features are important in what might be called the standard classifications: mud, sand, gravel, and so on. Others are important for more specialised classifications such as discriminating among sand/mud mixtures. For any particular data set, PCA selects the features that are most useful for the discrimination task at hand. Features that are close to constant are largely disregarded. Redundancies, that is, correlated features, are also acceptable, but only one remains significant. What is left is a reduced feature set that compactly describes the diversity of the data set. While some features may have little diversity or be tightly correlated when used to describe one set of seabed sediments such as open continental shelf sand and gravel, they may be found to give useful discrimination in other cases, such as on deltaic sediments. Thus, the connection between features and classification adapts to the character of the data set.

For each patch of each image, the features are calculated and then arranged as a row vector containing 132 elements. The name we give to these rows of features is Full Feature Vectors (FFVs). This information must be optimised or reduced without losing any details of the sediment. The dimension of the FFVs is reduced by multivariate statistical processing to isolate the combinations of features that are responsible for most of the diversity in the data set. In general, the top three combinations capture a very high percentage of the variance, so the rest of the combinations can be disregarded. These top three combinations are called Q-values.

The result of this reduction process is contained in the reduction matrix. Any FFV can be reduced to three Q-values by matrix multiplication. The reduction matrix is part of the catalogue used for supervised classification. New FFVs, derived from any subsequent acoustic survey, can be reduced to Q-values in this way as part of the supervised classification process. Alternatively, the multivariate statistical processing can be run on any partial or complete data set to find new information.

Cluster Analysis

The acoustic response - represented by Q1, Q2, and Q3 - from like seabeds will be similar. When plotted on a three-axis plot, called Q-space, points with similar values, for example from a single seabed type, form a cluster. Thus, data from three different seabeds form three clusters and new data points are classified based on their locations relative to the clusters in Q-space.

Each catalogue is specific to the sonar system used for data collection and may also be specific to particular operating conditions of that sonar.

Catalogues can be based on a set of sample sonar images or by sampling the whole data set. Over time, a library of classes could be produced from which various catalogues can be created, depending on the application. With the catalogue selected, the complete data file can be classified.

Classification of Seabed

Classify Seabed is the process of applying a catalogue to a data set. If the entire data set is used in an unsupervised classification process, the result is both a catalogue and a classified data set. Confidence and probability values are also calculated during Classify Seabed. If less than the entire data set was clustered, this step is used to classify all the data. Both these processes are unsupervised classification.

Catalogues can also be useful for supervised classification. In this process, each new patch is assigned to one of the clusters, or sediment types, based on a pre-existing catalogue.

Presentation

The final product is an ASCII comma-delimited file that can be imported into mapping software for the production of plots and 3D models. GIS systems are often used to demonstrate correlations between acoustic classes and other GIS layers. Another popular presentation is of the classifications draped over a bathymetric model of the surveyed area.

SIDESCAN DATA QUALITY

Data Challenges

The Klein 3000 data provided by Geodynamics presented significant quality challenges. The survey vessel was a small boat, operating in open seas with a substantial swell from the southeast. The maximum water depth was about 10 m. The sidescan was towed from a sheave supported overboard on the starboard side, on enough cable that it was about 6 m aft of the sheave (which was 4.3 m to starboard of the ship reference point). Other acoustic equipment that affected the sidescan images were an EM3002 on a pole on the vessel's port side and a sounder on the towfish.

Preparing the images for classification in QTC SIDEVIEW required an atypical amount of effort. Also, towfish instability introduced some artefacts into the images that could not be removed by pre-processing. These issues included:

Towfish yaw

Figure 1 shows towfish heading and yaw rate on a line from this survey. A heading is plotted for each ping time, and pings were 0.1 s apart. Because the horizontal beam width on the Klein 3000 is very small, yaw rates exceeding a few degrees per second can give non-recoverable gaps in images. The explanation goes like this: In plan view, sound is transmitted into a narrow fan. It takes a few milliseconds for sound to reach the seabed at typical ranges and for the echo to return to the towfish. The transmit and receive beams are identical, so as the towfish yaws they both sweep around. If they have swept more than some angle, the echo arrives at the towfish outside the receive beamwidth and is not recorded. The Klein 3000 has transmit and receive beamwidths of 0.3° (taken together, they give the advertised system beamwidth of 0.21°). It takes 67 ms for the round-trip to 50 m range. Thus echoes from 50 m are lost if the yaw rate exceeds 0.3°/0.067 s = 4.5 °/s. Much of the time, the yaw rates in Figure 1 are much larger than this. 31% of the time, they are less than 4.5 °/s. This is the primary explanation for bright and dark streaks in the outer parts of the images.

Towfish pitch

Erratic towfish motion is caused by vessel heave being transmitted down the towcable. This causes heave, which drives pitch unless the connection is precisely at the hydrodynamic centre of effort (which moves about, so this is impossible). Pitch and heave lead to yaw, roll, sway, and surge. Yaw has the most serious effect on the sonar image, with pitch second. In this survey, towfish pitch (Figure 2) had some effects, but it would be difficult to isolate these from those caused by yaw.

Towfish roll

Towfish roll does not lead to parts of the image going missing but can affect the image in other ways. The vertical beam pattern is very broad (about 40° for the Klein 3000), far exceeding any occurring towfish roll. However details of the beam pattern move across the image with roll. There is less backscatter amplitude near nadir to port, suggesting that this towfish tows slightly port up.

Low altitude

The towfish altitude, that is, its height above the seabed, ranged from 0 to 6.5 m during this survey, and was often only 2 m or so. At the ranges used, 50 or 75 m, the angle between the sound ray and the bottom, the grazing angle, is very small, less than 1° through most of the range. Very small grazing angles give very large shadows for even small bottom irregularities, and indeed big parts of these images are shadow. This is not ideal for acoustic seabed classification since the amplitude and texture of seabed backscatter from these areas have been lost.

Bottom Picking

There is a sounder on the towfish to record towfish altitude. This is often done on sidescan towfish because the sidescan transducers send very little power vertically down, meaning that the start of the sidescan seabed echo is often not a reliable measure of altitude. Altitude is needed for slant-range correction and for image compensation. (QTC SIDEVIEW does slant-range correction of classified positions, not of the image). During this survey, though,

only an erratic small fraction of these altitudes was logged. This meant several hours of work manually tracing a bottom pick for each line.

Interference from a multibeam echosounder

Crosstalk between different acoustic systems operated simultaneously is often found, even if their primary frequencies are quite different. If one is an imaging sonar, interference is often called walkover, because the extraneous echoes appear atop the image. If the systems are unsynchronised, as they often are, the interference appears in regular patterns, loosely suggesting footprints. In this survey, the EM3002 on the port side walked over the port sidescan image. Typically, it can be seen only at ranges greater than about 40 m, because the sidescan gain increases with range. In some lines the walkover is a major interference; in others it can barely be seen. One reason may be that the towfish was astern of the multibeam, and thus receives the multibeam echoes only when yawed appropriately. Walkover can have a major effect on classification because it adds a major artificial texture. Either it has to be filtered away, or these regions must be excluded from the classification process. In QTC SIDEVIEW, the despeckle filter is effective at averaging away the walkover, but also smoothes the entire image. While this may have been effective in this survey, the approach that was taken was to mark a border on the images, the inner boundary at which the walkover appears. In 14 lines, borders were drawn on the port side at ranges near 40 m. On half of these, multipath reverberation caused some walkover to starboard at long ranges (where the gain is high), so border s were drawn near 60 m, typically, to exclude ranges beyond that from classification.

Wake

With the towfish 6 m aft of the sheave, the vessel wake was above it and to port. It could be seen clearly on six lines, at a range of 4 m. Eddies from the wake sometimes extended to almost 6 m. QTC SIDEVIEW contains a filter for this situation, called the surface-return filter. It was used to mask the image from 3.7 to 5.5 m on these lines. This filter operates on both sides, so the same mask had to be applied to the starboard image, even though it was not needed there.

Artificial samples at end of each ping

A common artefact in Klein imagery is that the last 40 or so samples of each ping are artificially large, often at or close to the maximum possible digital value. QTC SIDEVIEW has a filter for this. It was used to remove the last 3% of each ping from the region to be classified.

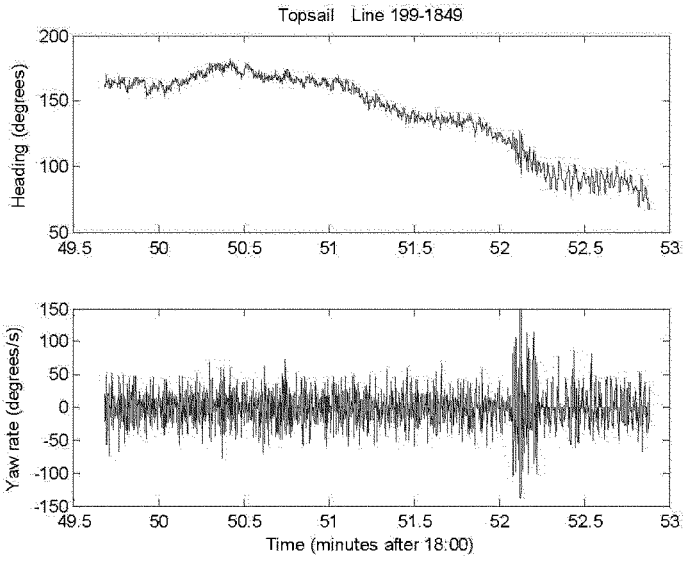


Figure 1: Towfish heading and yaw rate in a line of Topsail data set

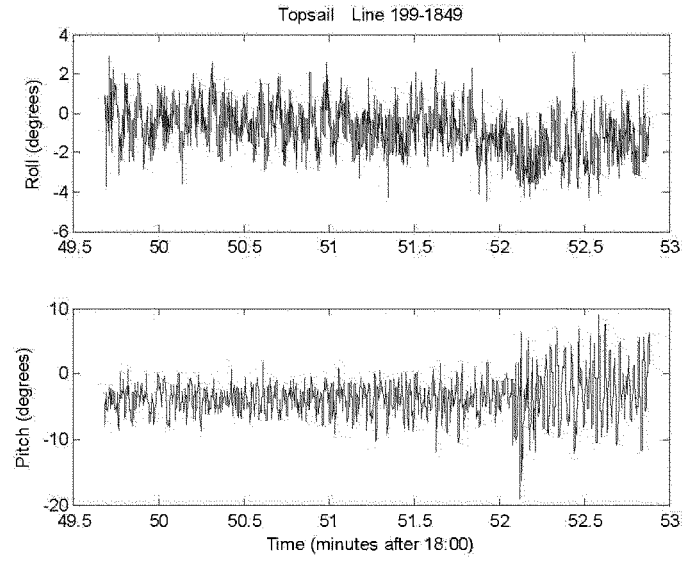


Figure 2: Towfish pitch and roll in a line of the Topsail data set

Individual Line Cleaning

Table 2 shows an assessment of each line and the cleaning process used for it. In addition, bottom picking was done for each line.

Line number	Sonar range (m)	Typical altitude (m)	EM3002 walkover on port image	Border cleaning applied	Wake cleaning applied
199-1104	50	0 – 4	> 40 m, important	Yes	Yes
199-1122	50	1.4 – 4	Not evident		
199-1139	50	0.8 – 2	Not evident		
199-1157	50	3 – 4	Not evident		
199-1214	50	2.5 – 4	Not evident		
199-1232	50	3	Not evident		
199-1312	75	4	> 50 m, important	Yes	
199-1317	75	3.5 – 5	Negligible		
199-1335	75	4	Negligible		
199-1353	75	4	Negligible		
199-1410	75	4	Negligible		
199-1428	75	4	Negligible		
199-1446	75	0 – 4	> 55 m, important	Yes	
199-1507	75	1.5	> 35 m, important	Yes	
199-1508	75		Issues with altitude	Ignore line	Ignore line
199-1509	75	2 – 4	> 45 m, important	Yes	
199-1527	75	4 – 5	> 60 m, important		
199-1545	75	5	> 60 m, important		
199-1603	75	5	Negligible		
199-1620	75	5.5 – 6.3	> 650 m, important		
199-1638	75	5.5 – 6.5	Negligible		
199-1656	75	6	Negligible		
199-1658	75	1 – 5	Negligible		
199-1701	75		Often on bottom	Ignore line	Ignore line
199-1703	75	1 – 2.5	> 40 m, important	Yes	
199-1720	75	1.4 – 4	> 40 m, important	Yes	
199-1738	75	1	> 40 m, important	Yes	Yes
199-1756	75	1 – 2	> 40 m, important	Yes	Yes
199-1814	75	1.5 – 3.4	> 40 m, important	Yes	Yes
199-1831	75	0.5 – 2.2	> 40 m, important	Yes	Yes
199-1849	75	1.3 – 4	> 40 m, important	Yes	Yes
199-1853	75	5	> 40 m, important	Yes	
199-1911	75	5	> 50 m, important	Yes	
199-1919	75	5	Negligible		
199-1920	75	4 – 5.5	Negligible		
199-1938	75	4	Negligible		

Table 2. Survey lines in Topsail data set

Processing Parameters

In addition to the line by line cleaning detailed in Table 2, Table 3 outlines additional cleaning parameters used. Rectangle size was 17 pixels along track by 129 pixels across track, which generated 388017 records. This represents an approximate seafloor footprint of 4.0 metres by 4.0 metres.

Name	Value
Preserve Bottom Edits	Yes
Magnetic Variation	24^0
Angle	As specified in Table 2
Range (m)	As specified in Table 2
Surface Echo (m)	Yes, where applicable
Preserve Border Edits	Yes
Despeckle	No

Table 3: Cleaning parameters.

Additional Filtering

Additional filtering of the FFV data was done as follows:

Time

From 18:49:40 to 18:54:10, to remove the 180° turn in the southwest corner. Filtered 3082 records.
From 19:19:13 to 19:22:22, to remove the 180° turn part ways up the east edge. Filtered 686 records.

Slant range

Slant range > 50 m. Filtered 70873 records. This aids somewhat in reducing range dependence, in that it hides the longest-range rectangles.

CLASSIFICATION RESULTS

Prior to the presentation of the classification results it helps to understand the nature of the backscatter from the entire survey area. This is important when analyzing the relationship between the geology, its backscatter response and the results of the automated classification. This is accomplished by the generation of a backscatter mosaic as shown in Figure 3.

Unsupervised classification was applied on a line by line basis and 8 classes were identified. The results are presented in Figure 4 as a series of data points, where individual points are assigned a class. Additionally, the data can be interpolated to provide a gridded plot suitable for overlay on bathymetry. QTC CLAMS was used to generate such a plot (figure 5). The class colours used in Figure 5 are termed "similarity colours". Acoustically similar seabeds are displayed using similar colours. It is important to understand that the plot is a map of acoustic diversity. It is incumbent on the interpreter to assign labels such as "reef" to the classes based on an interpretation of the original backscatter data or ground truth data.

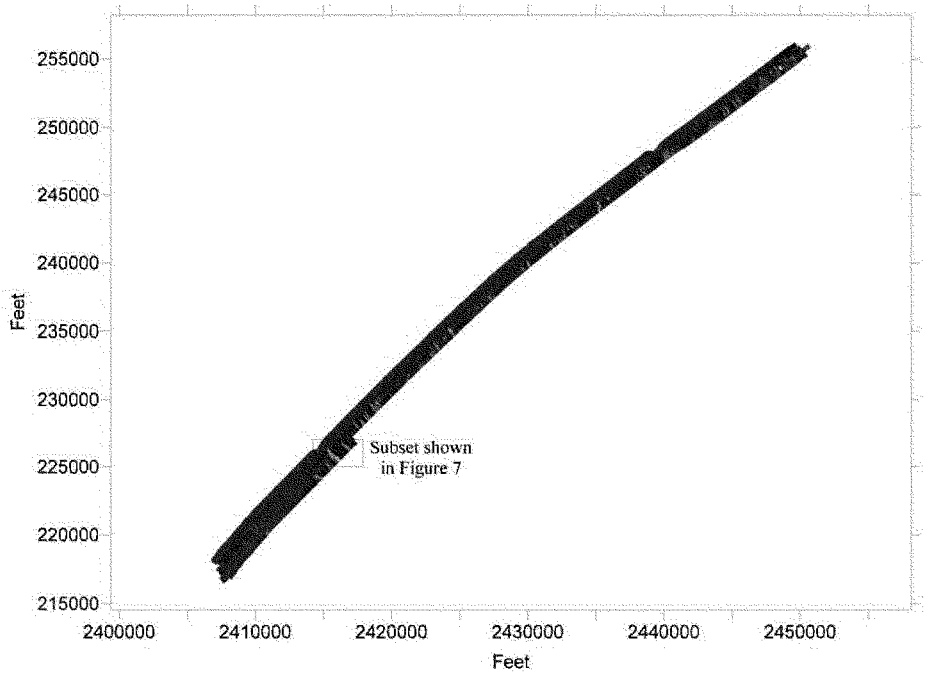


Figure 3. : Backscatter Mosaic of "Topsail" survey area. (source: Geodynamics Group)

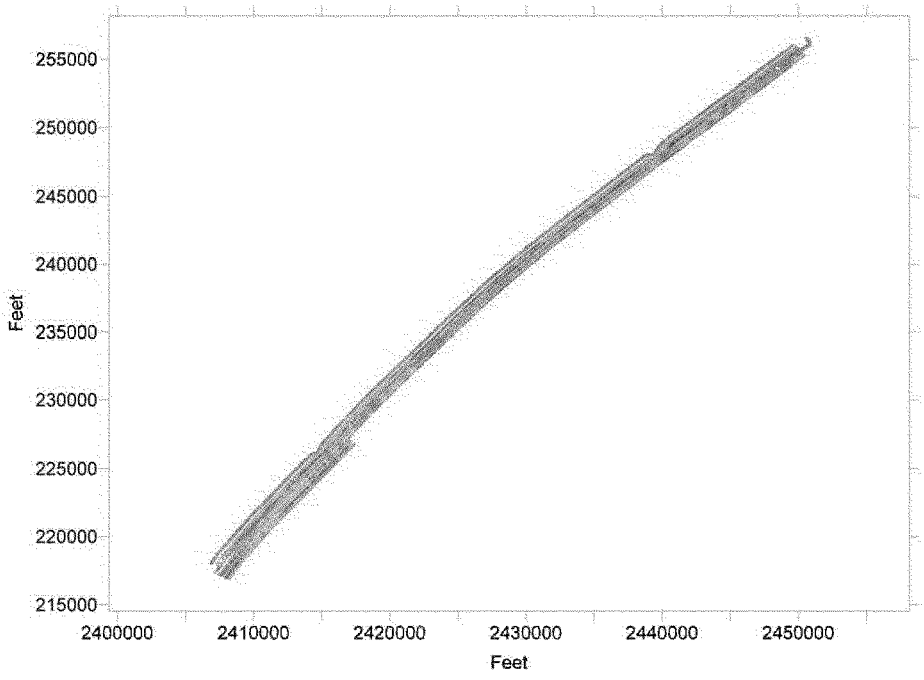


Figure 4: Acoustic Classes Overlaid on Bathymetry

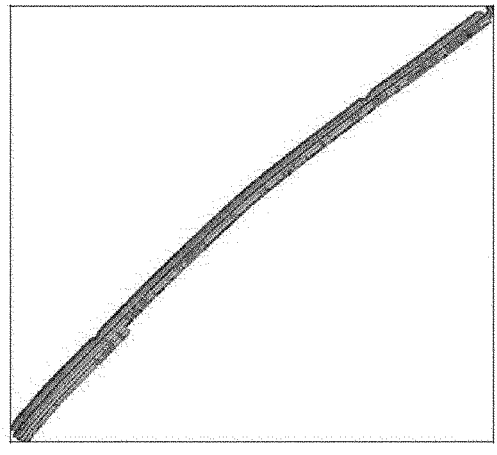


Figure 5 Interpolated classified point data set.

The results were not of the high quality normally achieved when processing data in QTC SIDEVIEW. Several examples of Klein 3000 data in XTF format have been processed previously with excellent results. The striping in the classification particularly evident on Figure 5 is a result of the original data quality. The classification has nevertheless identified the reef areas as a unique class, as shown in Figure 6.

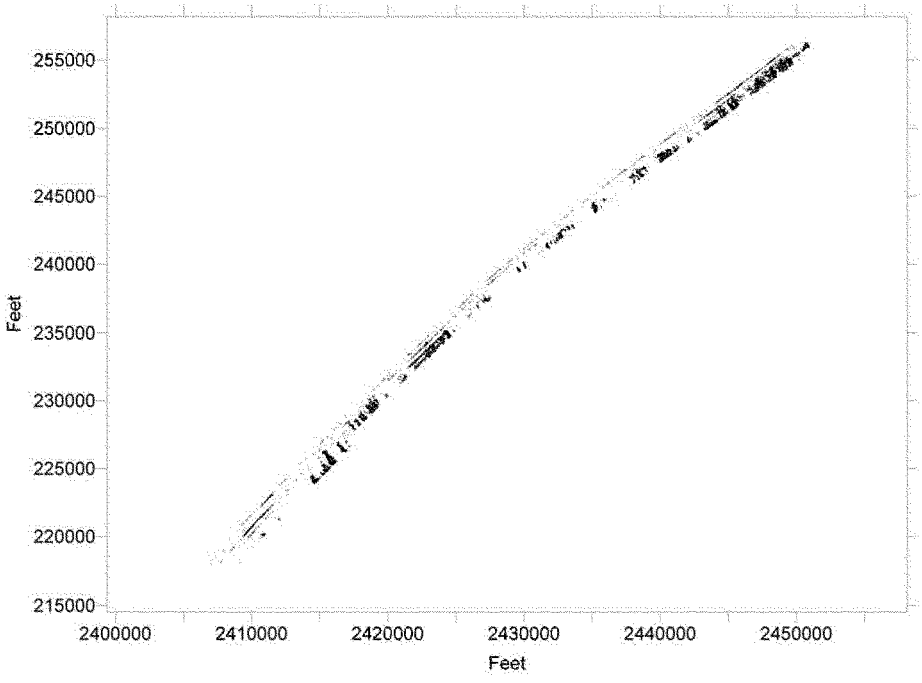


Figure 6: The results of automatic classification showing only Class 5 which is interpreted as reef.

A subset of the imagery is shown in Figure 7. The individual records associated with each original rectangular patch on the image are plotted on the backscatter mosaic. There is a clear correlation between the high intensity backscatter interpreted as reef and the purple class. The other note is the apparent offset in the heading causing the records associated with each ping to be somewhat oblique to vessel track.

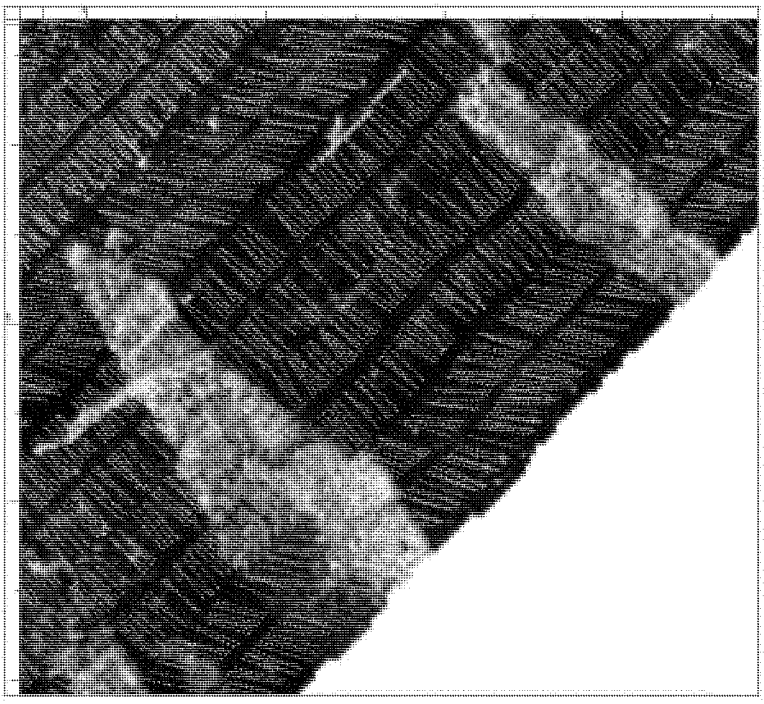


Figure 7: Class 5 interpreted as reef only. The purple class (Class 5) correlates with the reef class seen on the sidescan sonar mosaic. Please see Figure 3 for location of this area.

DISCUSSION AND RECOMMENDATIONS

While there are numerous challenges relating to the acquisition of sidescan sonar, data perhaps the two that stand out are the stability of the towfish and the towfish altitude. Given the environment in which the data were collected this is not surprising. Indeed, the results as shown in the sidescan sonar mosaic are quite acceptable for manual interpretation of the geology. The combination of these acquisition challenges however, diminish the ability automatic classification of all except for the most broad features (e.g. reefs) and perhaps even the subtleties of the geology as interpreted by a marine geologist or geophysicist.

Based in information passed on by the client there exist a veneer of sand over top of some of the reefs. This is evident from the existence of sandwaves. Typically sandwaves exhibit a regular pattern in texture that can be identified in QTC SIDEVIEW. Only the "reef class" could, for example, be submitted to the statistical analysis and clustering to identify "subclasses" of reef with a veneer of sand. Given the data quality previously mentioned this advanced processing was not considered.

Recommendations

1. Given the environment it might be advisable to experiment with a fixed hull or pole-mounted towfish to maximize altitude (rule-of-thumb is altitude 10% to 15% of max. range). This should have the added advantage of reducing fish yaw.

2. If possible, refrain from having an echosounder at similar frequency running at the same time as the sidescan sonar data are being collected.

3. Having access to good quality bottom picks would have decreased the amount of time taken for automatic classification. We recommend an analysis of the reasons for the poor quality bottom picks in the data.

SELECTED READING

J. T. Anderson, R.S. Gregory, and W.T. Collins, Acoustic classifications of marine habitats in coastal Newfoundland, *ICES J of Marine Science* vol. 59, pp. 156-167, 2002.

J.M. Preston and A.C. Christney, Compensation of sonar image data primarily for seabed classification, US Patent Application serial number 427624, 2004.

N.G. Pace and H. Gao, Swathe Seabed Classification, *IEEE J. Oc. Eng.*, 13, pp. 83-90, 1988.

J.M. Preston, A.C. Christney, L.S. Beran and W.T Collins, Statistical seabed segmentation – from images and echoes to objective clustering. In *Proc. of the 7th. European Conference on Underwater Acoustics*, 813-818, Delft, Netherlands, 2004.

J.M. Preston, A.C. Christney, L.S. Beran and W.T Collins, R.A. McConnaughey, and S.E. Syrjala, Considerations in large-scale acoustic seabed characterization for mapping seabed habitats. *ICES Annual Science Conference*, CM 2004/T:13, Vigo, Spain, 2004.

R.M. Haralick, K. Shanmugam, and I. Dinstein, Textural features for image classification, *IEEE Trans. Syst. Man Cybern.* SMC-3, pp. 610-621, 1973.

APPENDIX A FORMAT OF SEABED FILE

The default position format is geographical decimal degrees. For this survey the data were converted to survey feet.

An example of a *.seabed file is given below:

20030406,170547453,-122.85029029,48.60624788,-25.22,18.86254692,-4.39753675,-99.68022919,99,
72,01,CLASS_01,MIDDLEBANK,20030406,114_1705,9,0

The above sample classification record is interpreted as follows:

Field Index	Field Value	Representation
A	20030406	the date-stamp (yyyymmdd) for that record
B	170547453	the time stamp (hhmmssms) for that record
C	-122.85029029	the longitude in decimal degrees
D	48.60624788	the latitude in decimal degrees
E	-25.22	the depth expressed in metres, displayed as a negative value
F	18.86254692	Q-Space value Q1
G	-4.39753675	Q-Space value Q2
H	-99.68022919	Q-Space value Q3
I	99	the class confidence in percent
J	72	the class probability in percent
K	01	the class ID
L	CLASS_01	the class name
M	MIDDLEBANK	the source vessel or survey name
N	20030406	the source date-stamp
O	114_1705	the source data set name
P	9	the source FFV file ID
Q	0	the source FFV file record index

Feasibility Report
and
Final Environmental Impact Statement

on

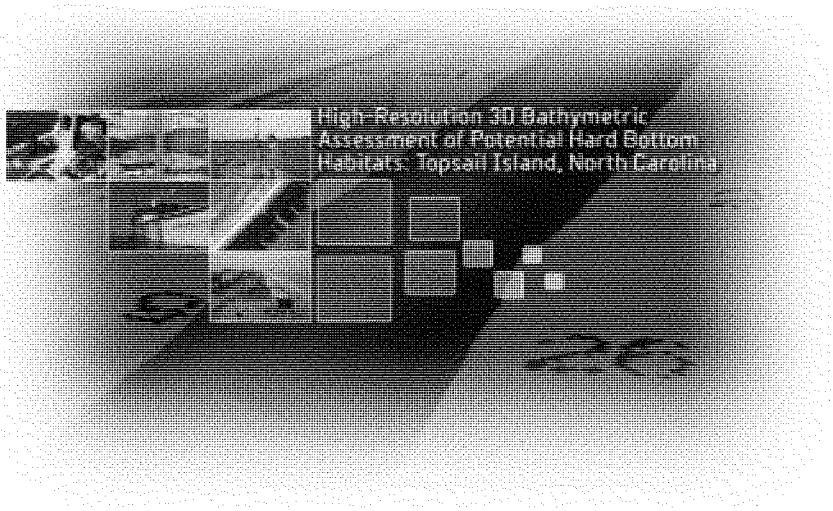
Coastal Storm Damage Reduction

SURF CITY AND NORTH TOPSAIL BEACH
NORTH CAROLINA

Appendix R
Attachment 3

High-Resolution 3D Bathymetric Assessment of Potential Hard Bottom Habitats: Topsail Island, Surf City and North Topsail Island, NC

High-Resolution 3D Bathymetric Assessment of Potential Hard Bottom Habitats: Topsail Island, Surf City and North Topsail Island, NC January / February 2007



Survey Report

Project No. DACW54-02-D-0006, Delivery Order 0035 Modification 01 Nearshore Hardbottom Sidescan Survey for Multibeam Data Collections Topsail Island, NC
G&O Project Number 146046.T35.6481.GEO

Submitted by:

GREENHORNE & O'MARA
CONSULTING ENGINEERS

With Subconsultant:

geodynamics
COMPLEX COASTAL CHANGE MADE CLEAR

TABLE OF CONTENTS

TABLE OF CONTENTS ii

Executive Summary 1

Survey Preparation 1

Survey Area 1

RTK-GPS Survey Control & Multibeam Calibration 3

Introduction & Purpose 3

RTK-GPS Network Adjustment & Site Calibration 3

Multibeam Echosounder Calibration Report 8

Data Processing Routines & QA/QC Information 14

Introduction 14

Bathymetry Processing 14

TPE (Total Propagated Error) 15

Topsail Island Multibeam Workflow Diagram 17

Topsail Island Multibeam QA/QC Workflow Diagram 18

Graphical Summary of Deliverables 19

Appendix B – Field Notes 30

Appendix C – Equipment & Instrument Accuracies 56

Executive Summary

Geodynamics LLC was contracted by the USACE Wilmington District through Greenhorne & O'Mara Inc. on January 16th 2007 to perform a detailed bathymetric survey (phase 2) of zones identified as potential hard bottoms from the July 2006 side-scan sonar study performed by Geodynamics in July 2006 (phase 1). The January 26 – February 6th multibeam surveys employed a Simrad EM3002 shallow water multibeam sonar system to collect spatially dense bathymetric data across 0.85 square miles of seafloor for the development of an accurate surface model as described in the official Scope of Work (Appendix A). The system runs at 300 kHz and is compensated for motion and heading with an Applanix POS MV 320 v4 inertial navigation system. Sensor offsets have been surveyed to close within 1 millimeter by the National Geodetic Survey. The EM3002 produces a swath of sonar approximately 4 times the water depth and collects approximately 400 soundings per square meter. Sound velocity was calculated in real-time at the transducer head with an Applied Microsystems miniSV and profile data was collected with an Odom Digibar Pro.

Tidal corrections and positioning information were acquired using a site calibrated Trimble 5700 Real-Time Kinematic GPS (RTK-GPS) system integrated with the POS MV 320 through a Pacific Crest PDL radio modem. The RTK-GPS system uses a land-based station coupled with a 25-watt radio and a Maxrad 5 dB high-gain antenna to broadcast the computed real-time horizontal and vertical corrections at 10 Hz to the hydro survey platform. To compute centimeter-scale position and elevation information, determine the relationship between WGS-84 and local grid coordinates, and to evaluate the local geoid-spheroid separation, we first performed a detailed network adjustment and site calibration. Information on the site calibration can be found in the corresponding section of this final report and published accuracies on each of the systems can be found in Appendix C.

Survey Preparation

Survey Area

Topsail Island is located approximately 20 miles northeast of Wilmington and separates Lee Island to the south and Onslow Beach to the north. The Topsail Island nearshore survey was comprised of 18 planned survey lines (6 line per survey area) spaced 70' to 90' apart to obtain 100% seafloor coverage (Figure 1). The total area of the survey encompassed 0.85 square miles with a total of 57 line miles.

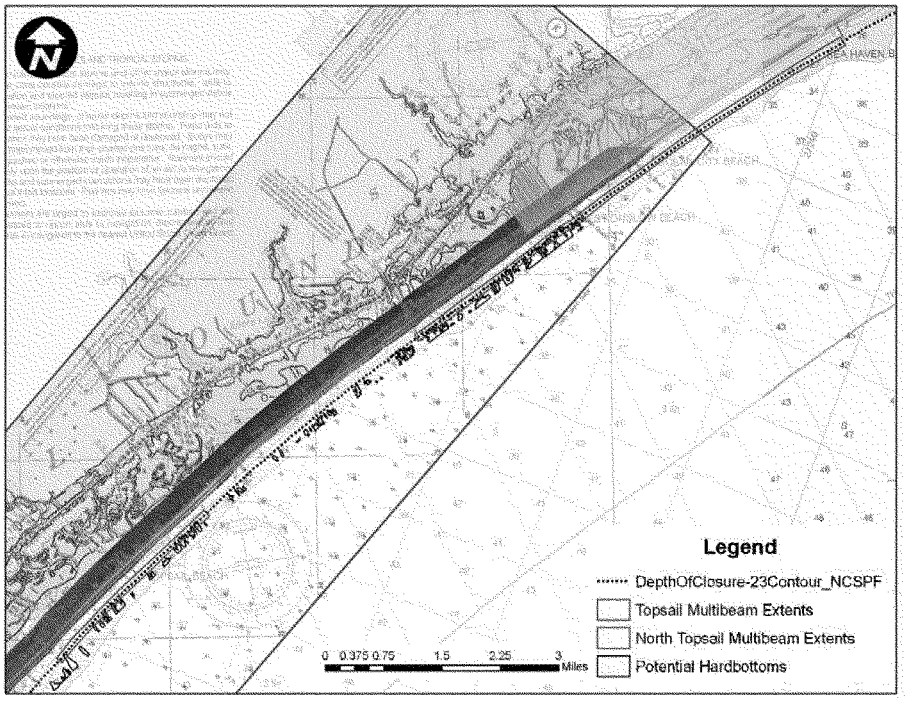


Figure 1. Map of Topsail, Surf City and North Topsail Island survey extents.

RTK-GPS Survey Control & Multibeam Calibration

Introduction & Purpose

The most common problem in accurately measuring the seafloor with any sonar-based system, especially in and around a tidal inlet, is the calculation of the tidal elevation offset. Commonly a tide staff or gauge is deployed in one location near the survey site and is used to calculate the tides for the entire survey area. However, it is widely understood that non-linear tidal phenomena, phase lags and tidal gradients can drastically influence the tidal elevation spatially across a tidal inlet and therefore the use of a single point measurement is often unreliable.

To avoid these potential tidal elevation errors which can translate into significant departures from the true bottom depth, we use geodetic Global Positioning Systems (GPS) with real-time kinematic (RTK) baseline processing that is integrated with the multibeam and inertial navigation instruments. The motion and Geoid 03 compensated positions and orthometric elevations of the RTK-GPS data stream are tagged with each sonar ping. In effect, the RTK-GPS mounted on the hydrographic survey vessel acts as a roving tide gauge collecting the most accurate tidal measurements throughout the survey area.

Multibeam swath sonar systems combine a complex array of instruments, consisting of the transducer, motion sensor, inertial navigation, and geodetic GPS systems. Standards developed by the International Hydrographic Organization (IHO), USACE Standards for Hydrographic Surveys, and the NOS Hydrographic Surveys Specifications and Deliverables for shallow water (<30 m) hydrography (IHO 1987; USACE 2003; NOS 2006) are used as the protocol for calibration. Proper alignment of these instruments with one another and with the vessel's reference frame is critical to achieve the high-accuracy required in the SOW. Calculation of the horizontal and vertical offsets between each of the instruments completed by the National Geodetic Survey is followed by a series of sea-based measurements known as the patch test.

The patch test is performed to calculate several residual biases influenced by the dynamics of the survey vessel and the alignment of the instruments. Results of the patch test, documented in the following sections, are used to calculate a pitch, roll and heading offset and positioning time delay or navigation latency. Additional calibration measures are performed in the field including comparison of nadir depths with a lead line and frequent sound velocity profiles. The results of these daily field checks can be found in the html metadata file accompanying the final soundings.

RTK-GPS Network Adjustment & Site Calibration

There are many environmental and operator-based influences that can affect the accuracy of RTK-GPS and the resultant baseline solutions (Bilker 2001; Trimble

Navigation Limited 1998; Magellan Corporation 2001). Although RTK-GPS is an emerging tool among hydrographers, little attention has been given to an accuracy standard for this methodology—especially in the field of coastal mapping and monitoring (Morton et al., 1993). In an effort to limit operator error and to quantify daily environmental error, we have developed an internal standards protocol for RTK error estimation based on thresholds developed by the California Department of Transportation and the US Army Corps of Engineers (USACE) Topographic Accuracy Standards (CALTRANS 2002; USACE 1994).

The first step in our protocol is to determine an appropriate land-based GPS station that will provide the most accurate corrections and range to the outer limits of the survey area. Phase one of the project we used a benchmark atop a circa 1940's rocket observation platform called "Tower 3". Our initial plan was to use this mark for phase 2 of the project; however, after approximately 3 weeks of trying to contact the owner for access to the site we were unable to reach the current owners of the property. We then chose to use "A230", which is approximately 0.5 miles south of "Tower 3".

The second step in our RTK-GPS protocol was to perform a detailed GPS site calibration on the new basestation prior to the collection of any hydrographic survey data. The site calibration is used to determine the basestation quality relative to the local network of NGS and NOS survey control and to analyze any potential spatial separations between the local geoid heights (GEOID 03) and ellipsoidal values (WGS-84) that may influence the resulting orthometric elevations. The calibration entails selecting the control to be used for the RTK-GPS basestation receiver and radio broadcast system and then checking at least three known geodetic benchmarks of exceptional horizontal and vertical quality within and even outside the survey boundaries. The benchmarks are occupied in "site calibration mode" over 300 epochs or approximately 3 to 5 minutes.

A detailed RTK-GPS site calibration for phase 2 of this project was performed on January 26, 2007 prior to the start of the multibeam data acquisition phase. Three benchmarks from various government and state agencies were used in the calibration and results can be found in Table 1. Results showed an average deviation of 4.8cm (0.157') in the Northing, 1.5cm (0.049') in the Easting and 3.0cm (0.098') in the Elevation.

geodynamics
COMPLEX COASTAL CHANGE MADE CLEAR

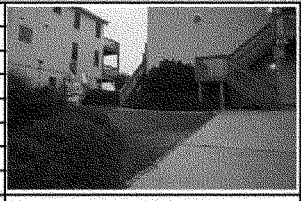
RTK-GPS Pre-Survey Site Calibration

General

Date	1/26/2007
Project	USACE Topsail Island Multibeam - phase 2
Surveyor(s)	Freeman / Bernstein
Equipment	Trimble 5700 Basestation, Trimmark III 25 watt RTK Radio, Maxrad 5dB gain Antenna, Zepher Geodetic base antenna, Trimble 5700 RTK rover, Zepher antenna
Weather	Sunny, Few Clouds, 45 F, NW Wind 15-25 kts, gust to 30 kts
Units	Meters
Notes	Access to Tower 3 basestaion used in phase 1 could not be obtained. A230 was then selected as the best possible RTK-GPS basestaion. Base was set on A230 and marks were checked to verify RTK quality throughout the survey extent.
Coordinate System	NC State Plane, NAD83 (horiz), NAVD88 (vert)

Basestation Information

Designation	A230
PID	EA0696
Agency	CGS
Horiz Order	1
Vert Order	2
N	71298.606
E	737877.413
Z	3.480



A230



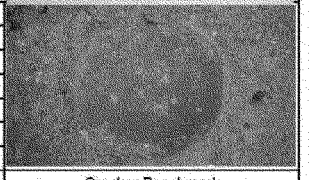
A230 Benchmark

Benchmark Checks

Designation	CROCKER
PID	AI0831
Agency	NCGS
Horiz Order	1
Vert Order	3

	Recorded	Published	Difference
N	68542.047	68542.046	-0.001
E	735010.569	735010.571	0.002
Z	1.323	1.33	0.007

Notes	Benchmark is at intersection of Crocker and S. Anderson

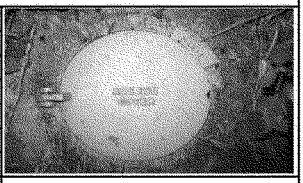


Crocker Benchmark

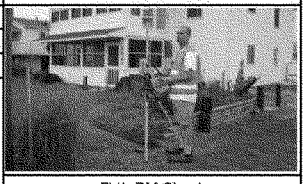


Crocker BM Check

Benchmark Checks (cont.)			
Designation	FIRTH		
PID	AI0904		
Agency	NGS		
Horiz Order	1		
Vert Order	3		
	Recorded	Published	Difference
N	78267.399	78267.452	0.053
E	746327.217	746327.233	0.016
Z	1.246	1.20	-0.05
Notes	Benchmark is on NW side of W 9th St. North of Surf City.		



Firth Benchmark

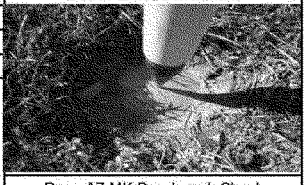


Firth BM Check

Benchmark Checks (cont.)			
Designation	DUNE AZ MK		
PID	AI0855		
Agency	NCGS		
Horiz Order	1		
Vert Order	3		
	Recorded	Published	Difference
N	82569.585	82569.674	0.089
E	752975.095	752975.121	0.026
Z	1.698	1.66	-0.038
Notes	see NGS datasheet for location description		



Dune AZ MK Benchmark



Dune AZ MK Benchmark Check

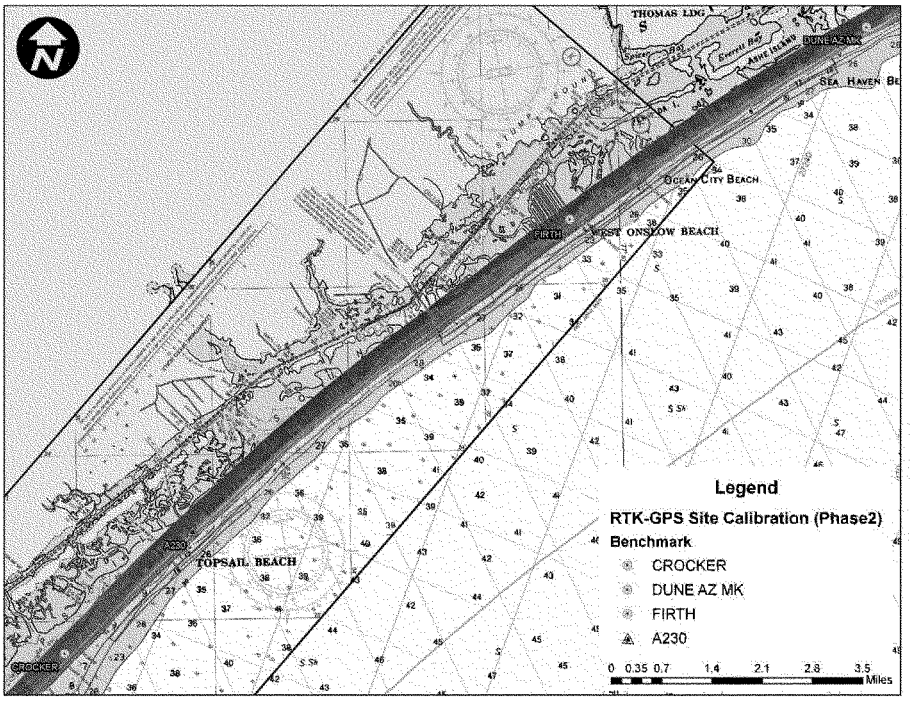


Figure 2. Map of new site calibration on A230 and the BM's checked.

Multibeam Echosounder Calibration Report

Calibration Date:	April 19, 2006
Ship	
Vessel	RV 4-Points
Echosounder System	EM3002
Positioning System	POS MV (tightly coupled)-RTK GPS
Attitude System	POS MV
Sound Velocity Probe	Odem Digibar Pro (profiler) / Valeport Mini SVS (at head)

Annual		
Installation	x	
System change	x	
Periodic/QC		
Other		

Calibration type: Multibeam Sonar

The following calibration report documents procedures used to measure and adjust sensor biases and offsets for multibeam echosounder systems. This report has been adopted and modified from NOAA. Calibration must be conducted A) prior to CY survey data acquisition B) after installation of echosounder, position and vessel attitude equipment C) after changes to equipment installation or acquisition systems D) whenever the Hydrographer suspects incorrect calibration results. The Hydrographer shall periodically demonstrate that calibration correctors are valid for appropriate vessels and that data quality meets survey requirements. In the event the Hydrographer determines these correctors are no longer valid, or any part of the echosounder system configuration is changed or damaged, the Hydrographer must conduct new system calibrations.

Multibeam echosounder calibrations must be designed carefully and individually in consideration of systems, vessel, location, environmental conditions and survey requirements. The calibration procedure should determine or verify system offsets and calibration correctors (residual system biases) for draft (static and dynamic), horizontal position control (DGPS), navigation timing error, heading, roll, and pitch. Standard calibration patch test procedures are described in *Field Procedures for the Calibration of Multibeam Echo-sounding Systems*, by André Godin (Documented in Chapter 17 of the Caris HIPS/SIPS 6.0 User Manual, 2006). Additional information is provided in *POS/MV Model 320 Ver 4 System Manual* (10/2003), Appendix F, Patch Test, and the NOAA Field Procedures Manual (FPM, 2003). The patch test method only corrects very basic alignment biases. These procedures are used to measure static navigation timing error, transducer pitch offset, transducer roll offset, and transducer azimuth offset (yaw). Dynamic and reference frame biases can be investigated using a reference surface.

Pre-calibration Survey Information

Reference Frame Survey

RV 4-Points was surveyed by the National Geodetic Survey on February 15, 2006 for precise centerline and instrument locations. Steve Breidenbach performed the survey with a Trimble 5603 total Station.

(IMU, Ref Pt., and XY of CG are all co-aligned and attitude and position is valid at the sensor. The values below are entered in POSview software.)

Reference to IMU Lever Arm

X(m)	Y (m)	Z (m)
0	0	0

Reference to Pri. GPS

X(m)	Y (m)	Z (m)
1.849	-1.061	-1.724

IMU frame w.r.t. Reference frame

X(deg)	Y (deg)	Z (deg)
0	0	0

Reference to Sensor Lever Arm

X(m)	Y (m)	Z (m)
-0.097	-2.130	0.849

Reference to CG

X(m)	Y (m)	Z (m)
0	0	0.313

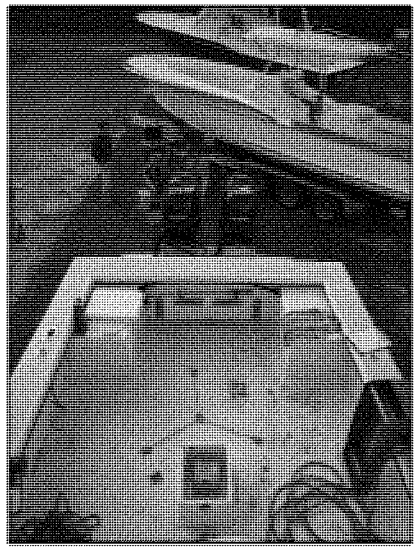


Figure 3. Photo of the centerline and instrument survey by NGS.

Reference to Vessel (Pt of validation for attitude and nav)

X(m)	Y (m)	Z (m)
-0.097	-2.130	0.849

__X__Measurements verified for this calibration.
____Drawing and table attached.
____Drawing and table included with project report

POS MV Configuration File: 4_points_022806. *

Notes: NGS vessel survey results were put in POSview and GAMS calibration was done on February 28, 2006.

Calibration Area

Site Description

This patch survey was conducted in the Port of Morehead City's turning basin near Beaufort Inlet, North Carolina (N34 41 39.16 W076 40 07.53). This site was selected for its particular bottom features, such small scale ripple fields, sand waves (wavelength: ±5m, amplitude: ±0.15m), deep flat areas, and high slopes.

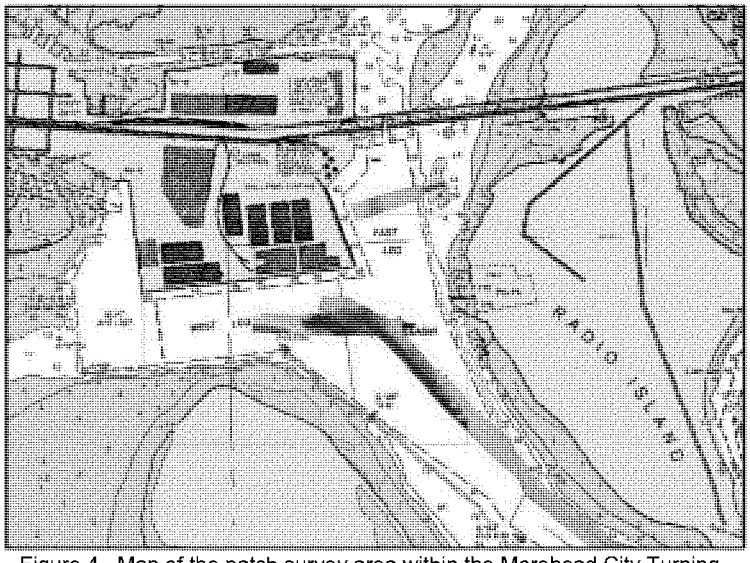


Figure 4. Map of the patch survey area within the Morehead City Turning Basin.

Survey Procedure

Vessel biases were determined through a patch test survey procedure. Data was acquired and analyzed in Kongsberg SIS package. The latency test was performed first by surveying the same survey line in the same direction at 2 different vessel speeds. The latency test was done twice to verify initial results. The pitch test was done second by surveying the same survey line in opposite directions at the same speed and evaluating the sloped portion of the survey line. The roll test was performed next by surveying the same survey line in opposite directions at the same speed and evaluating the deep flat portion of the survey line. The roll test was done twice to verify initial results. The yaw test was performed next by surveying 2 adjacent survey lines in the same direction, with similar speeds, with enough overlapping coverage such that the outer beams from each swath overlap (±40%).

Calibration Lines

Hypack Line	Line File	Az.	Spd	Correction			
				Pitch	Roll	Yaw	Latency
1	0000_20060301_163731_4points.all	57°	3.3kts				X
1	0001_20060301_164249_4points.all	57°	7.1kts				X
1	0002_20060301_165502_4points.all	237°	3.2kts				X
1	0003_20060301_165938_4points.all	237°	7.0kts				X
1	0002_20060301_155849_4points.all	237°	7.0kts	X			
1	0003_20060301_160222_4points.all	57°	7.0kts	X			
1	0000_20060301_172142_4points.all	57°	7.0kts		X		
1	0001_20060301_172427_4points.all	237°	7.0kts		X		
1	0000_20060301_183521_4points.all	237°	7.0kts		X		
1	0001_20060301_183741_4points.all	57°	7.0kts		X		
8	0001_20060301_191059_4points.all	280°	7.0kts			X	
7	0002_20060301_191957_4points.all	100°	7.0kts			X	

Sound Velocity Correction

Measure water sound velocity (SV) prior to survey operations in the immediate vicinity of the calibration site. Conduct SV observations as often as necessary to monitor changing conditions and acquire a SV observation at the conclusion of calibration proceedings. If SV measurements are measured at the transducer face, monitor surface SV for changes and record surface SV with profile measurements.

Sound Velocity Measurements

Time	Max Depth	Surface SV	Change Observed	Position	
				Latitude	Longitude
14:52:00	15.5m	1490.2		34 42.9705	76 41.6239
Continuous SV at head			<4 m/s throughout entire calibration		

Data Acquisition and Processing Guidelines

Initially, calibration measurement offsets should be set to zero in vessel configuration files. Static and dynamic draft offsets, inertial measurement unit (IMU) lever arm offsets, and vessel reference frame offsets must be entered in appropriate software applications prior to bias analysis. Perform minimal cleaning to eliminate gross flyers from sounding data.

Navigation Timing Error (NTE)
Measure NTE correction through examination of a profile of the center beams from lines run in the same direction at maximum and minimum vessel speeds. NTE is best observed in shallow water.

Transducer Pitch Offset (TPO)
Apply NTE correction. Measure TPO correction through examination of a profile of the center beams from lines run up and down a bounded slope or across a conspicuous feature. Acquire data on lines oriented in opposite directions, at the same vessel speed. TPO is best observed in deep water.

Transducer Roll Offset (TRO)
Apply NTE and TPO corrections. Measure the TRO correction through examination of roll on the outer beams across parallel overlapping lines. TRO is best observed over flat terrain in deep water. An additional check for TRO adjustment can be performed by running two lines parallel to a sloped surface.

Transducer Azimuth Offset (TAO or yaw)
Apply NTE, TPO and TRO corrections. Measure TAO correction through examination of a conspicuous topographic feature observed on the outer beams of lines run in opposite directions.

Patch Test Results and Correctors

Evaluator	NTE (sec)	TPO (deg)	TAO (deg)	TRO (deg)
Bernstein/Hohing	0.00	0.00	0.00	-0.65
Final Values	0.00	0.00	0.00	-0.65

Corrections Calculated in:	
Caris	
ISIS (BathyPro)	
Other	SIS

NOTE: TRO bias of -0.65 was put in SIS software.

Evaluator: Dave Bernstein
Reviewed by: Chris Freeman
Accepted by: Dave Bernstein
Date accepted: April 21, 2006

Graphical Examples of Calibration Acceptance

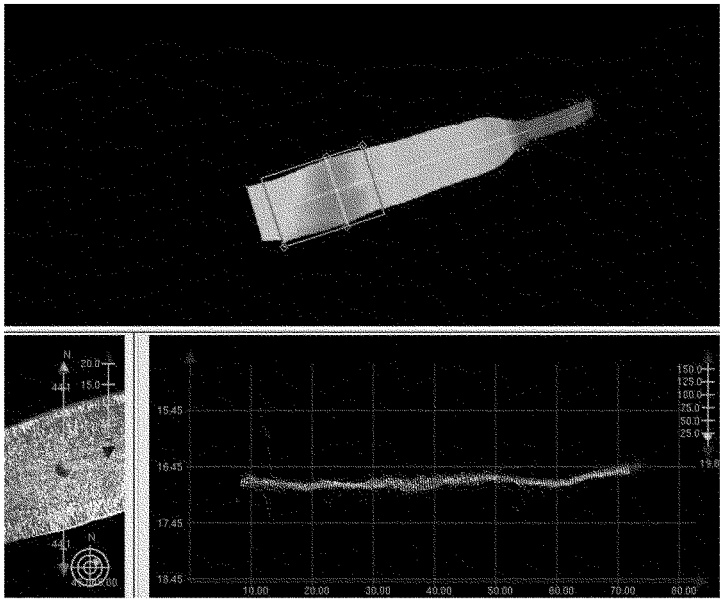


Figure 5. Caris screen grab illustrating acceptance of roll calibration.

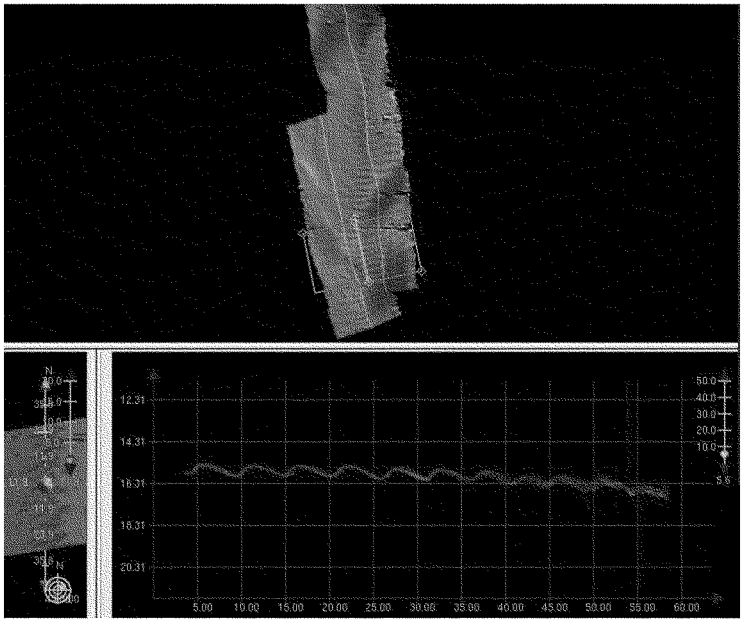


Figure 6. Caris screen grab illustrating acceptance of yaw calibration.

Data Processing Routines & QA/QC Information

Introduction

Processing high-density multibeam bathymetry and backscatter data requires a multitude of processing routines and data quality analyses. The following section will detail all aspects of data post-processing for the Topsail Island multibeam surveys. Also presented in this section is detailed QA/QC information and analysis generated throughout the various processing procedures.

Bathymetry Processing

The multibeam collects swath widths approximately 4 times the water depth. The portions of swath, mainly in the outer beams, that exhibit areas of inconsistent data are clipped and not included in the final digital file. Sounding track lines are generally parallel to each other and parallel to the seafloor contour. Sinuous lines and data acquired during turns are not included in the final processed data. To meet the accuracy and resolution standards for measured depths specified in the USACE Hydrographic Surveying Manual and the NOS Hydrographic Surveys, Specifications and Deliverables Manual, measured echosounder depths were corrected for all departures from true depths attributable to the method of sounding or to faults in the measuring apparatus. These corrections are subdivided into four categories, and are listed below in the sequence in which they were applied to the data.

1. Instrument error corrections: included to account for the sources of error related to the sounding equipment itself.

2. Vessel offsets: added to the observed soundings to account for the depth of the echosounder below the water surface, positioning of the motion reference unit, and GPS antenna.

3. Velocity of sound correctors: applied to the soundings to compensate for the fact that echosounders may only display depths based on an assumed sound velocity profile while the true velocity may vary in time and space.

4. Heave, pitch, roll, heading and navigation latency corrections: applied to the multibeam soundings to correct for the effect of vessel motion caused by waves and swells, the error in the vessel's heading, and the time delay from the moment the position is measured until the data is received by the GPS receiver.

Multibeam Data Processing Steps in CARIS HIPS software:

The EM3002 sonar system has a unique arrangement of data flow. Most settings that influence the data are put in before and during a survey and therefore are not a factor in data processing (these include vessel offsets, lever

arms, vessel biases, timing biases, and survey sound velocity). Vessel attitude is also processed real-time during a survey.

Post-processing of multibeam data consist of attitude and navigation editing, merging, swath editing, area-based editing, and exporting of final data.

1. Attitude & Navigation Editing: Errors or gaps in attitude and navigation information causing errors in soundings are edited.

2. Merging: Computing and integrating the GPS tide in the sounding data. Additional sound velocity corrections are made if needed in this phase.

3. Total Propagated Error (TPE) is calculated

4. Swath- and beam-based filters and TPE (IHO standards) filters are applied.

5. Swath Editing: Swaths are edited for erroneous data if needed

6. Base or CUBE Surface is created for area- and CUBE-based editing.

7. Area-based editing using the subset editor to edit/check erroneous data only within the desired subset.

8. CUBE filtering and editing

9. Recompute TPE

10. Recompute CUBE and/or base surfaces

11. Final export of base surface to XYZ decimated soundings.

TPE (Total Propagated Error)

Although tidal corrections are perhaps the largest source of error, the combination of multiple sensors, vessel geometry and sound velocity variations also contribute to uncertainty in shallow water hydrographic surveying (Allen, 2005). Precise calculations of these uncertainty values are fundamental to the field of hydrographic surveying. To accurately estimate uncertainty we analyze each individual error source and calculate a total propagated error (TPE) for the Topsail Island survey using CARIS HIPS Pro v 6.1. The TPE function with the Combined Uncertainty and Bathymetry Estimator (CUBE) filters data for soundings with uncertainty values that fall outside the limits set by the International Hydrographic Organization (IHO, 1998) and USACE standards (USACE, 2003). The average vertical TPE value for the Topsail Island survey is 0.43 ft (13 cm) and the average horizontal TPE value is 0.39 ft (12cm), allowing

us to achieve a vertical and horizontal accuracy that exceeds IHO special order and the highest USACE for Navigation and Dredging Support Surveys for individual soundings (not swath coverage).

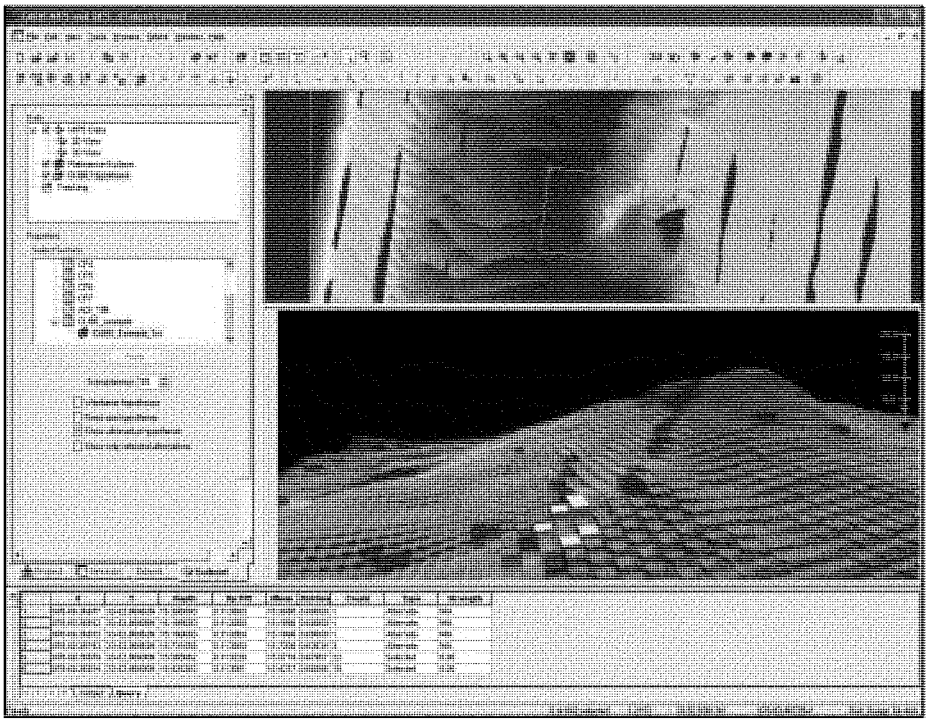
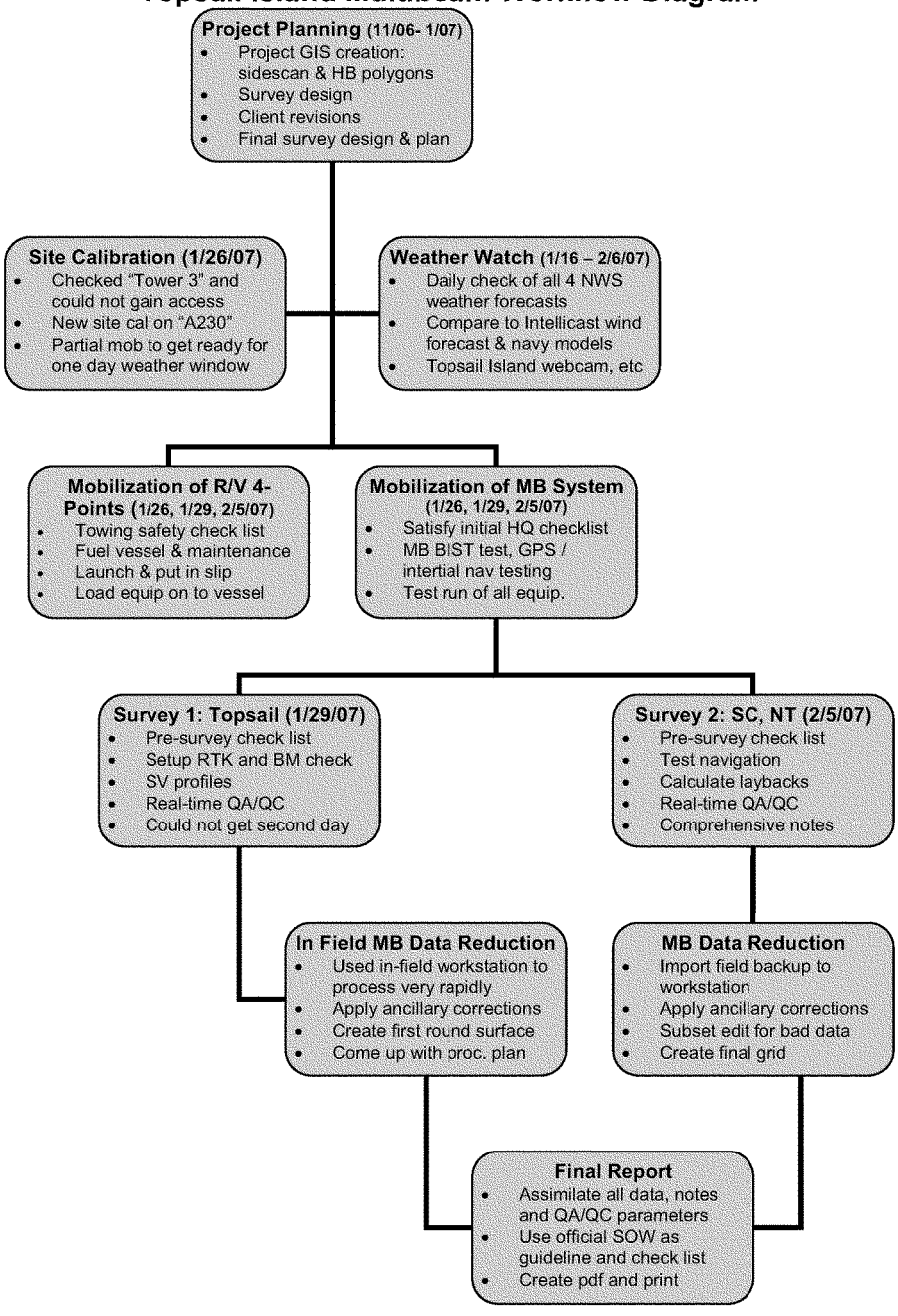
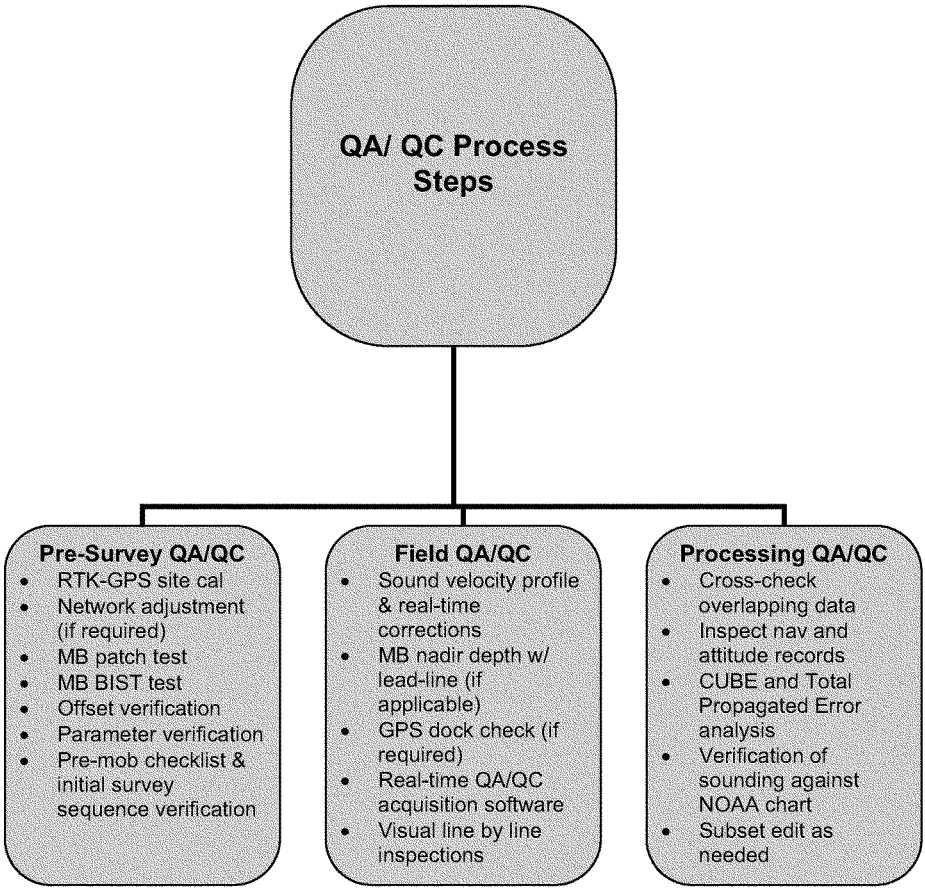


Figure 7. Screen capture showing an example of the CUBE editing process.

Topsail Island Multibeam Workflow Diagram



Topsail Island Multibeam QA/QC Workflow Diagram



Graphical Summary of Deliverables

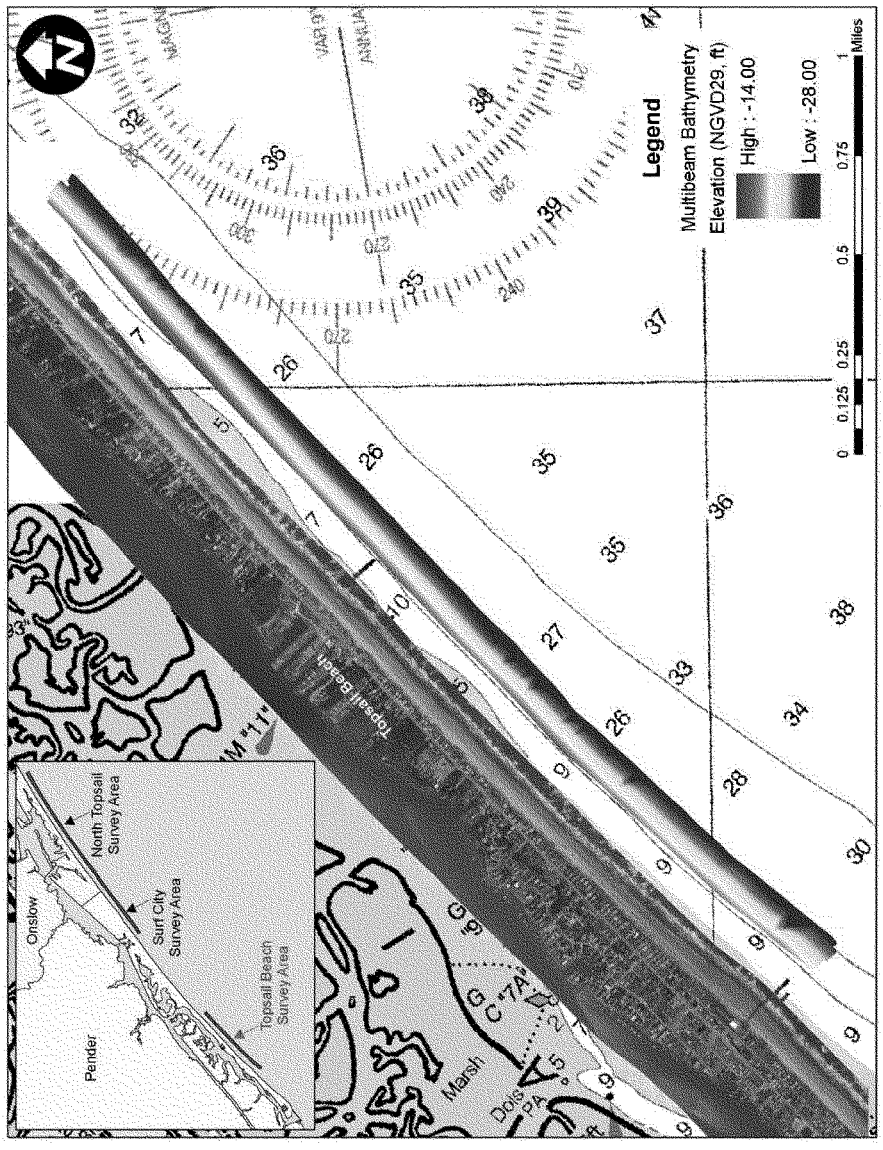


Figure 8. Plan view bathymetric map showing the "southern" survey reach.

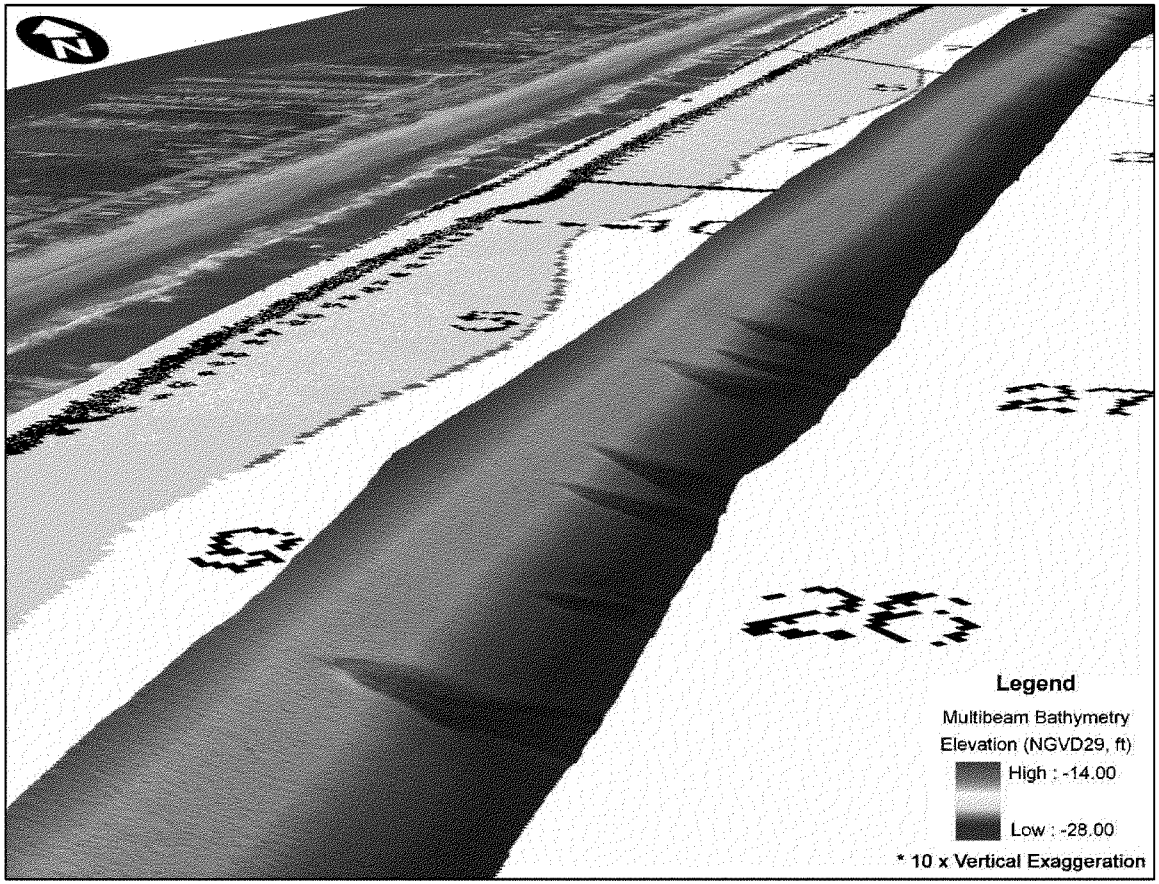


Figure 9. 3D perspective view of Topsail Island inner shoreface. Inshore signature or scour depressions that likely extend offshore.

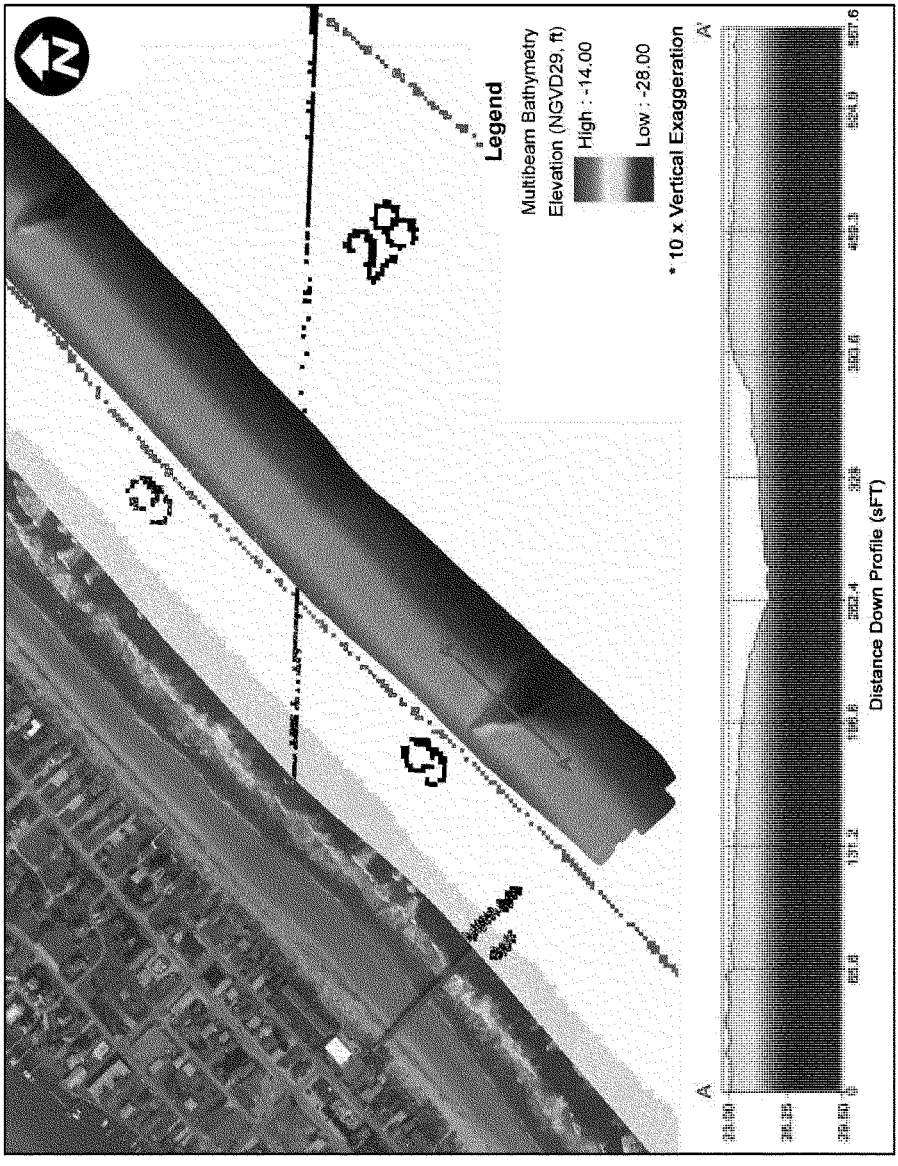


Figure 10. Zoom in on scour depression area for Topsail Island with profile cross section.

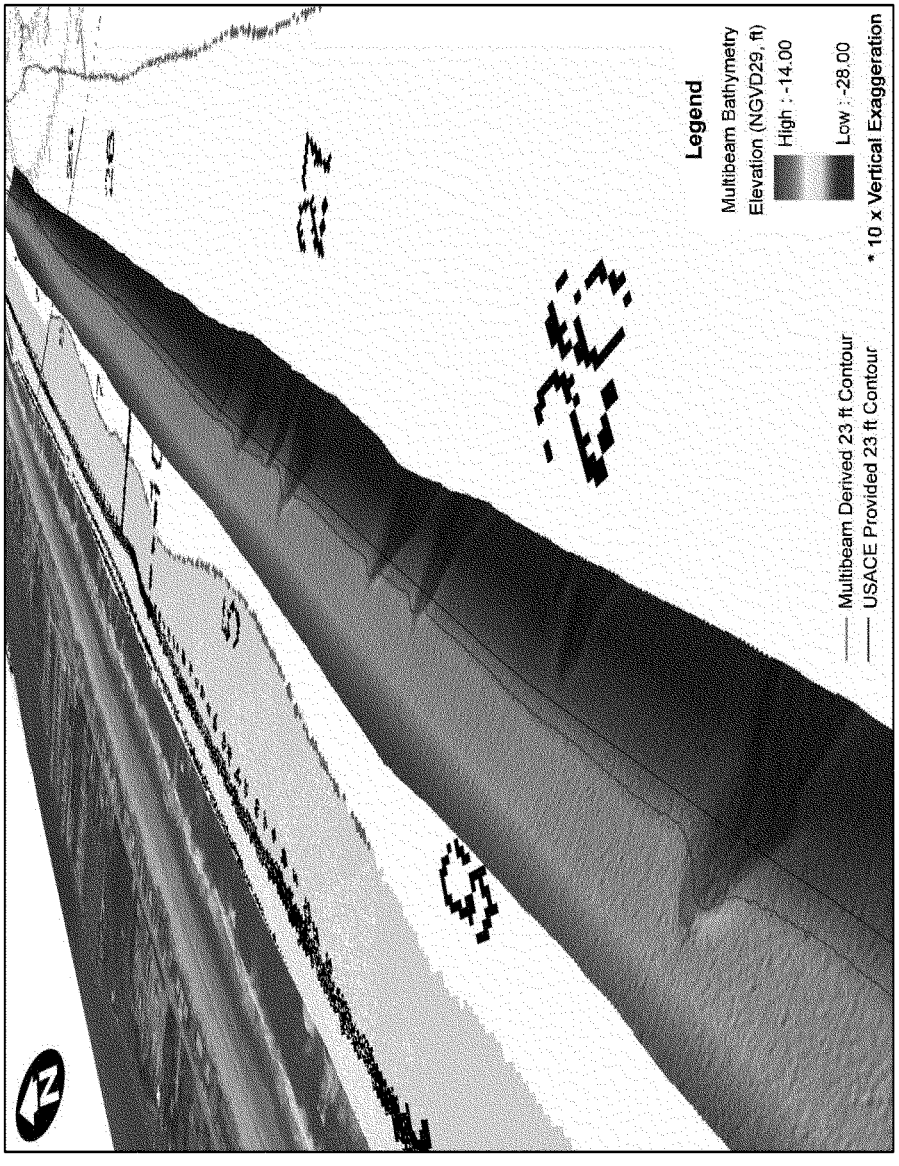


Figure 11. 23' multibeam and 23' USACE contours draped on 3D perspective view of the Topsail Beach inner shoreface.

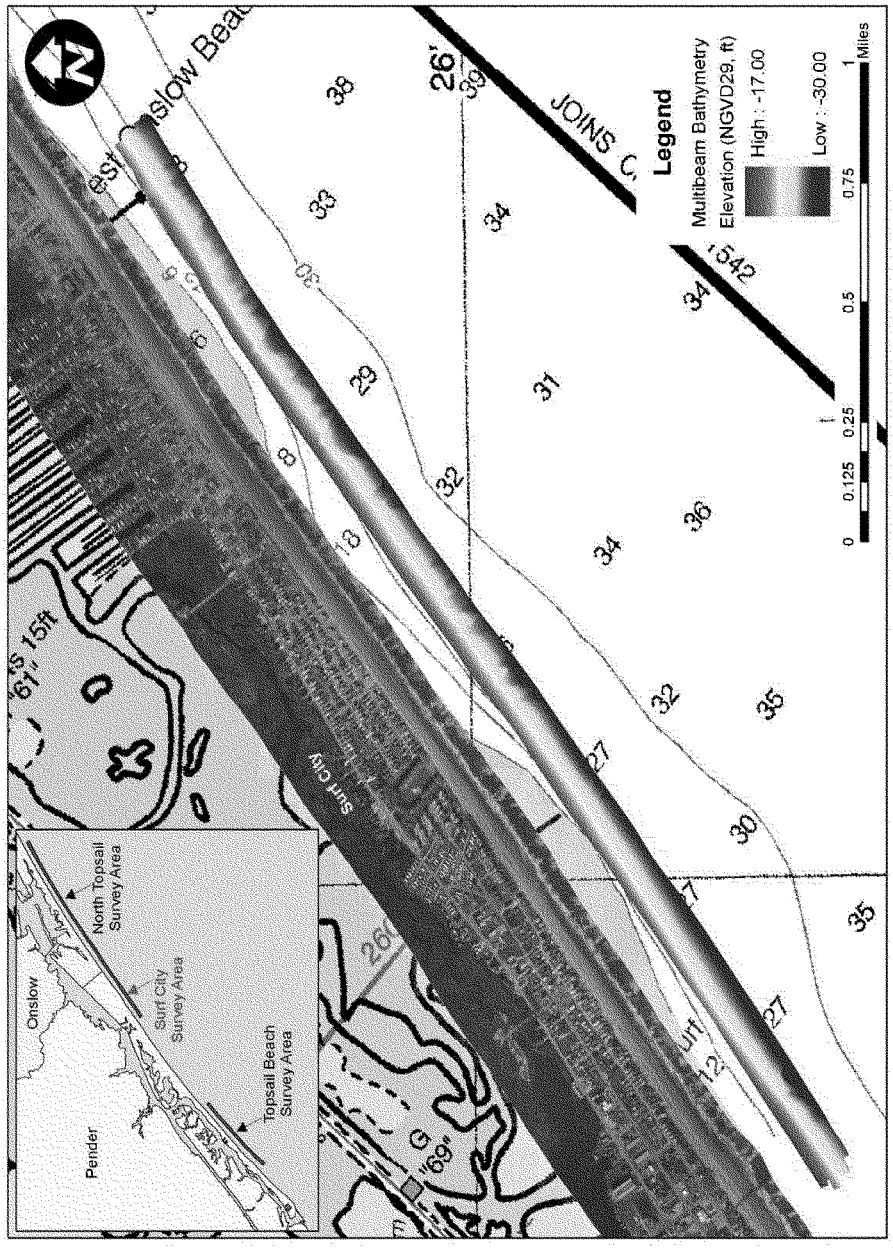


Figure 12. Plan view bathymetric map of the Surf City or "middle" survey area.

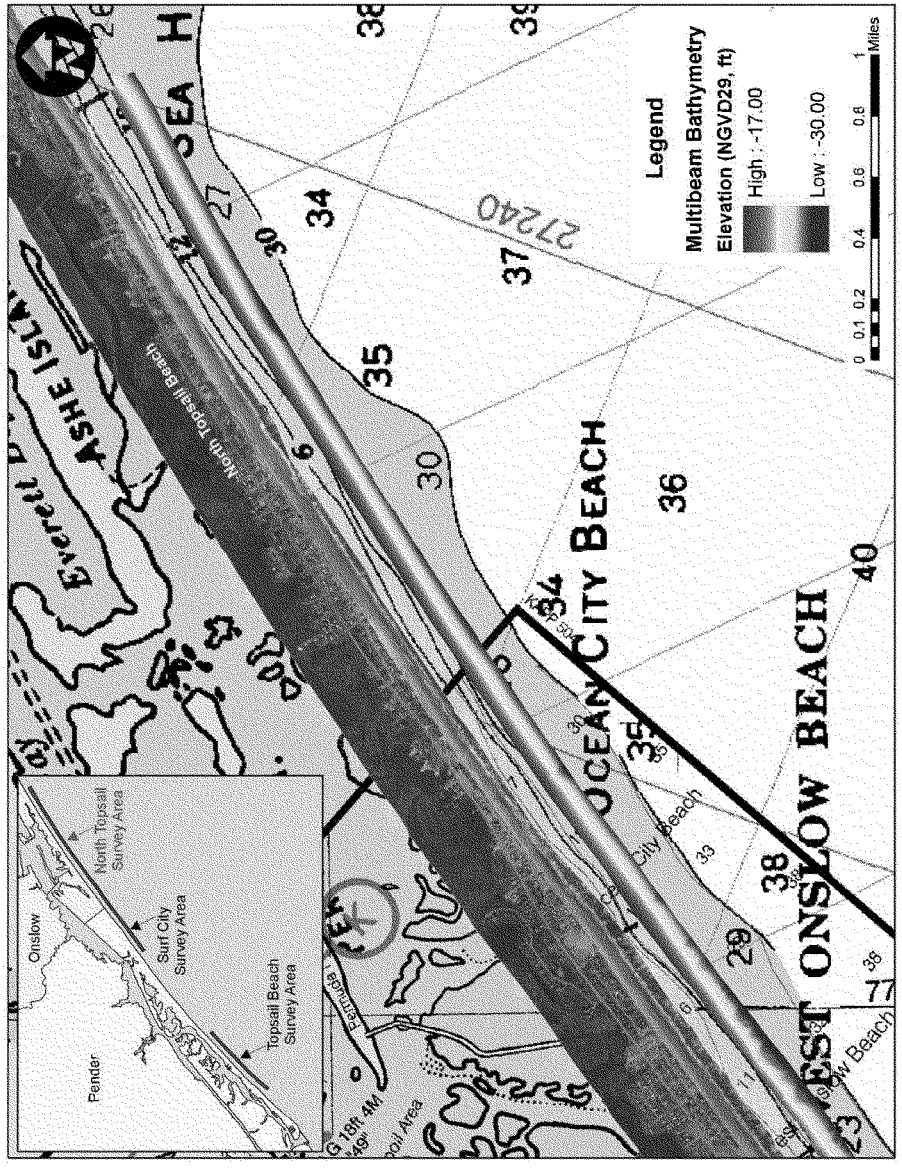


Figure 13. Plan view bathymetric map of the North Topsail or "northern" survey area.

Appendix A – Official USACE Scope of Work (Scanned G&O Copy)

CONTRACT DACW54-02-D-0006, TASK ORDER 00-5, MOD. 01

MODIFICATION
TO
SCOPE OF WORK
NEARSHORE HARD BOTTOM SIDESCAN SURVEY
FOR MULTIBEAM DATA COLLECTION
TOPSAIL ISLAND, NORTH CAROLINA

1. Location of Work. The tasks to be performed under this scope of work pertain to the geographic area of Topsail Island, North Carolina as indicated on figure 1.

2. General Requirements. The Contractor shall supply all necessary labor, materials, equipment, rentals, and travel expense to conduct and document the work as described herein.

3. Detailed Requirements. The Contractor shall acquire full coverage multibeam sonar data within zones identified to contain potential hardbottom regions as identified in Phase 1 of the project as well as those areas previously identified as potential hard bottom in North Topsail by CPE Inc.

The Contractor shall provide all necessary services, equipment, labor, and materials to perform a multibeam survey within the survey limits as indicated on figure 1, and the post processing of the collected field data into the required formats and deliverables as indicated. The following survey datums are required:

Horizontal – North Carolina State Plan, NAD83, US Survey, Feet
Vertical – NGVD 1929, Feet

A. Hydrographic Data. Hydrographic survey coverage for the area depicted on the attached map shall be provided. The Contractor shall conduct the multibeam surveys as to ensure 100% coverage to the extent practical of the survey area shown on the attached map. Survey lines should be taken at sufficient intervals to ensure this coverage. Coordinates shown on the attached map are in feet and reference the North Carolina State Plane Coordinate System, NAD83. All data shall meet the recommended minimum performance standards established in EM 1110-2-1003 (Table 3-1) for the "Other General Surveys and Studies" project classification.

B. System Calibration and Check. The Contractor shall calibrate and check the multibeam system in accordance with the procedures outlined in EM 1110-2-1003. A log (either written or digital) containing the results of all calibrations and checks shall be kept by the Contractor.

C. Data Editing. All hydrographic survey data shall be fully edited and corrected. The data shall undergo a gridded depth reduction using 5-foot cells or less, where the depth saved shall be the depth closest to the center of the cell.

Note: USACE documents can be downloaded from the following web site: http://www.usace.army.mil/inet/usace-docs/eng-manuals/em.htm

4. Survey Control. Phase 2 multibeam surveys will use US Coast and Geodetic Survey benchmark Tower Three 1947 for RTK-GPS corrections. A complete site calibration has been performed on this mark during Phase 1; however, prior to the start of surveying in Phase 2 Contractor shall check at least one mark within the control network to verify correct basestation setup.

5. Clearances. The Contractor shall acquire all Clearances necessary to obtain the required data. All discussions for access to private or public property or restricted waters or airspace must be included in the required weekly status report with name of person, address, and telephone number.

6. Required Deliverables. The Contractor is required to deliver Shapefiles, Raster Data Sets, Metadata Records, a Weekly Status Reports, and a Final Written Report.

6.1 GIS-Compatible Data The Contractor shall deliver data in a format compatible with ESRI ArcView/ArcInfo Version 9.x.

6.1.1 Multibeam Data. The Contractor shall deliver an ArcGrid of each Multibeam Survey area specified in the attached project design map. The ArcGrid shall represent the final data with all appropriate corrections (motion, tides, CUBE, TPE, etc) applied.

6.1.2 Point Shapefiles. The Contractor shall deliver any ancillary data that could possibly be imported into a geodatabase in shape file format.

6.2 Metadata Record. An FGDC compliant metadata record for each spatial data deliverable shall be created using ESRI ArcView/ArcInfo ArcCatalog version 9.0. Appropriate information shall be entered in all required fields. The Contractor shall attach the appropriate metadata record to each spatial data file using ArcCatalog so that no importing or formatting of the metadata record is required by the Government.

7. Weekly Status Report. **The Contractor is required to submit a Weekly Status Report each week, beginning on the Task Order Award Date, until all deliverables are received and accepted by the Government.** The Weekly Status Report shall be delivered via e-mail no later than 8:00 AM each Monday and shall document the Contractor's progress from the previous Monday through the previous Sunday. The status report shall itemize each scope item with percent of work complete and an estimated date of completion. The report shall also include the number and type of field crews working, a description of any problems and/or delays encountered, and any

photographs of the site and/or significant site features (such as outlet structures, retaining walls, escarpments, etc.) and/or specialized data collection activities.

8. Final Written Report. A written report summarizing all data collection activities shall be submitted as a Portable Document File (PDF) and in bound hardcopy. The following items shall be included in the survey report:

- Written description of workflow to complete task order (start to finish) including flowchart diagram and detailed description of QA/QC process
- Dates and times of each data collection activity
- Atmospheric Conditions for each day of data collection activity
- All Horizontal and Vertical Control used including monument name, establishing agency, date established, description, and published horizontal and vertical values
- TBM descriptions with vertical values (N/A)
- Copy of all field notes
- Complete and detailed list of all survey equipment used including copy of last factory calibration report
- Metadata Records as described in 4.4 above
- Photographs of the site and any significant features or data collection techniques used

9. Quality Control. If work is found to be in error, incomplete, illegible or unsatisfactory after assignment is completed, the Contractor shall be liable for all cost in connection with correcting such errors. Corrective work may be performed by Government personnel or Contractor personnel at the discretion of the Contracting Officer. In any event, the Contractor shall be responsible for all costs incurred for correction of such errors, including salaries, automotive expenses, equipment rental, supervision, and any other costs in connection therewith. All data and deliverables shall be reviewed for the following:

- Required coverage of the project limits
- Capture of all required features
- Required accuracies
- Required horizontal and vertical datum
- Adherence to the delivery order requirements

10. Technical POC. All technical questions concerning work under this task order shall be directed to Jim Jacaruso at (910) 251-4064.

11. Schedule & Completion Date. A completed product for the Topsail Beach portion of this modification shall be delivered in its entirety no later than 31 January 2007. Upon award of this modification, fieldwork for the Phase 2 multibeam survey project should proceed such that the final deliverables are completed and delivered no later than 21 days from the modification date, weather conditions permitting. Safety of field

personnel is the priority, followed by timeliness of schedule. The Contractor is to use judgment on the exact days of data collection for both safety and data quality concerns. Scheduling of surveys should be coordinated with the POC in advance and weekly updates of progress to obtain field data will be provided. Data analysis, documentation, and computer files should be delivered by early February pending the ultimate schedule for data acquisition. This schedule is subject to adjustment by the Contracting Officer.

12. Deliver To. All work shall be delivered to:

U. S. Army Corps of Engineers
Wilmington District
Attn: Jim Jacaruso, TS-EE
69 Darlington Avenue
PO Box 1890
Wilmington, NC 28402-1890

Appendix B – Field Notes

geodynamics
COMPLEX COASTAL CHANGE MADE CLEAR

Project Timeline & General Field Notes

Project: Topsail Island Phase 2 Multibeam 1/26-2/5/07

US Navy Astronomical Data

Sunday: Surf City, Pender County, North Carolina (longitude W77.5, latitude N34.4)

15 January 2006	Eastern Standard Time
Begin civil twilight	6:49 a.m.
Sunrise	7:16 a.m.
Sun transit	12:20 p.m.
Sunset	5:23 p.m.
End civil twilight	5:50 p.m.

Total Daylight: 10-11hrs

DATE: 1/26/07

TIME	TASK	NOTES
6:30am	mobilization of 4-Points and trailer check, fuel vessel, travel to Topsail, put vessel in the water and moor	There was a change in the survey plan by the Corps to get on site and mobilize to try and get one of these one day windows we are having. So we can get the data before the 31st deadline
11:30am	New site calibration	Could not gain access to Tower 3. Could not reach owners of property for ~3 weeks now. Even found a possible number for them in Jacksonville but no answering machines on either line. After putting vessel in we started hunting for A230
12:00pm	Bench mark and range check.	Found A230 and were able to put radio antenna out on the beach with the 100' GPS cable. First step was to get all the way to the northern survey extents and check marks. Thing checked out w/in 3cm. Then we worked our way south checking various marks.
5:30pm	Wrap up site cal and break down GPS equipment. Get boat safe in slip.	Weather forecast changed once again. In fact wind was already SW at about 15 ~4pm and the marine forecast is still calling it NW? Looks like tomorrow is a wash. Will leave boat in slip for the next couple days
6:00pm - 7:30	Drive back to PKS	After getting boat secure we headed back to HQ. Get GPS equipment on charge and semi unpacked

geodynamics
COMPLEX COASTAL CHANGE MADE CLEAR

Project Timeline & General Field Notes

Project: Topsail Island Phase 2 Multibeam 1/26-2/5/07

US Navy Astronomical Data	
Sunday: Surf City, Pender County, North Carolina (longitude W77.5, latitude N34.4)	
15 January 2006	Eastern Standard Time
Begin civil twilight	6:49 a.m.
Sunrise	7:16 a.m.
Sun transit	12:20 p.m.
Sunset	5:23 p.m.
End civil twilight	5:50 p.m.
Total Daylight: 10-11hrs	

DATE: 1/27/07

TIME	TASK	NOTES
		SW wind. No survey

SURF CITY TO CAPE FEAR NC OUT 20 NM-
559 AM EST SAT JAN 27 2007

SMALL CRAFT ADVISORY REMAINS IN EFFECT FROM 1 PM EST THIS
AFTERNOON THROUGH LATE TONIGHT

TODAY
W TO SW WINDS 15 TO 20 KT...BECOMING SW 20 TO 25 KT.
SEAS BUILDING TO 5 TO 6 FT. SEAS 2 TO 3 FT NEAR SHORE.

TONIGHT
SW WINDS 20 TO 25 KT...BECOMING W 15 TO 20 KT AFTER
MIDNIGHT. SEAS 5 TO 7 FT...EXCEPT AROUND 3 FT NEAR SHORE. A
SLIGHT CHANCE OF SHOWERS AFTER MIDNIGHT.

SUN
W WINDS 10 TO 15 KT WITH GUSTS UP TO 25 KT. SEAS 2 TO 4
FT. A CHANCE OF SHOWERS IN THE MORNING.

SUN NIGHT
W WINDS 15 TO 20 KT...BECOMING NW 25 TO 30 KT AFTER
MIDNIGHT. SEAS 5 TO 7 FT.

MON
NW WINDS 20 TO 25 KT...DIMINISHING TO 15 TO 20 KT IN THE
AFTERNOON. SEAS 4 TO 6 FT.

AFTERNOON. SEAS 4 TO 6 FT.

MON NIGHT
NW WINDS 10 TO 15 KT WITH GUSTS UP TO 20 KT. SEAS AROUND 3 FT.

TUE
W WINDS 10 TO 15 KT. SEAS 2 TO 3 FT.

WED
N WINDS 10 TO 15 KT. SEAS 2 TO 3 FT.
SURF CITY TO CAPE FEAR NC OUT 20 NM-
320 PM EST SAT JAN 27 2007

geodynamics
COMPLEX COASTAL CHANGE MADE CLEAR

Project Timeline & General Field Notes

Project: Topsail Island Phase 2 Multibeam 1/26-2/5/07

US Navy Astronomical Data	
Sunday: Surf City, Pender County, North Carolina (longitude W77.5, latitude N34.4)	
15 January 2006	Eastern Standard Time
Begin civil twilight	6:49 a.m.
Sunrise	7:16 a.m.
Sun transit	12:20 p.m.
Sunset	5:23 p.m.
End civil twilight	5:50 p.m.
Total Daylight: 10-11hrs	

DATE: 1/28/07

TIME	TASK	NOTES
		Gustsy winds. No survey

859 AM EST SUN JAN 28 2007

GALE WARNING REMAINS IN EFFECT FROM 4 PM EST THIS AFTERNOON
THROUGH MONDAY MORNING

TODAY
NW WINDS 10 TO 15 KT WITH GUSTS UP TO 20 KT...INCREASING TO 15 TO 20 KT WITH GUSTS UP TO 35 KT LATE THIS MORNING AND AFTERNOON. SEAS 4 TO 5 FT. SEAS AROUND 2 FT NEAR SHORE. RAIN EARLY THIS MORNING...THEN A SLIGHT CHANCE OF RAIN LATE THIS MORNING.

TONIGHT
W WINDS 20 TO 25 KT WITH GUSTS UP TO 30 KT...BECOMING NW 30 TO 35 KT WITH GUSTS UP TO 40 KT. SEAS 6 TO 8 FT...EXCEPT UP TO 3 FT NEAR SHORE. A SLIGHT CHANCE OF RAIN IN THE EVENING.

MON
NW WINDS AROUND 25 KT WITH GUSTS UP TO 35 KT... DIMINISHING TO 15 TO 20 KT IN THE AFTERNOON. SEAS 6 TO 7 FT... SUBSIDING TO 3 TO 5 FT IN THE AFTERNOON.

MON NIGHT
W WINDS 10 TO 15 KT...INCREASING TO 15 TO 20 KT AFTER MIDNIGHT. SEAS BUILDING TO 3 TO 5 FT.

TUE

TUE
W WINDS 15 TO 20 KT WITH GUSTS UP TO 25 KT. SEAS 4 TO 5 FT.

TUE NIGHT
NW WINDS 15 TO 20 KT...BECOMING N AFTER MIDNIGHT. SEAS
3 TO 5 FT.

WED
N WINDS 10 TO 15 KT...BECOMING NE. SEAS 2 TO 4 FT.

geodynamics
COMPLEX COASTAL CHANGE MADE CLEAR

Project Timeline & General Field Notes

Project: Topsail Island Phase 2 Multibeam 1/26-2/5/07

US Navy Astronomical Data	
Sunday: Surf City, Pender County, North Carolina (longitude W77.5, latitude N34.4)	
15 January 2006	Eastern Standard Time
Begin civil twilight	6:49 a.m.
Sunrise	7:16 a.m.
Sun transit	12:20 p.m.
Sunset	5:23 p.m.
End civil twilight	5:50 p.m.
Total Daylight: 10-11hrs	

DATE: 1/29/07

TIME	TASK	NOTES
6:30am	Check weather and verified a go. Packed GPS equipment	Drove down ~ 7am
9:00am	Setup base and check mark	Set the base up and checked BM Crocker
9:45am	Prepare boat	Had to wait for the winds to die down a bit. Was blowing up to 30knts in the am and then died to ~20knts mid day. Unclear if surface conditions will allow good data at this stage
11:45am	Begin transit to site	on the transit to site we marked some of the nav aids for safe return home.
12:30pm	On site and start survey	Started survey in southern section. Was able to get both the southern and middle sections. This is the data that is needed by the 31st. Looks like we'll make the deadline but still have to process. Got the base surface generated on the way home! Thank goodness for new mobile workstation
5:30pm	Dock	Got to the dock just before dark. Moored and prepared for tomorrow. Forecast still looking decent for tomorrow am but they have the winds increasing out of the west. Will check updated intellicast at hotel
6:30pm - 9:30pm	In-field data processing	Was able to get some level of processing completed this evening. Data is looking very clean. Hopefully we can make some headway offshore tomorrow

geodynamics
COMPLEX COASTAL CHANGE MADE CLEAR

Project Timeline & General Field Notes

Project: Topsail Island Phase 2 Multibeam 1/26-2/5/07

US Navy Astronomical Data

Sunday: Surf City, Pender County, North Carolina (longitude W77.5, latitude N34.4)

15 January 2006	Eastern Standard Time
Begin civil twilight	6:49 a.m.
Sunrise	7:16 a.m.
Sun transit	12:20 p.m.
Sunset	5:23 p.m.
End civil twilight	5:50 p.m.

Total Daylight: 10-11hrs

DATE: 1/30/07

TIME	TASK	NOTES
5:30am to 1:30pm	Tried to survey but got blow out, pulled boat out of water, packed gps gear, head back and get gps gear on charge	1/2 acqusition day. The south forcast had winds W at 15-20 for today but it was blowing light SW at prior to first light. By 9am it was blowing 15 plus out of the SW. They finally changed the forecast to reflect this at at the 10am forecast

SURF CITY TO CAPE FEAR NC OUT 20 NM-
307 PM EST TUE JAN 30 2007

SMALL CRAFT ADVISORY REMAINS IN EFFECT FROM 8 PM EST THIS EVENING
THROUGH WEDNESDAY MORNING

THROUGH 6 PM
SW WINDS 15 TO 20 KT. SEAS AROUND 3 FT. SEAS AROUND 2 FT NEAR SHORE.

TONIGHT
W WINDS 15 TO 20 KT...INCREASING TO 20 TO 25 KT LATE THIS EVENING AND EARLY MORNING...THEN BECOMING NW LATE. SEAS 4 TO 5 FT. SEAS AROUND 3 FT NEAR SHORE.

WED
NW WINDS 20 TO 25 KT...BECOMING N 10 TO 15 KT IN THE AFTERNOON. SEAS 3 TO 5 FT...SUBSIDING TO 2 TO 3 FT IN THE AFTERNOON.

WED NIGHT
N WINDS AROUND 10 KT...BECOMING E AFTER MIDNIGHT. SEAS 2 TO 3 FT.

THU
SE WINDS AROUND 10 KT...BECOMING SW WITH GUSTS UP TO 20 KT IN THE AFTERNOON. SEAS 2 TO 4 FT...BUILDING TO 4 TO 6 FT IN THE

THE AFTERNOON. SEAS 2 TO 4 FT...BUILDING TO 4 TO 6 FT IN THE AFTERNOON. A SLIGHT CHANCE OF RAIN IN THE MORNING...THEN SHOWERS LIKELY IN THE AFTERNOON.

THU NIGHT
SW WINDS 15 TO 20 KT...INCREASING TO 20 TO 25 KT WITH GUSTS UP TO 30 KT AFTER MIDNIGHT. SEAS 6 TO 9 FT. SHOWERS IN THE EVENING...THEN RAIN AFTER MIDNIGHT.

FRI
W WINDS 20 TO 25 KT...DIMINISHING TO 15 TO 20 KT IN THE AFTERNOON. SEAS 6 TO 9 FT. NEAR SHORE...SEAS 4 TO 6 FT... SUBSIDING TO 2 TO 4 FT IN THE AFTERNOON. A CHANCE OF RAIN IN THE MORNING.

FRI NIGHT
W WINDS 20 TO 25 KT...BECOMING NW 15 TO 20 KT AFTER MIDNIGHT. SEAS 4 TO 6 FT...EXCEPT UP TO 3 FT NEAR SHORE.

SAT
N WINDS 10 TO 15 KT. SEAS 2 TO 4 FT.

SUN
N WINDS 10 TO 15 KT. SEAS 3 TO 5 FT.

S OF CAPE LOOKOUT TO N OF SURF CITY NC OUT 20 NM

geodynamics
COMPLEX COASTAL CHANGE MADE CLEAR

Project Timeline & General Field Notes

Project: Topsail Island Phase 2 Multibeam 1/26-2/5/07

US Navy Astronomical Data	
Sunday: Surf City, Pender County, North Carolina (longitude W77.5, latitude N34.4)	
15 January 2006	Eastern Standard Time
Begin civil twilight	6:49 a.m.
Sunrise	7:16 a.m.
Sun transit	12:20 p.m.
Sunset	5:23 p.m.
End civil twilight	5:50 p.m.
Total Daylight: 10-11hrs	

DATE: 1/31/07

TIME	TASK	NOTES
		N winds in forecast. No survey

S OF CAPE LOOKOUT TO N OF SURF CITY NC OUT 20 NM-
409 PM EST TUE JAN 30 2007

SMALL CRAFT ADVISORY REMAINS IN EFFECT THROUGH WEDNESDAY AFTERNOON

TONIGHT
W WINDS 20 TO 25 KT. SEAS 3 TO 5 FT...BUILDING TO 5 TO 7 FT AFTER MIDNIGHT.

WED
NW WINDS 20 TO 25 KT...BECOMING N 15 TO 20 KT IN THE AFTERNOON. SEAS 4 TO 6 FT.

WED NIGHT
N WINDS AROUND 5 KT...BECOMING E AFTER MIDNIGHT. SEAS AROUND 2 FT.

THU
S WINDS 5 TO 10 KT...INCREASING TO 20 TO 25 KT IN THE AFTERNOON. SEAS 3 TO 5 FT BUILDING TO 4 TO 6 FT. SHOWERS LIKELY.

THU NIGHT
S WINDS 20 TO 25 KT. SEAS 6 TO 8 FT. A CHANCE OF SHOWERS.

FRI

FRI
SW WINDS 20 TO 25 KT...BECOMING W 15 TO 20 KT IN THE AFTERNOON. SEAS 6 TO 8 FT...SUBSIDING TO 5 TO 7 FT IN THE AFTERNOON.

FRI NIGHT
W WINDS 15 TO 20 KT. SEAS 4 TO 6 FT.

SAT
NW WINDS 10 TO 15 KT...BECOMING N 15 TO 20 KT. SEAS 3 TO 5 FT.

SUN
N WINDS 15 TO 20 KT. SEAS 3 TO 5 FT.

geodynamics
COMPLEX COASTAL CHANGE MADE CLEAR

Project Timeline & General Field Notes

Project: Topsail Island Phase 2 Multibeam 1/26-2/5/07

US Navy Astronomical Data

Sunday: Surf City, Pender County, North Carolina (longitude W77.5, latitude N34.4)

15 January 2006	Eastern Standard Time
Begin civil twilight	6:49 a.m.
Sunrise	7:16 a.m.
Sun transit	12:20 p.m.
Sunset	5:23 p.m.
End civil twilight	5:50 p.m.
Total Daylight:	10-11hrs

DATE: 2/1/07

TIME	TASK	NOTES
		Stong NE winds in forecast. No survey

SURF CITY TO CAPE FEAR NC OUT 20 NM-
317 PM EST THU FEB 1 2007

SMALL CRAFT ADVISORY REMAINS IN EFFECT THROUGH FRIDAY EVENING

THROUGH 6 PM
NE WINDS 15 TO 20 KT. SEAS 4 TO 6 FT. SEAS AROUND 2 FT NEAR SHORE. LIGHT RAIN WITH AREAS OF DRIZZLE.

TONIGHT
NE WINDS 10 TO 15 KT WITH GUSTS UP TO 20 KT...BECOMING N WITH GUSTS UP TO 20 KT LATE. SEAS AROUND 7 FT. SEAS AROUND 3 FT NEAR SHORE. RAIN LIKELY WITH AREAS OF DRIZZLE THIS EVENING...THEN RAIN LIKELY AFTER MIDNIGHT.

FRI
NW WINDS 10 TO 15 KT...BECOMING W IN THE AFTERNOON. GUSTS UP TO 25 KT. SEAS 6 TO 9 FT...EXCEPT UP TO 6 FT NEAR SHORE. A CHANCE OF RAIN IN THE MORNING.

FRI NIGHT
W WINDS 20 TO 25 KT. SEAS 4 TO 7 FT... SUBSIDING TO 3 TO 5 FT AFTER MIDNIGHT. NEAR SHORE...SEAS 2 TO 4 FT.

SAT
NW WINDS 10 TO 15 KT WITH GUSTS UP TO 20 KT. SEAS 3 TO 5 FT.

NW WINDS 10 TO 15 KT WITH GUSTS UP TO 20 KT. SEAS 3 TO 5 FT.

SAT NIGHT
W WINDS 10 TO 15 KT...INCREASING TO 20 TO 25 KT AFTER MIDNIGHT. SEAS 2 TO 4 FT.

SUN
NW WINDS 15 TO 20 KT WITH GUSTS UP TO 25 KT. SEAS 2 TO 4 FT.

SUN NIGHT
NW WINDS 10 TO 15 KT. SEAS 2 TO 3 FT.

MON
NW WINDS 10 TO 15 KT...INCREASING TO 15 TO 20 KT. SEAS 2 TO 4 FT.

TUE
N WINDS 20 TO 25 KT...DIMINISHING TO 15 TO 20 KT. SEAS 3 TO 5 FT.

geodynamics
COMPLEX COASTAL CHANGE MADE CLEAR

Project Timeline & General Field Notes

Project: Topsail Island Phase 2 Multibeam 1/26-2/5/07

US Navy Astronomical Data	
Sunday: Surf City, Pender County, North Carolina (longitude W77.5, latitude N34.4)	
15 January 2006	Eastern Standard Time
Begin civil twilight	6:49 a.m.
Sunrise	7:16 a.m.
Sun transit	12:20 p.m.
Sunset	5:23 p.m.
End civil twilight	5:50 p.m.
Total Daylight: 10-11hrs	

DATE: 2/2/07

TIME	TASK	NOTES
		Gusty winds. No survey

SURF CITY TO CAPE FEAR NC OUT 20 NM-
616 PM EST SAT FEB 3 2007

SMALL CRAFT ADVISORY REMAINS IN EFFECT FROM SUNDAY EVENING THROUGH MONDAY MORNING

TONIGHT
W WINDS 10 TO 15 KT WITH GUSTS UP TO 20 KT. SEAS AROUND 3 FT. SEAS 2 FT OR LESS NEAR SHORE.

SUN
W WINDS 10 TO 15 KT WITH GUSTS UP TO 20 KT...INCREASING TO 15 TO 20 KT WITH GUSTS UP TO 25 KT IN THE AFTERNOON. SEAS 3 TO 5 FT...EXCEPT 2 TO 3 FT NEAR SHORE.

SUN NIGHT
W WINDS 20 TO 25 KT...BECOMING NW. SEAS 4 TO 6 FT.

MON AND MON NIGHT
NW WINDS 20 TO 25 KT WITH GUSTS UP TO 30 KT. SEAS 4 TO 6 FT.

TUE AND TUE NIGHT
NW TO W WINDS 10 TO 15 KT WITH GUSTS UP TO 20 KT. SEAS 2 TO 4 FT.

WED
N WINDS 10 TO 15 KT...INCREASING TO 15 TO 20 KT. SEAS
BUILDING TO 3 TO 5 FT.

THU
N WINDS 15 TO 20 KT...BECOMING NW 10 TO 15 KT. SEAS 3 TO
5 FT.

geodynamics
COMPLEX COASTAL CHANGE MADE CLEAR

Project Timeline & General Field Notes

Project: Topsail Island Phase 2 Multibeam 1/26-2/5/07

US Navy Astronomical Data	
Sunday: Surf City, Pender County, North Carolina (longitude W77.5, latitude N34.4)	
15 January 2006	Eastern Standard Time
Begin civil twilight	6:49 a.m.
Sunrise	7:16 a.m.
Sun transit	12:20 p.m.
Sunset	5:23 p.m.
End civil twilight	5:50 p.m.
Total Daylight: 10-11hrs	

DATE: 2/3/07

TIME	TASK	NOTES
		Gusy winds in forecast. No survey.

SURF CITY TO CAPE FEAR NC OUT 20 NM-
616 PM EST SAT FEB 3 2007

SMALL CRAFT ADVISORY REMAINS IN EFFECT FROM SUNDAY EVENING THROUGH MONDAY MORNING

TONIGHT
W WINDS 10 TO 15 KT WITH GUSTS UP TO 20 KT. SEAS AROUND 3 FT. SEAS 2 FT OR LESS NEAR SHORE.

SUN
W WINDS 10 TO 15 KT WITH GUSTS UP TO 20 KT...INCREASING TO 15 TO 20 KT WITH GUSTS UP TO 25 KT IN THE AFTERNOON. SEAS 3 TO 5 FT...EXCEPT 2 TO 3 FT NEAR SHORE.

SUN NIGHT
W WINDS 20 TO 25 KT...BECOMING NW. SEAS 4 TO 6 FT.

MON AND MON NIGHT
NW WINDS 20 TO 25 KT WITH GUSTS UP TO 30 KT. SEAS 4 TO 6 FT.

TUE AND TUE NIGHT
NW TO W WINDS 10 TO 15 KT WITH GUSTS UP TO 20 KT. SEAS 2 TO 4 FT.

WED
N WINDS 10 TO 15 KT...INCREASING TO 15 TO 20 KT. SEAS BUILDING TO 3 TO 5 FT.

THU
N WINDS 15 TO 20 KT...BECOMING NW 10 TO 15 KT. SEAS 3 TO 5 FT.

geodynamics
COMPLEX COASTAL CHANGE MADE CLEAR

Project Timeline & General Field Notes

Project: Topsail Island Phase 2 Multibeam 1/26-2/5/07

US Navy Astronomical Data	
Sunday: Surf City, Pender County, North Carolina (longitude W77.5, latitude N34.4)	
15 January 2006	Eastern Standard Time
Begin civil twilight	6:49 a.m.
Sunrise	7:16 a.m.
Sun transit	12:20 p.m.
Sunset	5:23 p.m.
End civil twilight	5:50 p.m.
Total Daylight: 10-11hrs	

DATE: 2/4/07

TIME	TASK	NOTES
		SW winds in forecast. No survey. They have offshore winds for tomorrow but pretty strong. Might have a chance if they change it tonight to be a little lighter. Anything can happen with how the forecasts have been lately.

640 AM EST SUN FEB 4 2007

SMALL CRAFT ADVISORY REMAINS IN EFFECT FROM 6 PM EST THIS EVENING
THROUGH MONDAY MORNING

TODAY
W WINDS 10 TO 15 KT WITH GUSTS UP TO 20 KT... INCREASING TO 15 TO 20 KT WITH GUSTS UP TO 25 KT LATE THIS MORNING AND EARLY AFTERNOON...THEN BECOMING SW 20 TO 25 KT WITH GUSTS UP TO 30 KT LATE. SEAS BUILDING TO 4 TO 5 FT. SEAS 2 TO 3 FT NEAR SHORE.

TONIGHT
W WINDS 20 TO 25 KT...BECOMING NW AFTER MIDNIGHT. GUSTS UP TO 35 KT. SEAS 4 TO 7 FT...EXCEPT UP TO 4 FT NEAR SHORE.

MON
NW WINDS 20 TO 25 KT WITH GUSTS UP TO 35 KT. SEAS 4 TO 7 FT.

MON NIGHT
NW WINDS 15 TO 20 KT WITH GUSTS UP TO 30 KT. SEAS 4 TO 6 FT.

TUE
NW WINDS 15 TO 20 KT...BECOMING W 10 TO 15 KT IN THE AFTERNOON. SEAS 2 TO 4 FT.

TUE NIGHT
W WINDS 15 TO 20 KT...BECOMING SW 20 TO 25 KT AFTER MIDNIGHT. SEAS 3 TO 5 FT.

WED
W WINDS 15 TO 20 KT...BECOMING N. SEAS 3 TO 5 FT.

THU
N WINDS 15 TO 20 KT...BECOMING NW 10 TO 15 KT. SEAS 3 TO 5 FT...SUBSIDING TO 2 TO 3 FT.

geodynamics
COMPLEX COASTAL CHANGE MADE CLEAR

Project Timeline & General Field Notes

Project: Topsail Island Phase 2 Multibeam 1/26-2/5/07

US Navy Astronomical Data

Sunday: Surf City, Pender County, North Carolina (longitude W77.5, latitude N34.4)

15 January 2006	Eastern Standard Time
Begin civil twilight	6:49 a.m.
Sunrise	7:16 a.m.
Sun transit	12:20 p.m.
Sunset	5:23 p.m.
End civil twilight	5:50 p.m.

Total Daylight: 10-11hrs

DATE: 2/5/07

TIME	TASK	NOTES
6:00am	Check forecast and verified a go for today. Packed GPS gear and drove down	Got all the gear ready and headed out the door by 7:45am. At this point not sure it will be favoritable but at least it is offshore. Might die like it did last week.
9:30am	Setup base and prepared boat for survey	Got the base going and checked a mark. Winds are still strong but the surface conditions are flat. Going to give it a go
10:45am	Transit to northern survey site	still having hydraulic steering problems but we were able to transit at 27knts
11:25am	Start survey	Had a brief sonar glitch that kept us in suspense. Was able to get it to lock in. Thinking it was just cold.
5:15pm	Dock and final demob	Got back to the dock and started the demob process. Got boat out of water and broke the base down.
6:45pm - 8pm	Head back to HQ	Check trailer for brake wear

geodynamics
COMPLEX COASTAL CHANGE MADE CLEAR

Multibeam Daily Operation Proceedures & Checklist

Pre-Survey Operations	Complete	Notes		
		Latitude (Northing)	Longitude (Easting)	Elev.
Perform Dock-side GPS Check	X	See Metadata for BM Check		
Power up POS MV	X			
Power up UPS	X			
Power up EM3002 PU	X			
Power up Acquisition PC	X			
Power up Navigation PC	X			
Power up Trimble GPS	X			
Perform BIST (head in water)	X			

Survey Operations		Latitude (Northing)	Longitude (Easting)	Value
Input Initial SV cast in SIS Runtime		34 21.7451	077 37.3611	1492.2
SV Cast #1		34 21.7451	077 37.3611	1492.2
SV Cast #2		34 25.2728	077 32.5627	1492.7
SV Cast #3				
SV Cast #4				
SV Cast #5				
SV Cast #6				
SV Cast #7				
SV Cast #8				
Vessel Draft Check (waterline to ducer)				0.53m

General Survey Notes	
Project	USACE Topsail MB 2
Survey Area	Multibeam Southern Area & Middle area
Sea State	2' SSE swell, wind chop on top
Wind	NW 15 gust to 25-30kts
Air Temperature	34 F at start
Sea Temperature	51.7 F at start
Tides	L:11:40 am H: 4:50 pm EST
Survey Features & Navigational Aids	N/A
Comments	Had to wait 1/2 day for winds to calm a bit.

Line Name	MS/CL	Direction	Notes
0	MS	NE	HP 2 Start 12:24 pm EST
1	MS	NE	HP 2 cont due to PPS off E 12:51
2	MS	SW	HP 3
3	MS	NE	HP 4
4	MS	SW	HP 5
5	MS	NE	HP 6
6	MS	SW	HP 1 - end S section E 2:41
7	MS	NE	HP 2 - S 2:59 E 3:20
8	MS	SW	HP 3
9	MS	NE	HP 4
10	MS	SW	HP 5
11	MS	NE	HP 6
End Survey Day			

geodynamics
COMPLEX COASTAL CHANGE MADE CLEAR

Multibeam Daily Operation Proceedures & Checklist

Pre-Survey Operations	Complete	Notes		
		Latitude (Northing)	Longitude (Easting)	Elev.
Perform Dock-side GPS Check	X	See Metadata for BM Check		
Power up POS MV	X			
Power up UPS	X			
Power up EM3002 PU	X			
Power up Acquisition PC	X			
Power up Navigation PC	X			
Power up Trimble GPS	X			
Perform BIST (head in water)	X			
Survey Operations		**Latitude (Northing)**	**Longitude (Easting)**	**Value**
Input Initial SV cast in SIS Runtime				
SV Cast #1				
SV Cast #2				
SV Cast #3				
SV Cast #4				
SV Cast #5				
SV Cast #6				
SV Cast #7				
SV Cast #8				
Vessel Draft Check (waterline to ducer)				0.53m

General Survey Notes	
Project	USACE Topsail MB 2
Survey Area	Multibeam Northern Area
Sea State	2' SSE swell, decent S wind chop on top
Wind	SSW 10-15kts at 7:00am
Air Temperature	31 F at start
Sea Temperature	51.7 F at start
Tides	L:12:35 pm H: 5:48 pm EST
Survey Features & Navigational Aids	N/A
Comments	SSW winds picking up seas building to 2-4 quickly. Survey terminated

Line Name	MS/CL	Direction	Notes
0	MS	NE	
1	MS		
2	MS		
3	MS		
4	MS		
5	MS		
6	MS		
7	MS		
8	MS		
9	MS		
10	MS		
11	MS		

geodynamics
COMPLEX COASTAL CHANGE MADE CLEAR

Multibeam Daily Operation Proceedures & Checklist

Pre-Survey Operations	Complete	Notes		
		Latitude (Northing)	Longitude (Easting)	Elev.
Perform Dock-side GPS Check	X	See Metadata for BM Check		
Power up POS MV	X			
Power up UPS	X			
Power up EM3002 PU	X			
Power up Acquisition PC	X			
Power up Navigation PC	X			
Power up Trimble GPS	X			
Perform BIST (head in water)	X			

Survey Operations		Latitude (Northing)	Longitude (Easting)	Value
Input Initial SV cast in SIS Runtime		34 26.5378	077 30.3729	1488.9
SV Cast #1		34 26.5378	077 30.3729	1488.9
SV Cast #2		34 28.0899	077 27.8448	1487.2
SV Cast #3				
SV Cast #4				
SV Cast #5				
SV Cast #6				
SV Cast #7				
SV Cast #8				
Vessel Draft Check (waterline to ducer)				0.53m

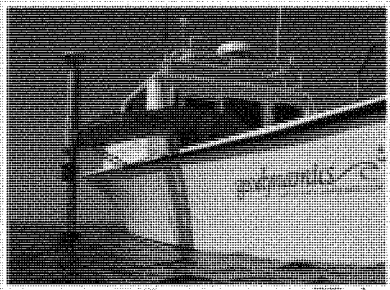
General Survey Notes	
Project	USACE Topsail MB 2
Survey Area	Multibeam Northern Area
Sea State	1-2' SSW swell, decent S wind chop on top
Wind	SSW 10-15kts at 7:00am
Air Temperature	31 F at start
Sea Temperature	49.8 F at start
Tides	H: 9:30 L: 4:26 pm EST
Survey Features & Navigational Aids	N/A
Comments	Initial BIST on Head =7 TX error, cleared on re-test out of water

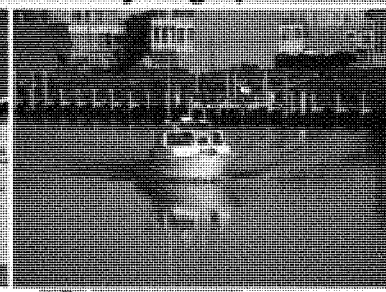
Line Name	MS/CL	Direction	Notes
0	MS	NE	HP 1 S 11:10am EST
1	MS	NE	HP 1
2	MS	NE	HP 1 S 11:26am EST E 11:58am Est
3	MS	SW	HP 2 S 12:01pm EST
4	MS	SW	HP 2 S 12:01pm EST
5	MS	NE	HP 3
6	MS	NE	HP 3
7	MS	SW	HP 4
8	MS	SW	HP 4
9	MS	NE	HP 5
10	MS	NE	HP 5
11	MS	SW	HP 2
12	MS	SW	HP 2
13	MS	NE	HP 1 Redo
14	MS	NE	HP 1 Redo
End Survey			

Appendix C – Equipment & Instrument Accuracies

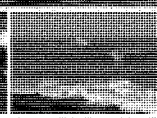
R/V 4-POINTS

Hydrographic Survey













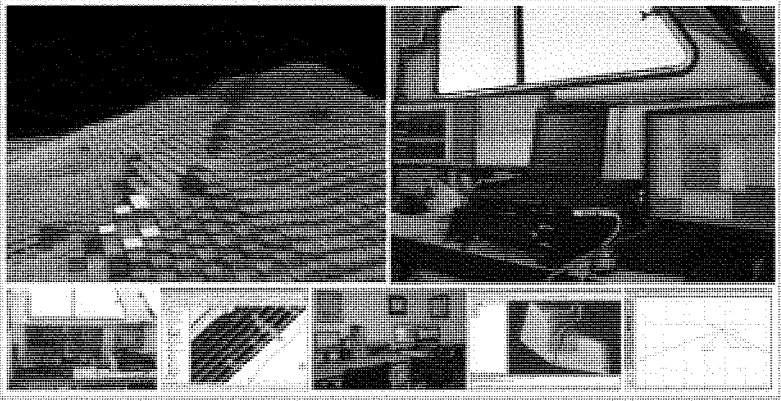


The research vessel 4-Points is a custom fiberglass survey boat designed specifically for shallow water sonar and acoustical operations. The vessel is 25' long with a 10' beam, the bottom tapers from a deep "Carolina" style Vee to a relatively flat-bottomed stern that provides a shallow draft of approximately 1.2'. Twin 140 four-stroke engines, hung on a stainless steel bracket, power the vessel. All electronics and generators are grounded to the sea via a bottom mounted bonding plate to eliminate all electrical noise. Side-scan instrumentation is deployed, towed and retrieved from custom davit on starboard side.

Instrumentation:

- **Simrad EM 3002 multibeam sonar**
  - Multi-Frequency: in 300 kHz band
  - Max ping rate: 40 Hz
  - No. of beams/ping: 254 Roll and Pitch stabilized
  - Beam width: 1.5° x 1.5°
  - Beam spacing: 0.9°
  - Depth range from sonar head: 1 to 150 m
  - Depth resolution: 1 cm
  - Depth accuracy: 5 cm RMS
  - Range sampling rate: 15 kHz
  - Bottom detection by phase or amplitude. Seabed imaging & classification with backscatter (sidescan like) output.
  - Full swath width accuracy to the latest IHO standard
- **POS MV 320 v4 (with RTK Corrections)**
  - Roll, Pitch accuracy: 0.02° (1 sigma with GPS or DGPS)
  - 0.01° (1 sigma with RTK)
  - Heave Accuracy: 5 cm or 5% (whichever is greater)
  - Heading Accuracy: 0.02° (1 sigma) with 2 m antenna baseline
  - Position Accuracy: 0.02 - 0.10 m (RTK) with input
- **Trimble 5700 dual frequency GPS system & RTK-Basestation**
  - Instrument used for topo/bathy positioning and tidal corrections
  - High precision L1 and L2 measurements
  - 24 channels L1 C/A code, L1/L2 full cycle carrier
  - Extremely low latency (20 milliseconds)
  - Published horizontal accuracy: 10 mm + 1ppm RMS
  - Published vertical accuracy: 20 mm + 1ppm RMS
- **Odom Hydrographics Digibar Pro sound velocity probe**
  - Sampling rate: 10 Hz
  - Depth accuracy: > 31 cm
  - Velocity accuracy: +/- 0.3 m/sec
- **Applied Microsystems MicroSV sound velocity sensor**
  - SV: time of flight
  - Sampling rate: 10 Hz or continuous programmable
  - Velocity accuracy: 0.05 m/sec
  - Sampling rate: 10 Hz
  - AC or DC power

Processing



GeoDynamics maintains a cluster of high-end computer workstations and fileserver servers for the most demanding geospatial data acquisition, processing and analysis. All geodynamics are specialized in high-end spatial data processing and analysis through geographic information science and 3D visualization.

Instrumentation:

Hardware

- **Field**
  - Custom rack mounted multibeam acquisition PC
  - 3.6 GHz Intel Pentium 4 processors with 800 MHz system bus
  - 2 GB of RAM
  - 512 Dual DVI graphics card
  - (2) 400 GB SATA hard drives
  - Shared SIS & Applanix POS View acquisition software
  - CARIS HIPS/SIPS
  - (3) Fujitsu laptop navigation PC
  - (3) Maxtor external backup hard drives – 850 GB of storage
- **Office**
  - (4) high-end Dell GIS processing workstations
  - (2) Dell workstation laptops
  - (2) 1 TB RAID network attached storage devices
  - (4) Maxtor / Seagate external backup drives – 1.2 TB of storage

Software

- **Multibeam / Side Scan**
  - Caris HIPS / SIPS 6 sp2
  - Triton Imaging ISIS
  - Triton Imaging SwathPro & DelphMap
- **Singlebeam**
  - **Hypack Max v. 5.2 sp1**
  - Caris HIPS / SIPS 6 sp2
- **Topographic**
  - Trimble Geomatics Office
  - Caris HIPS / SIPS 6 sp2 (Lidar)
- **GIS**
  - ArcView 9.2a (Spatial, 3D & Image Analyst)
  - ArcGIS 9.1 (Spatial, ArcScene, 3D, Survey & Geostatistical Analyst)
  - Surfer 8.0
  - ERDAS

Final General Reevaluation Report
and
Final Environmental Impact Statement

on

Hurricane Protection and Beach Erosion Control

SURF CITY AND NORTH TOPSAIL BEACH
NORTH CAROLINA

Appendix R
Attachment 4

Surf City / North Topsail Beach, N.C. Shore Protection Project, Hardbottom Resource Confirmation and Characterization Study



ANAMAR
Environmental Consulting, Inc.

FINAL REPORT

SURF CITY/NORTH TOPSAIL BEACH, N.C. SHORE PROTECTION PROJECT, HARDBOTTOM RESOURCE CONFIRMATION AND CHARACTERIZATION STUDY

This document has been saved as a PDF file that is bookmarked for easy navigation. To navigate the document using bookmarks, select the BOOKMARKS tab from the left side of the screen and expand as necessary. Clicking on a bookmark will take you to the appropriate section of the report.

Feasibility Report
and
Final Environmental Impact Statement

on

Coastal Storm Damage Reduction

SURF CITY AND NORTH TOPSAIL BEACH
NORTH CAROLINA

Appendix S -

Topsail Beach
Benthic Community Characterization Survey

Appendix S -

Topsail Beach
Benthic Community Characterization Survey

The following pages contain the technical memorandum prepared by Dial Cordy and Associates, Inc., Environmental Consultants under contract to the U.S. Army Corps of Engineers, Wilmington District. The technical memorandum describes the benthic study of the Topsail Beach offshore borrow sites. The study also includes 4 additional appendices, which are included in the CDROM version of the Final Feasibility and Final EIS, but are not in the printed version.

Technical Memorandum

Topsail Beach Benthic Community Characterization Survey Pender County, NC

Final

May 2007

Prepared for:
U.S. Army Corps of Engineers
Wilmington District
P.O. Box 1890
Wilmington, NC 28402

Prepared by:

DIAL CORDY
AND ASSOCIATES INC
Environmental Consultants

Topsail Beach Benthic Community Characterization Survey Pender County, NC

Technical Memorandum

FINAL

May 2007

Prepared for:

U.S. Army Corps of Engineers
Wilmington District
P.O. Box 1890
Wilmington, NC 28402

Prepared by:

Dial Cordy and Associates Inc.
201 North Front Street
Suite 601
Wilmington, NC 28401

(1290)

TABLE OF CONTENTS

Page

LIST OF TABLES iii

LIST OF FIGURES iii

1.0 INTRODUCTION 1

2.0 METHODS 1

3.0 RESULTS 4

3.1 Sediment Grain-size Analysis 4
3.2 Faunal Composition 6
3.3 Species Richness 6
3.4 Diversity Indices 6
3.5 Faunal Abundance 15
3.6 Biomass 15

4.0 DISCUSSION 20

5.0 LITERATURE CITED 21

Appendix A Data Quality Control Report

Appendix B Sediment Analysis Report

Appendix C Station Data Summary Report

Appendix D Supporting Data Tables

LIST OF TABLES

Page

Table 1. Depths and location coordinates for benthic sampling stations off Topsail Beach, NC. 4

Table 2. Sediment analysis results for benthic sampling stations off Topsail Beach, NC. 5

Table 3. Taxonomic species list for benthic sampling stations off Topsail Beach, NC. 7

Table 4. Comparison of major taxa occurrences and relative abundances for borrow sites off Topsail Beach, NC. 10

Table 5. Summary of community parameters for benthic sampling stations off Topsail Beach, NC. 13

Table 6. Total abundance and percent composition for taxa collected at borrow sites off Topsail Beach, NC. 16

Table 7. Mean biomass of major taxa at borrow sites off Topsail Beach, NC. 19

LIST OF FIGURES

Page

Figure 1. Location of borrow areas off Topsail Beach, NC. 2

Figure 2. Location of benthic sampling stations off Topsail Beach, NC. 3

Figure 3. Relative composition of major taxa for borrow sites off Topsail Beach, NC. 9

Figure 4. Mean number of species and density within borrow sites off Topsail Beach, NC. . 12

Figure 5. Mean Shannon Wiener index (H´) and Pielou Evenness value for borrow sites off Topsail Beach, NC. 14

1.0 INTRODUCTION

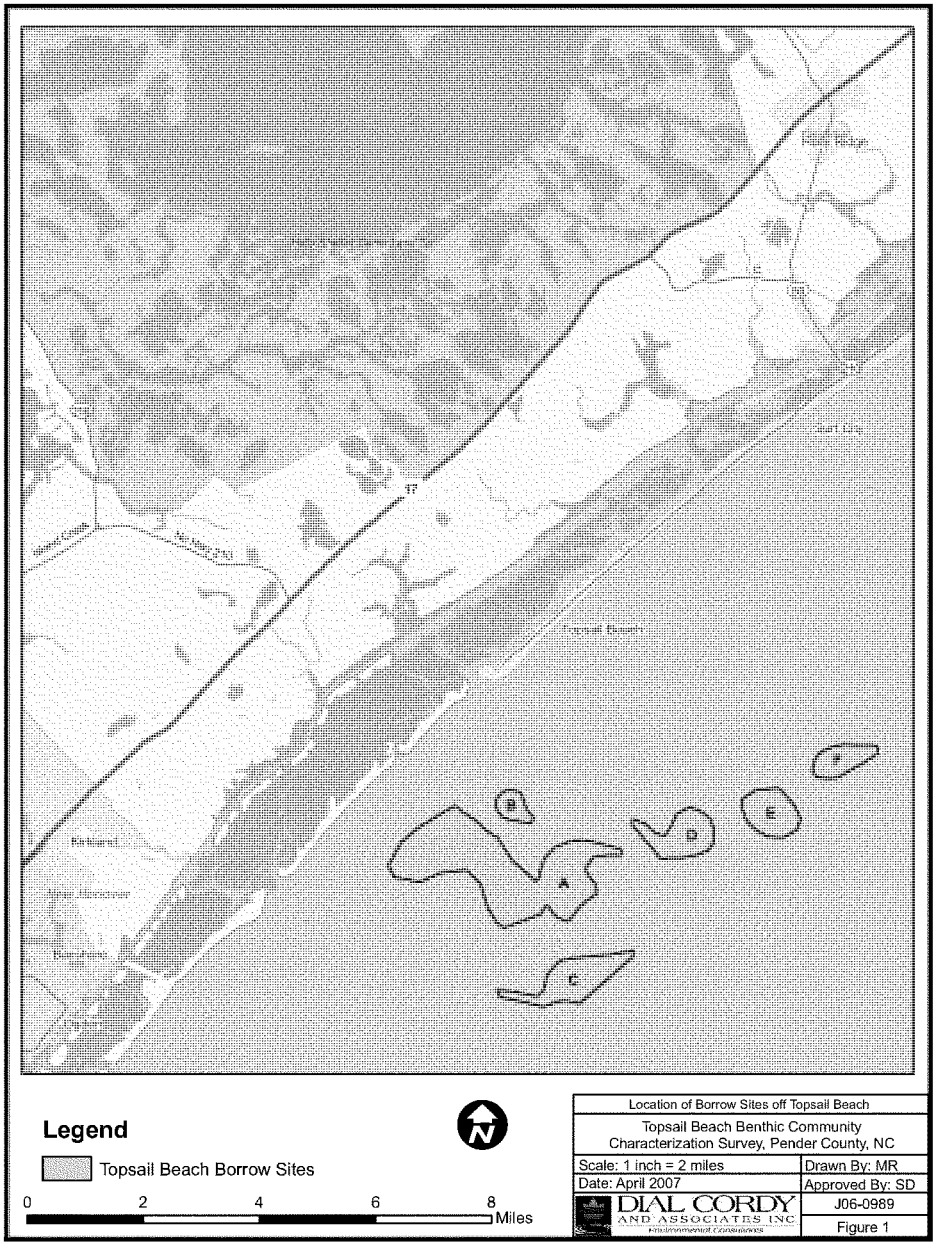
Dial Cordy and Associates Inc. (DC&A) was contracted (Contract DACW W912HN-05-D-0014) by the Wilmington District, Corps of Engineers, to conduct a characterization of the benthic community occurring within six proposed sand borrow sites selected for the proposed Shore Protection Project at Topsail Beach (Figure 1). The initial construction of the berm and dune project, extending along approximately five miles of oceanfront will require 3.2 million cubic yards of beach quality sand. The objectives of the study were to determine through benthic sampling the invertebrate abundance, species composition, and biomass within each of the borrow sites; and to perform a qualitative comparison of survey results to the results of other pertinent benthic studies completed along the coasts of North and South Carolina.

2.0 METHODS

Benthic infaunal samples were collected from three to five random locations within each of the six sand borrow sites shown in Figure 2. Five samples were taken at Borrow Site A, three samples at Borrow Site B, and four samples at each of Borrow Sites C, D, E and F. The borrow areas are located 3.0 to 5.5 miles off the south end of Topsail Island in the Atlantic Ocean. A total of 24 benthic samples were collected, along with one separate sediment sample per station (12 samples) for grain-size analysis. Coordinates for each of the 24 sampling stations are listed in Table 1.

Sampling was first attempted using a standard ponar grab on 13 November 2006; however, adequate bottom penetration was not achieved after 14 attempts within three of the six borrow areas. A Shipek grab (0.04 m^2) was used on November 28th and 29th to collect the benthic and sediment samples within each of the six borrow areas. Station positions were recorded using a Trimble GEO XT and real time positions were displayed on-board using a Hypach Navigation System. This allowed the boat operator to select stations throughout each of the borrow areas. To standardize samples, only grabs that collected full samples were saved for analysis. Faunal samples were sieved through a 0.5 mm sieve after collection, preserved in 10% buffered formalin, and subsequently transferred to 50% isoproponal once received by Barry Vittor and Associates Inc., prior to sorting and identification. Samples were sorted and all fauna identified to the lowest practical identification level possible. Wet weight biomass for the major taxa found in each sample was also performed following sample processing.

Grain-size analysis of the 12 sediment samples collected was completed using sieve sizes ranging from 4.75 mm (U.S. Standard Sieve No. 4) to 63 micron (U.S. Standard Sieve 230). A Data Quality Control Report summarizing the field activities for each survey day is provided in Appendix A.


Legend
Topsail Beach Borrow Sites
0
2
4
6
8
Miles
Location of Borrow Sites off Topsail Beach
Topsail Beach Benthic Community
Characterization Survey, Pender County, NC
Scale: 1 inch = 2 miles
Drawn By: MR
Date: April 2007
Approved By: SD
DIAL CORDY AND ASSOCIATES INC
J06-0989
Figure 1

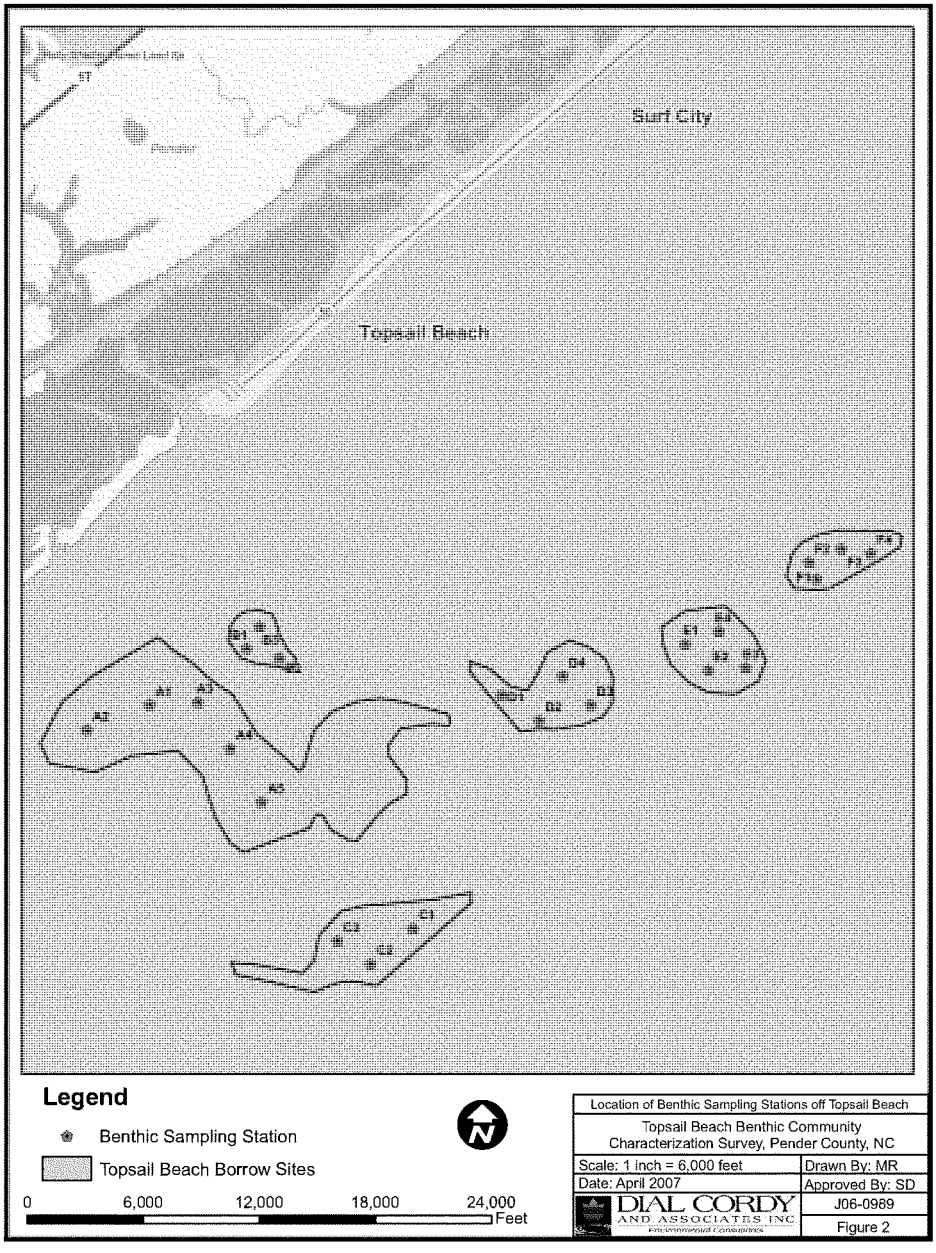

Surf City
Topsail Beach
Legend
Benthic Sampling Station
Topsail Beach Borrow Sites
0
6,000
12,000
18,000
24,000
Feet
Location of Benthic Sampling Stations off Topsail Beach
Topsail Beach Benthic Community
Characterization Survey, Pender County, NC
Scale: 1 inch = 6,000 feet
Drawn By: MR
Date: April 2007
Approved By: SD
DIAL CORDY AND ASSOCIATES INC
J06-0989
Figure 2

Table 1. Depths and location coordinates for benthic sampling stations off Topsail Beach, NC.

Borrow Site Station	Depth (m)	Station Coordinates	
A1	13.7	34°18'16.072"	77°39'47.647"
A2	13.3	34°18'02.486"	77°40'21.868"
A3	13.3	34°18'18.236"	77°39'14.008
A4	14.2	34°17'54.945"	77°38'53.466"
A5	15.1	34°17'28.093"	77°38'33.163"
B1	12.2	34°18'46.266"	77°38'44.909"
B2	13.5	34°18'41.749"	77°38'24.575"
B3	13.2	34°18'57.558"	77°38'37.370"
C1	14.1	34°16'25.432"	77°36'58.081"
C2	14.9	34°16'06.703"	77°37'23.427"
C3	14.6	34°16'18.018"	77°37'44.459"
C4	15.2	34°15'57.406"	77°38'16.160"
D1	14.2	34°18'25.705"	77°36'07.197"
D2	15.3	34°18'13.213"	77°35'43.565"
D3	14.9	34°18'21.953"	77°35'12.038"
D4	14.3	34°18'36.383"	77°35'29.818"
E1	15.7	34°18'54.333"	77°34'14.820"
E2	15.4	34°18'41.374"	77°34'00.078"
E3	14.7	34°18'43.009"	77°33'37.360"
E4	15.3	34°19'01.135"	77°33'54.375"
F1	15.8	34°19'29.216"	77°32'55.069"
F2	15.4	34°19'37.710"	77°32'59.961"
F3	15.5	34°19'44.872"	77°32'40.239"
F4	14.7	34°19'43.171"	77°32'22.118"

3.0 RESULTS

The following results include a review of data pertaining to sediment grain-size analysis, faunal composition, species richness, diversity indices, faunal abundance, and biomass. A sediment analysis report prepared by Dr. Wayne Isfording is provided in Appendix B. Appendix C contains individual data summary reports for each sampling station and Appendix D includes the biomass data for all sampling stations and other supporting tables.

3.1 Sediment Grain-size Analysis

Results of the sediment grain-size analysis are summarized in Table 2 for each sampling station. The mean percent sand for Sites A, B, C, D, E, and F were 99.31%, 98.09%, 99.78%, 99.24%, 99.81%, and 99.84; respectively. The mean percent silt-clay fraction was 0.94%, 1.91%, 0.21%, 0.76%, 0.19%, and 0.16% for Sites A through F; respectively. The highest silt-clay content was recorded for Station B-2, with 5.31%; however, the fine fraction left was considered coarse silt rather than clay. The median particle size and sorting

Table 2. Sediment analysis results for benthic sampling stations off Topsail Beach, NC.

Station	% Sand	% Silt + Clay	USACE Description	Median Particle Size (phi)	Sorting Coefficient
A1	98.73	1.27	Sand	2.515	0.454
A2	99.00	1.00	Sand	2.496	0.470
A3	99.22	0.78	Sand	2.476	0.433
A4	99.72	0.28	Sand	2.470	0.504
A5	99.89	0.11	Sand	2.436	0.497
B1	100.00	0.00	Sand	*	*
B2	94.69	5.31	Sand	2.449	0.609
B3	99.59	0.41	Sand	*	*
C1	99.92	0.08	Sand	2.413	0.488
C2	99.82	0.18	Sand	2.445	0.436
C3	99.78	0.22	Sand	2.465	0.429
C4	99.57	0.43	Sand	2.469	0.415
D1	99.86	0.14	Sand	2.268	0.708
D2	99.84	0.16	Sand	2.412	0.505
D3	99.94	0.06	Sand	2.358	0.643
D4	99.61	0.39	Sand	1.885	0.726
E1	97.57	2.43	Sand	2.344	0.627
E2	99.82	0.18	Sand	2.271	0.693
E3	99.95	0.05	Sand	1.679	0.663
E4	99.82	0.18	Sand	1.798	0.711
F1	99.67	0.33	Sand	2.217	0.714
F2	99.78	0.22	Sand	*	0.934
F3	99.85	0.15	Sand	2.375	0.571
F4	99.91	0.09	Sand	2.339	0.618

* Insufficient data for any statistical calculations (See Appendix B).

coefficient for Sites A and E varied little between sampling stations (Table 2), while these parameters varied more between sampling stations at Sites C and D. Median particle size (phi) and sorting coefficients for Stations B-1, B-3, and F-2 could not be statistically calculated due to insufficient data (See Appendix B).

3.2 Faunal Composition

A total of 104 taxa were collected from the 24 samples collected within the six proposed borrow sites (Table 3). Of the taxa collected, the dominant faunal groups included polychaetes (43), crustaceans (26), mollusks (24), and echinoderms (6). Major taxa composition within each of the six borrow sites are illustrated in Figure 3 and Table 4. As shown, polychaetes were the major component of the benthos within all borrow sites; except for Site C, where crustaceans were more prevalent. The taxa within Site D were generally distributed evenly between polychaetes, mollusks, and crustaceans. Other, less frequently occurring faunal groups, included rhynchocoela (ribbon worms) that occurred within all five borrow sites, ranging from 2.6% to 4.8% of the total taxa collected; and echinoderms, which occurred within four of the five borrow sites, ranging from 3.8% to 14.3% of the total taxa collected. The total number of taxa collected within all of the samples taken at each borrow site ranged from a low of 21 taxa at Site C (n=4) to a high of 39 taxa at Sites B (n=3), E (n=4), and F (n=4) (Table 4).

Based on the total count of individuals collected per taxa within each borrow site, polychaetes were the dominant taxa at Sites A, B, D, and F. Polychaetes comprised greater than 30% of the total count (Table 4, Figure 3). Mollusks were the dominant taxa at Site E (44.6%) and secondary dominant taxa at Sites A (37.5%), B (15.4%), D (31.7%), and E (44.6%). The distribution of the total number of individuals within all Site F samples were fairly evenly distributed between the three most abundant taxa groups (polychaetes, mollusks, and crustaceans).

3.3 Species Richness

The mean number of species present within the six borrow sites ranged from a low of 7.8 within Site C to a high of 16.7 within Site B. The mean number of species present within Sites A (8.4) and D (8) were similar to Site C, while the mean number of species within Site E (15.8) was more similar to the mean number of species present within Site B. The mean number of species within Site F was 12.3 (Figure 4, Table 5). The total number of taxa collected within Sites C and D was also lower than observed within the other four sites (Table 4).

3.4 Diversity Indices

Diversity indices were calculated for each sample collected within the borrow sites (Table 5). Mean Shannon Wiener indices and Pielou Evenness values for the six borrow sites are illustrated on Figure 5. Diversity values expressed as one of the three diversity indices were consistently higher at Sites B, E, and F. High Evenness (J´) and Equitability (e) values for samples collected within the six borrow sites indicate that within each station, the abundance was evenly distributed among the taxa collected. Evenness values were greater than 0.90 at all but two of the 24 stations. Mean evenness values for the six sites ranged from 0.91 at Site E to 0.96 at Sites A and D. Variability in the evenness values within each site was highest at Site F (Figure 5).

Table 3. Taxonomic species list for benthic sampling stations off Topsail Beach, NC.

- **ANNELIDA**
  - CLASS OLIGOCHAETA
    - Order TUBIFICIDA
      - FAMILY ENCHYTRAEIDAE
        - *Enchytraeidae (LPIL)*
      - FAMILY TUBIFICIDAE
        - *Tubificidae (LPIL)*
  - CLASS POLYCHAETA
    - Order CAPITELLIDA
      - FAMILY CAPITELLIDAE
        - *Capitellidae (LPIL)*
        - *Mediomastus (LPIL)*
        - *Mediomastus californiensis*
      - FAMILY MALDANIDAE
        - *Maldanidae (LPIL)*
    - Order EUNICIDA
      - FAMILY DORVILLEIDAE
        - *Schistomeringos pectinata*
      - FAMILY LUMBRINERIDAE
        - *Lumbrineris latreilli*
      - FAMILY OENONIDAE
        - *Arabella multidentata*
      - FAMILY ONUPHIDAE
        - *Onuphidae (LPIL)*
    - Order OPHELIIDA
      - FAMILY OPHELIIDAE
        - *Opheliidae (LPIL)*
        - *Armandia (LPIL)*
        - *Armandia maculata*
        - *Ophelia denticulata*
    - Order ORBINIIDA
      - FAMILY PARAONIDAE
        - *Aricidea (LPIL)*
        - *Aricidea catherinae*
        - *Aricidea suecica*
        - *Aricidea wassi*
        - *Cirrophorus (LPIL)*
    - Order OWENIIDA
      - FAMILY OWENIIDAE
        - *Owenia fusiformis*
    - Order PHYLLODOCIDA
      - FAMILY CHRYSOPETALIDAE
        - *Bhawania heteroseta*
      - FAMILY GLYCERIDAE
        - *Glyceridae (LPIL)*
      - FAMILY GONIADIDAE
        - *Goniada littorea*
        - *Goniadides carolinae*
      - FAMILY HESIONIDAE
        - *Microphthalmus (LPIL)*
      - FAMILY NEPHTYIDAE
        - *Aglaophamus verrilli*
        - *Nephtys picta*
        - *Nephtys simoni*
      - FAMILY NEREIDAE
        - *Nereididae (LPIL)*
        - *Ceratocephale oculata*
      - FAMILY PHYLLODOCIDAE
        - *Eumida sanguinea*
      - FAMILY PILARGIIDAE
        - *Ancistrosyllis (LPIL)*
        - *Ancistrosyllis hartmanae*
        - *Sigambra tentaculata*
    - Order SPIONIDA
      - FAMILY CHAETOPTERIDAE
        - *Spiochaetopterus oculatus*
      - FAMILY CIRRATULIDAE
        - *Cirratulidae (LPIL)*
        - *Caulleriella sp. J*
      - FAMILY MAGELONIDAE
        - *Magelona (LPIL)*
        - *Magelona papillicornis*
        - *Magelona pettiboneae*
      - FAMILY SPIONIDAE
        - *Spionidae (LPIL)*
        - *Paraprionospio pinnata*
        - *Spiophanes bombyx*
    - Order TEREBELLIDA
      - FAMILY PECTINARIIDAE
        - *Pectinaria gouldii*
      - FAMILY TEREBELLIDAE
        - *Terebellidae (LPIL)*
- **ARTHROPODA**
  - CLASS MALACOSTRACA
    - Order AMPHIPODA
      - Amphipoda (LPIL)
      - FAMILY AORIDAE
        - *Rildardanus laminosa*
        - *Unciola serrata*
      - FAMILY HAUSTORIIDAE
        - *Acanthohaustorius intermedius*
      - FAMILY ISAEIDAE
        - *Microprotopus raneyi*
      - FAMILY MELITIDAE
        - *Maera caroliniana*
      - FAMILY OEDICEROTIDAE
        - *Oedicerotidae (LPIL)*
        - *Americhelidium americanum*
      - FAMILY PHOXOCEPHALIDAE
        - *Metharpinia floridana*
        - *Rhepoxynius hudsoni*
      - FAMILY PLATYISCHNOPIDAE
        - *Eudevenopus honduranus*
      - FAMILY SYNOPIIDAE
        - *Metatiron (LPIL)*
        - *Metatiron triocellatus*
    - Order CUMACEA
      - FAMILY DIASTYLIDAE
        - *Oxyurostylis (LPIL)*
    - Order DECAPODA
      - FAMILY PAGURIDAE
        - *Pagurus (LPIL)*
      - FAMILY PASIPHAEIDAE
        - *Leptochela serratorbita*
      - FAMILY PINNOTHERIDAE
        - *Dissodactylus mellitae*
  - CLASS OSTRACODA
    - Order MYODOCOPINA
      - FAMILY PHILOMEDIDAE
        - *Philomedidae (LPIL)*
        - *Harbansus paucichelatus*
      - FAMILY SARSIELLIDAE
        - Eusarsiella (LPIL)
        - *Eusarsiella radiicosta*
        - *Eusarsiella texana*

Table 3. (concluded)

- Order PODOCOPIDA
  - *Podocopida (LPIL)*
- **BRYOZOA**
  - *Bryozoa (LPIL)*
- **CHORDATA**
  - CLASS LEPTOCARDIA
    - Order AMPHIOXI
      - FAMILY BRANCHIOSTOMIDAE
        - *Branchiostoma (LPIL)*
- **CNIDARIA**
  - CLASS HYDROZOA
    - *Hydrozoa (LPIL)*
- **ECHINODERMATA**
  - *Echinodermata (LPIL)*
  - CLASS ECHINOIDEA
    - *Echinoidea (LPIL)*
    - Order CLYPEASTEROIDA
      - FAMILY MELLITIDAE
        - *Mellitidae (LPIL)*
        - *Mellita isometra*
  - CLASS OPHIUROIDEA
    - *Ophiuroidea (LPIL)*
    - Order OPHIURIDA
      - FAMILY AMPHIURIDAE
        - *Amphiuridae (LPIL)*
- **MOLLUSCA**
  - CLASS BIVALVIA
    - *Bivalvia (LPIL)*
    - Order OSTREOIDA
      - FAMILY ANOMIIDAE
        - *Anomia simplex*
    - Order VENEROIDA
      - FAMILY CRASSATELLIDAE
        - *Crassinella dupliniana*
        - *Crassinella lunulata*
      - FAMILY LUCINIDAE
        - *Lucinidae (LPIL)*
        - *Lucina (LPIL)*
        - *Lucina multilineata*
      - FAMILY MESODESMATIDAE
        - *Ervilia concentrica*
      - FAMILY MONTACUTIDAE
        - *Montacutidae (LPIL)*
      - FAMILY SEMELIDAE
        - *Semelidae (LPIL)*
      - FAMILY TELLINIDAE
        - *Strigilla mirabilis*
        - *Tellina (LPIL)*
        - *Tellina iris*
  - CLASS GASTROPODA
    - Order CEPHALASPIDEA
      - FAMILY SCAPHANDRIDAE
        - *Acteocina canaliculata*
        - *Cylichna alba*
    - Order MESOGASTROPODA
      - FAMILY CAECIDAE
        - *Caecum pulchellum*
      - FAMILY EULIMIDAE
        - *Strombiformis bilineatus*
      - FAMILY NATICIDAE
        - *Tectonatica pusilla*
    - Order NEOGASTROPODA
      - FAMILY OLIVIDAE
        - *Olivella dealbata*
        - *Oliva sayana*
      - FAMILY TURRIDAE
        - *Kurtziella atrostyla*
    - Order PYRAMIDELLOIDA
      - FAMILY PYRAMIDELLIDAE
        - *Odostomia weberi*
        - *Turbonilla (LPIL)*
- **PHORONIDA**
  - FAMILY PHORONIDAE
    - *Phoronis (LPIL)*
- **PLATYHELMINTHES**
  - CLASS TURBELLARIA
    - *Turbellaria (LPIL)*
- **RHYNCHOCOELA**
  - *Rhynchocoela (LPIL)*
- **SIPUNCULA**
  - FAMILY ASPIDOSIPHONIDAE
    - *Aspidosiphon albus*

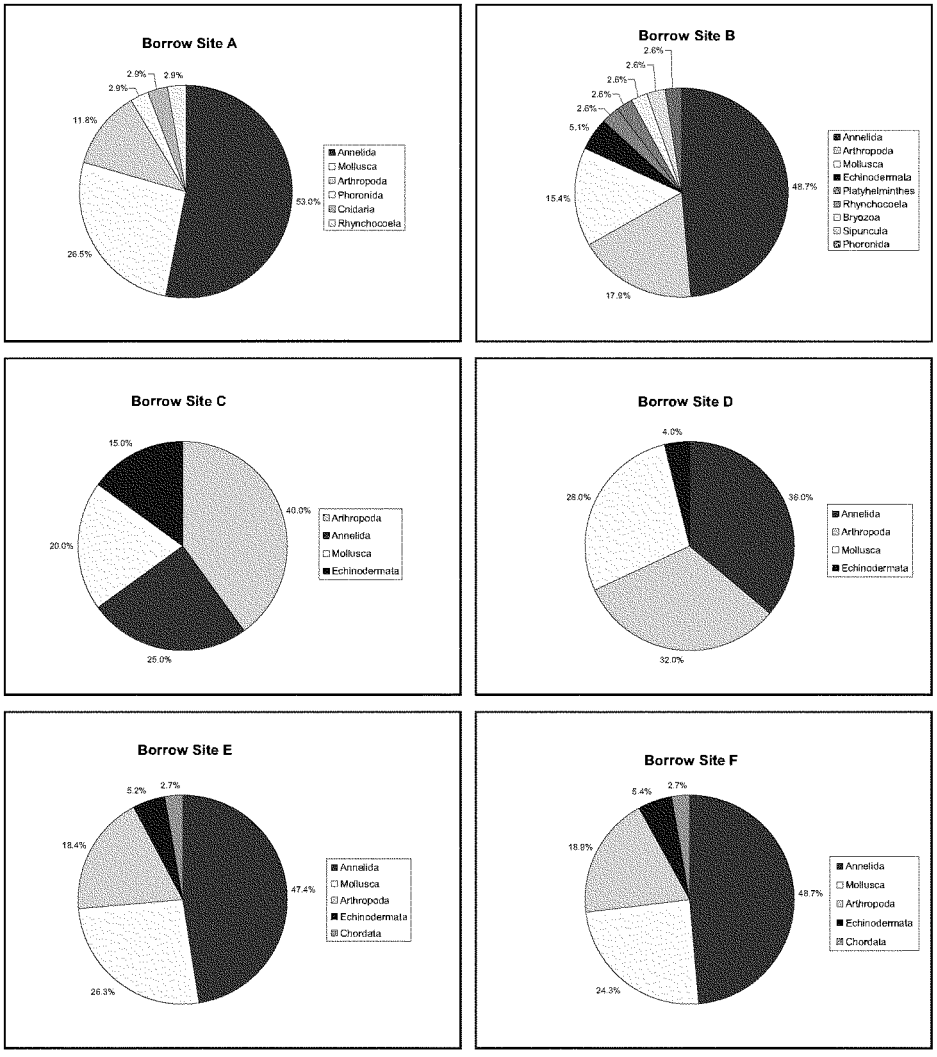


Figure 3. Relative composition of major taxa for borrow sites off Topsail Beach, NC.

Table 4. Comparison of major taxa occurrences and relative abundances for borrow sites off Topsail Beach, NC.

Site	Cnidaria	Rhynchocoela	Annelida	Mollusca	Platyhelminthes	Arthropoda	Bryozoa	Sipuncula	Phoronida	Echinodermata	Chordata	Total Per Site
Borrow Site A (n=5)												
Total # Taxa	1	1	18	9		4			1			34
Taxa % Total	2.9%	2.9%	52.9%	26.5%		11.8%			2.9%			
Total # Ind.	1	1	27	21		5			1			56
Ind. % Total	1.8%	1.8%	48.2%	37.5%		8.9%			1.8%			
Borrow Site B (n=3)												
Total # Taxa		1	19	6	1	7	1	1	1	2		39
Taxa % Total		2.6%	48.7%	15.4%	2.6%	17.9%	2.6%	2.6%	2.6%	5.1%		
Total # Ind.		3	44	16	4	9	1	1	1	9		88
Ind. % Total		3.4%	50.0%	18.2%	4.5%	10.2%	1.1%	1.1%	1.1%	10.2%		
Borrow Site C (n=4)												
Total # Taxa		1	5	4		8				3		21
Taxa % Total		4.8%	23.8%	19.0%		38.1%				14.3%		
Total # Ind.		1	12	16		20				6		55
Ind. % Total		1.8%	21.8%	29.1%		36.4%				10.9%		

1302

Table 4. (concluded)

Site	Cnidaria	Rhynchocoela	Annelida	Mollusca	Platyhelminthes	Arthropoda	Bryozoa	Sipuncula	Phoronida	Echinodermata	Chordata	Total Per Site
Borrow Site D (n=4)												
Total # Taxa		1	9	7		8				1		26
Taxa % Total		3.8%	34.6%	26.9%		30.8%				3.8%		
Total # Ind.		1	15	13		11				1		41
Ind. % Total		2.4%	36.6%	31.7%		26.8%				2.4%		
Borrow Site E (n=4)												
Total # Taxa		1	18	10		7				2	1	39
Taxa % Total		2.6%	46.2%	25.6%		17.9%				5.1%	2.6%	
Total # Ind.		4	31	50		23				2	2	112
Ind. % Total		3.6%	27.7%	44.6%		20.5%				1.8%	1.8%	
Borrow Site F (n=4)												
Total # Taxa		1	18	9	1	7				2	1	39
Taxa % Total		2.6%	46.2%	23.1%	2.6%	17.9%				5.1%	2.6%	
Total # Ind.		3	23	21	1	21				4	3	76
Ind. % Total		3.9%	30.3%	27.6%	1.3%	27.6%				5.3%	3.9%	

1303

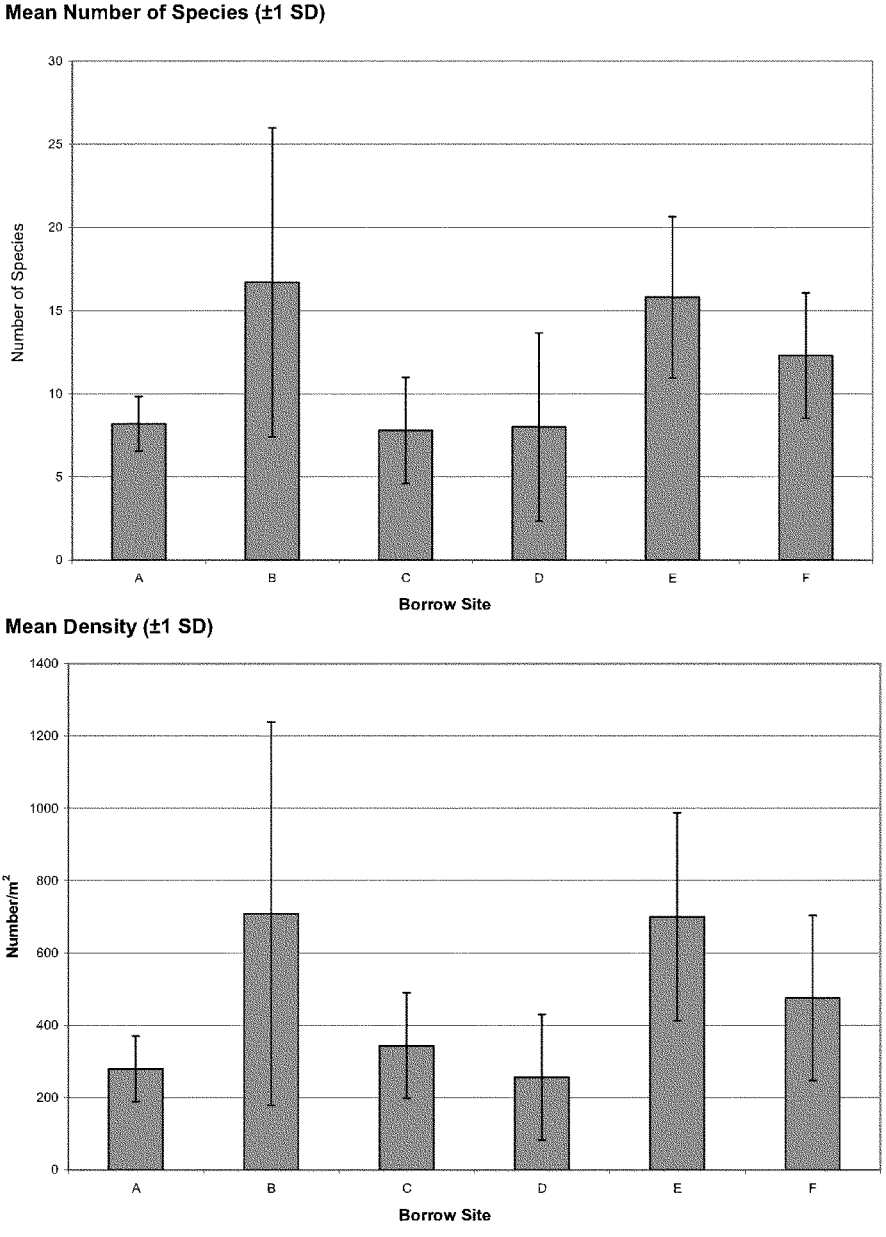


Figure 4. Mean number of species and density within borrow sites off Topsail Beach, NC.

Table 5. Summary of community parameters for benthic sampling stations off Topsail Beach, NC.

Station	Total No. Taxa	Total No. Individuals	Density (nos/m^2)	H' Shannon (log e)	d Diversity (log 2)	1/S Simpson Diversity	J' Pielou Evenness	D Margalef Richness	e Equitability
A1	6	7	175.0	1.75	2.52	21.00	0.98	2.57	1.33
A2	10	17	425.0	2.18	3.15	13.60	0.95	3.18	1.25
A3	9	10	250.0	2.16	3.12	45.00	0.98	3.47	1.37
A4	9	11	275.0	2.15	3.10	27.50	0.98	3.34	1.34
A5	7	11	275.0	1.80	2.59	9.17	0.92	2.50	1.20
B1	14	25	625.0	2.53	3.65	20.00	0.96	4.04	1.29
B2	9	9	225.0	2.20	3.17		1.00	3.64	1.41
B3	27	51	1275.0	2.98	4.29	19.92	0.90	6.61	1.06
C1	3	5	125.0	1.05	1.52	5.00	0.96	1.24	1.29
C2	9	17	425.0	2.04	2.94	10.46	0.93	2.82	1.20
C3	9	16	400.0	1.98	2.85	8.57	0.90	2.89	1.12
C4	10	17	425.0	2.15	3.10	12.36	0.93	3.18	1.21
D1	4	4	100.0	1.39	2.00		1.00	2.16	1.37
D2	8	10	250.0	1.97	2.85	15.00	0.95	3.04	1.26
D3	4	7	175.0	1.28	1.84	5.25	0.92	1.54	1.22
D4	16	20	500.0	2.67	3.85	31.67	0.96	5.01	1.30
E1	11	15	375.0	2.27	3.27	17.50	0.95	3.69	1.25
E2	13	26	650.0	2.34	3.38	11.21	0.91	3.68	1.14
E3	22	43	1075.0	2.64	3.82	10.38	0.86	5.58	0.92
E4	17	28	700.0	2.58	3.72	14.00	0.91	4.80	1.12
F1	9	9	225.0	2.20	3.17		1.00	3.64	1.41
F2	16	24	600.0	2.64	3.80	23.00	0.95	4.72	1.26
F3	9	14	350.0	2.14	3.09	18.20	0.98	3.03	1.34
F4	15	29	725.0	2.20	3.17	5.88	0.81	4.16	0.85

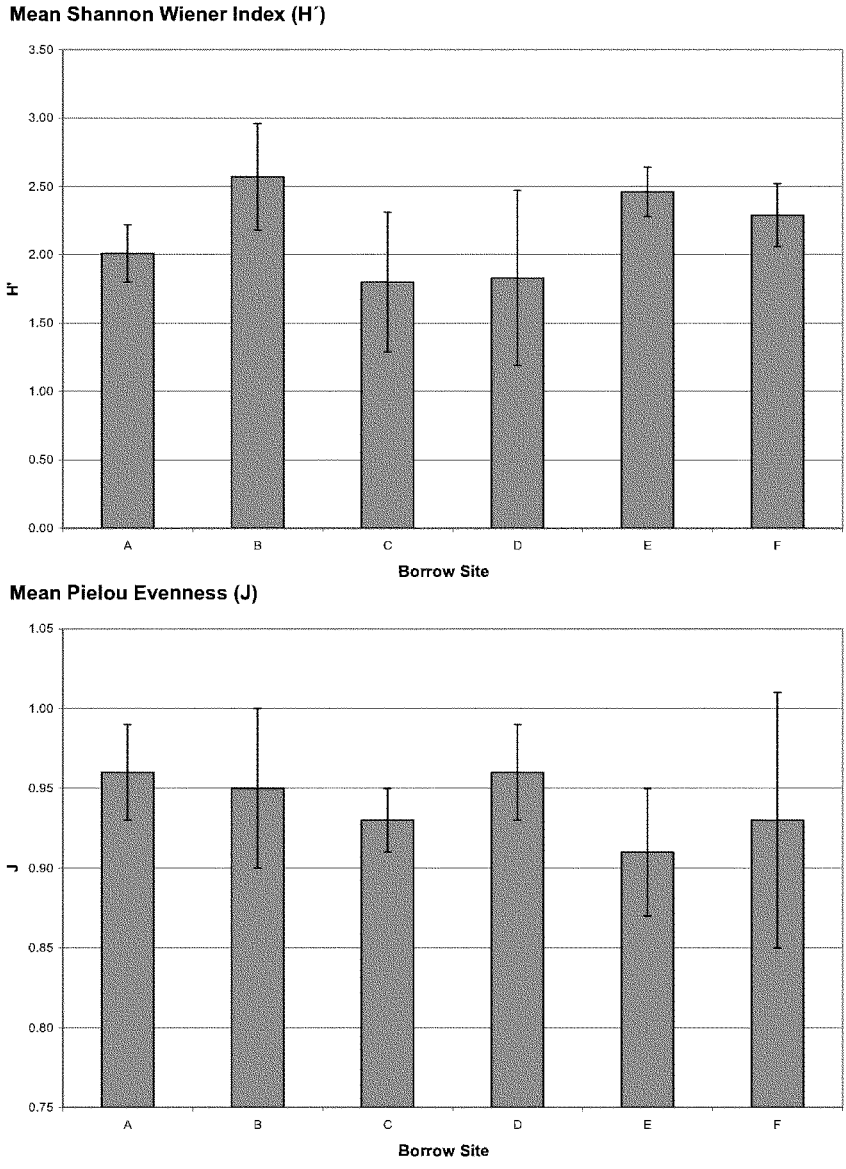


Figure 5. Mean Shannon Wiener index (H´) and Pielou Evenness value for borrow sites off Topsail Beach, NC.

3.5 Faunal Abundance

The total count and density of the benthic community collected at each station within the six borrow sites is provided in Table 5. The abundance and density for each species occurrence is provided in Tables D-1 and D-2 (Appendix D). A total of 425 individuals were collected during the study, ranging from a mean density of 256 individuals/m^2 within Site D to 708 individuals/m^2 at Site B (Figure 4). Variability in the density within each borrow site was highest at Site B, which ranged from 225 individuals/m^2 to 1,275 individuals/m^2 (n=3); followed by Site E, where density ranged from 375 individuals/m^2 to 1,075 individuals/m^2 (n=4). Mean density at Sites A, C, and D were all low compared to the mean density at Sites B, E, and F.

The ten most abundant species were: the polychaetes *Magelona papillicornis*, *Goniada littorea*, and *Goniadides carolinae*; the amphipod *Eudovenopus honduranus*; the bivalves *Crassinella lunicata*, *Lucinidae(LPIL)*, and *Tellina (LPIL)*; the gastropod *Caecum pulchellum*; the echinoderm *Ophiuroidea (LPIL)*; and the ribbon worm *Rhynchocoela (LPIL)*. These ten species together comprised 47.4% of the benthic infauna collected (Table 6). Other species found within at least two of the sites, and comprising about 2% of the total abundance included: the polychaetes *Onuphidae (LPIL)*, *Armandia maculata*, *Bhawania heteroseta*, and *Spionidae (LPIL);* the bivalve *Crassinella dupliniana*; and the gastropods *Acteocina canaliculata* and *Cylichna alba*. Of the balance of species remaining, 79 species each comprised less than 1% of the total abundance.

3.6 Biomass

The biomass for major faunal groups collected at all sampling stations is summarized in Table D-3 of Appendix D, while the mean biomass (g/m^2) for major faunal groups within each site is provided in Table 7. Mean biomass was lowest at Site A (36.69 g/m^2) and Site D (41.59 g/m^2); similar between Sites B (69.53 g/m^2), Site E (59.08 g/m^2), and Site F (57.85 g/m^2); and highest at Site C (182.61 g/m^2). Site C is skewed higher due to the occurrence of brittle stars (*Ophiuroidea*), which weigh more than other taxa present. Excluding this epibenthic taxa, the mean biomass for Site C would be 44.88 g/m^2.

Table 6. Total abundance and percent composition for taxa collected at borrow sites off Topsail Beach, NC.

Species	Total Count Per Site						% of Total
	A	B	C	D	E	F	
Enchytraeidae (LPIL)		2					0.48
Tubificidae (LPIL)		1					0.24
Capitellidae (LPIL)	1						0.24
Mediomastus (LPIL)		4			1		1.20
Mediomastus californiensis	1						0.24
Maldanidae (LPIL)					1		0.24
Schistomeringos pectinata		1					0.24
Lumbrineris latreilli				1		1	0.48
Arabella multidentata					1		0.24
Onuphidae (LPIL)	1	1	2	1		2	1.67
Opheliidae (LPIL)					2	1	0.72
Armandia (LPIL)					1		0.24
Armandia maculata	1	1	3		2		1.67
Ophelia denticulata						1	0.24
Aricidea (LPIL)				1	1		0.48
Aricidea catherinae	1	1					0.48
Aricidea suecica					1		0.24
Aricidea wassi				1	3		0.96
Cirrophorus (LPIL)		1			1		0.48
Owenia fusiformis	1			1			0.48
Bhawania heteroseta		7				1	1.91
Glyceridae (LPIL)	2	1	1		1		1.20
Goniada littorea	1		5	4	4	2	3.83
Goniadides carolinae		9				2	2.63
Microphthalmus (LPIL)						1	0.24
Aglaophamus verrilli	1						0.24
Nephtys picta						2	0.48
Nephtys simoni						1	0.24
Nereididae (LPIL)		1					0.24
Ceratocephale oculata					1	2	0.72
Eumida sanguinea		1					0.24
Ancistrosyllis (LPIL)		1			1		0.48
Ancistrosyllis hartmanae		1			1		0.48
Sigambra tentaculata	1						0.24
Spiochaetopterus oculatus	1		1				0.48
Cirratulidae (LPIL)		2				1	0.72
Caulleriella sp. J	4	1				1	1.44
Magelona (LPIL)	3						0.72

Table 6. (continued)

Species	Total Count Per Site						
	A	B	C	D	E	F	% of Total
Magelona papillicornis	3			4	7	2	3.83
Magelona pettiboneae						1	0.24
Spionidae (LPIL)	1	4		1	1	1	1.91
Paraprionospio pinnata	1				1	1	0.72
Spiophanes bombyx				1			0.24
Pectinaria gouldii	1						0.24
Terebellidae (LPIL)		1					0.24
Amphipoda (LPIL)			1	1			0.48
Rildardanus laminosa		1					0.24
Unciola serrata		1					0.24
Acanthohaustorius intermedius						2	0.48
Microprotopus raneyi		2					0.48
Maera caroliniana		2				1	0.72
Oedicerotidae (LPIL)		1					0.24
Americhelidium americanum				1	1		0.48
Metharpinia floridana					1		0.24
Rhepoxynius hudsoni			2	1	1	1	1.20
Eudevenopus honduranus			10	4	17	14	10.77
Metatiron (LPIL)		1					0.24
Metatiron triocellatus		1					0.24
Oxyurostylis (LPIL)				1	1	1	0.72
Pagurus (LPIL)		1			1		0.48
Leptochela serratorbita							
Dissodactylus mellitae			2				0.48
Philomedidae (LPIL)					1		0.24
Harbansus paucichelatus					1		0.24
Eusarsiella (LPIL)	1						0.24
Eusarsiella radiicosta						1	0.24
Eusarsiella texana	1		2	1	1	1	1.44
Podocopida (LPIL)			1				0.24
Bryozoa (LPIL)		1					0.24
Branchiostoma (LPIL)					2	3	1.20
Hydrozoa (LPIL)	1						0.24
Echinodermata (LPIL)					1		0.24
Echinoidea (LPIL)			2				0.48
Mellitidae (LPIL)						2	0.48
Mellita isometra			1				0.24
Ophiuroidea (LPIL)		8	3	1	1	2	3.59
Amphiuridae (LPIL)		1					0.24
Bivalvia (LPIL)	2	1					0.72

Table 6. (concluded)

Species	Total Count Per Site						
	A	B	C	D	E	F	% of Total
Anomia simplex						1	0.24
Crassinella dupliniana					4	4	1.91
Crassinella lunulata		10	2	3			3.59
Lucinidae (LPIL)	2			1	3	3	2.15
Lucina (LPIL)				1			0.24
Lucina multilineata		1			3		0.96
Ervilia concentrica	1			1		1	0.72
Montacutidae (LPIL)					1		0.24
Semelidae (LPIL)		1					0.24
Strigilla mirabilis					2		0.48
Tellina (LPIL)	5	1	9	1	3		4.54
Tellina iris	1						0.24
Acteocina canaliculata	1		1	1	4	1	1.91
Cylichna alba	5		2	1			1.91
Caecum pulchellum		1	4	7	24	3	9.33
Strombiformis bilineatus					2		0.48
Tectonatica pusilla		1			2		0.72
Oliva sayana	3						0.72
Olivella dealbata						2	0.48
Kurtziella atrostyla						1	0.24
Odostomia weberi	1						0.24
Turbonilla (LPIL)						1	0.24
Phoronis (LPIL)	1	1					0.48
Turbellaria (LPIL)		4				1	1.20
Rhynchocoela (LPIL)	1	3	1	1	4	3	3.11
Aspidosiphon albus		1					0.24

Table 7. Mean biomass of major taxa at borrow sites off Topsail Beach, NC.

Borrow Site A	
Faunal Group	**gm/m²**
Annelida	14.3835
Mollusca	14.0410
Arthropoda	5.5235
Echinodermata	0.0000
Other Taxa	2.7450
Total	36.6930

Borrow Site D	
Faunal Group	**gm/m²**
Annelida	14.1350
Mollusca	13.7320
Arthropoda	6.8550
Echinodermata	3.4325
Other Taxa	3.4325
Total	41.5881

Borrow Site B	
Faunal Group	**gm/m²**
Annelida	13.9200
Mollusca	13.7866
Arthropoda	13.9208
Echinodermata	13.9516
Other Taxa	13.9500
Total	69.5291

Borrow Site E	
Faunal Group	**gm/m²**
Annelida	14.0706
Mollusca	13.8350
Arthropoda	14.0100
Echinodermata	6.8643
Other Taxa	10.2950
Total	59.0750

Borrow Site C	
Faunal Group	**gm/m²**
Annelida	13.8419
Mollusca	13.7693
Arthropoda	13.8356
Echinodermata	137.7275
Other Taxa	3.4350
Total	182.6093

Borrow Site F	
Faunal Group	**gm/m²**
Annelida	15.0306
Mollusca	13.9231
Arthropoda	13.8325
Echinodermata	3.4350
Other Taxa	11.6306
Total	57.8518

4.0 DISCUSSION

In comparison to the results of baseline sampling performed for the Kure Beach restoration project (Posey and Alphin 2000, 2002) and for the Dare County beach shoreline protection project (Versar 2006), the benthic community found offshore of Topsail Beach was less diverse and abundant. Since the Topsail Beach benthic sampling in this survey was only performed in late fall/early winter, comparisons to other surveys should focus on the same seasonal time frame.

Baseline sampling performed off Kure Beach in October 1995 found 44 and 76 taxa, and faunal densities of 1,007 individuals/m^2 and 923 individuals/m^2, respectively, for the borrow and control sites (Posey and Alphin 2000). The number of total taxa occurring within each proposed borrow site off Topsail Beach ranged from 21 to 39 taxa, while mean density by site ranged from 280 individuals/m^2 to 708 individuals/m^2. Posey and Alphin (2000) reported 600 total taxa collected from the year long study, as compared to the 104 total taxa collected for the one-time sampling performed for the Topsail Beach study. However, the Kure Beach study was more extensive in that it involved five sampling periods, replicate samples at each location, and covered a variety of benthic substrates (some adjacent to hard bottom communities). All of these factors would be expected to yield a more diverse benthic community. The community studied off Kure Beach was dominated by polychaetes, with 29 taxa comprising at least 5% of the individuals sampled from a single sampling event. Off Topsail Beach, polychaetes dominated the community, comprising over 30% of the relative abundance at four of the six borrow sites.

Seasonal pre-construction benthic community sampling was performed within the proposed north borrow site and reference site for the Dare County shoreline protection project (Versar 2006). Sampling included benthic grabs at ten stations within each of the two sites during the four seasons from spring 2004 through winter 2005. A total of 168 taxa were collected during the study, with polychaetes being the dominant taxa group in occurrence and biomass, especially during the fall and winter. The mean number of taxa present in the fall at the proposed north borrow site was 16 (range of 8 to 26 taxa) and 8 (range of 6 to 11 taxa) in the winter. This is not too different than what was found in the six Topsail Beach borrow sites, where the mean number of species across the six borrow sites ranged from 8 to 17. However, the species richness in the Dare County reference site was significantly greater than the species richness found off Topsail Beach or in the Dare County proposed north borrow site. Mean faunal density in the fall at the Dare County proposed north borrow site (1,555 individuals/m^2) was slightly higher than the mean density within the Topsail Beach borrow sites (Figure 4, Table 5), while the mean density at the reference site (8,696 individuals/m^2) was significantly greater. Mean faunal density in the winter was exceptionally higher off Dare County than observed off Topsail Beach, with mean densities of 11,460 individuals/m^2 and 1,398 individuals/m^2 for the reference and borrow sites, respectively. The mean biomass of fall samples was 0.28 g/m^2 and 2.23 g/m^2 for the borrow and reference sites, respectively; as compared to a much higher mean biomass range of 37 g/m^2 to 182 g/m^2 for the six Topsail Beach borrow sites. This comparison also held true for the winter mean biomass values from Dare County.

In summary, the benthic community found within the six proposed borrow sites off Topsail Beach is similar in composition and taxa dominance to those described in other studies along the North Carolina and South Carolina coasts (Byrnes et al. 2003; Versar 2002, 2006; and

Posey and Alphin 2000, 2002). However, the number of species present and abundance were noticeably lower off Topsail Beach than found off Kure Beach (Posey and Alphin 2000) or Dare County (Versar 2006). It is likely that the differences between the benthic community off Topsail Beach, as reported here, and the two referenced studies are due to the more extensive sampling effort associated with baseline monitoring programs, as compared to a less intensive sampling regime for a general characterization study (e.g. ten sampling stations per site off Dare County as compared to three to five stations per site for this study)

5.0 LITERATURE CITED

Byrnes, M.R., R.M. Hammer, B.A. Vittor, S.W. Kelley, D.B. Snyder, J.M. Côté, J.S. Ramsey, T.D. Thibaut, N.W. Phillips, J.D. Wood, and J.D. Germano. 2003. Collection of environmental data within sand resource areas offshore North Carolina and the environmental implications of sand removal for coastal and beach restoration. U.S. Department of the Interior, Minerals Management Service, Leasing Division, Sand and Gravel Unit, Herndon, VA. OCS Report MMS 2000-056, Volume I: Main Text 256 pp. + Volume II: Appendices 69 pp.

Posey, M.H. and T.D. Alphin. 2000. Monitoring of benthic faunal responses to sediment removal associated with the Carolina Beach and vicinity - Area South Project. Prepared for the Wilmington District, US Army Corps of Engineers, Wilmington, NC. 20 pp. plus appendices.

Posey, M.H. and T.D. Alphin. 2002. Resilience and stability in an offshore benthic community: Responses to sediment borrow activities and hurricane disturbance. Journal of Coastal Research. 18(4): 685-697.

Versar. 2002. Effects of dredged material beach disposal on surf zone and nearshore fish and benthic resources on Bald Head Island, Caswell Beach, Oak Island, and Holden Beach, North Carolina: Interim study findings. Prepared by Versar, Inc., Columbia, MD, for U.S. Army Corps of Engineers, Wilmington District, Wilmington, NC. 2 volumes.

Versar. 2006. Year one pre-construction environmental monitoring for the Dare County beach shoreline protection project, Dare County, North Carolina. Prepared by Versar Inc., Columbia, MD, for the U.S. Army Corps of Engineers, Wilmington District, Wilmington, NC. 5 sections plus appendices.

APPENDIX A

Data Quality Control Report

Table A-1. Data Quality Control Report

Date: 13 Nov 06
Wind speed/direction (estimated): NW @ 10-12 knots
Wave height (estimated): 1' swells within 2 miles of shore. Beyond 2 miles, 2', steep and building slightly throughout the day.
Water temperature: 60.9°F
Vessel: F/V Emma K
Personnel on board: Capt. Jeff Coward, Duke Hunsaker
Sampling Equipment employed: Trimble GEO XT handheld gps (sub-meter accuracy)
SI-TEX CVS106 (120 kHz)
Standard Ponar grab

Sample Site	Time	Depth (m)	Sample Coordinates	Sediment Sample	Benthic sample?
F1	10:30	16.3		No	No
F1	10:40	16.3		No	No
F1	11:00	16.3		No	No
F1	11:25	16.3		No	No
F1	11:50	16.3		No	No
B1	12:15	13.4		No	No
B1	12:30	13.4		No	No
B1	12:50	13.4		No	No
B1	1:00	13.4		No	No
B1	1:20	13.4		No	No
B1	1:35	13.4		No	No
B1	1:45	13.4		No	No
B1	2:00	13.4		No	No
B1	2:20	13.4		No	No

Comments: Pot hauler works well in calm water, but sheaves aren't grooved deep enough. When trying to pull the sampler up in rolling sea, the line jumps off the pulley. To avoid injury and/or damage to the vessel, it was necessary to pull the ponar by hand all day. While we have listed 14 sampling attempts, there were numerous drops in between in which misfires occured or the ponar did not fire. When the ponar did fire properly, it was unable to penetrate the substrate. Only a light dusting of sand was retrieved with each grab. Not enough substrate for analysis. GPS points not taken, since no samples were obtained at the sites. Crossed the bar around 3:00pm. Off water at 3:45pm.

Table A-1. (continued)

Date: 28 Nov 06
Wind speed/direction (estimated): NE @ 10 knots
Wave height (estimated): 2-3' swells within 2.5 miles of shore. Beyond 2.5 miles, 3-4' rolling swells
Water temperature: 58.9°F
Vessel: F/V Emma K
Personnel on board: Capt. Jeff Coward, Duke Hunsaker, Ryan Lewis
Sampling Equipment employed: Trimble GEO XT handheld gps (sub-meter accuracy)
SI-TEX CVS106 (120 kHz)
Wildco Shipek grab sampler
Plastic jars/labels prepared for each station

Sample Site	Time	Depth (m)	Sample Coordinates	Sediment Sample	Benthic sample?
A1	8:40	13.7	34°18'16.072"	Yes	Yes
			77°39'47.647"	Yes	Yes
A2	9:05	13.3	34°18'02.486"	Yes	Yes
			77°40'21.868"	Yes	Yes
A3	9:30	13.3	34°18'18.236"	Yes	Yes
			77°39'14.008"	Yes	Yes
A4	9:55	14.2	34°17'54.945"	Yes	Yes
			77°38'53.466"	Yes	Yes
A5	10:30	15.1	34°17'28.093"	Yes	Yes
			77°38'33.163"	Yes	Yes
D1	11:15	14.2	34°18'25.705"	Yes	Yes
			77°36'07.197"	Yes	Yes
D2	11:40	15.3	34°18'13.213"	Yes	Yes
			77°35'43.565"	Yes	Yes
D3	12:00	14.9	34°18'21.953"	Yes	Yes
			77°35'12.038"	Yes	Yes
D4	12:35	14.3	34°18'36.383"	Yes	Yes
			77°35'29.818"	Yes	Yes
E1	1:00	15.7	34°18'54.333"	Yes	Yes
			77°34'14.820"	Yes	Yes
E2	1:25	15.4	34°18'41.374"	Yes	Yes
			77°34'00.078"	Yes	Yes
E3	1:45	14.7	34°18'43.009"	Yes	Yes
			77°33'37.360"	Yes	Yes
E4	2:10	15.3	34°19'01.135"	Yes	Yes
			77°33'54.375"	Yes	Yes
F1	2:40	15.8	34°19'29.216"	Yes	Yes
			77°32'55.069"	Yes	Yes
F2	3:15	15.4	34°19'37.710"	Yes	Yes
			77°32'59.961"	Yes	Yes
F3	3:40	15.5	34°19'44.872"	Yes	Yes
			77°32'40.239"	Yes	Yes
F4	4:15	14.7	34°19'43.171"	Yes	Yes
			77°32'22.118"	Yes	Yes

Comments: Ponar replaced with Wildco Shipek grab sampler. Shipek grab very effective. Sampling went very smoothly. Crossed the bar approximately 5:00pm. Off water at 5:45pm.

Table A-1. (concluded)

Date: 29 Nov 06
Wind speed/direction (estimated): ENE @ 5-10 knots
Wave height (estimated): 2' swells within 2 miles of shore. Beyond 2 miles, 3' swells with occasional 4' swell. Sea slightly confused.
Water temperature: 59.2°F
Vessel: F/V Emma K
Personnel on board: Capt. Jeff Coward, Duke Hunsaker, Ryan Lewis
Sampling Equipment employed: Trimble GEO XT handheld gps (sub-meter accuracy)
SI-TEX CVS106 (120 kHz)
Wildco Shipek grab sampler

Sample Site	Time	Depth (m)	Sample Coordinates	Sediment Sample	Benthic sample?
B1	9:30	12.2	34°18'46.266"	Yes	Yes
			77°38'44.909"	Yes	Yes
B2	10:00	13.5	34°18'41.749"	Yes	Yes
			77°38'24.575"	Yes	Yes
B3	10:20	13.2	34°18'57.558"	Yes	Yes
			77°38'37.370"	Yes	Yes
C1	10:55	14.1	34°16'25.432"	Yes	Yes
			77°36'58.081"	Yes	Yes
C2	11:20	14.9	34°16'06.703"	Yes	Yes
			77°37'23.427"	Yes	Yes
C3	11:40	14.6	34°16'18.018"	Yes	Yes
			77°37'44.459"	Yes	Yes
C4	11:55	15.2	34°15'57.406"	Yes	Yes
			77°38'16.160"	Yes	Yes

Comments: Sampling went smoothly. No problems. Crossed the bar at approximately 1:00pm. Off water at 1:45pm.

APPENDIX B

Sediment Analysis Report

TIERRA CONSULTING
SEDPET III: SEDIMENTARY PETROLOGY ANALYSIS PROGRAM

ANALYSIS OF SAMPLE: A-1

PAN=0.52=1.09%
BVA-DIAL CORDY 2-26-07

SIEVE ANALYSIS

SAMPLE WEIGHT = 47.33

SIEVE SIZE (MICRONS)	SIEVE SIZE (PHI)	SIEVE WT (GRAMS)	WEIGHT PERCENT RETAINED	CUMULATIVE PERCENT THROUGH	CUMULATIVE PERCENT RETAINED
1000.00	.00	.54	1.14	98.86	1.14
500.00	1.00	.63	1.33	97.53	2.47
250.00	2.00	4.23	8.94	88.59	11.41
125.00	3.00	35.47	74.94	13.65	86.35
62.50	4.00	5.86	12.38	1.27	98.73

TEXTURAL CLASSIFICATION AND PHI PERCENTILES SAMPLE A-1

SIZE CLASSIFICATION USED: STANDARD GEOLOGICAL SOILS CLASSIFICATION

GRAVEL/SAND CUTOFF 2000.00 MICRONS
SAND/SILT CUTOFF 62.50 MICRONS
SILT/CLAY CUTOFF 4.00 MICRONS

PERCENT GRAVEL .00
PERCENT SAND 98.73

PERCENT SILT AND CLAY 1.27

TEXTURAL DESCRIPTIONS

FOLK'S: SAND
SHEPARD'S: SAND
TREFETHEN'S: SAND
U.S. ARMY CORPS OF ENGINEERS: SAND
U.S. BUREAU OF SOILS: SAND

PHI PERCENTILES

PHI(05)	1.28 PHI	410.98 MICRONS
PHI(16)	2.06 PHI	239.61 MICRONS
PHI(25)	2.18 PHI	220.47 MICRONS
PHI(50)	2.51 PHI	174.96 MICRONS
PHI(75)	2.85 PHI	138.84 MICRONS
PHI(84)	2.97 PHI	127.75 MICRONS
PHI(95)	3.70 PHI	77.02 MICRONS

EXTRAPOLATION OF DATA TO CUMULATIVE 99.5% RETAINED.

INSUFFICIENT DATA TO PERFORM EXTRAPOLATION

INTERPOLATED PHI PERCENTILES SAMPLE A-1

PHI	MICRONS	MM	PCT. RET	PCT. FINER
.00	1000.00	.1000E+01	1.14	98.86
.25	840.90	.8409E+00	1.47	98.53
.50	707.11	.7071E+00	1.81	98.19
.75	594.60	.5946E+00	2.14	97.86
1.00	500.00	.5000E+00	2.47	97.53
1.25	420.45	.4204E+00	4.71	95.29
1.50	353.55	.3536E+00	6.94	93.06
1.75	297.30	.2973E+00	9.17	90.83
2.00	250.00	.2500E+00	11.41	88.59
2.25	210.22	.2102E+00	30.14	69.86
2.50	176.78	.1768E+00	48.88	51.12
2.75	148.65	.1487E+00	67.62	32.38
3.00	125.00	.1250E+00	86.35	13.65
3.25	105.11	.1051E+00	89.45	10.55
3.50	88.39	.8839E-01	92.54	7.46
3.75	74.33	.7433E-01	95.64	4.36
4.00	62.50	.6250E-01	98.73	1.27

STATISTICS AND ENGINEERING PARAMETERS SAMPLE A-1

INMAN'S STATISTICS:

MEDIAN	2.515 PHI	174.955 MICRONS
MEAN	2.515 PHI	174.955 MICRONS
STANDARD DEVIATION	.454	WELL SORTED
SKEWNESS	.000	NEAR-SYMMETRICAL
KURTOSIS	1.662	VERY LEPTOKURTIC

FOLK'S STATISTICS:

MEAN	2.515 PHI	174.955 MICRONS
STANDARD DEVIATION	.593	MODERATELY WELL SORTED
SKEWNESS	-.010	NEAR-SYMMETRICAL
KURTOSIS	1.484	LEPTOKURTIC

MOMENT MEASURES:

INSUFFICIENT DATA FOR MOMENT MEASURES

ENGINEERING PARAMETERS:

D60	2.382 PHI	191.909 MICRONS
D30	2.782 PHI	145.409 MICRONS
D10	3.295 PHI	101.905 MICRONS
COEF. OF UNIFORMITY	1.883	
COEF. OF CURVATURE	1.081	

TIERRA CONSULTING
SEDPET III: SEDIMENTARY PETROLOGY ANALYSIS PROGRAM

ANALYSIS OF SAMPLE: A-2

PAN=0.26=0.60%
BVA-DIAL CORDY 2-26-07

SIEVE ANALYSIS

SAMPLE WEIGHT = 42.99

SIEVE SIZE (MICRONS)	SIEVE SIZE (PHI)	SIEVE WT (GRAMS)	WEIGHT PERCENT RETAINED	CUMULATIVE PERCENT THROUGH	CUMULATIVE PERCENT RETAINED
1000.00	.00	.18	.42	99.58	.42
500.00	1.00	.73	1.70	97.88	2.12
250.00	2.00	5.17	12.03	85.86	14.14
125.00	3.00	31.07	72.27	13.58	86.42
62.50	4.00	5.41	12.58	1.00	99.00

TEXTURAL CLASSIFICATION AND PHI PERCENTILES SAMPLE A-2

SIZE CLASSIFICATION USED: STANDARD GEOLOGICAL SOILS CLASSIFICATION

GRAVEL/SAND CUTOFF	2000.00 MICRONS
SAND/SILT CUTOFF	62.50 MICRONS
SILT/CLAY CUTOFF	4.00 MICRONS
PERCENT GRAVEL	.00
PERCENT SAND	99.00
PERCENT SILT AND CLAY	1.00

TEXTURAL DESCRIPTIONS

FOLK'S: SAND
SHEPARD'S: SAND
TREFETHEN'S: SAND
U.S. ARMY CORPS OF ENGINEERS: SAND
U.S. BUREAU OF SOILS: SAND

PHI PERCENTILES

PHI(05)	1.24 PHI	423.45 MICRONS
PHI(16)	2.03 PHI	245.59 MICRONS
PHI(25)	2.15 PHI	225.28 MICRONS
PHI(50)	2.50 PHI	177.25 MICRONS
PHI(75)	2.84 PHI	139.46 MICRONS
PHI(84)	2.97 PHI	127.93 MICRONS
PHI(95)	3.68 PHI	77.90 MICRONS

EXTRAPOLATION OF DATA TO CUMULATIVE 99.5% RETAINED.

INSUFFICIENT DATA TO PERFORM EXTRAPOLATION

INTERPOLATED PHI PERCENTILES SAMPLE A-2

PHI	MICRONS	MM	PCT. RET	PCT. FINER
.00	1000.00	.1000E+01	.42	99.58
.25	840.90	.8409E+00	.84	99.16
.50	707.11	.7071E+00	1.27	98.73
.75	594.60	.5946E+00	1.69	98.31
1.00	500.00	.5000E+00	2.12	97.88
1.25	420.45	.4204E+00	5.12	94.88
1.50	353.55	.3536E+00	8.13	91.87
1.75	297.30	.2973E+00	11.14	88.86

2.00	250.00	.2500E+00	14.14	85.86
2.25	210.22	.2102E+00	32.21	67.79
2.50	176.78	.1768E+00	50.28	49.72
2.75	148.65	.1487E+00	68.35	31.65
3.00	125.00	.1250E+00	86.42	13.58
3.25	105.11	.1051E+00	89.56	10.44
3.50	88.39	.8839E-01	92.71	7.29
3.75	74.33	.7433E-01	95.85	4.15
4.00	62.50	.6250E-01	99.00	1.00

STATISTICS AND ENGINEERING PARAMETERS SAMPLE A-2

INMAN'S STATISTICS:

MEDIAN	2.496	PHI	177.251 MICRONS
MEAN	2.496	PHI	177.251 MICRONS
STANDARD DEVIATION	.470	WELL SORTED	
SKEWNESS	.000	NEAR-SYMMETRICAL	
KURTOSIS	1.596	VERY LEPTOKURTIC	

FOLK'S STATISTICS:

MEAN	2.496	PHI	177.251 MICRONS
STANDARD DEVIATION	.605	MODERATELY WELL SORTED	
SKEWNESS	-.014	NEAR-SYMMETRICAL	
KURTOSIS	1.447	LEPTOKURTIC	

MOMENT MEASURES:

INSUFFICIENT DATA FOR MOMENT MEASURES

ENGINEERING PARAMETERS:

D60	2.358	PHI	195.092 MICRONS
D30	2.773	PHI	146.313 MICRONS
D10	3.285	PHI	102.604 MICRONS
COEF. OF UNIFORMITY	1.901		
COEF. OF CURVATURE	1.069		

TIERRA CONSULTING
SEDPET III: SEDIMENTARY PETROLOGY ANALYSIS PROGRAM

ANALYSIS OF SAMPLE: A-3

PAN=.30=.6%
BVA DIAL CORDY 2-26-07

SIEVE ANALYSIS

SAMPLE WEIGHT = 47.21

SIEVE SIZE (MICRONS)	SIEVE SIZE (PHI)	SIEVE WT (GRAMS)	WEIGHT PERCENT RETAINED	CUMULATIVE PERCENT THROUGH	CUMULATIVE PERCENT RETAINED
1000.00	.00	.11	.23	99.77	.23
500.00	1.00	1.15	2.44	97.33	2.67
250.00	2.00	4.71	9.98	87.35	12.65
125.00	3.00	37.05	78.48	8.88	91.12
62.50	4.00	3.82	8.09	.78	99.22

TEXTURAL CLASSIFICATION AND PHI PERCENTILES SAMPLE A-3

SIZE CLASSIFICATION USED: STANDARD GEOLOGICAL SOILS CLASSIFICATION

GRAVEL/SAND CUTOFF 2000.00 MICRONS
SAND/SILT CUTOFF 62.50 MICRONS
SILT/CLAY CUTOFF 4.00 MICRONS

PERCENT GRAVEL .00
PERCENT SAND 99.22

PERCENT SILT AND CLAY .78

TEXTURAL DESCRIPTIONS

FOLK'S: SAND
SHEPARD'S: SAND
TREFETHEN'S: SAND
U.S. ARMY CORPS OF ENGINEERS: SAND
U.S. BUREAU OF SOILS: SAND

PHI PERCENTILES

PHI(05)	1.23 PHI	425.24 MICRONS
PHI(16)	2.04 PHI	242.70 MICRONS
PHI(25)	2.16 PHI	224.16 MICRONS
PHI(50)	2.48 PHI	179.74 MICRONS
PHI(75)	2.79 PHI	144.13 MICRONS
PHI(84)	2.91 PHI	133.12 MICRONS
PHI(95)	3.48 PHI	89.69 MICRONS

EXTRAPOLATION OF DATA TO CUMULATIVE 99.5% RETAINED.

INSUFFICIENT DATA TO PERFORM EXTRAPOLATION

INTERPOLATED PHI PERCENTILES — SAMPLE A-3

PHI	MICRONS	MM	PCT. RET	PCT. FINER
.00	1000.00	.1000E+01	.23	99.77
.25	840.90	.8409E+00	.84	99.16
.50	707.11	.7071E+00	1.45	98.55
.75	594.60	.5946E+00	2.06	97.94
1.00	500.00	.5000E+00	2.67	97.33
1.25	420.45	.4204E+00	5.16	94.84
1.50	353.55	.3536E+00	7.66	92.34
1.75	297.30	.2973E+00	10.15	89.85
2.00	250.00	.2500E+00	12.65	87.35
2.25	210.22	.2102E+00	32.27	67.73
2.50	176.78	.1768E+00	51.89	48.11
2.75	148.65	.1487E+00	71.50	28.50
3.00	125.00	.1250E+00	91.12	8.88
3.25	105.11	.1051E+00	93.15	6.85
3.50	88.39	.8839E-01	95.17	4.83
3.75	74.33	.7433E-01	97.19	2.81
4.00	62.50	.6250E-01	99.22	.78

STATISTICS AND ENGINEERING PARAMETERS — SAMPLE A-3

INMAN'S STATISTICS:

MEDIAN	2.476 PHI	179.745 MICRONS
MEAN	2.476 PHI	179.745 MICRONS
STANDARD DEVIATION	.433	WELL SORTED
SKEWNESS	.000	NEAR-SYMMETRICAL
KURTOSIS	1.591	VERY LEPTOKURTIC

FOLK'S STATISTICS:

MEAN	2.476 PHI	179.745 MICRONS
STANDARD DEVIATION	.557	MODERATELY WELL SORTED
SKEWNESS	-.053	NEAR-SYMMETRICAL
KURTOSIS	1.444	LEPTOKURTIC

MOMENT MEASURES:

INSUFFICIENT DATA FOR MOMENT MEASURES

ENGINEERING PARAMETERS:

D60	2.349 PHI	196.342 MICRONS
D30	2.731 PHI	150.640 MICRONS
D10	2.986 PHI	126.248 MICRONS

COEF. OF UNIFORMITY 1.555
COEF. OF CURVATURE .915

TIERRA CONSULTING
SEDPET III: SEDIMENTARY PETROLOGY ANALYSIS PROGRAM

ANALYSIS OF SAMPLE: A-4

PAN=0.07=.16%
BVA-DIAL CORDY 2-26-07

SIEVE ANALYSIS

SAMPLE WEIGHT = 42.79

SIEVE SIZE (MICRONS)	SIEVE SIZE (PHI)	SIEVE WT (GRAMS)	WEIGHT PERCENT RETAINED	CUMULATIVE PERCENT THROUGH	CUMULATIVE PERCENT RETAINED
1000.00	.00	.30	.70	99.30	.70
500.00	1.00	1.52	3.55	95.75	4.25
250.00	2.00	5.33	12.46	83.29	16.71
125.00	3.00	30.28	70.76	12.53	87.47
62.50	4.00	5.24	12.25	.28	99.72

TEXTURAL CLASSIFICATION AND PHI PERCENTILES SAMPLE A-4

SIZE CLASSIFICATION USED: STANDARD GEOLOGICAL SOILS CLASSIFICATION

GRAVEL/SAND CUTOFF 2000.00 MICRONS
SAND/SILT CUTOFF 62.50 MICRONS
SILT/CLAY CUTOFF 4.00 MICRONS

PERCENT GRAVEL .00
PERCENT SAND 99.72

PERCENT SILT AND CLAY .28

TEXTURAL DESCRIPTIONS

FOLK'S: SAND
SHEPARD'S: SAND
TREFETHEN'S: SAND
U.S. ARMY CORPS OF ENGINEERS: SAND
U.S. BUREAU OF SOILS: SAND

PHI PERCENTILES

PHI(05)	1.06 PHI	479.65 MICRONS
PHI(16)	1.94 PHI	260.07 MICRONS
PHI(25)	2.12 PHI	230.50 MICRONS
PHI(50)	2.47 PHI	180.44 MICRONS
PHI(75)	2.82 PHI	141.24 MICRONS
PHI(84)	2.95 PHI	129.33 MICRONS
PHI(95)	3.61 PHI	81.64 MICRONS

EXTRAPOLATION OF DATA TO CUMULATIVE 99.5% RETAINED.

***OVER 99.5% SAMPLE ACCOUNTED FOR BY INPUT DATA - NO EXTRAPOLATION REQUIRED.

INTERPOLATED PHI PERCENTILES SAMPLE A-4

PHI	MICRONS	MM	PCT. RET	PCT. FINER
.00	1000.00	.1000E+01	.70	99.30
.25	840.90	.8409E+00	1.59	98.41
.50	707.11	.7071E+00	2.48	97.52
.75	594.60	.5946E+00	3.37	96.63
1.00	500.00	.5000E+00	4.25	95.75
1.25	420.45	.4204E+00	7.37	92.63
1.50	353.55	.3536E+00	10.48	89.52
1.75	297.30	.2973E+00	13.60	86.40
2.00	250.00	.2500E+00	16.71	83.29
2.25	210.22	.2102E+00	34.40	65.60
2.50	176.78	.1768E+00	52.09	47.91
2.75	148.65	.1487E+00	69.78	30.22
3.00	125.00	.1250E+00	87.47	12.53
3.25	105.11	.1051E+00	90.54	9.46
3.50	88.39	.8839E-01	93.60	6.40
3.75	74.33	.7433E-01	96.66	3.34
4.00	62.50	.6250E-01	99.72	.28

STATISTICS AND ENGINEERING PARAMETERS SAMPLE A-4

INMAN'S STATISTICS:

MEDIAN	2.470 PHI	180.436 MICRONS
MEAN	2.447 PHI	183.395 MICRONS
STANDARD DEVIATION	.504	MODERATELY WELL SORTED
SKEWNESS	-.047	NEAR-SYMMETRICAL
KURTOSIS	1.535	VERY LEPTOKURTIC

FOLK'S STATISTICS:

MEAN	2.455 PHI	182.403 MICRONS
STANDARD DEVIATION	.639	MODERATELY WELL SORTED
SKEWNESS	-.075	NEAR-SYMMETRICAL
KURTOSIS	1.482	LEPTOKURTIC

MOMENT MEASURES:

MEAN	2.399	PHI	189.621 MICRONS
SECOND MOMENT	.443		
STANDARD DEVIATION	.666	MODERATELY WELL SORTED	
THIRD MOMENT	-.340		
SKEWNESS	-1.152	STRONGLY COARSE-SKEWED	
FOURTH MOMENT	1.218		
KURTOSIS	2.066	VERY LEPTOKURTIC	

ENGINEERING PARAMETERS:

D60	2.329	PHI	199.004 MICRONS
D30	2.753	PHI	148.335 MICRONS
D10	3.206	PHI	108.345 MICRONS
COEF. OF UNIFORMITY	1.837		
COEF. OF CURVATURE	1.021		

TIERRA CONSULTING
SEDPET III: SEDIMENTARY PETROLOGY ANALYSIS PROGRAM

ANALYSIS OF SAMPLE: A-5

PAN=0.05=.11%

BVA DIAL CORDY 2-26-07

SIEVE ANALYSIS

SAMPLE WEIGHT = 45.18

SIEVE SIZE (MICRONS)	SIEVE SIZE (PHI)	SIEVE WT (GRAMS)	WEIGHT PERCENT RETAINED	CUMULATIVE PERCENT THROUGH	CUMULATIVE PERCENT RETAINED
1000.00	.00	.17	.38	99.62	.38
500.00	1.00	.49	1.08	98.54	1.46
250.00	2.00	7.30	16.16	82.38	17.62
125.00	3.00	33.57	74.30	8.08	91.92
62.50	4.00	3.60	7.97	.11	99.89

TEXTURAL CLASSIFICATION AND PHI PERCENTILES SAMPLE A-5

SIZE CLASSIFICATION USED: STANDARD GEOLOGICAL SOILS CLASSIFICATION

GRAVEL/SAND CUTOFF	2000.00 MICRONS
SAND/SILT CUTOFF	62.50 MICRONS
SILT/CLAY CUTOFF	4.00 MICRONS
PERCENT GRAVEL	.00
PERCENT SAND	99.89
PERCENT SILT AND CLAY	.11

TEXTURAL DESCRIPTIONS

FOLK'S: SAND
SHEPARD'S: SAND
TREFETHEN'S: SAND
U.S. ARMY CORPS OF ENGINEERS: SAND
U.S. BUREAU OF SOILS: SAND

PHI PERCENTILES

PHI(05)	1.22 PHI	429.57 MICRONS
PHI(16)	1.90 PHI	267.97 MICRONS
PHI(25)	2.10 PHI	233.36 MICRONS
PHI(50)	2.44 PHI	184.82 MICRONS
PHI(75)	2.77 PHI	146.37 MICRONS
PHI(84)	2.89 PHI	134.59 MICRONS
PHI(95)	3.39 PHI	95.63 MICRONS

EXTRAPOLATION OF DATA TO CUMULATIVE 99.5% RETAINED.

***OVER 99.5% SAMPLE ACCOUNTED FOR BY INPUT DATA - NO EXTRAPOLATION REQUIRED.

INTERPOLATED PHI PERCENTILES SAMPLE A-5

PHI	MICRONS	MM	PCT. RET	PCT. FINER
.00	1000.00	.1000E+01	.38	99.62
.25	840.90	.8409E+00	.65	99.35
.50	707.11	.7071E+00	.92	99.08
.75	594.60	.5946E+00	1.19	98.81
1.00	500.00	.5000E+00	1.46	98.54
1.25	420.45	.4204E+00	5.50	94.50
1.50	353.55	.3536E+00	9.54	90.46
1.75	297.30	.2973E+00	13.58	86.42
2.00	250.00	.2500E+00	17.62	82.38

2.25	210.22	.2102E+00	36.19	63.81
2.50	176.78	.1768E+00	54.77	45.23
2.75	148.65	.1487E+00	73.35	26.65
3.00	125.00	.1250E+00	91.92	8.08
3.25	105.11	.1051E+00	93.91	6.09
3.50	88.39	.8839E-01	95.91	4.09
3.75	74.33	.7433E-01	97.90	2.10
4.00	62.50	.6250E-01	99.89	.11

STATISTICS AND ENGINEERING PARAMETERS SAMPLE A-5

INMAN'S STATISTICS:

MEDIAN	2.436 PHI	184.820 MICRONS
MEAN	2.397 PHI	189.910 MICRONS
STANDARD DEVIATION	.497	WELL SORTED
SKEWNESS	-.079	NEAR-SYMMETRICAL
KURTOSIS	1.181	LEPTOKURTIC

FOLK'S STATISTICS:

MEAN	2.410 PHI	188.198 MICRONS
STANDARD DEVIATION	.577	MODERATELY WELL SORTED
SKEWNESS	-.101	COARSE-SKEWED
KURTOSIS	1.320	LEPTOKURTIC

MOMENT MEASURES:

MEAN	2.382 PHI	191.795 MICRONS
SECOND MOMENT	.305	
STANDARD DEVIATION	.553	MODERATELY WELL SORTED
THIRD MOMENT	-.161	
SKEWNESS	-.954	STRONGLY COARSE-SKEWED
FOURTH MOMENT	.618	
KURTOSIS	2.211	VERY LEPTOKURTIC

ENGINEERING PARAMETERS:

D60	2.301 PHI	202.891 MICRONS
D30	2.705 PHI	153.363 MICRONS
D10	2.974 PHI	127.260 MICRONS
COEF. OF UNIFORMITY	1.594	
COEF. OF CURVATURE	.911	

TIERRA CONSULTING
SEDPET III: SEDIMENTARY PETROLOGY ANALYSIS PROGRAM

TIERRA CONSULTING
SEDPET III: SEDIMENTARY PETROLOGY ANALYSIS PROGRAM

ANALYSIS OF SAMPLE: B-1

PAN=0.00
BVA DIAL CORDY 2-26-07

SIEVE ANALYSIS

SAMPLE WEIGHT = 48.25

SIEVE SIZE (MICRONS)	SIEVE SIZE (PHI)	SIEVE WT (GRAMS)	WEIGHT PERCENT RETAINED	CUMULATIVE PERCENT THROUGH	CUMULATIVE PERCENT RETAINED
1000.00	.00	24.92	51.65	48.35	51.65
500.00	1.00	8.30	17.20	31.15	68.85
250.00	2.00	9.19	19.05	12.10	87.90
125.00	3.00	5.56	11.52	.58	99.42
62.50	4.00	.43	.89	-.31	100.31

****
* ***ERROR*** ***ERROR*** CUMULATIVE PERCENT RETAINED GREATER THAN 100% *
*
****

TEXTURAL CLASSIFICATION AND PHI PERCENTILES SAMPLE B-1

SIZE CLASSIFICATION USED: STANDARD GEOLOGICAL SOILS CLASSIFICATION

GRAVEL/SAND CUTOFF 2000.00 MICRONS
SAND/SILT CUTOFF 62.50 MICRONS
SILT/CLAY CUTOFF 4.00 MICRONS

PERCENT GRAVEL .00
PERCENT SAND 100.31

PERCENT SILT AND CLAY -.31

TEXTURAL DESCRIPTIONS

FOLK'S: SAND
SHEPARD'S: SAND
TREFETHEN'S: SAND
U.S. ARMY CORPS OF ENGINEERS: SAND
U.S. BUREAU OF SOILS: SAND

PHI PERCENTILES

PHI(75)	1.32 PHI	399.73 MICRONS
PHI(84)	1.80 PHI	288.09 MICRONS
PHI(95)	2.62 PHI	163.07 MICRONS

EXTRAPOLATION OF DATA TO CUMULATIVE 99.5% RETAINED.

***OVER 99.5% SAMPLE ACCOUNTED FOR BY INPUT DATA - NO EXTRAPOLATION REQUIRED.

INTERPOLATED PHI PERCENTILES SAMPLE B-1

PHI	MICRONS	MM	PCT. RET	PCT. FINER
.00	1000.00	.1000E+01	51.65	48.35
.25	840.90	.8409E+00	55.95	44.05
.50	707.11	.7071E+00	60.25	39.75
.75	594.60	.5946E+00	64.55	35.45
1.00	500.00	.5000E+00	68.85	31.15
1.25	420.45	.4204E+00	73.61	26.39
1.50	353.55	.3536E+00	78.37	21.63
1.75	297.30	.2973E+00	83.13	16.87
2.00	250.00	.2500E+00	87.90	12.10
2.25	210.22	.2102E+00	90.78	9.22
2.50	176.78	.1768E+00	93.66	6.34
2.75	148.65	.1487E+00	96.54	3.46
3.00	125.00	.1250E+00	99.42	.58
3.25	105.11	.1051E+00	99.64	.36
3.50	88.39	.8839E-01	99.87	.13
3.75	74.33	.7433E-01	100.09	-.09
4.00	62.50	.6250E-01	100.31	-.31

STATISTICS AND ENGINEERING PARAMETERS SAMPLE B-1

INSUFFICIENT DATA FOR ANY STATISTICAL CALCULATIONS

ENGINEERING PARAMETERS:

D60 IS NOT CALCULATED--FIRST SIEVE RETAINS OVER 40%

D30	1.060 PHI	479.502 MICRONS
D10	2.183 PHI	220.285 MICRONS

COEF. OF UNIFORMITY IS NOT CALCULATED

COEF. OF CURVATURE IS NOT CALCULATED

TIERRA CONSULTING
SEDPET III: SEDIMENTARY PETROLOGY ANALYSIS PROGRAM

ANALYSIS OF SAMPLE: B-2

PAN=.05=.10%
BVA-DIAL CORDY 2-26-07

SIEVE ANALYSIS

SAMPLE WEIGHT = 49.36

SIEVE SIZE (MICRONS)	SIEVE SIZE (PHI)	SIEVE WT (GRAMS)	WEIGHT PERCENT RETAINED	CUMULATIVE PERCENT THROUGH	CUMULATIVE PERCENT RETAINED
1000.00	.00	.55	1.11	98.89	1.11
500.00	1.00	1.62	3.28	95.60	4.40
250.00	2.00	7.73	15.66	79.94	20.06
125.00	3.00	32.93	66.71	13.23	86.77
62.50	4.00	3.91	7.92	5.31	94.69

TEXTURAL CLASSIFICATION AND PHI PERCENTILES SAMPLE B-2

SIZE CLASSIFICATION USED: STANDARD GEOLOGICAL SOILS CLASSIFICATION

GRAVEL/SAND CUTOFF 2000.00 MICRONS
SAND/SILT CUTOFF 62.50 MICRONS
SILT/CLAY CUTOFF 4.00 MICRONS

PERCENT GRAVEL .00
PERCENT SAND 94.69
PERCENT SILT AND CLAY 5.31

TEXTURAL DESCRIPTIONS

FOLK'S: SAND
SHEPARD'S: SAND
TREFETHEN'S: SAND
U.S. ARMY CORPS OF ENGINEERS: SAND
U.S. BUREAU OF SOILS: SAND

PHI PERCENTILES

PHI(05)	1.04 PHI	486.82 MICRONS
PHI(16)	1.74 PHI	299.17 MICRONS
PHI(25)	2.07 PHI	237.48 MICRONS
PHI(50)	2.45 PHI	183.16 MICRONS
PHI(75)	2.82 PHI	141.26 MICRONS
PHI(84)	2.96 PHI	128.65 MICRONS

EXTRAPOLATION OF DATA TO CUMULATIVE 99.5% RETAINED.

INSUFFICIENT DATA TO PERFORM EXTRAPOLATION

INTERPOLATED PHI PERCENTILES SAMPLE B-2

PHI	MICRONS	MM	PCT. RET	PCT. FINER
.00	1000.00	.1000E+01	1.11	98.89
.25	840.90	.8409E+00	1.93	98.07
.50	707.11	.7071E+00	2.76	97.24
.75	594.60	.5946E+00	3.58	96.42
1.00	500.00	.5000E+00	4.40	95.60
1.25	420.45	.4204E+00	8.31	91.69
1.50	353.55	.3536E+00	12.23	87.77
1.75	297.30	.2973E+00	16.14	83.86
2.00	250.00	.2500E+00	20.06	79.94
2.25	210.22	.2102E+00	36.74	63.26
2.50	176.78	.1768E+00	53.41	46.59
2.75	148.65	.1487E+00	70.09	29.91
3.00	125.00	.1250E+00	86.77	13.23
3.25	105.11	.1051E+00	88.75	11.25
3.50	88.39	.8839E-01	90.73	9.27
3.75	74.33	.7433E-01	92.71	7.29
4.00	62.50	.6250E-01	94.69	5.31

STATISTICS AND ENGINEERING PARAMETERS SAMPLE B-2

INMAN'S STATISTICS:

MEDIAN	2.449 PHI	183.159 MICRONS
MEAN	2.350 PHI	196.185 MICRONS
STANDARD DEVIATION	.609	MODERATELY WELL SORTED
SKEWNESS	-.163	COARSE-SKEWED

FOLK'S STATISTICS:

MEAN	2.383 PHI	191.743 MICRONS

MOMENT MEASURES:

INSUFFICIENT DATA FOR MOMENT MEASURES

ENGINEERING PARAMETERS:

D60	2.299 PHI	203.213 MICRONS
D30	2.749 PHI	148.793 MICRONS
D10	3.408 PHI	94.230 MICRONS
COEF. OF UNIFORMITY	2.157	
COEF. OF CURVATURE	1.156	

TIERRA CONSULTING
SEDPET III: SEDIMENTARY PETROLOGY ANALYSIS PROGRAM

ANALYSIS OF SAMPLE: B-3

PAN=0.11=0.25%
BVA DIAL CORDY 2-26-07

SIEVE ANALYSIS

SAMPLE WEIGHT = 43.90

SIEVE SIZE (MICRONS)	SIEVE SIZE (PHI)	SIEVE WT (GRAMS)	WEIGHT PERCENT RETAINED	CUMULATIVE PERCENT THROUGH	CUMULATIVE PERCENT RETAINED
1000.00	.00	27.79	63.30	36.70	63.30
500.00	1.00	9.11	20.75	15.95	84.05
250.00	2.00	3.80	8.66	7.29	92.71
125.00	3.00	2.70	6.15	1.14	98.86
62.50	4.00	.32	.73	.41	99.59

TEXTURAL CLASSIFICATION AND PHI PERCENTILES SAMPLE B-3

SIZE CLASSIFICATION USED: STANDARD GEOLOGICAL SOILS CLASSIFICATION

GRAVEL/SAND CUTOFF	2000.00 MICRONS
SAND/SILT CUTOFF	62.50 MICRONS
SILT/CLAY CUTOFF	4.00 MICRONS
PERCENT GRAVEL	.00
PERCENT SAND	99.59
PERCENT SILT AND CLAY	.41

TEXTURAL DESCRIPTIONS

FOLK'S: SAND
SHEPARD'S: SAND
TREFETHEN'S: SAND
U.S. ARMY CORPS OF ENGINEERS: SAND
U.S. BUREAU OF SOILS: SAND

PHI PERCENTILES

PHI(75)	.56 PHI	676.58 MICRONS
PHI(84)	1.00 PHI	500.91 MICRONS
PHI(95)	2.37 PHI	193.15 MICRONS

EXTRAPOLATION OF DATA TO CUMULATIVE 99.5% RETAINED.

***OVER 99.5% SAMPLE ACCOUNTED FOR BY INPUT DATA - NO EXTRAPOLATION REQUIRED.

INTERPOLATED PHI PERCENTILES SAMPLE B-3

PHI	MICRONS	MM	PCT. RET	PCT. FINER
.00	1000.00	.1000E+01	63.30	36.70
.25	840.90	.8409E+00	68.49	31.51
.50	707.11	.7071E+00	73.68	26.32
.75	594.60	.5946E+00	78.87	21.13
1.00	500.00	.5000E+00	84.05	15.95
1.25	420.45	.4204E+00	86.22	13.78
1.50	353.55	.3536E+00	88.38	11.62
1.75	297.30	.2973E+00	90.55	9.45
2.00	250.00	.2500E+00	92.71	7.29
2.25	210.22	.2102E+00	94.25	5.75
2.50	176.78	.1768E+00	95.79	4.21
2.75	148.65	.1487E+00	97.32	2.68
3.00	125.00	.1250E+00	98.86	1.14
3.25	105.11	.1051E+00	99.04	.96
3.50	88.39	.8839E-01	99.23	.77
3.75	74.33	.7433E-01	99.41	.59
4.00	62.50	.6250E-01	99.59	.41

STATISTICS AND ENGINEERING PARAMETERS SAMPLE B-3

INSUFFICIENT DATA FOR ANY STATISTICAL CALCULATIONS

ENGINEERING PARAMETERS:

D60 IS NOT CALCULATED--FIRST SIEVE RETAINS OVER 40%

D30	.323 PHI	799.560 MICRONS
D10	1.687 PHI	310.606 MICRONS

COEF. OF UNIFORMITY IS NOT CALCULATED
COEF. OF CURVATURE IS NOT CALCULATED

TIERRA CONSULTING
SEDPET III: SEDIMENTARY PETROLOGY ANALYSIS PROGRAM

ANALYSIS OF SAMPLE: C-3

PAN=.08=.17%
BVA- DIAL CORDY 2-26-07

SIEVE ANALYSIS

SAMPLE WEIGHT = 44.59

SIEVE SIZE (MICRONS)	SIEVE SIZE (PHI)	SIEVE WT (GRAMS)	WEIGHT PERCENT RETAINED	CUMULATIVE PERCENT THROUGH	CUMULATIVE PERCENT RETAINED
1000.00	.00	.02	.04	99.96	.04
500.00	1.00	.28	.63	99.33	.67
250.00	2.00	5.58	12.51	86.81	13.19
125.00	3.00	35.30	79.17	7.65	92.35
62.50	4.00	3.31	7.42	.22	99.78

TEXTURAL CLASSIFICATION AND PHI PERCENTILES SAMPLE C-3

SIZE CLASSIFICATION USED: STANDARD GEOLOGICAL SOILS CLASSIFICATION

GRAVEL/SAND CUTOFF 2000.00 MICRONS
SAND/SILT CUTOFF 62.50 MICRONS
SILT/CLAY CUTOFF 4.00 MICRONS

PERCENT GRAVEL .00
PERCENT SAND 99.78

PERCENT SILT AND CLAY .22

TEXTURAL DESCRIPTIONS

FOLK'S: SAND
SHEPARD'S: SAND
TREFETHEN'S: SAND
U.S. ARMY CORPS OF ENGINEERS: SAND
U.S. BUREAU OF SOILS: SAND

PHI PERCENTILES

PHI(05)	1.35 PHI	393.44 MICRONS
PHI(16)	2.04 PHI	243.92 MICRONS
PHI(25)	2.15 PHI	225.43 MICRONS
PHI(50)	2.47 PHI	181.12 MICRONS
PHI(75)	2.78 PHI	145.51 MICRONS
PHI(84)	2.89 PHI	134.48 MICRONS
PHI(95)	3.36 PHI	97.62 MICRONS

EXTRAPOLATION OF DATA TO CUMULATIVE 99.5% RETAINED.

***OVER 99.5% SAMPLE ACCOUNTED FOR BY INPUT DATA - NO EXTRAPOLATION REQUIRED.

INTERPOLATED PHI PERCENTILES SAMPLE C-3

PHI	MICRONS	MM	PCT. RET	PCT. FINER
.00	1000.00	.1000E+01	.04	99.96
.25	840.90	.8409E+00	.20	99.80
.50	707.11	.7071E+00	.36	99.64
.75	594.60	.5946E+00	.52	99.48
1.00	500.00	.5000E+00	.67	99.33
1.25	420.45	.4204E+00	3.80	96.20
1.50	353.55	.3536E+00	6.93	93.07
1.75	297.30	.2973E+00	10.06	89.94
2.00	250.00	.2500E+00	13.19	86.81
2.25	210.22	.2102E+00	32.98	67.02
2.50	176.78	.1768E+00	52.77	47.23
2.75	148.65	.1487E+00	72.56	27.44
3.00	125.00	.1250E+00	92.35	7.65
3.25	105.11	.1051E+00	94.21	5.79
3.50	88.39	.8839E-01	96.06	3.94
3.75	74.33	.7433E-01	97.92	2.08
4.00	62.50	.6250E-01	99.78	.22

STATISTICS AND ENGINEERING PARAMETERS SAMPLE C-3

INMAN'S STATISTICS:

MEDIAN	2.465 PHI	181.116 MICRONS
MEAN	2.465 PHI	181.116 MICRONS
STANDARD DEVIATION	.429	WELL SORTED
SKEWNESS	.000	NEAR-SYMMETRICAL
KURTOSIS	1.341	LEPTOKURTIC

FOLK'S STATISTICS:

MEAN	2.465	PHI	181.116 MICRONS
STANDARD DEVIATION	.519	MODERATELY WELL SORTED	
SKEWNESS	-.057	NEAR-SYMMETRICAL	
KURTOSIS	1.305	LEPTOKURTIC	

MOMENT MEASURES:

MEAN	2.430	PHI	185.619 MICRONS
SECOND MOMENT	.224		
STANDARD DEVIATION	.474	WELL SORTED	
THIRD MOMENT	-.066		
SKEWNESS	-.617	STRONGLY COARSE-SKEWED	
FOURTH MOMENT	.311		
KURTOSIS	2.060	VERY LEPTOKURTIC	

ENGINEERING PARAMETERS:

D60	2.339	PHI	197.689 MICRONS
D30	2.718	PHI	152.022 MICRONS
D10	2.970	PHI	127.601 MICRONS
COEF. OF UNIFORMITY	1.549		
COEF. OF CURVATURE	.916		

TIERRA CONSULTING
SEDPET III: SEDIMENTARY PETROLOGY ANALYSIS PROGRAM

ANALYSIS OF SAMPLE: C-4

PAN=.06=.12%
BVA- DIAL CORDY 2-26-07

SIEVE ANALYSIS

SAMPLE WEIGHT = 48.86

SIEVE SIZE (MICRONS)	SIEVE SIZE (PHI)	SIEVE WT (GRAMS)	WEIGHT PERCENT RETAINED	CUMULATIVE PERCENT THROUGH	CUMULATIVE PERCENT RETAINED
1000.00	.00	.06	.12	99.88	.12
500.00	1.00	1.00	2.05	97.83	2.17
250.00	2.00	4.59	9.39	88.44	11.56
125.00	3.00	40.06	81.99	6.45	93.55
62.50	4.00	2.94	6.02	.43	99.57

TEXTURAL CLASSIFICATION AND PHI PERCENTILES SAMPLE C-4

SIZE CLASSIFICATION USED: STANDARD GEOLOGICAL SOILS CLASSIFICATION

GRAVEL/SAND CUTOFF	2000.00 MICRONS
SAND/SILT CUTOFF	62.50 MICRONS
SILT/CLAY CUTOFF	4.00 MICRONS
PERCENT GRAVEL	.00
PERCENT SAND	99.57
PERCENT SILT AND CLAY	.43

TEXTURAL DESCRIPTIONS

FOLK'S: SAND
SHEPARD'S: SAND
TREFETHEN'S: SAND
U.S. ARMY CORPS OF ENGINEERS: SAND
U.S. BUREAU OF SOILS: SAND

PHI PERCENTILES

PHI(05)	1.30 PHI	405.76 MICRONS
PHI(16)	2.05 PHI	240.80 MICRONS
PHI(25)	2.16 PHI	223.16 MICRONS
PHI(50)	2.47 PHI	180.64 MICRONS
PHI(75)	2.77 PHI	146.23 MICRONS
PHI(84)	2.88 PHI	135.51 MICRONS
PHI(95)	3.24 PHI	105.81 MICRONS

EXTRAPOLATION OF DATA TO CUMULATIVE 99.5% RETAINED.

***OVER 99.5% SAMPLE ACCOUNTED FOR BY INPUT DATA - NO EXTRAPOLATION REQUIRED.

INTERPOLATED PHI PERCENTILES SAMPLE C-4

PHI	MICRONS	MM	PCT. RET	PCT. FINER
.00	1000.00	.1000E+01	.12	99.88
.25	840.90	.8409E+00	.63	99.37
.50	707.11	.7071E+00	1.15	98.85
.75	594.60	.5946E+00	1.66	98.34
1.00	500.00	.5000E+00	2.17	97.83
1.25	420.45	.4204E+00	4.52	95.48
1.50	353.55	.3536E+00	6.87	93.13
1.75	297.30	.2973E+00	9.22	90.78
2.00	250.00	.2500E+00	11.56	88.44
2.25	210.22	.2102E+00	32.06	67.94
2.50	176.78	.1768E+00	52.56	47.44

2.75	148.65	.1487E+00	73.06	26.94
3.00	125.00	.1250E+00	93.55	6.45
3.25	105.11	.1051E+00	95.06	4.94
3.50	88.39	.8839E-01	96.56	3.44
3.75	74.33	.7433E-01	98.07	1.93
4.00	62.50	.6250E-01	99.57	.43

STATISTICS AND ENGINEERING PARAMETERS SAMPLE C-4

INMAN'S STATISTICS:

MEDIAN	2.469	PHI	180.642 MICRONS
MEAN	2.469	PHI	180.642 MICRONS
STANDARD DEVIATION	.415	WELL SORTED	
SKEWNESS	.000	NEAR-SYMMETRICAL	
KURTOSIS	1.338	LEPTOKURTIC	

FOLK'S STATISTICS:

MEAN	2.469	PHI	180.642 MICRONS
STANDARD DEVIATION	.501	MODERATELY WELL SORTED	
SKEWNESS	-.102	COARSE-SKEWED	
KURTOSIS	1.303	LEPTOKURTIC	

MOMENT MEASURES:

MEAN	2.411	PHI	188.043 MICRONS
SECOND MOMENT	.241		
STANDARD DEVIATION	.491	WELL SORTED	
THIRD MOMENT	-.166		
SKEWNESS	-1.401	STRONGLY COARSE-SKEWED	
FOURTH MOMENT	.510		
KURTOSIS	2.930	VERY LEPTOKURTIC	

ENGINEERING PARAMETERS:

D60	2.347	PHI	196.578 MICRONS
D30	2.713	PHI	152.541 MICRONS
D10	2.957	PHI	128.812 MICRONS
COEF. OF UNIFORMITY	1.526		
COEF. OF CURVATURE	.919		

TIERRA CONSULTING
SEDPET III: SEDIMENTARY PETROLOGY ANALYSIS PROGRAM

ANALYSIS OF SAMPLE: C1

PAN=.03=.06%
BVA DIAL CORDY 2-26-07

SIEVE ANALYSIS

SAMPLE WEIGHT = 48.84

SIEVE SIZE (MICRONS)	SIEVE SIZE (PHI)	SIEVE WT (GRAMS)	WEIGHT PERCENT RETAINED	CUMULATIVE PERCENT THROUGH	CUMULATIVE PERCENT RETAINED
500.00	1.00	1.12	2.29	97.71	2.29
250.00	2.00	7.65	15.66	82.04	17.96
125.00	3.00	37.92	77.64	4.40	95.60
62.50	4.00	2.11	4.32	.08	99.92

TEXTURAL CLASSIFICATION AND PHI PERCENTILES SAMPLE C1

SIZE CLASSIFICATION USED: STANDARD GEOLOGICAL SOILS CLASSIFICATION

GRAVEL/SAND CUTOFF	2000.00 MICRONS
SAND/SILT CUTOFF	62.50 MICRONS
SILT/CLAY CUTOFF	4.00 MICRONS
PERCENT GRAVEL	.00
PERCENT SAND	99.92
PERCENT SILT AND CLAY	.08

TEXTURAL DESCRIPTIONS

FOLK'S: SAND
SHEPARD'S: SAND
TREFETHEN'S: SAND
U.S. ARMY CORPS OF ENGINEERS: SAND
U.S. BUREAU OF SOILS: SAND

PHI PERCENTILES

PHI(05)	1.17 PHI	443.56 MICRONS
PHI(16)	1.88 PHI	272.61 MICRONS
PHI(25)	2.09 PHI	234.76 MICRONS
PHI(50)	2.41 PHI	187.80 MICRONS
PHI(75)	2.73 PHI	150.24 MICRONS
PHI(84)	2.85 PHI	138.64 MICRONS
PHI(95)	2.99 PHI	125.67 MICRONS

EXTRAPOLATION OF DATA TO CUMULATIVE 99.5% RETAINED.

***OVER 99.5% SAMPLE ACCOUNTED FOR BY INPUT DATA - NO EXTRAPOLATION REQUIRED.

INTERPOLATED PHI PERCENTILES SAMPLE C1

PHI	MICRONS	MM	PCT. RET	PCT. FINER
1.00	500.00	.5000E+00	2.29	97.71
1.25	420.45	.4204E+00	6.21	93.79
1.50	353.55	.3536E+00	10.12	89.88
1.75	297.30	.2973E+00	14.04	85.96
2.00	250.00	.2500E+00	17.96	82.04
2.25	210.22	.2102E+00	37.37	62.63
2.50	176.78	.1768E+00	56.78	43.22
2.75	148.65	.1487E+00	76.19	23.81
3.00	125.00	.1250E+00	95.60	4.40
3.25	105.11	.1051E+00	96.68	3.32
3.50	88.39	.8839E-01	97.76	2.24
3.75	74.33	.7433E-01	98.84	1.16
4.00	62.50	.6250E-01	99.92	.08

STATISTICS AND ENGINEERING PARAMETERS SAMPLE C1

INMAN'S STATISTICS:

MEDIAN	2.413 PHI	187.803 MICRONS	
MEAN	2.363 PHI	194.406 MICRONS	
STANDARD DEVIATION	.488	WELL SORTED	
SKEWNESS	-.102	COARSE-SKEWED	
KURTOSIS	.865	PLATYKURTIC	

FOLK'S STATISTICS:

MEAN	2.379 PHI	192.180 MICRONS	
STANDARD DEVIATION	.520	MODERATELY WELL SORTED	
SKEWNESS	-.233	COARSE-SKEWED	
KURTOSIS	1.158	LEPTOKURTIC	

MOMENT MEASURES:

MEAN	2.339 PHI	197.694 MICRONS	
SECOND MOMENT	.266		
STANDARD DEVIATION	.516	MODERATELY WELL SORTED	
THIRD MOMENT	-.164		
SKEWNESS	-1.194	STRONGLY COARSE-SKEWED	
FOURTH MOMENT	.419		
KURTOSIS	1.970	VERY LEPTOKURTIC	

ENGINEERING PARAMETERS:

D60	2.284 PHI	205.340 MICRONS
D30	2.670 PHI	157.093 MICRONS
D10	2.928 PHI	131.406 MICRONS
COEF. OF UNIFORMITY	1.563	
COEF. OF CURVATURE	.915	

TIERRA CONSULTING
SEDPET III: SEDIMENTARY PETROLOGY ANALYSIS PROGRAM

ANALYSIS OF SAMPLE: C-2

PAN=0.06g=.12%
BVA DIAL CORDY 2-26-07

SIEVE ANALYSIS

SAMPLE WEIGHT = 49.58

SIEVE SIZE (MICRONS)	SIEVE SIZE (PHI)	SIEVE WT (GRAMS)	WEIGHT PERCENT RETAINED	CUMULATIVE PERCENT THROUGH	CUMULATIVE PERCENT RETAINED
1000.00	.00	.07	.14	99.86	.14
500.00	1.00	.75	1.51	98.35	1.65
250.00	2.00	6.78	13.67	84.67	15.33
125.00	3.00	38.64	77.93	6.74	93.26
62.50	4.00	3.25	6.56	.18	99.82

TEXTURAL CLASSIFICATION AND PHI PERCENTILES SAMPLE C-2

SIZE CLASSIFICATION USED: STANDARD GEOLOGICAL SOILS CLASSIFICATION

GRAVEL/SAND CUTOFF	2000.00 MICRONS
SAND/SILT CUTOFF	62.50 MICRONS
SILT/CLAY CUTOFF	4.00 MICRONS
PERCENT GRAVEL	.00
PERCENT SAND	99.82
PERCENT SILT AND CLAY	.18

TEXTURAL DESCRIPTIONS

FOLK'S: SAND
SHEPARD'S: SAND
TREFETHEN'S: SAND
U.S. ARMY CORPS OF ENGINEERS: SAND
U.S. BUREAU OF SOILS: SAND

PHI PERCENTILES

PHI(05)	1.24 PHI	422.00 MICRONS
PHI(16)	2.01 PHI	248.51 MICRONS
PHI(25)	2.12 PHI	229.39 MICRONS
PHI(50)	2.44 PHI	183.66 MICRONS
PHI(75)	2.77 PHI	147.05 MICRONS
PHI(84)	2.88 PHI	135.73 MICRONS
PHI(95)	3.26 PHI	104.03 MICRONS

EXTRAPOLATION OF DATA TO CUMULATIVE 99.5% RETAINED.

***OVER 99.5% SAMPLE ACCOUNTED FOR BY INPUT DATA - NO EXTRAPOLATION REQUIRED.

INTERPOLATED PHI PERCENTILES SAMPLE C-2

PHI	MICRONS	MM	PCT. RET	PCT. FINER
.00	1000.00	.1000E+01	.14	99.86
.25	840.90	.8409E+00	.52	99.48
.50	707.11	.7071E+00	.90	99.10
.75	594.60	.5946E+00	1.28	98.72
1.00	500.00	.5000E+00	1.65	98.35
1.25	420.45	.4204E+00	5.07	94.93
1.50	353.55	.3536E+00	8.49	91.51
1.75	297.30	.2973E+00	11.91	88.09
2.00	250.00	.2500E+00	15.33	84.67
2.25	210.22	.2102E+00	34.81	65.19
2.50	176.78	.1768E+00	54.30	45.70
2.75	148.65	.1487E+00	73.78	26.22
3.00	125.00	.1250E+00	93.26	6.74
3.25	105.11	.1051E+00	94.90	5.10
3.50	88.39	.8839E-01	96.54	3.46
3.75	74.33	.7433E-01	98.18	1.82
4.00	62.50	.6250E-01	99.82	.18

STATISTICS AND ENGINEERING PARAMETERS SAMPLE C-2

INMAN'S STATISTICS:

MEDIAN	2.445	PHI	183.662 MICRONS
MEAN	2.445	PHI	183.662 MICRONS
STANDARD DEVIATION	.436	WELL SORTED	
SKEWNESS	.000	NEAR-SYMMETRICAL	
KURTOSIS	1.315	LEPTOKURTIC	

FOLK'S STATISTICS:

MEAN	2.445	PHI	183.662 MICRONS
STANDARD DEVIATION	.524	MODERATELY WELL SORTED	
SKEWNESS	-.094	NEAR-SYMMETRICAL	
KURTOSIS	1.291	LEPTOKURTIC	

MOMENT MEASURES:

MEAN	2.390	PHI	190.812 MICRONS
SECOND MOMENT	.264		
STANDARD DEVIATION	.514	MODERATELY WELL SORTED	
THIRD MOMENT	-.142		
SKEWNESS	-1.043	STRONGLY COARSE-SKEWED	
FOURTH MOMENT	.477		
KURTOSIS	2.274	VERY LEPTOKURTIC	

ENGINEERING PARAMETERS:

D60	2.317	PHI	200.745 MICRONS
D30	2.702	PHI	153.733 MICRONS
D10	2.958	PHI	128.681 MICRONS
COEF. OF UNIFORMITY	1.560		
COEF. OF CURVATURE	.915		

TIERRA CONSULTING
SEDPET III: SEDIMENTARY PETROLOGY ANALYSIS PROGRAM

ANALYSIS OF SAMPLE: D-1

PAN=0.05=<5%
BVA DIAL CORDY 2-26-07

SIEVE ANALYSIS

SAMPLE WEIGHT = 49.48

SIEVE SIZE (MICRONS)	SIEVE SIZE (PHI)	SIEVE WT (GRAMS)	WEIGHT PERCENT RETAINED	CUMULATIVE PERCENT THROUGH	CUMULATIVE PERCENT RETAINED
1000.00	.00	.21	.42	99.58	.42
500.00	1.00	2.48	5.01	94.56	5.44
250.00	2.00	13.61	27.51	67.06	32.94
125.00	3.00	31.55	63.76	3.29	96.71
62.50	4.00	1.56	3.15	.14	99.86

TEXTURAL CLASSIFICATION AND PHI PERCENTILES SAMPLE D-1

SIZE CLASSIFICATION USED: STANDARD GEOLOGICAL SOILS CLASSIFICATION

GRAVEL/SAND CUTOFF 2000.00 MICRONS
SAND/SILT CUTOFF 62.50 MICRONS
SILT/CLAY CUTOFF 4.00 MICRONS

PERCENT GRAVEL .00
PERCENT SAND 99.86

PERCENT SILT AND CLAY .14

TEXTURAL DESCRIPTIONS

FOLK'S: SAND
SHEPARD'S: SAND
TREFETHEN'S: SAND
U.S. ARMY CORPS OF ENGINEERS: SAND
U.S. BUREAU OF SOILS: SAND

PHI PERCENTILES

PHI(05)	.91 PHI	531.12 MICRONS
PHI(16)	1.38 PHI	383.14 MICRONS
PHI(25)	1.71 PHI	305.40 MICRONS
PHI(50)	2.27 PHI	207.69 MICRONS
PHI(75)	2.66 PHI	158.26 MICRONS
PHI(84)	2.80 PHI	143.51 MICRONS
PHI(95)	2.97 PHI	127.34 MICRONS

EXTRAPOLATION OF DATA TO CUMULATIVE 99.5% RETAINED.

***OVER 99.5% SAMPLE ACCOUNTED FOR BY INPUT DATA - NO EXTRAPOLATION REQUIRED.

INTERPOLATED PHI PERCENTILES SAMPLE D-1

PHI	MICRONS	MM	PCT. RET	PCT. FINER
.00	1000.00	.1000E+01	.42	99.58
.25	840.90	.8409E+00	1.68	98.32
.50	707.11	.7071E+00	2.93	97.07
.75	594.60	.5946E+00	4.18	95.82
1.00	500.00	.5000E+00	5.44	94.56
1.25	420.45	.4204E+00	12.31	87.69
1.50	353.55	.3536E+00	19.19	80.81
1.75	297.30	.2973E+00	26.07	73.93
2.00	250.00	.2500E+00	32.94	67.06
2.25	210.22	.2102E+00	48.88	51.12
2.50	176.78	.1768E+00	64.82	35.18
2.75	148.65	.1487E+00	80.76	19.24
3.00	125.00	.1250E+00	96.71	3.29
3.25	105.11	.1051E+00	97.49	2.51
3.50	88.39	.8839E-01	98.28	1.72
3.75	74.33	.7433E-01	99.07	.93
4.00	62.50	.6250E-01	99.86	.14

STATISTICS AND ENGINEERING PARAMETERS SAMPLE D-1

INMAN'S STATISTICS:

MEDIAN	2.268	PHI	207.688 MICRONS
MEAN	2.092	PHI	234.492 MICRONS
STANDARD DEVIATION	.708	MODERATELY WELL SORTED	
SKEWNESS	-.247	COARSE-SKEWED	
KURTOSIS	.454	VERY PLATYKURTIC	

FOLK'S STATISTICS:

MEAN	2.151	PHI	225.194 MICRONS
STANDARD DEVIATION	.666	MODERATELY WELL SORTED	
SKEWNESS	-.281	COARSE-SKEWED	
KURTOSIS	.890	PLATYKURTIC	

MOMENT MEASURES:

MEAN	2.140	PHI	226.887 MICRONS
SECOND MOMENT	.418		
STANDARD DEVIATION	.647	MODERATELY WELL SORTED	
THIRD MOMENT	-.262		
SKEWNESS	-.970	STRONGLY COARSE-SKEWED	
FOURTH MOMENT	.733		
KURTOSIS	1.399	LEPTOKURTIC	

ENGINEERING PARAMETERS:

D60	2.111 PHI	231.538 MICRONS
D30	2.581 PHI	167.105 MICRONS
D10	2.895 PHI	134.452 MICRONS
COEF. OF UNIFORMITY	1.722	
COEF. OF CURVATURE	.897	

TIERRA CONSULTING
SEDPET III: SEDIMENTARY PETROLOGY ANALYSIS PROGRAM

ANALYSIS OF SAMPLE: D-2

PAN=.07=.1%
BVA-DIAL CORDY 2-26-07

SIEVE ANALYSIS

SAMPLE WEIGHT = 44.00

SIEVE SIZE (MICRONS)	SIEVE SIZE (PHI)	SIEVE WT (GRAMS)	WEIGHT PERCENT RETAINED	CUMULATIVE PERCENT THROUGH	CUMULATIVE PERCENT RETAINED
1000.00	.00	.16	.36	99.64	.36
500.00	1.00	.89	2.02	97.61	2.39
250.00	2.00	7.08	16.09	81.52	18.48
125.00	3.00	33.69	76.57	4.95	95.05
62.50	4.00	2.11	4.80	.16	99.84

TEXTURAL CLASSIFICATION AND PHI PERCENTILES SAMPLE D-2

SIZE CLASSIFICATION USED: STANDARD GEOLOGICAL SOILS CLASSIFICATION

GRAVEL/SAND CUTOFF	2000.00 MICRONS
SAND/SILT CUTOFF	62.50 MICRONS
SILT/CLAY CUTOFF	4.00 MICRONS
PERCENT GRAVEL	.00
PERCENT SAND	99.84
PERCENT SILT AND CLAY	.16

TEXTURAL DESCRIPTIONS

FOLK'S: SAND
SHEPARD'S: SAND
TREFETHEN'S: SAND
U.S. ARMY CORPS OF ENGINEERS: SAND
U.S. BUREAU OF SOILS: SAND

PHI PERCENTILES

PHI(05)	1.16 PHI	446.76 MICRONS
PHI(16)	1.85 PHI	278.15 MICRONS
PHI(25)	2.09 PHI	235.67 MICRONS
PHI(50)	2.41 PHI	187.93 MICRONS
PHI(75)	2.74 PHI	149.87 MICRONS
PHI(84)	2.86 PHI	138.15 MICRONS
PHI(95)	3.00 PHI	125.05 MICRONS

EXTRAPOLATION OF DATA TO CUMULATIVE 99.5% RETAINED.

***OVER 99.5% SAMPLE ACCOUNTED FOR BY INPUT DATA - NO EXTRAPOLATION REQUIRED.

INTERPOLATED PHI PERCENTILES SAMPLE D-2

PHI	MICRONS	MM	PCT. RET	PCT. FINER
.00	1000.00	.1000E+01	.36	99.64
.25	840.90	.8409E+00	.87	99.13
.50	707.11	.7071E+00	1.38	98.63
.75	594.60	.5946E+00	1.88	98.12
1.00	500.00	.5000E+00	2.39	97.61
1.25	420.45	.4204E+00	6.41	93.59
1.50	353.55	.3536E+00	10.43	89.57
1.75	297.30	.2973E+00	14.45	85.55
2.00	250.00	.2500E+00	18.48	81.52
2.25	210.22	.2102E+00	37.62	62.38
2.50	176.78	.1768E+00	56.76	43.24
2.75	148.65	.1487E+00	75.90	24.10
3.00	125.00	.1250E+00	95.05	4.95
3.25	105.11	.1051E+00	96.24	3.76
3.50	88.39	.8839E-01	97.44	2.56
3.75	74.33	.7433E-01	98.64	1.36
4.00	62.50	.6250E-01	99.84	.16

STATISTICS AND ENGINEERING PARAMETERS SAMPLE D-2

INMAN'S STATISTICS:

MEDIAN	2.412	PHI	187.935 MICRONS
MEAN	2.351	PHI	196.024 MICRONS
STANDARD DEVIATION	.505	MODERATELY WELL SORTED	
SKEWNESS	-.120	COARSE-SKEWED	
KURTOSIS	.819	PLATYKURTIC	

FOLK'S STATISTICS:

MEAN	2.371	PHI	193.290 MICRONS
STANDARD DEVIATION	.531	MODERATELY WELL SORTED	
SKEWNESS	-.240	COARSE-SKEWED	
KURTOSIS	1.153	LEPTOKURTIC	

MOMENT MEASURES:

MEAN	2.332	PHI	198.649 MICRONS
SECOND MOMENT	.295		
STANDARD DEVIATION	.544	MODERATELY WELL SORTED	
THIRD MOMENT	-.219		
SKEWNESS	-1.366	STRONGLY COARSE-SKEWED	
FOURTH MOMENT	.628		
KURTOSIS	2.400	VERY LEPTOKURTIC	

ENGINEERING PARAMETERS:

D60	2.281	PHI	205.742 MICRONS
D30	2.673	PHI	156.811 MICRONS
D10	2.934	PHI	130.842 MICRONS
COEF. OF UNIFORMITY	1.572		
COEF. OF CURVATURE	.913		

TIERRA CONSULTING
SEDPET III: SEDIMENTARY PETROLOGY ANALYSIS PROGRAM

ANALYSIS OF SAMPLE: D-3

PAN=0.02=.04%

BVA-DIAL CORDY 2-26-07

SIEVE ANALYSIS

SAMPLE WEIGHT = 47.34

SIEVE SIZE (MICRONS)	SIEVE SIZE (PHI)	SIEVE WT (GRAMS)	WEIGHT PERCENT RETAINED	CUMULATIVE PERCENT THROUGH	CUMULATIVE PERCENT RETAINED
1000.00	.00	.82	1.73	98.27	1.73
500.00	1.00	1.87	3.95	94.32	5.68
250.00	2.00	8.89	18.78	75.54	24.46
125.00	3.00	33.77	71.34	4.20	95.80
62.50	4.00	1.96	4.14	.06	99.94

TEXTURAL CLASSIFICATION AND PHI PERCENTILES SAMPLE D-3

SIZE CLASSIFICATION USED: STANDARD GEOLOGICAL SOILS CLASSIFICATION

GRAVEL/SAND CUTOFF	2000.00 MICRONS
SAND/SILT CUTOFF	62.50 MICRONS
SILT/CLAY CUTOFF	4.00 MICRONS
PERCENT GRAVEL	.00
PERCENT SAND	99.94
PERCENT SILT AND CLAY	.06

TEXTURAL DESCRIPTIONS

FOLK'S: SAND
SHEPARD'S: SAND
TREFETHEN'S: SAND
U.S. ARMY CORPS OF ENGINEERS: SAND
U.S. BUREAU OF SOILS: SAND

PHI PERCENTILES

PHI(05)	.83 PHI	563.59 MICRONS
PHI(16)	1.55 PHI	341.65 MICRONS
PHI(25)	2.01 PHI	248.69 MICRONS
PHI(50)	2.36 PHI	195.06 MICRONS
PHI(75)	2.71 PHI	152.99 MICRONS
PHI(84)	2.83 PHI	140.18 MICRONS
PHI(95)	2.99 PHI	125.97 MICRONS

EXTRAPOLATION OF DATA TO CUMULATIVE 99.5% RETAINED.

***OVER 99.5% SAMPLE ACCOUNTED FOR BY INPUT DATA - NO EXTRAPOLATION REQUIRED.

INTERPOLATED PHI PERCENTILES — SAMPLE D-3

PHI	MICRONS	MM	PCT. RET	PCT. FINER
.00	1000.00	.1000E+01	1.73	98.27
.25	840.90	.8409E+00	2.72	97.28
.50	707.11	.7071E+00	3.71	96.29
.75	594.60	.5946E+00	4.69	95.31
1.00	500.00	.5000E+00	5.68	94.32
1.25	420.45	.4204E+00	10.38	89.62
1.50	353.55	.3536E+00	15.07	84.93
1.75	297.30	.2973E+00	19.77	80.23
2.00	250.00	.2500E+00	24.46	75.54
2.25	210.22	.2102E+00	42.30	57.70
2.50	176.78	.1768E+00	60.13	39.87
2.75	148.65	.1487E+00	77.96	22.04
3.00	125.00	.1250E+00	95.80	4.20
3.25	105.11	.1051E+00	96.83	3.17
3.50	88.39	.8839E-01	97.87	2.13
3.75	74.33	.7433E-01	98.90	1.10
4.00	62.50	.6250E-01	99.94	.06

STATISTICS AND ENGINEERING PARAMETERS — SAMPLE D-3

INMAN'S STATISTICS:

MEDIAN	2.358	PHI	195.060 MICRONS
MEAN	2.192	PHI	218.843 MICRONS
STANDARD DEVIATION	.643	MODERATELY WELL SORTED	
SKEWNESS	-.258	COARSE-SKEWED	
KURTOSIS	.682	PLATYKURTIC	

FOLK'S STATISTICS:

MEAN	2.247	PHI	210.610 MICRONS
STANDARD DEVIATION	.649	MODERATELY WELL SORTED	
SKEWNESS	-.337	STRONGLY COARSE-SKEWED	
KURTOSIS	1.264	LEPTOKURTIC	

MOMENT MEASURES:

MEAN	2.221	PHI	214.484 MICRONS
SECOND MOMENT	.466		
STANDARD DEVIATION	.683	MODERATELY WELL SORTED	
THIRD MOMENT	-.519		
SKEWNESS	-1.630	STRONGLY COARSE-SKEWED	
FOURTH MOMENT	1.462		
KURTOSIS	2.243	VERY LEPTOKURTIC	

ENGINEERING PARAMETERS:

D60	2.218 PHI	214.965 MICRONS
D30	2.638 PHI	160.609 MICRONS
D10	2.919 PHI	132.242 MICRONS
COEF. OF UNIFORMITY	1.626	
COEF. OF CURVATURE	.907	

==========

TIERRA CONSULTING
SEDPET III: SEDIMENTARY PETROLOGY ANALYSIS PROGRAM

==========

ANALYSIS OF SAMPLE: D-4

PAN=.01=.02%

BVA-DIAL CORDY 2-26-07

SIEVE ANALYSIS
==========

SAMPLE WEIGHT = 44.00

SIEVE SIZE (MICRONS)	SIEVE SIZE (PHI)	SIEVE WT (GRAMS)	WEIGHT PERCENT RETAINED	CUMULATIVE PERCENT THROUGH	CUMULATIVE PERCENT RETAINED
1000.00	.00	.13	.30	99.70	.30
500.00	1.00	1.84	4.18	95.52	4.48
250.00	2.00	22.62	51.41	44.11	55.89
125.00	3.00	18.28	41.55	2.57	97.43
62.50	4.00	.96	2.18	.39	99.61

==========

TEXTURAL CLASSIFICATION AND PHI PERCENTILES SAMPLE D-4

==========

SIZE CLASSIFICATION USED: STANDARD GEOLOGICAL SOILS CLASSIFICATION

GRAVEL/SAND CUTOFF	2000.00 MICRONS
SAND/SILT CUTOFF	62.50 MICRONS
SILT/CLAY CUTOFF	4.00 MICRONS
PERCENT GRAVEL	.00
PERCENT SAND	99.61
PERCENT SILT AND CLAY	.39

==========

TEXTURAL DESCRIPTIONS

FOLK'S: SAND
SHEPARD'S: SAND
TREFETHEN'S: SAND
U.S. ARMY CORPS OF ENGINEERS: SAND
U.S. BUREAU OF SOILS: SAND

PHI PERCENTILES

PHI(05)	1.01 PHI	496.49 MICRONS
PHI(16)	1.22 PHI	428.05 MICRONS
PHI(25)	1.40 PHI	379.14 MICRONS
PHI(50)	1.89 PHI	270.65 MICRONS
PHI(75)	2.46 PHI	181.74 MICRONS
PHI(84)	2.68 PHI	156.40 MICRONS
PHI(95)	2.94 PHI	130.18 MICRONS

EXTRAPOLATION OF DATA TO CUMULATIVE 99.5% RETAINED.

***OVER 99.5% SAMPLE ACCOUNTED FOR BY INPUT DATA - NO EXTRAPOLATION REQUIRED.

INTERPOLATED PHI PERCENTILES SAMPLE D-4

PHI	MICRONS	MM	PCT. RET	PCT. FINER
.00	1000.00	.1000E+01	.30	99.70
.25	840.90	.8409E+00	1.34	98.66
.50	707.11	.7071E+00	2.39	97.61
.75	594.60	.5946E+00	3.43	96.57
1.00	500.00	.5000E+00	4.48	95.52
1.25	420.45	.4204E+00	17.33	82.67
1.50	353.55	.3536E+00	30.18	69.82
1.75	297.30	.2973E+00	43.03	56.97
2.00	250.00	.2500E+00	55.89	44.11
2.25	210.22	.2102E+00	66.27	33.73
2.50	176.78	.1768E+00	76.66	23.34
2.75	148.65	.1487E+00	87.05	12.95
3.00	125.00	.1250E+00	97.43	2.57
3.25	105.11	.1051E+00	97.98	2.02
3.50	88.39	.8839E-01	98.52	1.48
3.75	74.33	.7433E-01	99.07	.93
4.00	62.50	.6250E-01	99.61	.39

STATISTICS AND ENGINEERING PARAMETERS SAMPLE D-4

INMAN'S STATISTICS:

MEDIAN	1.885 PHI	270.650 MICRONS
MEAN	1.950 PHI	258.741 MICRONS

STANDARD DEVIATION	.726	MODERATELY SORTED
SKEWNESS	.089	NEAR-SYMMETRICAL
KURTOSIS	.330	VERY PLATYKURTIC

FOLK'S STATISTICS:

MEAN	1.929	PHI	262.652 MICRONS
STANDARD DEVIATION	.656	MODERATELY WELL SORTED	
SKEWNESS	.091	NEAR-SYMMETRICAL	
KURTOSIS	.746	PLATYKURTIC	

MOMENT MEASURES:

MEAN	1.906	PHI	266.911 MICRONS
SECOND MOMENT	.387		
STANDARD DEVIATION	.622	MODERATELY WELL SORTED	
THIRD MOMENT	-.016		
SKEWNESS	-.066	NEAR-SYMMETRICAL	
FOURTH MOMENT	.469		
KURTOSIS	1.046	MESOKURTIC	

ENGINEERING PARAMETERS:

D60	1.691	PHI	309.716 MICRONS
D30	2.340	PHI	197.549 MICRONS
D10	2.821	PHI	141.501 MICRONS
COEF. OF UNIFORMITY	2.189		
COEF. OF CURVATURE	.890		

TIERRA CONSULTING
SEDPET III: SEDIMENTARY PETROLOGY ANALYSIS PROGRAM

ANALYSIS OF SAMPLE: E-1

PAN=1.15=2.34%
BVA- DIAL CORDY 2-26-07

SIEVE ANALYSIS

SAMPLE WEIGHT = 48.95

SIEVE SIZE (MICRONS)	SIEVE SIZE (PHI)	SIEVE WT (GRAMS)	WEIGHT PERCENT RETAINED	CUMULATIVE PERCENT THROUGH	CUMULATIVE PERCENT RETAINED
1000.00	.00	.26	.53	99.47	.53
500.00	1.00	.89	1.82	97.65	2.35
250.00	2.00	11.58	23.66	73.99	26.01
125.00	3.00	34.19	69.85	4.15	95.85
62.50	4.00	.84	1.72	2.43	97.57

TEXTURAL CLASSIFICATION AND PHI PERCENTILES SAMPLE E-1

SIZE CLASSIFICATION USED: STANDARD GEOLOGICAL SOILS CLASSIFICATION

GRAVEL/SAND CUTOFF	2000.00 MICRONS
SAND/SILT CUTOFF	62.50 MICRONS
SILT/CLAY CUTOFF	4.00 MICRONS
PERCENT GRAVEL	.00
PERCENT SAND	97.57
PERCENT SILT AND CLAY	2.43

TEXTURAL DESCRIPTIONS

FOLK'S: SAND
SHEPARD'S: SAND
TREFETHEN'S: SAND
U.S. ARMY CORPS OF ENGINEERS: SAND
U.S. BUREAU OF SOILS: SAND

PHI PERCENTILES

PHI(05)	1.11 PHI	462.64 MICRONS
PHI(16)	1.58 PHI	335.17 MICRONS
PHI(25)	1.96 PHI	257.48 MICRONS
PHI(50)	2.34 PHI	197.03 MICRONS
PHI(75)	2.70 PHI	153.74 MICRONS
PHI(84)	2.83 PHI	140.60 MICRONS
PHI(95)	2.99 PHI	126.06 MICRONS

EXTRAPOLATION OF DATA TO CUMULATIVE 99.5% RETAINED.

INSUFFICIENT DATA TO PERFORM EXTRAPOLATION

INTERPOLATED PHI PERCENTILES SAMPLE E-1

PHI	MICRONS	MM	PCT. RET	PCT. FINER
.00	1000.00	.1000E+01	.53	99.47
.25	840.90	.8409E+00	.99	99.01
.50	707.11	.7071E+00	1.44	98.56
.75	594.60	.5946E+00	1.89	98.11
1.00	500.00	.5000E+00	2.35	97.65
1.25	420.45	.4204E+00	8.26	91.74
1.50	353.55	.3536E+00	14.18	85.82
1.75	297.30	.2973E+00	20.09	79.91
2.00	250.00	.2500E+00	26.01	73.99
2.25	210.22	.2102E+00	43.47	56.53

2.50	176.78	.1768E+00	60.93	39.07
2.75	148.65	.1487E+00	78.39	21.61
3.00	125.00	.1250E+00	95.85	4.15
3.25	105.11	.1051E+00	96.28	3.72
3.50	88.39	.8839E-01	96.71	3.29
3.75	74.33	.7433E-01	97.14	2.86
4.00	62.50	.6250E-01	97.57	2.43

STATISTICS AND ENGINEERING PARAMETERS SAMPLE E-1

INMAN'S STATISTICS:

MEDIAN	2.344 PHI	197.029 MICRONS
MEAN	2.204 PHI	217.085 MICRONS
STANDARD DEVIATION	.627	MODERATELY WELL SORTED
SKEWNESS	-.223	COARSE-SKEWED
KURTOSIS	.497	VERY PLATYKURTIC

FOLK'S STATISTICS:

MEAN	2.250 PHI	210.183 MICRONS
STANDARD DEVIATION	.598	MODERATELY WELL SORTED
SKEWNESS	-.268	COARSE-SKEWED
KURTOSIS	1.033	MESOKURTIC

MOMENT MEASURES:

INSUFFICIENT DATA FOR MOMENT MEASURES

ENGINEERING PARAMETERS:

D60	2.200 PHI	217.585 MICRONS
D30	2.630 PHI	161.559 MICRONS
D10	2.916 PHI	132.475 MICRONS
COEF. OF UNIFORMITY	1.642	
COEF. OF CURVATURE	.906	

TIERRA CONSULTING
SEDPET III: SEDIMENTARY PETROLOGY ANALYSIS PROGRAM

ANALYSIS OF SAMPLE: E-2

PAN=.05=.1%
BVA- DIAL CORDY 2-26-07

SIEVE ANALYSIS

SAMPLE WEIGHT = 49.98

SIEVE SIZE (MICRONS)	SIEVE SIZE (PHI)	SIEVE WT (GRAMS)	WEIGHT PERCENT RETAINED	CUMULATIVE PERCENT THROUGH	CUMULATIVE PERCENT RETAINED
1000.00	.00	.16	.32	99.68	.32
500.00	1.00	2.15	4.30	95.38	4.62
250.00	2.00	13.90	27.81	67.57	32.43
125.00	3.00	32.44	64.91	2.66	97.34
62.50	4.00	1.24	2.48	.18	99.82

TEXTURAL CLASSIFICATION AND PHI PERCENTILES SAMPLE E-2

SIZE CLASSIFICATION USED: STANDARD GEOLOGICAL SOILS CLASSIFICATION

GRAVEL/SAND CUTOFF	2000.00 MICRONS
SAND/SILT CUTOFF	62.50 MICRONS
SILT/CLAY CUTOFF	4.00 MICRONS
PERCENT GRAVEL	.00
PERCENT SAND	99.82
PERCENT SILT AND CLAY	.18

TEXTURAL DESCRIPTIONS

FOLK'S: SAND
SHEPARD'S: SAND
TREFETHEN'S: SAND
U.S. ARMY CORPS OF ENGINEERS: SAND
U.S. BUREAU OF SOILS: SAND

PHI PERCENTILES

PHI(05)	1.01 PHI	495.31 MICRONS
PHI(16)	1.41 PHI	376.54 MICRONS
PHI(25)	1.73 PHI	300.88 MICRONS
PHI(50)	2.27 PHI	207.24 MICRONS
PHI(75)	2.66 PHI	158.68 MICRONS
PHI(84)	2.79 PHI	144.14 MICRONS
PHI(95)	2.96 PHI	128.16 MICRONS

EXTRAPOLATION OF DATA TO CUMULATIVE 99.5% RETAINED.
***OVER 99.5% SAMPLE ACCOUNTED FOR BY INPUT DATA - NO EXTRAPOLATION REQUIRED.

INTERPOLATED PHI PERCENTILES SAMPLE E-2

PHI	MICRONS	MM	PCT. RET	PCT. FINER
.00	1000.00	.1000E+01	.32	99.68
.25	840.90	.8409E+00	1.40	98.60
.50	707.11	.7071E+00	2.47	97.53
.75	594.60	.5946E+00	3.55	96.45
1.00	500.00	.5000E+00	4.62	95.38
1.25	420.45	.4204E+00	11.57	88.43
1.50	353.55	.3536E+00	18.53	81.47
1.75	297.30	.2973E+00	25.48	74.52
2.00	250.00	.2500E+00	32.43	67.57
2.25	210.22	.2102E+00	48.66	51.34
2.50	176.78	.1768E+00	64.89	35.11
2.75	148.65	.1487E+00	81.11	18.89
3.00	125.00	.1250E+00	97.34	2.66
3.25	105.11	.1051E+00	97.96	2.04
3.50	88.39	.8839E-01	98.58	1.42
3.75	74.33	.7433E-01	99.20	.80
4.00	62.50	.6250E-01	99.82	.18

STATISTICS AND ENGINEERING PARAMETERS SAMPLE E-2

INMAN'S STATISTICS:

MEDIAN	2.271	PHI	207.236 MICRONS
MEAN	2.102	PHI	232.967 MICRONS
STANDARD DEVIATION	.693	MODERATELY WELL SORTED	
SKEWNESS	-.244	COARSE-SKEWED	
KURTOSIS	.408	VERY PLATYKURTIC	

FOLK'S STATISTICS:

MEAN	2.158	PHI	224.053 MICRONS
STANDARD DEVIATION	.642	MODERATELY WELL SORTED	
SKEWNESS	-.266	COARSE-SKEWED	
KURTOSIS	.866	PLATYKURTIC	

MOMENT MEASURES:

MEAN	2.147	PHI	225.851 MICRONS
SECOND MOMENT	.382		
STANDARD DEVIATION	.618	MODERATELY WELL SORTED	
THIRD MOMENT	-.236		
SKEWNESS	-1.002	STRONGLY COARSE-SKEWED	
FOURTH MOMENT	.615		
KURTOSIS	1.407	LEPTOKURTIC	

ENGINEERING PARAMETERS:

D60	2.117 PHI	230.592 MICRONS
D30	2.579 PHI	167.381 MICRONS
D10	2.887 PHI	135.191 MICRONS
COEF. OF UNIFORMITY	1.706	
COEF. OF CURVATURE	.899	

==========

TIERRA CONSULTING
SEDPET III: SEDIMENTARY PETROLOGY ANALYSIS PROGRAM

==========

ANALYSIS OF SAMPLE: E-3

PAN=.02=.04%
BVA-DIAL CORDY 2-26-07

SIEVE ANALYSIS
==========

SAMPLE WEIGHT = 43.54

SIEVE SIZE (MICRONS)	SIEVE SIZE (PHI)	SIEVE WT (GRAMS)	WEIGHT PERCENT RETAINED	CUMULATIVE PERCENT THROUGH	CUMULATIVE PERCENT RETAINED
1000.00	.00	.01	.02	99.98	.02
500.00	1.00	2.86	6.57	93.41	6.59
250.00	2.00	27.82	63.90	29.51	70.49
125.00	3.00	12.44	28.57	.94	99.06
62.50	4.00	.39	.90	.05	99.95

==========

TEXTURAL CLASSIFICATION AND PHI PERCENTILES SAMPLE E-3

==========

SIZE CLASSIFICATION USED: STANDARD GEOLOGICAL SOILS CLASSIFICATION

GRAVEL/SAND CUTOFF	2000.00 MICRONS
SAND/SILT CUTOFF	62.50 MICRONS
SILT/CLAY CUTOFF	4.00 MICRONS
PERCENT GRAVEL	.00
PERCENT SAND	99.95
PERCENT SILT AND CLAY	.05

==========

TEXTURAL DESCRIPTIONS

FOLK'S: SAND
SHEPARD'S: SAND
TREFETHEN'S: SAND
U.S. ARMY CORPS OF ENGINEERS: SAND
U.S. BUREAU OF SOILS: SAND

PHI PERCENTILES

PHI(05)	.76 PHI	591.44 MICRONS
PHI(16)	1.15 PHI	451.49 MICRONS
PHI(25)	1.29 PHI	409.49 MICRONS
PHI(50)	1.68 PHI	312.22 MICRONS
PHI(75)	2.16 PHI	224.07 MICRONS
PHI(84)	2.47 PHI	180.12 MICRONS
PHI(95)	2.86 PHI	137.93 MICRONS

EXTRAPOLATION OF DATA TO CUMULATIVE 99.5% RETAINED.

***OVER 99.5% SAMPLE ACCOUNTED FOR BY INPUT DATA - NO EXTRAPOLATION REQUIRED.

INTERPOLATED PHI PERCENTILES SAMPLE E-3

PHI	MICRONS	MM	PCT. RET	PCT. FINER
.00	1000.00	.1000E+01	.02	99.98
.25	840.90	.8409E+00	1.67	98.33
.50	707.11	.7071E+00	3.31	96.69
.75	594.60	.5946E+00	4.95	95.05
1.00	500.00	.5000E+00	6.59	93.41
1.25	420.45	.4204E+00	22.57	77.43
1.50	353.55	.3536E+00	38.54	61.46
1.75	297.30	.2973E+00	54.51	45.49
2.00	250.00	.2500E+00	70.49	29.51
2.25	210.22	.2102E+00	77.63	22.37
2.50	176.78	.1768E+00	84.77	15.23
2.75	148.65	.1487E+00	91.92	8.08
3.00	125.00	.1250E+00	99.06	.94
3.25	105.11	.1051E+00	99.28	.72
3.50	88.39	.8839E-01	99.51	.49
3.75	74.33	.7433E-01	99.73	.27
4.00	62.50	.6250E-01	99.95	.05

STATISTICS AND ENGINEERING PARAMETERS SAMPLE E-3

INMAN'S STATISTICS:

MEDIAN	1.679 PHI	312.220 MICRONS
MEAN	1.810 PHI	285.171 MICRONS
STANDARD DEVIATION	.663	MODERATELY WELL SORTED
SKEWNESS	.197	FINE-SKEWED
KURTOSIS	.584	VERY PLATYKURTIC

FOLK'S STATISTICS:

MEAN	1.767	PHI	293.916 MICRONS
STANDARD DEVIATION	.650	MODERATELY WELL SORTED	
SKEWNESS	.160	FINE-SKEWED	
KURTOSIS	.990	MESOKURTIC	

MOMENT MEASURES:

MEAN	1.737	PHI	300.036 MICRONS
SECOND MOMENT	.332		
STANDARD DEVIATION	.576	MODERATELY WELL SORTED	
THIRD MOMENT	.041		
SKEWNESS	.214	FINE-SKEWED	
FOURTH MOMENT	.345		
KURTOSIS	1.045	MESOKURTIC	

ENGINEERING PARAMETERS:

D60	1.523	PHI	347.995 MICRONS
D30	1.992	PHI	251.324 MICRONS
D10	2.683	PHI	155.722 MICRONS
COEF. OF UNIFORMITY	2.235		
COEF. OF CURVATURE	1.166		

TIERRA CONSULTING
SEDPET III: SEDIMENTARY PETROLOGY ANALYSIS PROGRAM

ANALYSIS OF SAMPLE: E-4

PAN=.02=.04%
BVA DIAL CORDY 2-26-07

SIEVE ANALYSIS

SAMPLE WEIGHT = 48.72

SIEVE SIZE (MICRONS)	SIEVE SIZE (PHI)	SIEVE WT (GRAMS)	WEIGHT PERCENT RETAINED	CUMULATIVE PERCENT THROUGH	CUMULATIVE PERCENT RETAINED
1000.00	.00	.06	.12	99.88	.12
500.00	1.00	2.71	5.56	94.31	5.69
250.00	2.00	27.05	55.52	38.79	61.21
125.00	3.00	18.26	37.48	1.31	98.69
62.50	4.00	.55	1.13	.18	99.82

TEXTURAL CLASSIFICATION AND PHI PERCENTILES SAMPLE E-4

SIZE CLASSIFICATION USED: STANDARD GEOLOGICAL SOILS CLASSIFICATION

GRAVEL/SAND CUTOFF	2000.00 MICRONS
SAND/SILT CUTOFF	62.50 MICRONS
SILT/CLAY CUTOFF	4.00 MICRONS
PERCENT GRAVEL	.00
PERCENT SAND	99.82
PERCENT SILT AND CLAY	.18

TEXTURAL DESCRIPTIONS

FOLK'S: SAND
SHEPARD'S: SAND
TREFETHEN'S: SAND
U.S. ARMY CORPS OF ENGINEERS: SAND
U.S. BUREAU OF SOILS: SAND

PHI PERCENTILES

PHI(05)	.88 PHI	544.59 MICRONS
PHI(16)	1.19 PHI	439.59 MICRONS
PHI(25)	1.35 PHI	392.87 MICRONS
PHI(50)	1.80 PHI	287.54 MICRONS
PHI(75)	2.37 PHI	193.71 MICRONS
PHI(84)	2.61 PHI	164.01 MICRONS
PHI(95)	2.90 PHI	133.82 MICRONS

EXTRAPOLATION OF DATA TO CUMULATIVE 99.5% RETAINED.

***OVER 99.5% SAMPLE ACCOUNTED FOR BY INPUT DATA - NO EXTRAPOLATION REQUIRED.

INTERPOLATED PHI PERCENTILES SAMPLE E-4

PHI	MICRONS	MM	PCT. RET	PCT. FINER
.00	1000.00	.1000E+01	.12	99.88
.25	840.90	.8409E+00	1.51	98.49
.50	707.11	.7071E+00	2.90	97.10
.75	594.60	.5946E+00	4.29	95.71
1.00	500.00	.5000E+00	5.69	94.31
1.25	420.45	.4204E+00	19.57	80.43
1.50	353.55	.3536E+00	33.45	66.55
1.75	297.30	.2973E+00	47.33	52.67
2.00	250.00	.2500E+00	61.21	38.79
2.25	210.22	.2102E+00	70.58	29.42
2.50	176.78	.1768E+00	79.95	20.05
2.75	148.65	.1487E+00	89.32	10.68
3.00	125.00	.1250E+00	98.69	1.31

3.25	105.11	.1051E+00	98.97	1.03
3.50	88.39	.8839E-01	99.25	.75
3.75	74.33	.7433E-01	99.53	.47
4.00	62.50	.6250E-01	99.82	.18

STATISTICS AND ENGINEERING PARAMETERS SAMPLE E-4

INMAN'S STATISTICS:

MEDIAN	1.798	PHI	287.543 MICRONS
MEAN	1.897	PHI	268.508 MICRONS
STANDARD DEVIATION	.711	MODERATELY SORTED	
SKEWNESS	.139	FINE-SKEWED	
KURTOSIS	.424	VERY PLATYKURTIC	

FOLK'S STATISTICS:

MEAN	1.864	PHI	274.709 MICRONS
STANDARD DEVIATION	.662	MODERATELY WELL SORTED	
SKEWNESS	.114	FINE-SKEWED	
KURTOSIS	.813	PLATYKURTIC	

MOMENT MEASURES:

MEAN	1.837	PHI	279.997 MICRONS
SECOND MOMENT	.365		
STANDARD DEVIATION	.604	MODERATELY WELL SORTED	
THIRD MOMENT	-.008		
SKEWNESS	-.037	NEAR-SYMMETRICAL	
FOURTH MOMENT	.380		
KURTOSIS	.951	MESOKURTIC	

ENGINEERING PARAMETERS:

D60	1.618	PHI	325.778 MICRONS
D30	2.235	PHI	212.479 MICRONS
D10	2.768	PHI	146.784 MICRONS
COEF. OF UNIFORMITY	2.219		
COEF. OF CURVATURE	.944		

TIERRA CONSULTING
SEDPET III: SEDIMENTARY PETROLOGY ANALYSIS PROGRAM

ANALYSIS OF SAMPLE: F-1

PAN=0.10=.2%
BVA DIAL CORDY 2-26-07

SIEVE ANALYSIS

SAMPLE WEIGHT = 44.93

SIEVE SIZE (MICRONS)	SIEVE SIZE (PHI)	SIEVE WT (GRAMS)	WEIGHT PERCENT RETAINED	CUMULATIVE PERCENT THROUGH	CUMULATIVE PERCENT RETAINED
1000.00	.00	.13	.29	99.71	.29
500.00	1.00	2.16	4.81	94.90	5.10
250.00	2.00	14.22	31.65	63.25	36.75
125.00	3.00	27.48	61.16	2.09	97.91
62.50	4.00	.79	1.76	.33	99.67

TEXTURAL CLASSIFICATION AND PHI PERCENTILES SAMPLE F-1

SIZE CLASSIFICATION USED: STANDARD GEOLOGICAL SOILS CLASSIFICATION

GRAVEL/SAND CUTOFF 2000.00 MICRONS
SAND/SILT CUTOFF 62.50 MICRONS
SILT/CLAY CUTOFF 4.00 MICRONS

PERCENT GRAVEL .00
PERCENT SAND 99.67

PERCENT SILT AND CLAY .33

TEXTURAL DESCRIPTIONS

FOLK'S: SAND
SHEPARD'S: SAND
TREFETHEN'S: SAND
U.S. ARMY CORPS OF ENGINEERS: SAND
U.S. BUREAU OF SOILS: SAND

PHI PERCENTILES

PHI(05)	.98 PHI	507.03 MICRONS
PHI(16)	1.34 PHI	393.79 MICRONS
PHI(25)	1.63 PHI	323.34 MICRONS
PHI(50)	2.22 PHI	215.13 MICRONS
PHI(75)	2.63 PHI	162.05 MICRONS
PHI(84)	2.77 PHI	146.34 MICRONS
PHI(95)	2.95 PHI	129.19 MICRONS

EXTRAPOLATION OF DATA TO CUMULATIVE 99.5% RETAINED.

***OVER 99.5% SAMPLE ACCOUNTED FOR BY INPUT DATA - NO EXTRAPOLATION REQUIRED.

INTERPOLATED PHI PERCENTILES SAMPLE F-1

PHI	MICRONS	MM	PCT. RET	PCT. FINER
.00	1000.00	.1000E+01	.29	99.71
.25	840.90	.8409E+00	1.49	98.51
.50	707.11	.7071E+00	2.69	97.31
.75	594.60	.5946E+00	3.89	96.11
1.00	500.00	.5000E+00	5.10	94.90
1.25	420.45	.4204E+00	13.01	86.99
1.50	353.55	.3536E+00	20.92	79.08
1.75	297.30	.2973E+00	28.83	71.17
2.00	250.00	.2500E+00	36.75	63.25
2.25	210.22	.2102E+00	52.04	47.96
2.50	176.78	.1768E+00	67.33	32.67
2.75	148.65	.1487E+00	82.62	17.38
3.00	125.00	.1250E+00	97.91	2.09
3.25	105.11	.1051E+00	98.35	1.65
3.50	88.39	.8839E-01	98.79	1.21
3.75	74.33	.7433E-01	99.23	.77
4.00	62.50	.6250E-01	99.67	.33

STATISTICS AND ENGINEERING PARAMETERS SAMPLE F-1

INMAN'S STATISTICS:

MEDIAN	2.217 PHI	215.132 MICRONS	
MEAN	2.059 PHI	240.057 MICRONS	
STANDARD DEVIATION	.714	MODERATELY SORTED	
SKEWNESS	-.221	COARSE-SKEWED	
KURTOSIS	.381	VERY PLATYKURTIC	

FOLK'S STATISTICS:

MEAN	2.111 PHI	231.443 MICRONS	
STANDARD DEVIATION	.656	MODERATELY WELL SORTED	
SKEWNESS	-.238	COARSE-SKEWED	
KURTOSIS	.811	PLATYKURTIC	

MOMENT MEASURES:

MEAN	2.088 PHI	235.220 MICRONS	
SECOND MOMENT	.389		
STANDARD DEVIATION	.624	MODERATELY WELL SORTED	
THIRD MOMENT	-.215		
SKEWNESS	-.885	STRONGLY COARSE-SKEWED	
FOURTH MOMENT	.561		
KURTOSIS	1.236	LEPTOKURTIC	

ENGINEERING PARAMETERS:

D60	2.053 PHI	240.949 MICRONS
D30	2.544 PHI	171.502 MICRONS
D10	2.871 PHI	136.720 MICRONS
COEF. OF UNIFORMITY	1.762	
COEF. OF CURVATURE	.893	

TIERRA CONSULTING
SEDPET III: SEDIMENTARY PETROLOGY ANALYSIS PROGRAM

ANALYSIS OF SAMPLE: F-2

PAN=.05=.11%
BVA DIAL CORDY 2-26-07

SIEVE ANALYSIS

SAMPLE WEIGHT = 44.73

SIEVE SIZE (MICRONS)	SIEVE SIZE (PHI)	SIEVE WT (GRAMS)	WEIGHT PERCENT RETAINED	CUMULATIVE PERCENT THROUGH	CUMULATIVE PERCENT RETAINED
1000.00	.00	9.78	21.86	78.14	21.86
500.00	1.00	19.82	44.31	33.83	66.17
250.00	2.00	9.72	21.73	12.09	87.91
125.00	3.00	5.13	11.47	.63	99.37
62.50	4.00	.18	.40	.22	99.78

TEXTURAL CLASSIFICATION AND PHI PERCENTILES SAMPLE F-2

SIZE CLASSIFICATION USED: STANDARD GEOLOGICAL SOILS CLASSIFICATION

GRAVEL/SAND CUTOFF	2000.00 MICRONS
SAND/SILT CUTOFF	62.50 MICRONS
SILT/CLAY CUTOFF	4.00 MICRONS
PERCENT GRAVEL	.00
PERCENT SAND	99.78
PERCENT SILT AND CLAY	.22

TEXTURAL DESCRIPTIONS

FOLK'S: SAND
SHEPARD'S: SAND
TREFETHEN'S: SAND
U.S. ARMY CORPS OF ENGINEERS: SAND
U.S. BUREAU OF SOILS: SAND

PHI PERCENTILES

PHI(25)	.07 PHI	952.14 MICRONS
PHI(50)	.63 PHI	643.96 MICRONS
PHI(75)	1.41 PHI	377.32 MICRONS
PHI(84)	1.82 PHI	283.16 MICRONS
PHI(95)	2.62 PHI	162.82 MICRONS

EXTRAPOLATION OF DATA TO CUMULATIVE 99.5% RETAINED.

***OVER 99.5% SAMPLE ACCOUNTED FOR BY INPUT DATA - NO EXTRAPOLATION REQUIRED.

INTERPOLATED PHI PERCENTILES SAMPLE F-2

PHI	MICRONS	MM	PCT. RET	PCT. FINER
.00	1000.00	.1000E+01	21.86	78.14
.25	840.90	.8409E+00	32.94	67.06
.50	707.11	.7071E+00	44.02	55.98
.75	594.60	.5946E+00	55.10	44.90
1.00	500.00	.5000E+00	66.17	33.83
1.25	420.45	.4204E+00	71.61	28.39
1.50	353.55	.3536E+00	77.04	22.96
1.75	297.30	.2973E+00	82.47	17.53
2.00	250.00	.2500E+00	87.91	12.09
2.25	210.22	.2102E+00	90.77	9.23
2.50	176.78	.1768E+00	93.64	6.36
2.75	148.65	.1487E+00	96.51	3.49
3.00	125.00	.1250E+00	99.37	.63
3.25	105.11	.1051E+00	99.47	.53
3.50	88.39	.8839E-01	99.58	.42
3.75	74.33	.7433E-01	99.68	.32
4.00	62.50	.6250E-01	99.78	.22

STATISTICS AND ENGINEERING PARAMETERS SAMPLE F-2

INMAN'S STATISTICS:

MEDIAN	.635 PHI	643.957 MICRONS

FOLK'S STATISTICS:

INSUFFICIENT DATA FOR FOLK'S STATISTICS

MOMENT MEASURES:

WARNING ACCURACY OF MOMENT MEASURES MAY BE
ADVERSELY AFFECTED BY THE LARGE AMOUNT OF
MATERIAL RETAINED IN THE FIRST SIEVE **

MEAN	.739	PHI	599.159 MICRONS
SECOND MOMENT	.873		
STANDARD DEVIATION	.934	MODERATELY SORTED	
THIRD MOMENT	.385		
SKEWNESS	.472	STRONGLY FINE-SKEWED	
FOURTH MOMENT	1.926		
KURTOSIS	.842	PLATYKURTIC	

ENGINEERING PARAMETERS:

D60	.409	PHI	752.997 MICRONS
D30	1.176	PHI	442.568 MICRONS
D10	2.183	PHI	220.271 MICRONS
COEF. OF UNIFORMITY	3.419		
COEF. OF CURVATURE	1.181		

TIERRA CONSULTING
SEDPET III: SEDIMENTARY PETROLOGY ANALYSIS PROGRAM

ANALYSIS OF SAMPLE: F-3

PAN=0.04=.08%

SIEVE ANALYSIS

SAMPLE WEIGHT = 46.34

SIEVE SIZE (MICRONS)	SIEVE SIZE (PHI)	SIEVE WT (GRAMS)	WEIGHT PERCENT RETAINED	CUMULATIVE PERCENT THROUGH	CUMULATIVE PERCENT RETAINED
1000.00	.00	.19	.41	99.59	.41
500.00	1.00	1.43	3.09	96.50	3.50
250.00	2.00	8.47	18.28	78.23	21.77
125.00	3.00	34.92	75.36	2.87	97.13
62.50	4.00	1.26	2.72	.15	99.85

TEXTURAL CLASSIFICATION AND PHI PERCENTILES SAMPLE F-3

SIZE CLASSIFICATION USED: STANDARD GEOLOGICAL SOILS CLASSIFICATION

GRAVEL/SAND CUTOFF	2000.00 MICRONS
SAND/SILT CUTOFF	62.50 MICRONS
SILT/CLAY CUTOFF	4.00 MICRONS
PERCENT GRAVEL	.00
PERCENT SAND	99.85
PERCENT SILT AND CLAY	.15

TEXTURAL DESCRIPTIONS

FOLK'S: SAND
SHEPARD'S: SAND
TREFETHEN'S: SAND
U.S. ARMY CORPS OF ENGINEERS: SAND
U.S. BUREAU OF SOILS: SAND

PHI PERCENTILES

PHI(05)	1.08 PHI	472.28 MICRONS
PHI(16)	1.68 PHI	311.20 MICRONS
PHI(25)	2.04 PHI	242.69 MICRONS
PHI(50)	2.37 PHI	192.83 MICRONS
PHI(75)	2.71 PHI	153.22 MICRONS
PHI(84)	2.83 PHI	141.05 MICRONS
PHI(95)	2.97 PHI	127.47 MICRONS

EXTRAPOLATION OF DATA TO CUMULATIVE 99.5% RETAINED.

***OVER 99.5% SAMPLE ACCOUNTED FOR BY INPUT DATA - NO EXTRAPOLATION REQUIRED.

INTERPOLATED PHI PERCENTILES SAMPLE F-3

PHI	MICRONS	MM	PCT. RET	PCT. FINER
.00	1000.00	.1000E+01	.41	99.59
.25	840.90	.8409E+00	1.18	98.82
.50	707.11	.7071E+00	1.95	98.05
.75	594.60	.5946E+00	2.72	97.28
1.00	500.00	.5000E+00	3.50	96.50
1.25	420.45	.4204E+00	8.07	91.93
1.50	353.55	.3536E+00	12.63	87.37

1.75	297.30	.2973E+00	17.20	82.80
2.00	250.00	.2500E+00	21.77	78.23
2.25	210.22	.2102E+00	40.61	59.39
2.50	176.78	.1768E+00	59.45	40.55
2.75	148.65	.1487E+00	78.29	21.71
3.00	125.00	.1250E+00	97.13	2.87
3.25	105.11	.1051E+00	97.81	2.19
3.50	88.39	.8839E-01	98.49	1.51
3.75	74.33	.7433E-01	99.17	.83
4.00	62.50	.6250E-01	99.85	.15

STATISTICS AND ENGINEERING PARAMETERS SAMPLE F-3

INMAN'S STATISTICS:

MEDIAN	2.375	PHI	192.834 MICRONS
MEAN	2.255	PHI	209.506 MICRONS
STANDARD DEVIATION	.571	MODERATELY WELL SORTED	
SKEWNESS	-.210	COARSE-SKEWED	
KURTOSIS	.655	VERY PLATYKURTIC	

FOLK'S STATISTICS:

MEAN	2.295	PHI	203.794 MICRONS
STANDARD DEVIATION	.572	MODERATELY WELL SORTED	
SKEWNESS	-.289	COARSE-SKEWED	
KURTOSIS	1.167	LEPTOKURTIC	

MOMENT MEASURES:

MEAN	2.267	PHI	207.817 MICRONS
SECOND MOMENT	.318		
STANDARD DEVIATION	.563	MODERATELY WELL SORTED	
THIRD MOMENT	-.279		
SKEWNESS	-1.558	STRONGLY COARSE-SKEWED	
FOURTH MOMENT	.669		
KURTOSIS	2.212	VERY LEPTOKURTIC	

ENGINEERING PARAMETERS:

D60	2.242	PHI	211.413 MICRONS
D30	2.640	PHI	160.431 MICRONS
D10	2.905	PHI	133.473 MICRONS
COEF. OF UNIFORMITY	1.584		
COEF. OF CURVATURE	.912		

TIERRA CONSULTING
SEDPET III: SEDIMENTARY PETROLOGY ANALYSIS PROGRAM

ANALYSIS OF SAMPLE: F-4

PAN=.03=.06%
BVA-DIAL CORDY 2-26-07

SIEVE ANALYSIS
==========

SAMPLE WEIGHT = 44.28

SIEVE SIZE (MICRONS)	SIEVE SIZE (PHI)	SIEVE WT (GRAMS)	WEIGHT PERCENT RETAINED	CUMULATIVE PERCENT THROUGH	CUMULATIVE PERCENT RETAINED
1000.00	.00	.13	.29	99.71	.29
500.00	1.00	1.41	3.18	96.52	3.48
250.00	2.00	9.70	21.91	74.62	25.38
125.00	3.00	32.14	72.58	2.03	97.97
62.50	4.00	.86	1.94	.09	99.91

==========
TEXTURAL CLASSIFICATION AND PHI PERCENTILES SAMPLE F-4
==========

SIZE CLASSIFICATION USED: STANDARD GEOLOGICAL SOILS CLASSIFICATION

GRAVEL/SAND CUTOFF 2000.00 MICRONS
SAND/SILT CUTOFF 62.50 MICRONS
SILT/CLAY CUTOFF 4.00 MICRONS

PERCENT GRAVEL .00
PERCENT SAND 99.91

PERCENT SILT AND CLAY .09
==========

TEXTURAL DESCRIPTIONS

FOLK'S: SAND
SHEPARD'S: SAND
TREFETHEN'S: SAND
U.S. ARMY CORPS OF ENGINEERS: SAND
U.S. BUREAU OF SOILS: SAND
==========

PHI PERCENTILES

PHI(05)	1.07 PHI	476.49 MICRONS
PHI(16)	1.57 PHI	336.43 MICRONS
PHI(25)	1.98 PHI	253.06 MICRONS
PHI(50)	2.34 PHI	197.63 MICRONS
PHI(75)	2.68 PHI	155.66 MICRONS

PHI(84)	2.81 PHI	142.84 MICRONS
PHI(95)	2.96 PHI	128.59 MICRONS

EXTRAPOLATION OF DATA TO CUMULATIVE 99.5% RETAINED.

***OVER 99.5% SAMPLE ACCOUNTED FOR BY INPUT DATA - NO EXTRAPOLATION REQUIRED.

INTERPOLATED PHI PERCENTILES SAMPLE F-4

PHI	MICRONS	MM	PCT. RET	PCT. FINER
.00	1000.00	.1000E+01	.29	99.71
.25	840.90	.8409E+00	1.09	98.91
.50	707.11	.7071E+00	1.89	98.11
.75	594.60	.5946E+00	2.68	97.32
1.00	500.00	.5000E+00	3.48	96.52
1.25	420.45	.4204E+00	8.95	91.05
1.50	353.55	.3536E+00	14.43	85.57
1.75	297.30	.2973E+00	19.91	80.09
2.00	250.00	.2500E+00	25.38	74.62
2.25	210.22	.2102E+00	43.53	56.47
2.50	176.78	.1768E+00	61.68	38.32
2.75	148.65	.1487E+00	79.82	20.18
3.00	125.00	.1250E+00	97.97	2.03
3.25	105.11	.1051E+00	98.45	1.55
3.50	88.39	.8839E-01	98.94	1.06
3.75	74.33	.7433E-01	99.42	.58
4.00	62.50	.6250E-01	99.91	.09

STATISTICS AND ENGINEERING PARAMETERS SAMPLE F-4

INMAN'S STATISTICS:

MEDIAN	2.339 PHI	197.628 MICRONS
MEAN	2.190 PHI	219.213 MICRONS
STANDARD DEVIATION	.618	MODERATELY WELL SORTED
SKEWNESS	-.242	COARSE-SKEWED
KURTOSIS	.529	VERY PLATYKURTIC

FOLK'S STATISTICS:

MEAN	2.239 PHI	211.768 MICRONS
STANDARD DEVIATION	.595	MODERATELY WELL SORTED
SKEWNESS	-.293	COARSE-SKEWED
KURTOSIS	1.105	MESOKURTIC

MOMENT MEASURES:

MEAN	2.226	PHI	213.808 MICRONS
SECOND MOMENT	.318		
STANDARD DEVIATION	.564	MODERATELY WELL SORTED	
THIRD MOMENT	-.252		
SKEWNESS	-1.402	STRONGLY COARSE-SKEWED	
FOURTH MOMENT	.560		
KURTOSIS	1.846	VERY LEPTOKURTIC	

ENGINEERING PARAMETERS:

D60	2.201	PHI	217.431 MICRONS
D30	2.615	PHI	163.268 MICRONS
D10	2.890	PHI	134.882 MICRONS
COEF. OF UNIFORMITY	1.612		
COEF. OF CURVATURE	.909		

APPENDIX C

Station Data Summary Report

Station Data Summary Report
Station A1

Client: Wilmington District, USACE
Project: Topsail Benthic Survey
Location: Topsail Beach
Sample Date: 28-29 Nov 06

Station: A1
Sample Type: Macrofauna
Replicates: 1
Sample Area: 0.0400

TAXON	Rep 1		Station		
	Count	Density	Total	Percent	Mean Density
Annelida					
Polychaeta					
Oweniida					
Oweniidae					
Owenia fusiformis	1	25	1	14.3	25
Spionida					
Chaetopteridae					
Spiochaetopterus oculatus	1	25	1	14.3	25
Cirratulidae					
Caulleriella sp. J	1	25	1	14.3	25
Magelonidae					
Magelona (LPIL)	2	50	2	28.6	50
Terebellida					
Pectinariidae					
Pectinaria gouldii	1	25	1	14.3	25
Mollusca					
Bivalvia					
Bivalvia (LPIL)	1	25	1	14.3	25

Note LPIL designates the LOWEST PRACTICAL IDENTIFICATION LEVEL

Station Data Summary Report
Station A1

Client: Wilmington District, USACE
Project: Topsail Benthic Survey
Location: Topsail Beach
Sample Date: 28-29 Nov 06

Station: A1
Sample Type: Macrofauna
Replicates: 1
Sample Area: 0.0400

DATA SUMMARY

FAUNAL PARAMETERS	Station	Rep 1	Mean	Std Dev
Total Taxa	6	6	6	0
Total Individuals	7	7	7	0
Density (nos/sq.m.)		175	175	0

FAUNAL INDICES			
Species Diversity (Shannon; log base e)	H'	=	1.75
Species Diversity (Shannon; log base 2)	d	=	2.52
Species Diversity (Shannon; log base 10)	H	=	0.76
Species Diversity (Simpson; 1/S)	1/S	=	21
Species Evenness (Pielou)	J'	=	0.98
Species Richness (Margalef)	D	=	2.57
Equitability Index (Lloyd & Ghelardi)	e	=	1.33

MAJOR TAXONOMIC GROUPS	Total No. Taxa	Taxa % Total	Total No. Individuals	Individuals % Total
Annelida	5	83.3	6	85.7
Mollusca	1	16.6	1	14.2
TOTALS	**6**		**7**	

Station Data Summary Report
Station A2

Client: Wilmington District, USACE
Project: Topsail Benthic Survey
Location: Topsail Beach
Sample Date: 28-29 Nov 06

Station: A2
Sample Type: Macrofauna
Replicates: 1
Sample Area: 0.0400

TAXON	Rep 1		Station		
	Count	Density	Total	Percent	Mean Density
Annelida					
Polychaeta					
Capitellida					
Capitellidae					
Capitellidae (LPIL)	1	25	1	5.9	25
Opheliida					
Opheliidae					
Armandia maculata	1	25	1	5.9	25
Phyllodocida					
Glyceridae					
Glyceridae (LPIL)	2	50	2	11.8	50
Nephtyidae					
Aglaophamus verrilli	1	25	1	5.9	25
Spionida					
Cirratulidae					
Caulleriella sp. J	2	50	2	11.8	50
Magelonidae					
Magelona (LPIL)	1	25	1	5.9	25
Mollusca					
Bivalvia					
Veneroida					
Lucinidae					
Lucinidae (LPIL)	2	50	2	11.8	50
Tellinidae					
Tellina (LPIL)	2	50	2	11.8	50
Tellina iris	1	25	1	5.9	25

Station Data Summary Report
Station A2

Client: Wilmington District, USACE
Project: Topsail Benthic Survey
Location: Topsail Beach
Sample Date: 28-29 Nov 06

Station: A2
Sample Type: Macrofauna
Replicates: 1
Sample Area: 0.0400

TAXON	Rep 1		Station		
	Count	Density	Total	Percent	Mean Density
Gastropoda					
Cephalaspidea					
Scaphandridae					
Cylichna alba	4	100	4	23.5	100

Note: LPIL designates the LOWEST PRACTICAL IDENTIFICATION LEVEL

Station Data Summary Report
Station A2

Client: Wilmington District, USACE
Project: Topsail Benthic Survey
Location: Topsail Beach
Sample Date: 28-29 Nov 06

Station: A2
Sample Type: Macrofauna
Replicates: 1
Sample Area: 0.0400

DATA SUMMARY

FAUNAL PARAMETERS	Station	Rep 1	Mean	Std Dev
Total Taxa	10	10	10	0
Total Individuals	17	17	17	0
Density (nos/sq.m.)		425	425	0

FAUNAL INDICES

Species Diversity (Shannon; log base e)	H'	=	2.18
Species Diversity (Shannon; log base 2)	d	=	3.15
Species Diversity (Shannon; log base 10)	H	=	0.95
Species Diversity (Simpson; 1/S)	1/S	=	13.6
Species Evenness (Pielou)	J'	=	0.95
Species Richness (Margalef)	D	=	3.18
Equitability Index (Lloyd & Ghelardi)	e	=	1.25

MAJOR TAXONOMIC GROUPS	Total No. Taxa	Taxa % Total	Total No. Individuals	Individuals % Total
Annelida	6	60	8	47
Mollusca	4	40	9	52.9
TOTALS	**10**		**17**	

Station Data Summary Report
Station A3

Client: Wilmington District, USACE
Project: Topsail Benthic Survey
Location: Topsail Beach
Sample Date: 28-29 Nov 06

Station: A3
Sample Type: Macrofauna
Replicates: 1
Sample Area: 0.0400

TAXON	Rep 1		Station		
	Count	Density	Total	Percent	Mean Density
Annelida					
Polychaeta					
Spionida					
Magelonidae					
Magelona papillicornis	2	50	2	20	50
Spionidae					
Paraprionospio pinnata	1	25	1	10	25
Spionidae (LPIL)	1	25	1	10	25
Arthropoda					
Ostracoda					
Myodocopina					
Sarsiellidae					
Eusarsiella (LPIL)	1	25	1	10	25
Cnidaria					
Hydrozoa					
Hydrozoa (LPIL)	1	25	1	10	25
Mollusca					
Gastropoda					
Cephalaspidea					
Scaphandridae					
Acteocina canaliculata	1	25	1	10	25
Cylichna alba	1	25	1	10	25

Station Data Summary Report

Client: Wilmington District, USACE
Project: Topsail Benthic Survey
Location: Topsail Beach
Sample Date: 28-29 Nov 06

Station A3

Station: A3
Sample Type: Macrofauna
Replicates: 1
Sample Area: 0.0400

TAXON	Rep 1		Station		
	Count	Density	Total	Percent	Mean Density
Phoronida					
Phoronidae					
Phoronis (LPIL)	1	25	1	10	25
Rhynchocoela					
Rhynchocoela (LPIL)	1	25	1	10	25

Note:
LPIL designates the LOWEST PRACTICAL IDENTIFICATION LEVEL

Station Data Summary Report
Station A3

Client: Wilmington District, USACE
Project: Topsail Benthic Survey
Location: Topsail Beach
Sample Date: 28-29 Nov 06

Station: A3
Sample Type: Macrofauna
Replicates: 1
Sample Area: 0.0400

DATA SUMMARY

FAUNAL PARAMETERS	Station	Rep 1	Mean	Std Dev
Total Taxa	9	9	9	0
Total Individuals	10	10	10	0
Density (nos/sq.m.)		250	250	0

FAUNAL INDICES			
Species Diversity (Shannon; log base e)	H'	=	2.16
Species Diversity (Shannon; log base 2)	d	=	3.12
Species Diversity (Shannon; log base 10)	H	=	0.94
Species Diversity (Simpson; 1/S)	1/S	=	45
Species Evenness (Pielou)	J'	=	0.98
Species Richness (Margalef)	D	=	3.47
Equitability Index (Lloyd & Ghelardi)	e	=	1.37

MAJOR TAXONOMIC GROUPS	Total No. Taxa	Taxa % Total	Total No. Individuals	Individuals % Total
Cnidaria	1	11.1	1	10
Rhynchocoela	1	11.1	1	10
Annelida	3	33.3	4	40
Mollusca	2	22.2	2	20
Arthropoda	1	11.1	1	10
Phoronida	1	11.1	1	10
TOTALS	**9**		**10**	

Station Data Summary Report
Station A4

Client: Wilmington District, USACE
Project: Topsail Benthic Survey
Location: Topsail Beach
Sample Date: 28-29 Nov 06

Station: A4
Sample Type: Macrofauna
Replicates: 1
Sample Area: 0.0400

TAXON	Rep 1		Station		
	Count	Density	Total	Percent	Mean Density
Annelida					
Polychaeta					
Capitellida					
Capitellidae					
Mediomastus californiensis	1	25	1	9.1	25
Eunicida					
Onuphidae					
Onuphidae (LPIL)	1	25	1	9.1	25
Phyllodocida					
Goniadidae					
Goniada littorea	1	25	1	9.1	25
Spionida					
Cirratulidae					
Caulleriella sp. J	1	25	1	9.1	25
Arthropoda					
Malacostraca					
Amphipoda					
Platyischnopidae					
Eudevenopus honduranus	1	25	1	9.1	25
Synopiidae					
Synopiidae (LPIL)	2	50	2	18.2	50
Mollusca					
Bivalvia					
Bivalvia (LPIL)	1	25	1	9.1	25

Station Data Summary Report
Station A4

Client: Wilmington District, USACE
Project: Topsail Benthic Survey
Location: Topsail Beach
Sample Date: 28-29 Nov 06

Station: A4
Sample Type: Macrofauna
Replicates: 1
Sample Area: 0.0400

TAXON	Rep 1		Station		
	Count	Density	Total	Percent	Mean Density
Veneroida					
Mesodesmatidae					
Ervilia concentrica	1	25	1	9.1	25
Gastropoda					
Neogastropoda					
Olividae					
Oliva sayana	2	50	2	18.2	50

Note: LPIL designates the LOWEST PRACTICAL IDENTIFICATION LEVEL

Station Data Summary Report
Station A4

Client: Wilmington District, USACE
Project: Topsail Benthic Survey
Location: Topsail Beach
Sample Date: 28-29 Nov 06

Station: A4
Sample Type: Macrofauna
Replicates: 1
Sample Area: 0.0400

DATA SUMMARY

FAUNAL PARAMETERS	Station	Rep 1	Mean	Std Dev
Total Taxa	9	9	9	0
Total Individuals	11	11	11	0
Density (nos/sq.m.)		275	275	0

FAUNAL INDICES

Species Diversity (Shannon; log base e)	H'	=	2.15
Species Diversity (Shannon; log base 2)	d	=	3.1
Species Diversity (Shannon; log base 10)	H	=	0.93
Species Diversity (Simpson; 1/S)	1/S	=	27.5
Species Evenness (Pielou)	J'	=	0.98
Species Richness (Margalef)	D	=	3.34
Equitability Index (Lloyd & Ghelardi)	e	=	1.34

MAJOR TAXONOMIC GROUPS	Total No. Taxa	Taxa % Total	Total No. Individuals	Individuals % Total
Annelida	4	44.4	4	36.3
Mollusca	3	33.3	4	36.3
Arthropoda	2	22.2	3	27.2
TOTALS	**9**		**11**	

Station Data Summary Report
Station A5

Client: Wilmington District, USACE
Project: Topsail Benthic Survey
Location: Topsail Beach
Sample Date: 28-29 Nov 06

Station: A5
Sample Type: Macrofauna
Replicates: 1
Sample Area: 0.0400

TAXON	Rep 1		Station		
	Count	Density	Total	Percent	Mean Density
Annelida					
Polychaeta					
Orbiniida					
Paraonidae					
Aricidea catherinae	1	25	1	9.1	25
Phyllodocida					
Pilargiidae					
Sigambra tentaculata	1	25	1	9.1	25
Spionida					
Magelonidae					
Magelona papillicornis	3	75	3	27.3	75
Arthropoda					
Ostracoda					
Myodocopina					
Sarsiellidae					
Eusarsiella texana	1	25	1	9.1	25
Mollusca					
Bivalvia					
Veneroida					
Tellinidae					
Tellina (LPIL)	3	75	3	27.3	75
Gastropoda					
Neogastropoda					
Olividae					
Oliva sayana	1	25	1	9.1	25

Station Data Summary Report
Station A5

Client: Wilmington District, USACE
Project: Topsail Benthic Survey
Location: Topsail Beach
Sample Date: 28-29 Nov 06

Station: A5
Sample Type: Macrofauna
Replicates: 1
Sample Area: 0.0400

TAXON	Rep 1		Station		
	Count	Density	Total	Percent	Mean Density
Pyramidelloida					
Pyramidellidae					
Odostomia weberi	1	25	1	9.1	25

Note: LPIL designates the LOWEST PRACTICAL IDENTIFICATION LEVEL

Station Data Summary Report
Station A5

Client: Wilmington District, USACE
Project: Topsail Benthic Survey
Location: Topsail Beach
Sample Date: 28-29 Nov 06

Station: A5
Sample Type: Macrofauna
Replicates: 1
Sample Area: 0.0400

DATA SUMMARY

FAUNAL PARAMETERS	Station	Rep 1	Mean	Std Dev
Total Taxa	7	7	7	0
Total Individuals	11	11	11	0
Density (nos/sq.m.)		275	275	0

FAUNAL INDICES			
Species Diversity (Shannon; log base e)	H'	=	1.8
Species Diversity (Shannon; log base 2)	d	=	2.59
Species Diversity (Shannon; log base 10)	H	=	0.78
Species Diversity (Simpson; 1/S)	1/S	=	9.17
Species Evenness (Pielou)	J'	=	0.92
Species Richness (Margalef)	D	=	2.5
Equitability Index (Lloyd & Ghelardi)	e	=	1.2

MAJOR TAXONOMIC GROUPS	Total No. Taxa	Taxa % Total	Total No. Individuals	Individuals % Total
Annelida	3	42.8	5	45.4
Mollusca	3	42.8	5	45.4
Arthropoda	1	14.2	1	9
TOTALS	**7**		**11**	

Station Data Summary Report
Station B1

Client: Wilmington District, USACE
Project: Topsail Benthic Survey
Location: Topsail Beach
Sample Date: 28-29 Nov 06

Station: B7
Sample Type: Macrofauna
Replicates: 1
Sample Area: 0.0400

TAXON	Rep 1		Station		
	Count	Density	Total	Percent	Mean Density
Annelida					
Polychaeta					
Capitellida					
Capitellidae					
Mediomastus (LPIL)	3	75	3	12	75
Eunicida					
Dorvilleidae					
Schistomeringos pectinata	1	25	1	4	25
Phyllodocida					
Chrysopetalidae					
Bhawania heteroseta	2	50	2	8	50
Goniadidae					
Goniadides carolinae	2	50	2	8	50
Spionida					
Cirratulidae					
Cirratulidae (LPIL)	1	25	1	4	25
Arthropoda					
Malacostraca					
Amphipoda					
Aoridae					
Rildardanus laminosa	1	25	1	4	25
Melitidae					
Maera caroliniana	2	50	2	8	50
Synopiidae					
Metatiron triocellatus	1	25	1	4	25

Station Data Summary Report
Station B1

Client: Wilmington District, USACE
Project: Topsail Benthic Survey
Location: Topsail Beach
Sample Date: 28-29 Nov 06

Station: B7
Sample Type: Macrofauna
Replicates: 1
Sample Area: 0.0400

TAXON	Rep 1		Station		
	Count	Density	Total	Percent	Mean Density
Echinodermata					
Ophiuroidea					
Ophiuroidea (LPIL)	2	50	2	8	50
Ophiurida					
Amphiuridae					
Amphiuridae (LPIL)	1	25	1	4	25
Mollusca					
Bivalvia					
Veneroida					
Crassatellidae					
Crassinella lunulata	4	100	4	16	100
Gastropoda					
Mesogastropoda					
Caecidae					
Caecum pulchellum	1	25	1	4	25
Platyhelminthes					
Turbellaria					
Turbellaria (LPIL)	2	50	2	8	50
Rhynchocoela					
Rhynchocoela (LPIL)	2	50	2	8	50

Note: LPIL designates the LOWEST PRACTICAL IDENTIFICATION LEVEL

Station Data Summary Report
Station B1

Client: Wilmington District, USACE
Project: Topsail Benthic Survey
Location: Topsail Beach
Sample Date: 28-29 Nov 06

Station: B7
Sample Type: Macrofauna
Replicates: 1
Sample Area: 0.0400

DATA SUMMARY

FAUNAL PARAMETERS	Station	Rep 1	Mean	Std Dev
Total Taxa	14	14	14	0
Total Individuals	25	25	25	0
Density (nos/sq.m.)		625	625	0

FAUNAL INDICES			
Species Diversity (Shannon; log base e)	H'	=	2.53
Species Diversity (Shannon; log base 2)	d	=	3.65
Species Diversity (Shannon; log base 10)	H	=	1.1
Species Diversity (Simpson; 1/S)	1/S	=	20
Species Evenness (Pielou)	J'	=	0.96
Species Richness (Margalef)	D	=	4.04
Equitability Index (Lloyd & Ghelardi)	e	=	1.29

MAJOR TAXONOMIC GROUPS	Total No. Taxa	Taxa % Total	Total No. Individuals	Individuals % Total
Platyhelminthes	1	7.1	2	8
Rhynchocoela	1	7.1	2	8
Annelida	5	35.7	9	36
Mollusca	2	14.2	5	20
Arthropoda	3	21.4	4	16
Echinodermata	2	14.2	3	12
TOTALS	**14**		**25**	

Station Data Summary Report
Station B2

Client: Wilmington District, USACE
Project: Topsail Benthic Survey
Location: Topsail Beach
Sample Date: 28-29 Nov 06

Station: B2
Sample Type: Macrofauna
Replicates: 1
Sample Area: 0.0400

TAXON	Rep 1		Station		
	Count	Density	Total	Percent	Mean Density
Annelida					
Polychaeta					
Capitellida					
Capitellidae					
Mediomastus (LPIL)	1	25	1	11.1	25
Spionida					
Cirratulidae					
Caulleriella sp. J	1	25	1	11.1	25
Arthropoda					
Malacostraca					
Amphipoda					
Synopiidae					
Metatiron (LPIL)	1	25	1	11.1	25
Echinodermata					
Ophiuroidea					
Ophiuroidea (LPIL)	1	25	1	11.1	25
Mollusca					
Bivalvia					
Veneroida					
Lucinidae					
Lucina multilineata	1	25	1	11.1	25
Tellinidae					
Tellina (LPIL)	1	25	1	11.1	25

Station Data Summary Report
Station B2

Client: Wilmington District, USACE
Project: Topsail Benthic Survey
Location: Topsail Beach
Sample Date: 28-29 Nov 06

Station: B2
Sample Type: Macrofauna
Replicates: 1
Sample Area: 0.0400

TAXON	Rep 1		Station		
	Count	Density	Total	Percent	Mean Density
Platyhelminthes					
Turbellaria					
Turbellaria (LPIL)	1	25	1	11.1	25
Rhynchocoela					
Rhynchocoela (LPIL)	1	25	1	11.1	25
Sipuncula					
Aspidosiphonidae					
Aspidosiphon albus	1	25	1	11.1	25

Note: LPIL designates the LOWEST PRACTICAL IDENTIFICATION LEVEL

Station Data Summary Report
Station B2

Client: Wilmington District, USACE
Project: Topsail Benthic Survey
Location: Topsail Beach
Sample Date: 28-29 Nov 06

Station: B2
Sample Type: Macrofauna
Replicates: 1
Sample Area: 0.0400

DATA SUMMARY

FAUNAL PARAMETERS	Station	Rep 1	Mean	Std Dev
Total Taxa	9	9	9	0
Total Individuals	9	9	9	0
Density (nos/sq.m.)		225	225	0

FAUNAL INDICES			
Species Diversity (Shannon; log base e)	H'	=	2.2
Species Diversity (Shannon; log base 2)	d	=	3.17
Species Diversity (Shannon; log base 10)	H	=	0.95
Species Diversity (Simpson; 1/S)	1/S	=	
Species Evenness (Pielou)	J'	=	1
Species Richness (Margalef)	D	=	3.64
Equitability Index (Lloyd & Ghelardi)	e	=	1.41

MAJOR TAXONOMIC GROUPS	Total No. Taxa	Taxa % Total	Total No. Individuals	Individuals % Total
Platyhelminthes	1	11.1	1	11.1
Rhynchocoela	1	11.1	1	11.1
Annelida	2	22.2	2	22.2
Mollusca	2	22.2	2	22.2
Sipuncula	1	11.1	1	11.1
Arthropoda	1	11.1	1	11.1
Echinodermata	1	11.1	1	11.1
TOTALS	**9**		**9**	

Station Data Summary Report
Station B3

Client: Wilmington District, USACE | Page 1 | Station: B3
Project: Topsail Benthic Survey | Sample Type: Macrofauna
Location: | Replicates: 1
Sample Date: 28-29 Nov 06 | Sample Area: 0.0400

TAXON	Rep 1		Station		
	Count	Density	Total	Percent	Mean Density
Annelida					
Oligochaeta					
Tubificida					
Enchytraeidae					
Enchytraeidae (LPIL)	2	50	2	3.9	50
Tubificidae					
Tubificidae (LPIL)	1	25	1	2	25
Polychaeta					
Eunicida					
Onuphidae					
Onuphidae (LPIL)	1	25	1	2	25
Opheliida					
Opheliidae					
Armandia maculata	1	25	1	2	25
Orbiniida					
Paraonidae					
Aricidea catherinae	1	25	1	2	25
Cirrophorus (LPIL)	1	25	1	2	25
Phyllodocida					
Chrysopetalidae					
Bhawania heteroseta	5	125	5	9.8	125
Glyceridae					
Glyceridae (LPIL)	1	25	1	2	25
Goniadidae					
Goniadides carolinae	7	175	7	13.7	175
Nereidae					
Nereididae (LPIL)	1	25	1	2	25

Station Data Summary Report
Station B3

Client: Wilmington District, USACE | Page 1 | Station: B3
Project: Topsail Benthic Survey | Sample Type: Macrofauna
Location: Topsail Beach | Replicates: 1
Sample Date: 28-29 Nov 06 | Sample Area: 0.0400

TAXON	Rep 1		Station		
	Count	Density	Total	Percent	Mean Density
Phyllodocidae					
Eumida sanguinea	1	25	1	2	25
Pilargiidae					
Ancistrosyllis (LPIL)	1	25	1	2	25
Ancistrosyllis hartmanae	1	25	1	2	25
Spionida					
Cirratulidae					
Cirratulidae (LPIL)	1	25	1	2	25
Spionidae					
Spionidae (LPIL)	4	100	4	7.8	100
Terebellida					
Terebellidae					
Terebellidae (LPIL)	1	25	1	2	25
Arthropoda					
Malacostraca					
Amphipoda					
Aoridae					
Unciola serrata	1	25	1	2	25
Isaeidae					
Microprotopus raneyi	2	50	2	3.9	50
Decapoda					
Paguridae					
Paguridae (LPIL)	1	25	1	2	25
Bryozoa					
Bryozoa (LPIL)	1	25	1	2	25

Station Data Summary Report
Station B3

Client: Wilmington District, USACE
Project: Topsail Benthic Survey
Location: Topsail Beach
Sample Date: 28-29 Nov 06

Station: B3
Sample Type: Macrofauna
Replicates: 1
Sample Area: 0.0400

TAXON	Rep 1		Station		
	Count	Density	Total	Percent	Mean Density
Echinodermata					
Ophiuroidea					
Ophiuroidea (LPIL)	5	125	5	9.8	125
Mollusca					
Bivalvia					
Bivalvia (LPIL)	1	25	1	2	25
Veneroida					
Crassatellidae					
Crassinella lunulata	6	150	6	11.8	150
Semelidae					
Semelidae (LPIL)	1	25	1	2	25
Gastropoda					
Mesogastropoda					
Naticidae					
Tectonatica pusilla	1	25	1	2	25
Phoronida					
Phoronidae					
Phoronis (LPIL)	1	25	1	2	25
Platyhelminthes					
Turbellaria					
Turbellaria (LPIL)	1	25	1	2	25

Note: LPIL designates the LOWEST PRACTICAL IDENTIFICATION LEVEL

Station Data Summary Report
Station B3

Client: Wilmington District, USACE
Project: Topsail Benthic Survey
Location: Topsail Beach
Sample Date: 28-29 Nov 06

Station: B3
Sample Type: Macrofauna
Replicates: 1
Sample Area: 0.0400

DATA SUMMARY

FAUNAL PARAMETERS	Station	Rep 1	Mean	Std Dev
Total Taxa	27	27	27	0
Total Individuals	51	51	51	0
Density (nos/sq.m.)		1275	1275	0

FAUNAL INDICES

Species Diversity (Shannon; log base e)	H'	=	2.98
Species Diversity (Shannon; log base 2)	d	=	4.29
Species Diversity (Shannon; log base 10)	H	=	1.29
Species Diversity (Simpson; 1/S)	1/S	=	19.92
Species Evenness (Pielou)	J'	=	0.9
Species Richness (Margalef)	D	=	6.61
Equitability Index (Lloyd & Ghelardi)	e	=	1.06

MAJOR TAXONOMIC GROUPS	Total No. Taxa	Taxa % Total	Total No. Individuals	Individuals % Total
Platyhelminthes	1	3.7	1	1.9
Annelida	16	59.2	30	58.8
Mollusca	4	14.8	9	17.6
Arthropoda	3	11.1	4	7.8
Phoronida	1	3.7	1	1.9
Bryozoa	1	3.7	1	1.9
Echinodermata	1	3.7	5	9.8
TOTALS	**27**		**51**	

Station Data Summary Report
Station C1

Client: Wilmington District, USACE
Project: Topsail Benthic Survey
Location: Topsail Beach
Sample Date: 28-29 Nov 06

Station: C1
Sample Type: Macrofauna
Replicates: 1
Sample Area: 0.0400

TAXON	Rep 1		Station		
	Count	Density	Total	Percent	Mean Density
Annelida					
Polychaeta					
Phyllodocida					
Goniadidae					
Goniada littorea	2	50	2	40	50
Arthropoda					
Malacostraca					
Amphipoda					
Phoxocephalidae					
Rhepoxynius hudsoni	2	50	2	40	50
Mollusca					
Gastropoda					
Cephalaspidea					
Scaphandridae					
Cylichna alba	1	25	1	20	25

Note: LPIL designates the LOWEST PRACTICAL IDENTIFICATION LEVEL

Station Data Summary Report
Station C1

Client: Wilmington District, USACE
Project: Topsail Benthic Survey
Location: Topsail Beach
Sample Date: 28-29 Nov 06

Station: C1
Sample Type: Macrofauna
Replicates: 1
Sample Area: 0.0400

DATA SUMMARY

FAUNAL PARAMETERS	Station	Rep 1	Mean	Std Dev
Total Taxa	3	3	3	0
Total Individuals	5	5	5	0
Density (nos/sq.m.)		125	125	0

FAUNAL INDICES

Species Diversity (Shannon; log base e)	H'	=	1.05
Species Diversity (Shannon; log base 2)	d	=	1.52
Species Diversity (Shannon; log base 10)	H	=	0.46
Species Diversity (Simpson; 1/S)	1/S	=	5
Species Evenness (Pielou)	J'	=	0.96
Species Richness (Margalef)	D	=	1.24
Equitability Index (Lloyd & Ghelardi)	e	=	1.29

MAJOR TAXONOMIC GROUPS	Total No. Taxa	Taxa % Total	Total No. Individuals	Individuals % Total
Annelida	1	33.3	2	40
Mollusca	1	33.3	1	20
Arthropoda	1	33.3	2	40
TOTALS	**3**		**5**	

Station Data Summary Report
Station C2

Client: Wilmington District, USACE
Project: Topsail Benthic Survey
Location: Topsail Beach
Sample Date: 28-29 Nov 06

Station: C2
Sample Type: Macrofauna
Replicates: 1
Sample Area: 0.0400

TAXON	Rep 1		Station		
	Count	Density	Total	Percent	Mean Density
Annelida					
Polychaeta					
Phyllodocida					
Goniadidae					
Goniada littorea	3	75	3	17.6	75
Arthropoda					
Malacostraca					
Amphipoda					
Amphipoda (LPIL)	1	25	1	5.9	25
Oedicerotidae					
Oedicerotidae (LPIL)	1	25	1	5.9	25
Platyischnopidae					
Eudevenopus honduranus	3	75	3	17.6	75
Decapoda					
Pasiphaeidae					
Leptochela serratorbita	1	25	1	5.9	25
Ostracoda					
Myodocopina					
Sarsiellidae					
Eusarsiella texana	1	25	1	5.9	25
Echinodermata					
Ophiuroidea					
Ophiuroidea (LPIL)	2	50	2	11.8	50

Station Data Summary Report
Station C2

Client: Wilmington District, USACE
Project: Topsail Benthic Survey
Location: Topsail Beach
Sample Date: 28-29 Nov 06

Station: C2
Sample Type: Macrofauna
Replicates: 1
Sample Area: 0.0400

TAXON	Rep 1		Station		
	Count	Density	Total	Percent	Mean Density
Annelida					
Mollusca					
Bivalvia					
Veneroida					
Tellinidae					
Tellina (LPIL)	4	100	4	23.5	100
Gastropoda					
Mesogastropoda					
Caecidae					
Caecum pulchellum	1	25	1	5.9	25

Note: LPIL designates the LOWEST PRACTICAL IDENTIFICATION LEVEL

Station Data Summary Report
Station C2

Client: Wilmington District, USACE
Project: Topsail Benthic Survey
Location: Topsail Beach
Sample Date: 28-29 Nov 06

Station: C2
Sample Type: Macrofauna
Replicates: 1
Sample Area: 0.0400

DATA SUMMARY

FAUNAL PARAMETERS	Station	Rep 1	Mean	Std Dev
Total Taxa	9	9	9	0
Total Individuals	17	17	17	0
Density (nos/sq.m.)		425	425	0

FAUNAL INDICES			
Species Diversity (Shannon; log base e)	H'	=	2.04
Species Diversity (Shannon; log base 2)	d	=	2.94
Species Diversity (Shannon; log base 10)	H	=	0.88
Species Diversity (Simpson; 1/S)	1/S	=	10.46
Species Evenness (Pielou)	J'	=	0.93
Species Richness (Margalef)	D	=	2.82
Equitability Index (Lloyd & Ghelardi)	e	=	1.2

MAJOR TAXONOMIC GROUPS	Total No. Taxa	Taxa % Total	Total No. Individuals	Individuals % Total
Annelida	1	11.1	3	17.6
Mollusca	2	22.2	5	29.4
Arthropoda	5	55.5	7	41.1
Echinodermata	1	11.1	2	11.7
TOTALS	**9**		**17**	

Station Data Summary Report
Station C3

Client: Wilmington District, USACE
Project: Topsail Benthic Survey
Location: Topsail Beach
Sample Date: 28-29 Nov 06

Station: C3
Sample Type: Macrofauna
Replicates: 1
Sample Area: 0.0400

TAXON	Rep 1		Station		
	Count	Density	Total	Percent	Mean Density
Annelida					
Polychaeta					
Eunicida					
Onuphidae					
Onuphidae (LPIL)	1	25	1	6.3	25
Phyllodocida					
Glyceridae					
Glyceridae (LPIL)	1	25	1	6.3	25
Arthropoda					
Malacostraca					
Amphipoda					
Platyischnopidae					
Eudevenopus honduranus	3	75	3	18.8	75
Echinodermata					
Echinoidea					
Echinoidea (LPIL)	2	50	2	12.5	50
Ophiuroidea					
Ophiuroidea (LPIL)	1	25	1	6.3	25
Mollusca					
Bivalvia					
Veneroida					
Tellinidae					
Tellina (LPIL)	5	125	5	31.3	125

Station Data Summary Report
Station C3

Client: Wilmington District, USACE
Project: Topsail Benthic Survey
Location: Topsail Beach
Sample Date: 28-29 Nov 06

Station: C3
Sample Type: Macrofauna
Replicates: 1
Sample Area: 0.0400

TAXON	Rep 1		Station		
	Count	Density	Total	Percent	Mean Density
Gastropoda					
Cephalaspidea					
Scaphandridae					
Acteocina canaliculata	1	25	1	6.3	25
Mesogastropoda					
Caecidae					
Caecum pulchellum	1	25	1	6.3	25
Rhynchocoela					
Rhynchocoela (LPIL)	1	25	1	6.3	25

Note: LPIL designates the LOWEST PRACTICAL IDENTIFICATION LEVEL

Station Data Summary Report
Station C3

Client: Wilmington District, USACE
Project: Topsail Benthic Survey
Location: Topsail Beach
Sample Date: 28-29 Nov 06

Station: C3
Sample Type: Macrofauna
Replicates: 1
Sample Area: 0.0400

DATA SUMMARY

FAUNAL PARAMETERS	Station	Rep 1	Mean	Std Dev
Total Taxa	9	9	9	0
Total Individuals	16	16	16	0
Density (nos/sq.m.)		400	400	0

FAUNAL INDICES			
Species Diversity (Shannon; log base e)	H'	=	1.98
Species Diversity (Shannon; log base 2)	d	=	2.85
Species Diversity (Shannon; log base 10)	H	=	0.86
Species Diversity (Simpson; 1/S)	1/S	=	8.57
Species Evenness (Pielou)	J'	=	0.9
Species Richness (Margalef)	D	=	2.89
Equitability Index (Lloyd & Ghelardi)	e	=	1.12

MAJOR TAXONOMIC GROUPS	Total No. Taxa	Taxa % Total	Total No. Individuals	Individuals % Total
Rhynchocoela	1	11.1	1	6.2
Annelida	2	22.2	2	12.5
Mollusca	3	33.3	7	43.7
Arthropoda	1	11.1	3	18.7
Echinodermata	2	22.2	3	18.7
TOTALS	**9**		**16**	

Station Data Summary Report
Station C4

Client: Wilmington District, USACE
Project: Topsail Benthic Survey
Location: Topsail Beach
Sample Date: 28-29 Nov 06

Station: C4
Sample Type: Macrofauna
Replicates: 1
Sample Area: 0.0400

TAXON	Rep 1		Station		
	Count	Density	Total	Percent	Mean Density
Annelida					
Polychaeta					
Eunicida					
Onuphidae					
Onuphidae (LPIL)	1	25	1	5.9	25
Opheliida					
Opheliidae					
Armandia maculata	3	75	3	17.6	75
Spionida					
Chaetopteridae					
Spiochaetopterus oculatus	1	25	1	5.9	25
Arthropoda					
Malacostraca					
Amphipoda					
Platyischnopidae					
Eudevenopus honduranus	4	100	4	23.5	100
Decapoda					
Pinnotheridae					
Dissodactylus mellitae	2	50	2	11.8	50
Ostracoda					
Myodocopina					
Sarsiellidae					
Eusarsiella texana	1	25	1	5.9	25
Podocopida					
Podocopida (LPIL)	1	25	1	5.9	25

Station Data Summary Report
Station C4

Client: Wilmington District, USACE
Project: Topsail Benthic Survey
Location: Topsail Beach
Sample Date: 28-29 Nov 06

Station: C4
Sample Type: Macrofauna
Replicates: 1
Sample Area: 0.0400

TAXON	Rep 1		Station		
	Count	Density	Total	Percent	Mean Density
Echinodermata					
Echinoidea					
Clypeasteroida					
Mellitidae					
Mellita isometra	1	25	1	5.9	25
Mollusca					
Gastropoda					
Cephalaspidea					
Scaphandridae					
Cylichna alba	1	25	1	5.9	25
Mesogastropoda					
Caecidae					
Caecum pulchellum	2	50	2	11.8	50

Note: LPIL designates the LOWEST PRACTICAL IDENTIFICATION LEVEL

Station Data Summary Report
Station C4

Client: Wilmington District, USACE
Project: Topsail Benthic Survey
Location: Topsail Beach
Sample Date: 28-29 Nov 06

Station: C4
Sample Type: Macrofauna
Replicates: 1
Sample Area: 0.0400

DATA SUMMARY

FAUNAL PARAMETERS	Station	Rep 1	Mean	Std Dev
Total Taxa	10	10	10	0
Total Individuals	17	17	17	0
Density (nos/sq.m.)		425	425	0

FAUNAL INDICES			
Species Diversity (Shannon; log base e)	H'	=	2.15
Species Diversity (Shannon; log base 2)	d	=	3.1
Species Diversity (Shannon; log base 10)	H	=	0.93
Species Diversity (Simpson; 1/S)	1/S	=	12.36
Species Evenness (Pielou)	J'	=	0.93
Species Richness (Margalef)	D	=	3.18
Equitability Index (Lloyd & Ghelardi)	e	=	1.21

MAJOR TAXONOMIC GROUPS	Total No. Taxa	Taxa % Total	Total No. Individuals	Individuals % Total
Annelida	3	30	5	29.4
Mollusca	2	20	3	17.6
Arthropoda	4	40	8	47
Echinodermata	1	10	1	5.8
TOTALS	**10**		**17**	

Station Data Summary Report
Station D1

Client: Wilmington District, USACE
Project: Topsail Benthic Survey
Location: Topsail Beach
Sample Date: 28-29 Nov 06

Station: D1
Sample Type: Macrofauna
Replicates: 1
Sample Area: 0.0400

TAXON	Rep 1		Station		
	Count	Density	Total	Percent	Mean Density
Annelida					
Polychaeta					
Oweniida					
Oweniidae					
Owenia fusiformis	1	25	1	25	25
Arthropoda					
Malacostraca					
Amphipoda					
Platyischnopidae					
Eudevenopus honduranus	1	25	1	25	25
Ostracoda					
Myodocopina					
Sarsiellidae					
Eusarsiella texana	1	25	1	25	25
Mollusca					
Gastropoda					
Cephalaspidea					
Scaphandridae					
Cylichna alba	1	25	1	25	25

Note: LPIL designates the LOWEST PRACTICAL IDENTIFICATION LEVEL

Station Data Summary Report
Station D1

Client: Wilmington District, USACE
Project: Topsail Benthic Survey
Location: Topsail Beach
Sample Date: 28-29 Nov 06

Station: D1
Sample Type: Macrofauna
Replicates: 1
Sample Area: 0.0400

DATA SUMMARY

FAUNAL PARAMETERS	Station	Rep 1	Mean	Std Dev
Total Taxa	4	4	4	0
Total Individuals	4	4	4	0
Density (nos/sq.m.)		100	100	0

FAUNAL INDICES			
Species Diversity (Shannon; log base e)	H'	=	1.39
Species Diversity (Shannon; log base 2)	d	=	2
Species Diversity (Shannon; log base 10)	H	=	0.6
Species Diversity (Simpson; 1/S)	1/S	=	
Species Evenness (Pielou)	J'	=	1
Species Richness (Margalef)	D	=	2.16
Equitability Index (Lloyd & Ghelardi)	e	=	1.37

MAJOR TAXONOMIC GROUPS	Total No. Taxa	Taxa % Total	Total No. Individuals	Individuals % Total
Annelida	1	25	1	25
Mollusca	1	25	1	25
Arthropoda	2	50	2	50
TOTALS	**4**		**4**	

Station Data Summary Report
Station D2

Client: Wilmington District, USACE
Project: Topsail Benthic Survey
Location: Topsail Beach
Sample Date: 28-29 Nov 06

Station: D2
Sample Type: Macrofauna
Replicates: 1
Sample Area: 0.0400

TAXON	Rep 1		Station		
	Count	Density	Total	Percent	Mean Density
Annelida					
Polychaeta					
Eunicida					
Onuphidae					
Onuphidae (LPIL)	1	25	1	10	25
Phyllodocida					
Goniadidae					
Goniada littorea	1	25	1	10	25
Spionida					
Magelonidae					
Magelona papillicornis	3	75	3	30	75
Spionidae					
Spiophanes bombyx	1	25	1	10	25
Mollusca					
Bivalvia					
Veneroida					
Lucinidae					
Lucinidae (LPIL)	1	25	1	10	25
Mesodesmatidae					
Ervilia concentrica	1	25	1	10	25
Gastropoda					
Mesogastropoda					
Caecidae					
Caecum pulchellum	1	25	1	10	25

Station Data Summary Report
Station D2

Client: Wilmington District, USACE
Project: Topsail Benthic Survey
Location:
Sample Date: 28-29 Nov 06

Station: D2
Sample Type: Macrofauna
Replicates: 1
Sample Area: 0.0400

TAXON	Rep 1		Station		
	Count	Density	Total	Percent	Mean Density
Rhynchocoela					
Rhynchocoela (LPIL)	1	25	1	10	25

Note: LPIL designates the LOWEST PRACTICAL IDENTIFICATION LEVEL

Station Data Summary Report
Station D2

Client: Wilmington District, USACE
Project: Topsail Benthic Survey
Location: Topsail Beach
Sample Date: 28-29 Nov 06

Station: D2
Sample Type: Macrofauna
Replicates: 1
Sample Area: 0.0400

DATA SUMMARY

FAUNAL PARAMETERS	Station	Rep 1	Mean	Std Dev
Total Taxa	8	8	8	0
Total Individuals	10	10	10	0
Density (nos/sq.m.)		250	250	0

FAUNAL INDICES			
Species Diversity (Shannon; log base e)	H'	=	1.97
Species Diversity (Shannon; log base 2)	d	=	2.85
Species Diversity (Shannon; log base 10)	H	=	0.86
Species Diversity (Simpson; 1/S)	1/S	=	15
Species Evenness (Pielou)	J'	=	0.95
Species Richness (Margalef)	D	=	3.04
Equitability Index (Lloyd & Ghelardi)	e	=	1.26

MAJOR TAXONOMIC GROUPS	Total No. Taxa	Taxa % Total	Total No. Individuals	Individuals % Total
Rhynchocoela	1	12.5	1	10
Annelida	4	50	6	60
Mollusca	3	37.5	3	30
TOTALS	**8**		**10**	

Station Data Summary Report
Station D3

Client: Wilmington District, USACE
Project: Topsail Benthic Survey
Location: Topsail Beach
Sample Date: 28-29 Nov 06

Station: D3
Sample Type: Macrofauna
Replicates: 1
Sample Area: 0.0400

TAXON	Rep 1		Station		
	Count	Density	Total	Percent	Mean Density
Annelida					
Polychaeta					
Phyllodocida					
Goniadidae					
Goniada littorea	2	50	2	28.6	50
Spionida					
Spionidae					
Spionidae (LPIL)	1	25	1	14.3	25
Mollusca					
Gastropoda					
Cephalaspidea					
Scaphandridae					
Acteocina canaliculata	1	25	1	14.3	25
Mesogastropoda					
Caecidae					
Caecum pulchellum	3	75	3	42.9	75

Note: LPIL designates the LOWEST PRACTICAL IDENTIFICATION LEVEL

Station Data Summary Report
Station D3

Client: Wilmington District, USACE
Project: Topsail Benthic Survey
Location: Topsail Beach
Sample Date: 28-29 Nov 06

Station: D3
Sample Type: Macrofauna
Replicates: 1
Sample Area: 0.0400

DATA SUMMARY

FAUNAL PARAMETERS	Station	Rep 1	Mean	Std Dev
Total Taxa	4	4	4	0
Total Individuals	7	7	7	0
Density (nos/sq.m.)		175	175	0

FAUNAL INDICES			
Species Diversity (Shannon; log base e)	H'	=	1.28
Species Diversity (Shannon; log base 2)	d	=	1.84
Species Diversity (Shannon; log base 10)	H	=	0.55
Species Diversity (Simpson; 1/S)	1/S	=	5.25
Species Evenness (Pielou)	J'	=	0.92
Species Richness (Margalef)	D	=	1.54
Equitability Index (Lloyd & Ghelardi)	e	=	1.22

MAJOR TAXONOMIC GROUPS	Total No. Taxa	Taxa % Total	Total No. Individuals	Individuals % Total
Annelida	2	50	3	42.8
Mollusca	2	50	4	57.1
TOTALS	**4**		**7**	

Station Data Summary Report
Station D4

Client: Wilmington District, USACE
Project: Topsail Benthic Survey
Location: Topsail Beach
Sample Date: 28-29 Nov 06

Station: D4
Sample Type: Macrofauna
Replicates: 1
Sample Area: 0.0400

TAXON	Rep 1		Station		
	Count	Density	Total	Percent	Mean Density
Annelida					
Polychaeta					
Eunicida					
Lumbrineridae					
Lumbrineris latreilli	1	25	1	5	25
Orbiniida					
Paraonidae					
Aricidea (LPIL)	1	25	1	5	25
Aricidea wassi	1	25	1	5	25
Phyllodocida					
Goniadidae					
Goniada littorea	1	25	1	5	25
Spionida					
Magelonidae					
Magelona papillicornis	1	25	1	5	25
Arthropoda					
Malacostraca					
Amphipoda					
Amphipoda (LPIL)	1	25	1	5	25
Oedicerotidae					
Americhelidium americanum	1	25	1	5	25
Phoxocephalidae					
Rhepoxynius hudsoni	1	25	1	5	25
Platyischnopidae					
Eudevenopus honduranus	3	75	3	15	75

Station Data Summary Report
Station D4

Client: Wilmington District, USACE
Project: Topsail Benthic Survey
Location: Topsail Beach
Sample Date: 28-29 Nov 06

Station: D4
Sample Type: Macrofauna
Replicates: 1
Sample Area: 0.0400

TAXON	Rep 1		Station		
	Count	Density	Total	Percent	Mean Density
Cumacea					
Diastylidae					
Oxyurostylis (LPIL)	1	25	1	5	25
Ostracoda					
Myodocopina					
Philomedidae					
Harbansus paucichelatus	1	25	1	5	25
Philomedidae (LPIL)	1	25	1	5	25
Echinodermata					
Ophiuroidea					
Ophiuroidea (LPIL)	1	25	1	5	25
Mollusca					
Bivalvia					
Veneroida					
Lucinidae					
Lucina (LPIL)	1	25	1	5	25
Tellinidae					
Tellina (LPIL)	1	25	1	5	25
Gastropoda					
Mesogastropoda					
Caecidae					
Caecum pulchellum	3	75	3	15	75

Note: LPIL designates the LOWEST PRACTICAL IDENTIFICATION LEVEL

Station Data Summary Report
Station D4

Client: Wilmington District, USACE
Project: Topsail Benthic Survey
Location: Topsail Beach
Sample Date: 28-29 Nov 06

Station: D4
Sample Type: Macrofauna
Replicates: 1
Sample Area: 0.0400

DATA SUMMARY

FAUNAL PARAMETERS	Station	Rep 1	Mean	Std Dev
Total Taxa	16	16	16	0
Total Individuals	20	20	20	0
Density (nos/sq.m.)		500	500	0

FAUNAL INDICES			
Species Diversity (Shannon; log base e)	H'	=	2.67
Species Diversity (Shannon; log base 2)	d	=	3.85
Species Diversity (Shannon; log base 10)	H	=	1.16
Species Diversity (Simpson; 1/S)	1/S	=	31.67
Species Evenness (Pielou)	J'	=	0.96
Species Richness (Margalef)	D	=	5.01
Equitability Index (Lloyd & Ghelardi)	e	=	1.3

MAJOR TAXONOMIC GROUPS	Total No. Taxa	Taxa % Total	Total No. Individuals	Individuals % Total
Annelida	5	31.2	5	25
Mollusca	3	18.7	5	25
Arthropoda	7	43.7	9	45
Echinodermata	1	6.2	1	5
TOTALS	**16**		**20**	

Station Data Summary Report
Station E1

Client: Wilmington District, USACE
Project: Topsail Benthic Survey
Location: Topsail Beach
Sample Date: 28-29 Nov 06

Station: E1
Sample Type: Macrofauna
Replicates: 1
Sample Area: 0.0400

TAXON	Rep 1		Station		
	Count	Density	Total	Percent	Mean Density
Annelida					
Polychaeta					
Orbiniida					
Paraonidae					
Aricidea wassi	1	25	1	6.7	25
Phyllodocida					
Glyceridae					
Glyceridae (LPIL)	1	25	1	6.7	25
Goniadidae					
Goniada littorea	3	75	3	20	75
Pilargiidae					
Ancistrosyllis (LPIL)	1	25	1	6.7	25
Spionida					
Magelonidae					
Magelona papillicornis	1	25	1	6.7	25
Spionidae					
Spionidae (LPIL)	1	25	1	6.7	25
Arthropoda					
Malacostraca					
Amphipoda					
Oedicerotidae					
Americhelidium americanum	1	25	1	6.7	25
Platyischnopidae					
Eudevenopus honduranus	1	25	1	6.7	25

Station Data Summary Report
Station E1

Client: Wilmington District, USACE
Project: Topsail Benthic Survey
Location:
Sample Date: 28-29 Nov 06

Station: E1
Sample Type: Macrofauna
Replicates: 1
Sample Area: 0.0400

TAXON	Rep 1		Station		
	Count	Density	Total	Percent	Mean Density
Decapoda					
Paguridae					
Pagurus (LPIL)	1	25	1	6.7	25
Mollusca					
Bivalvia					
Veneroida					
Lucinidae					
Lucinidae (LPIL)	1	25	1	6.7	25
Gastropoda					
Mesogastropoda					
Caecidae					
Caecum pulchellum	3	75	3	20	75

Note: LPIL designates the LOWEST PRACTICAL IDENTIFICATION LEVEL

Station Data Summary Report
Station E1

Client: Wilmington District, USACE
Project: Topsail Benthic Survey
Location: Topsail Beach
Sample Date: 28-29 Nov 06

Station: E1
Sample Type: Macrofauna
Replicates: 1
Sample Area: 0.0400

DATA SUMMARY

FAUNAL PARAMETERS	Station	Rep 1	Mean	Std Dev
Total Taxa	11	11	11	0
Total Individuals	15	15	15	0
Density (nos/sq.m.)		375	375	0

FAUNAL INDICES			
Species Diversity (Shannon; log base e)	H'	=	2.27
Species Diversity (Shannon; log base 2)	d	=	3.27
Species Diversity (Shannon; log base 10)	H	=	0.99
Species Diversity (Simpson; 1/S)	1/S	=	17.5
Species Evenness (Pielou)	J'	=	0.95
Species Richness (Margalef)	D	=	3.69
Equitability Index (Lloyd & Ghelardi)	e	=	1.25

MAJOR TAXONOMIC GROUPS	Total No. Taxa	Taxa % Total	Total No. Individuals	Individuals % Total
Annelida	6	54.5	8	53.3
Mollusca	2	18.1	4	26.6
Arthropoda	3	27.2	3	20
TOTALS	**11**		**15**	

Station Data Summary Report
Station E2

Client: Wilmington District, USACE
Project: Topsail Benthic Survey
Location: Topsail Beach
Sample Date: 28-29 Nov 06

Station: E2
Sample Type: Macrofauna
Replicates: 1
Sample Area: 0.0400

TAXON	Rep 1		Station		
	Count	Density	Total	Percent	Mean Density
Annelida					
Polychaeta					
Capitellida					
Capitellidae					
Mediomastus (LPIL)	1	25	1	3.8	25
Opheliida					
Opheliidae					
Opheliidae (LPIL)	1	25	1	3.8	25
Orbiniida					
Paraonidae					
Aricidea (LPIL)	1	25	1	3.8	25
Aricidea wassi	2	50	2	7.7	50
Spionida					
Magelonidae					
Magelona papillicornis	2	50	2	7.7	50
Arthropoda					
Malacostraca					
Amphipoda					
Platyischnopidae					
Eudevenopus honduranus	3	75	3	11.5	75
Echinodermata					
Ophiuroidea					
Ophiuroidea (LPIL)	1	25	1	3.8	25

Station Data Summary Report
Station E2

Client: Wilmington District, USACE
Project: Topsail Benthic Survey
Location:
Sample Date: 28-29 Nov 06

Station: E2
Sample Type: Macrofauna
Replicates: 1
Sample Area: 0.0400

TAXON	Rep 1		Station		
	Count	Density	Total	Percent	Mean Density
Mollusca					
Bivalvia					
Veneroida					
Lucinidae					
Lucinidae (LPIL)	2	50	2	7.7	50
Tellinidae					
Tellina (LPIL)	1	25	1	3.8	25
Gastropoda					
Cephalaspidea					
Scaphandridae					
Acteocina canaliculata	2	50	2	7.7	50
Mesogastropoda					
Caecidae					
Caecum pulchellum	7	175	7	26.9	175
Eulimidae					
Strombiformis bilineatus	1	25	1	3.8	25
Rhynchocoela					
Rhynchocoela (LPIL)	2	50	2	7.7	50

Note: LPIL designates the LOWEST PRACTICAL IDENTIFICATION LEVEL

Station Data Summary Report
Station E2

Client: Wilmington District, USACE
Project: Topsail Benthic Survey
Location: Topsail Beach
Sample Date: 28-29 Nov 06

Station: E2
Sample Type: Macrofauna
Replicates: 1
Sample Area: 0.0400

DATA SUMMARY

FAUNAL PARAMETERS	Station	Rep 1	Mean	Std Dev
Total Taxa	13	13	13	0
Total Individuals	26	26	26	0
Density (nos/sq.m.)		650	650	0

FAUNAL INDICES

Species Diversity (Shannon; log base e)	H'	=	2.34
Species Diversity (Shannon; log base 2)	d	=	3.38
Species Diversity (Shannon; log base 10)	H	=	1.02
Species Diversity (Simpson; 1/S)	1/S	=	11.21
Species Evenness (Pielou)	J'	=	0.91
Species Richness (Margalef)	D	=	3.68
Equitability Index (Lloyd & Ghelardi)	e	=	1.14

MAJOR TAXONOMIC GROUPS	Total No. Taxa	Taxa % Total	Total No. Individuals	Individuals % Total
Rhynchocoela	1	7.6	2	7.6
Annelida	5	38.4	7	26.9
Mollusca	5	38.4	13	50
Arthropoda	1	7.6	3	11.5
Echinodermata	1	7.6	1	3.8
TOTALS	**13**		**26**	

Station Data Summary Report
Station E3

Client: Wilmington District, USACE
Project: Topsail Benthic Survey
Location: Topsail Beach
Sample Date: 28-29 Nov 06

Station: E3
Sample Type: Macrofauna
Replicates: 1
Sample Area: 0.0400

TAXON	Rep 1		Station		
	Count	Density	Total	Percent	Mean Density
Annelida					
Polychaeta					
Capitellida					
Maldanidae					
Maldanidae (LPIL)	1	25	1	2.3	25
Opheliida					
Opheliidae					
Armandia (LPIL)	1	25	1	2.3	25
Orbiniida					
Paraonidae					
Aricidea suecica	1	25	1	2.3	25
Cirrophorus (LPIL)	1	25	1	2.3	25
Phyllodocida					
Goniadidae					
Goniada littorea	1	25	1	2.3	25
Pilargiidae					
Ancistrosyllis hartmanae	1	25	1	2.3	25
Spionida					
Magelonidae					
Magelona papillicornis	2	50	2	4.7	50
Arthropoda					
Malacostraca					
Amphipoda					
Phoxocephalidae					
Metharpinia floridana	1	25	1	2.3	25

Station Data Summary Report
Station E3

Client: Wilmington District, USACE
Project: Topsail Benthic Survey
Location: Topsail Beach
Sample Date: 28-29 Nov 06

Station: E3
Sample Type: Macrofauna
Replicates: 1
Sample Area: 0.0400

TAXON	Rep 1		Station		
	Count	Density	Total	Percent	Mean Density
Platyischnopidae					
Eudevenopus honduranus	6	150	6	14	150
Cumacea					
Diastylidae					
Oxyurostylis (LPIL)	1	25	1	2.3	25
Chordata					
Leptocardia					
Amphioxi					
Branchiostomidae					
Branchiostoma (LPIL)	2	50	2	4.7	50
Echinodermata					
Echinodermata (LPIL)	1	25	1	2.3	25
Mollusca					
Bivalvia					
Veneroida					
Crassatellidae					
Crassinella dupliniana	3	75	3	7	75
Crassinella lunulata	2	50	2	4.7	50
Montacutidae					
Montacutidae (LPIL)	1	25	1	2.3	25
Tellinidae					
Strigilla mirabilis	1	25	1	2.3	25
Tellina (LPIL)	1	25	1	2.3	25

Station Data Summary Report
Station E3

Client: Wilmington District, USACE
Project: Topsail Benthic Survey
Location: Topsail Beach
Sample Date: 28-29 Nov 06

Station: E3
Sample Type: Macrofauna
Replicates: 1
Sample Area: 0.0400

TAXON	Rep 1		Station		
	Count	Density	Total	Percent	Mean Density
Gastropoda					
Cephalaspidea					
Scaphandridae					
Acteocina canaliculata	1	25	1	2.3	25
Mesogastropoda					
Caecidae					
Caecum pulchellum	12	300	12	27.9	300
Eulimidae					
Strombiformis bilineatus	1	25	1	2.3	25
Naticidae					
Tectonatica pusilla	1	25	1	2.3	25
Rhynchocoela					
Rhynchocoela (LPIL)	1	25	1	2.3	25

Note: LPIL designates the LOWEST PRACTICAL IDENTIFICATION LEVEL

Station Data Summary Report
Station E3

Client: Wilmington District, USACE
Project: Topsail Benthic Survey
Location: Topsail Beach
Sample Date: 28-29 Nov 06

Station: E3
Sample Type: Macrofauna
Replicates: 1
Sample Area: 0.0400

DATA SUMMARY

FAUNAL PARAMETERS	Station	Rep 1	Mean	Std Dev
Total Taxa	22	22	22	0
Total Individuals	43	43	43	0
Density (nos/sq.m.)		1075	1075	0

FAUNAL INDICES

Species Diversity (Shannon; log base e)	H'	=	2.64
Species Diversity (Shannon; log base 2)	d	=	3.82
Species Diversity (Shannon; log base 10)	H	=	1.15
Species Diversity (Simpson; 1/S)	1/S	=	10.38
Species Evenness (Pielou)	J'	=	0.86
Species Richness (Margalef)	D	=	5.58
Equitability Index (Lloyd & Ghelardi)	e	=	0.92

MAJOR TAXONOMIC GROUPS	Total No. Taxa	Taxa % Total	Total No. Individuals	Individuals % Total
Rhynchocoela	1	4.5	1	2.3
Annelida	7	31.8	8	18.6
Mollusca	9	40.9	23	53.4
Arthropoda	3	13.6	8	18.6
Echinodermata	1	4.5	1	2.3
Chordata	1	4.5	2	4.6
TOTALS	**22**		**43**	

Station Data Summary Report
Station E4

Client: Wilmington District, USACE
Project: Topsail Benthic Survey
Location: Topsail Beach
Sample Date: 28-29 Nov 06

Station: E4
Sample Type: Macrofauna
Replicates: 1
Sample Area: 0.0400

TAXON	Rep 1		Station		
	Count	Density	Total	Percent	Mean Density
Annelida					
Polychaeta					
Eunicida					
Oenonidae					
Arabella multidentata	1	25	1	3.6	25
Opheliida					
Opheliidae					
Armandia maculata	2	50	2	7.1	50
Opheliidae (LPIL)	1	25	1	3.6	25
Phyllodocida					
Nereidae					
Ceratocephale oculata	1	25	1	3.6	25
Spionida					
Magelonidae					
Magelona papillicornis	2	50	2	7.1	50
Spionidae					
Paraprionospio pinnata	1	25	1	3.6	25
Arthropoda					
Malacostraca					
Amphipoda					
Phoxocephalidae					
Rhepoxynius hudsoni	1	25	1	3.6	25
Platyischnopidae					
Eudevenopus honduranus	7	175	7	25	175

Station Data Summary Report
Station E4

Client: Wilmington District, USACE
Project: Topsail Benthic Survey
Location: Topsail Beach
Sample Date: 28-29 Nov 06

Station: E4
Sample Type: Macrofauna
Replicates: 1
Sample Area: 0.0400

TAXON	Rep 1		Station		
	Count	Density	Total	Percent	Mean Density
Ostracoda					
Myodocopina					
Sarsiellidae					
Eusarsiella texana	1	25	1	3.6	25
Mollusca					
Bivalvia					
Veneroida					
Crassatellidae					
Crassinella dupliniana	1	25	1	3.6	25
Lucinidae					
Lucina multilineata	3	75	3	10.7	75
Tellinidae					
Strigilla mirabilis	1	25	1	3.6	25
Tellina (LPIL)	1	25	1	3.6	25
Gastropoda					
Cephalaspidea					
Scaphandridae					
Acteocina canaliculata	1	25	1	3.6	25
Mesogastropoda					
Caecidae					
Caecum pulchellum	2	50	2	7.1	50
Naticidae					
Tectonatica pusilla	1	25	1	3.6	25

Station Data Summary Report
Station E4

Client: Wilmington District, USACE
Project: Topsail Benthic Survey
Location: Topsail Beach
Sample Date: 28-29 Nov 06

Station: E4
Sample Type: Macrofauna
Replicates: 1
Sample Area: 0.0400

TAXON	Rep 1		Station		
	Count	Density	Total	Percent	Mean Density
Rhynchocoela					
Rhynchocoela (LPIL)	1	25	1	3.6	25

Note: LPIL designates the LOWEST PRACTICAL IDENTIFICATION LEVEL

Station Data Summary Report
Station E4

Client: Wilmington District, USACE
Project: Topsail Benthic Survey
Location: Topsail Beach
Sample Date: 28-29 Nov 06

Station: E4
Sample Type: Macrofauna
Replicates: 1
Sample Area: 0.0400

DATA SUMMARY

FAUNAL PARAMETERS	Station	Rep 1	Mean	Std Dev
Total Taxa	17	17	17	0
Total Individuals	28	28	28	0
Density (nos/sq.m.)		700	700	0

FAUNAL INDICES			
Species Diversity (Shannon; log base e)	H'	=	2.58
Species Diversity (Shannon; log base 2)	d	=	3.72
Species Diversity (Shannon; log base 10)	H	=	1.12
Species Diversity (Simpson; 1/S)	1/S	=	14
Species Evenness (Pielou)	J'	=	0.91
Species Richness (Margalef)	D	=	4.8
Equitability Index (Lloyd & Ghelardi)	e	=	1.12

MAJOR TAXONOMIC GROUPS	Total No. Taxa	Taxa % Total	Total No. Individuals	Individuals % Total
Rhynchocoela	1	5.8	1	3.5
Annelida	6	35.2	8	28.5
Mollusca	7	41.1	10	35.7
Arthropoda	3	17.6	9	32.1
TOTALS	**17**		**28**	

Station Data Summary Report
Station F1

Client: Wilmington District, USACE
Project: Topsail Benthic Survey
Location: Topsail Beach
Sample Date: 28-29 Nov 06

Station: F1
Sample Type: Macrofauna
Replicates: 1
Sample Area: 0.0400

TAXON	Rep 1		Station		
	Count	Density	Total	Percent	Mean Density
Annelida					
Polychaeta					
Opheliida					
Opheliidae					
Opheliidae (LPIL)	1	25	1	11.1	25
Spionida					
Cirratulidae					
Caulleriella sp. J	1	25	1	11.1	25
Magelonidae					
Magelona papillicornis	1	25	1	11.1	25
Magelona pettiboneae	1	25	1	11.1	25
Arthropoda					
Malacostraca					
Cumacea					
Diastylidae					
Oxyurostylis (LPIL)	1	25	1	11.1	25
Ostracoda					
Myodocopina					
Sarsiellidae					
Eusarsiella texana	1	25	1	11.1	25
Chordata					
Leptocardia					
Amphioxi					
Branchiostomidae					
Branchiostoma (LPIL)	1	25	1	11.1	25

Station Data Summary Report
Station F1

Client: Wilmington District, USACE
Project: Topsail Benthic Survey
Location: Topsail Beach
Sample Date: 28-29 Nov 06

Station: F1
Sample Type: Macrofauna
Replicates: 1
Sample Area: 0.0400

TAXON	Rep 1		Station		
	Count	Density	Total	Percent	Mean Density
Mollusca					
Bivalvia					
Veneroida					
Crassatellidae					
Crassinella lunulata	1	25	1	11.1	25
Platyhelminthes					
Turbellaria					
Turbellaria (LPIL)	1	25	1	11.1	25

Note: LPIL designates the LOWEST PRACTICAL IDENTIFICATION LEVEL

Station Data Summary Report
Station F1

Client: Wilmington District, USACE
Project: Topsail Benthic Survey
Location: Topsail Beach
Sample Date: 28-29 Nov 06

Station: F1
Sample Type: Macrofauna
Replicates: 1
Sample Area: 0.0400

DATA SUMMARY

FAUNAL PARAMETERS	Station	Rep 1	Mean	Std Dev
Total Taxa	9	9	9	0
Total Individuals	9	9	9	0
Density (nos/sq.m.)		225	225	0

FAUNAL INDICES

Species Diversity (Shannon; log base e)	H'	=	2.2
Species Diversity (Shannon; log base 2)	d	=	3.17
Species Diversity (Shannon; log base 10)	H	=	0.95
Species Diversity (Simpson; 1/S)	1/S	=	
Species Evenness (Pielou)	J'	=	1
Species Richness (Margalef)	D	=	3.64
Equitability Index (Lloyd & Ghelardi)	e	=	1.41

MAJOR TAXONOMIC GROUPS	Total No. Taxa	Taxa % Total	Total No. Individuals	Individuals % Total
Platyhelminthes	1	11.1	1	11.1
Annelida	4	44.4	4	44.4
Mollusca	1	11.1	1	11.1
Arthropoda	2	22.2	2	22.2
Chordata	1	11.1	1	11.1
TOTALS	**9**		**9**	

Station Data Summary Report
Station F2

Client: Wilmington District, USACE
Project: Topsail Benthic Survey
Location: Topsail Beach
Sample Date: 28-29 Nov 06

Station: F2
Sample Type: Macrofauna
Replicates: 1
Sample Area: 0.0400

TAXON	Rep 1		Station		
	Count	Density	Total	Percent	Mean Density
Annelida					
Polychaeta					
Opheliida					
Opheliidae					
Ophelia denticulata	1	25	1	4.2	25
Phyllodocida					
Chrysopetalidae					
Bhawania heteroseta	1	25	1	4.2	25
Goniadidae					
Goniadides carolinae	2	50	2	8.3	50
Hesionidae					
Microphthalmus (LPIL)	1	25	1	4.2	25
Nephtyidae					
Nephtys simoni	1	25	1	4.2	25
Spionida					
Cirratulidae					
Cirratulidae (LPIL)	1	25	1	4.2	25
Arthropoda					
Malacostraca					
Amphipoda					
Melitidae					
Maera caroliniana	1	25	1	4.2	25

Station Data Summary Report
Station F2

Client: Wilmington District, USACE
Project: Topsail Benthic Survey
Location: Topsail Beach
Sample Date: 28-29 Nov 06

Station: F2
Sample Type: Macrofauna
Replicates: 1
Sample Area: 0.0400

DATA SUMMARY

FAUNAL PARAMETERS	Station	Rep 1	Mean	Std Dev
Total Taxa	16	16	16	0
Total Individuals	24	24	24	0
Density (nos/sq.m.)		600	600	0

FAUNAL INDICES			
Species Diversity (Shannon; log base e)	H'	=	2.64
Species Diversity (Shannon; log base 2)	d	=	3.8
Species Diversity (Shannon; log base 10)	H	=	1.14
Species Diversity (Simpson; 1/S)	1/S	=	23
Species Evenness (Pielou)	J'	=	0.95
Species Richness (Margalef)	D	=	4.72
Equitability Index (Lloyd & Ghelardi)	e	=	1.26

MAJOR TAXONOMIC GROUPS	Total No. Taxa	Taxa % Total	Total No. Individuals	Individuals % Total
Rhynchocoela	1	6.2	3	12.5
Annelida	6	37.5	7	29.1
Mollusca	7	43.7	11	45.8
Arthropoda	1	6.2	1	4.1
Chordata	1	6.2	2	8.3
TOTALS	**16**		**24**	

Station Data Summary Report
Station F2

Client: Wilmington District, USACE
Project: Topsail Benthic Survey
Location: Topsail Beach
Sample Date: 28-29 Nov 06

Station: F2
Sample Type: Macrofauna
Replicates: 1
Sample Area: 0.0400

TAXON	Rep 1		Station		
	Count	Density	Total	Percent	Mean Density
Chordata					
Leptocardia					
Amphioxi					
Branchiostomidae					
Branchiostoma (LPIL)	2	50	2	8.3	50
Mollusca					
Bivalvia					
Bivalvia (LPIL)	1	25	1	4.2	25
Ostreoida					
Anomiidae					
Anomia simplex	1	25	1	4.2	25
Veneroida					
Crassatellidae					
Crassinella dupliniana	4	100	4	16.7	100
Crassinella lunulata	2	50	2	8.3	50
Gastropoda					
Cephalaspidea					
Scaphandridae					
Acteocina canaliculata	1	25	1	4.2	25
Mesogastropoda					
Caecidae					
Caecum pulchellum	1	25	1	4.2	25
Pyramidelloida					
Pyramidellidae					
Turbonilla (LPIL)	1	25	1	4.2	25

Station Data Summary Report
Station F2

Client: Wilmington District, USACE
Project: Topsail Benthic Survey
Location: Topsail Beach
Sample Date: 28-29 Nov 06

Station: F2
Sample Type: Macrofauna
Replicates: 1
Sample Area: 0.0400

TAXON	Rep 1		Station		
	Count	Density	Total	Percent	Mean Density
Rhynchocoela					
Rhynchocoela (LPIL)	3	75	3	12.5	75

Note: LPIL designates the LOWEST PRACTICAL IDENTIFICATION LEVEL

Station Data Summary Report
Station F2

Client: Wilmington District, USACE
Project: Topsail Benthic Survey
Location: Topsail Beach
Sample Date: 28-29 Nov 06

Station: F2
Sample Type: Macrofauna
Replicates: 1
Sample Area: 0.0400

DATA SUMMARY

FAUNAL PARAMETERS	Station	Rep 1	Mean	Std Dev
Total Taxa	16	16	16	0
Total Individuals	24	24	24	0
Density (nos/sq.m.)		600	600	0

FAUNAL INDICES			
Species Diversity (Shannon; log base e)	H'	=	2.64
Species Diversity (Shannon; log base 2)	d	=	3.8
Species Diversity (Shannon; log base 10)	H	=	1.14
Species Diversity (Simpson; 1/S)	1/S	=	23
Species Evenness (Pielou)	J'	=	0.95
Species Richness (Margalef)	D	=	4.72
Equitability Index (Lloyd & Ghelardi)	e	=	1.26

MAJOR TAXONOMIC GROUPS	Total No. Taxa	Taxa % Total	Total No. Individuals	Individuals % Total
Rhynchocoela	1	6.2	3	12.5
Annelida	6	37.5	7	29.1
Mollusca	7	43.7	11	45.8
Arthropoda	1	6.2	1	4.1
Chordata	1	6.2	2	8.3
TOTALS	**16**		**24**	

Station Data Summary Report
Station F3

Client: Wilmington District, USACE
Project: Topsail Benthic Survey
Location: Topsail Beach
Sample Date: 28-29 Nov 06

Station: F3
Sample Type: Macrofauna
Replicates: 1
Sample Area: 0.0400

TAXON	Rep 1		Station		
	Count	Density	Total	Percent	Mean Density
Annelida					
Polychaeta					
Eunicida					
Onuphidae					
Onuphidae (LPIL)	1	25	1	7.1	25
Phyllodocida					
Goniadidae					
Goniada littorea	1	25	1	7.1	25
Nereidae					
Ceratocephale oculata	1	25	1	7.1	25
Spionida					
Spionidae					
Paraprionospio pinnata	1	25	1	7.1	25
Arthropoda					
Malacostraca					
Amphipoda					
Platyischnopidae					
Eudevenopus honduranus	2	50	2	14.3	50
Echinodermata					
Ophiuroidea					
Ophiuroidea (LPIL)	2	50	2	14.3	50

Station Data Summary Report
Station F3

Client: Wilmington District, USACE
Project: Topsail Benthic Survey
Location: Topsail Beach
Sample Date: 28-29 Nov 06

Station: F3
Sample Type: Macrofauna
Replicates: 1
Sample Area: 0.0400

TAXON	Rep 1		Station		
	Count	Density	Total	Percent	Mean Density
Mollusca					
Bivalvia					
Veneroida					
Lucinidae					
Lucinidae (LPIL)	2	50	2	14.3	50
Gastropoda					
Mesogastropoda					
Caecidae					
Caecum pulchellum	2	50	2	14.3	50
Neogastropoda					
Olividae					
Olivella dealbata	2	50	2	14.3	50

Note: LPIL designates the LOWEST PRACTICAL IDENTIFICATION LEVEL

Station Data Summary Report
Station F3

Client: Wilmington District, USACE
Project: Topsail Benthic Survey
Location: Topsail Beach
Sample Date: 28-29 Nov 06

Station: F3
Sample Type: Macrofauna
Replicates: 1
Sample Area: 0.0400

DATA SUMMARY

FAUNAL PARAMETERS	Station	Rep 1	Mean	Std Dev
Total Taxa	9	9	9	0
Total Individuals	14	14	14	0
Density (nos/sq.m.)		350	350	0

FAUNAL INDICES			
Species Diversity (Shannon; log base e)	H'	=	2.14
Species Diversity (Shannon; log base 2)	d	=	3.09
Species Diversity (Shannon; log base 10)	H	=	0.93
Species Diversity (Simpson; 1/S)	1/S	=	18.2
Species Evenness (Pielou)	J'	=	0.98
Species Richness (Margalef)	D	=	3.03
Equitability Index (Lloyd & Ghelardi)	e	=	1.34

MAJOR TAXONOMIC GROUPS	Total No. Taxa	Taxa % Total	Total No. Individuals	Individuals % Total
Annelida	4	44.4	4	28.5
Mollusca	3	33.3	6	42.8
Arthropoda	1	11.1	2	14.2
Echinodermata	1	11.1	2	14.2
TOTALS	**9**		**14**	

Station Data Summary Report
Station F4

Client: Wilmington District, USACE
Project: Topsail Benthic Survey
Location: Topsail Beach
Sample Date: 28-29 Nov 06

Station: F4
Sample Type: Macrofauna
Replicates: 1
Sample Area: 0.0400

TAXON	Rep 1		Station		
	Count	Density	Total	Percent	Mean Density
Annelida					
Polychaeta					
Eunicida					
Lumbrineridae					
Lumbrineris latreilli	1	25	1	3.4	25
Oenonidae					
Arabella multidentata	1	25	1	3.4	25
Phyllodocida					
Goniadidae					
Goniada littorea	1	25	1	3.4	25
Nephtyidae					
Nephtys picta	2	50	2	6.9	50
Nereidae					
Ceratocephale oculata	1	25	1	3.4	25
Spionida					
Magelonidae					
Magelona papillicornis	1	25	1	3.4	25
Spionidae					
Spionidae (LPIL)	1	25	1	3.4	25
Arthropoda					
Malacostraca					
Amphipoda					
Haustoriidae					
Acanthohaustorius intermedius	2	50	2	6.9	50

Station Data Summary Report
Station F4

Client: Wilmington District, USACE
Project: Topsail Benthic Survey
Location: Topsail Beach
Sample Date: 28-29 Nov 06

Station: F4
Sample Type: Macrofauna
Replicates: 1
Sample Area: 0.0400

TAXON	Rep 1		Station		
	Count	Density	Total	Percent	Mean Density
Phoxocephalidae					
Rhepoxynius hudsoni	1	25	1	3.4	25
Platyischnopidae					
Eudevenopus honduranus	12	300	12	41.4	300
Ostracoda					
Myodocopina					
Sarsiellidae					
Eusarsiella radiicosta	1	25	1	3.4	25
Echinodermata					
Echinoidea					
Clypeasteroida					
Mellitidae					
Mellitidae (LPIL)	2	50	2	6.9	50
Mollusca					
Bivalvia					
Veneroida					
Lucinidae					
Lucinidae (LPIL)	1	25	1	3.4	25
Mesodesmatidae					
Ervilia concentrica	1	25	1	3.4	25
Gastropoda					
Neogastropoda					
Turridae					
Kurtziella atrostyla	1	25	1	3.4	25

Note: LPIL designates the LOWEST PRACTICAL IDENTIFICATION LEVEL

Station Data Summary Report
Station F4

Client: Wilmington District, USACE
Project: Topsail Benthic Survey
Location: Topsail Beach
Sample Date: 28-29 Nov 06

Station: F4
Sample Type: Macrofauna
Replicates: 1
Sample Area: 0.0400

DATA SUMMARY

FAUNAL PARAMETERS	Station	Rep 1	Mean	Std Dev
Total Taxa	15	15	15	0
Total Individuals	29	29	29	0
Density (nos/sq.m.)		725	725	0

FAUNAL INDICES			
Species Diversity (Shannon; log base e)	H'	=	2.2
Species Diversity (Shannon; log base 2)	d	=	3.17
Species Diversity (Shannon; log base 10)	H	=	0.95
Species Diversity (Simpson; 1/S)	1/S	=	5.88
Species Evenness (Pielou)	J'	=	0.81
Species Richness (Margalef)	D	=	4.16
Equitability Index (Lloyd & Ghelardi)	e	=	0.85

MAJOR TAXONOMIC GROUPS	Total No. Taxa	Taxa % Total	Total No. Individuals	Individuals % Total
Annelida	7	46.6	8	27.5
Mollusca	3	20	3	10.3
Arthropoda	4	26.6	16	55.1
Echinodermata	1	6.6	2	6.8
TOTALS	**15**		**29**	

APPENDIX D

Supporting Data Tables

Table D-1. Species abundance and density at sampling stations within borrow sites A, B, and C off Topsail Beach, NC.

	A1		A2		A3		A4		A5		Mean A		B1		B2		B3		Mean B		C1		C2		C3		C4		Mean C	
Species List	**Count**	**Density**	**Count**	**Density**	**Count**	**Density**	**Count**	**Density**	**Count**	**Density**	**Count**	**Density**	**Count**	**Density**	**Count**	**Density**	**Count**	**Density**	**Count**	**Density**	**Count**	**Density**	**Count**	**Density**	**Count**	**Density**	**Count**	**Density**	**Count**	**Density**
ANNELIDA																														
CLASS OLIGOCHAETA																														
Order TUBIFICIDA																														
FAMILY ENCHYTRAEIDAE																														
Enchytraeidae (LPIL)																	2	50	.67	16.67										
FAMILY TUBIFICIDAE																														
Tubificidae (LPIL)																	1	25	.33	8.33										
CLASS POLYCHAETA																														
Order CAPITELLIDA																														
FAMILY CAPITELLIDAE																														
Capitellidae (LPIL)			1	25							.20	5.00																		
Mediomastus (LPIL)													3	75	1	25			1.33	33.33										
Mediomastus californiensis							1	25			.20	5																		
FAMILY MALDANIDAE																														
Maldanidae (LPIL)																														
Order EUNICIDA																														
FAMILY DORVILLEIDAE																														
Schistomeringos pectinata													1	25					.33	8.33										
FAMILY LUMBRINERIDAE																														
Lumbrineris latreilli																														
FAMILY OENONIDAE																														
Arabella multidentata																														
FAMILY ONUPHIDAE																														
Onuphidae (LPIL)							1	25			.20	5.00					1	25	.33	8.33					1	25	1	25	.50	12.50
Order OPHELIIDA																														
FAMILY OPHELIIDAE																														
Opheliidae (LPIL)																														
Armandia (LPIL)																														
Armandia maculata			1	25							.20	5.00					1	25	.33	8.33							3	75	.75	18.75
Ophelia denticulata																														
Order ORBINIIDA																														
FAMILY PARAONIDAE																														
Aricidea (LPIL)																														
Aricidea catherinae									1	25	.20	5.00					1	25	.33	8.33										
Aricidea suecica																														
Aricidea wassi																														
Cirrophorus (LPIL)																	1	25	.33	8.33										

1451

Table D-1. (continued)

	A1		A2		A3		A4		A5		Mean A		B1		B2		B3		Mean B		C1		C2		C3		C4		Mean C	
Species List	**Count**	**Density**	**Count**	**Density**	**Count**	**Density**	**Count**	**Density**	**Count**	**Density**	**Count**	**Density**	**Count**	**Density**	**Count**	**Density**	**Count**	**Density**	**Count**	**Density**	**Count**	**Density**	**Count**	**Density**	**Count**	**Density**	**Count**	**Density**	**Count**	**Density**
Order OWENIIDA																														
FAMILY OWENIIDAE																														
Owenia fusiformis	1	25									.20	5.00																		
Order PHYLLODOCIDA																														
FAMILY CHRYSOPETALIDAE																														
Bhawania heteroseta													2	50			5	125	2.33	58.33										
FAMILY GLYCERIDAE																														
Glyceridae (LPIL)			2	50							.40	10.00					1	25	.33	8.33					1	25			.25	6.25
FAMILY GONIADIDAE																														
Goniada littorea							1	25			.20	5.00									2	50	3	75					1.25	31.25
Goniadides carolinae													2	50			7	175	3	75.00										
FAMILY HESIONIDAE																														
Microphthalmus (LPIL)																														
FAMILY NEPHTYIDAE																														
Aglaophamus verrilli			1	25							.20	5.00																		
Nephtys picta																														
Nephtys simoni																														
FAMILY NEREIDAE																														
Nereididae (LPIL)																	1	25	.33	8.33										
Ceratocephale oculata																														
FAMILY PHYLLODOCIDAE																														
Eumida sanguinea																	1	25	.33	8.33										
FAMILY PILARGIIDAE																														
Ancistrosyllis (LPIL)																	1	25	.33	8.33										
Ancistrosyllis hartmanae																	1	25	.33	8.33										
Sigambra tentaculata									1	25	.20	5.00																		
Order SPIONIDA																														
FAMILY CHAETOPTERIDAE																														
Spiochaetopterus oculatus	1	25									.20	5.00															1	25	.25	6.25
FAMILY CIRRATULIDAE																														
Cirratulidae (LPIL)													1	25			1	25	.67	16.67										
Caulleriella sp. J	1	25	2	50			1	25			.80	20.00			1	25			.33	8.33										
FAMILY MAGELONIDAE																														
Magelona (LPIL)	2	50	1	25							.60	15.00																		
Magelona papillicornis					2	50			3	75	1.00	25.00																		
Magelona pettiboneae																														
FAMILY SPIONIDAE																														
Spionidae (LPIL)					1	25					.20	5.00					4	100	1.33	33.33										
Paraprionospio pinnata					1	25					.20	5.00																		
Spiophanes bombyx																														

Table D-1. (continued)

	A1		A2		A3		A4		A5		Mean A		B1		B2		B3		Mean B		C1		C2		C3		C4		Mean C	
Species List	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density
Order TEREBELLIDA																														
FAMILY PECTINARIIDAE																														
Pectinaria gouldii	1	25									.20	5.00																		
FAMILY TEREBELLIDAE																														
Terebellidae (LPIL)																	1	25	.33	8.33										
ARTHROPODA																														
CLASS MALACOSTRACA																														
Order AMPHIPODA																														
Amphipoda (LPIL)																							1	25					25	6.25
FAMILY AORIDAE																														
Rildardanus laminosa													1	25					.33	8.33										
Unciola serrata																	1	25	.33	8.33										
FAMILY HAUSTORIIDAE																														
Acanthohaustorius intermedius																														
FAMILY ISAEIDAE																														
Microprotopus raneyi																	2	50	.67	16.67										
FAMILY MELITIDAE																														
Maera caroliniana													2	50					.67	16.67										
FAMILY OEDICEROTIDAE																														
Oedicerotidae (LPIL)																							1	25					25	6.25
Americhelidium americanum																														
FAMILY PHOXOCEPHALIDAE																														
Metharpinia floridana																														
Rhepoxynius hudsoni																					2	50							50	12.50
FAMILY PLATYISCHNOPIDAE																														
Eudevenopus honduranus																							3	75	3	75	4	100	2.50	62.50
FAMILY SYNOPIIDAE																														
Metatiron (LPIL)															1	25			.33	8.33										
Metatiron triocellatus													1	25					.33	8.33										
Order CUMACEA																														
FAMILY DIASTYLIDAE																														
Oxyurostylis (LPIL)																														
Order DECAPODA																														
FAMILY PAGURIDAE																														
Pagurus (LPIL)																	1	25	.33	8.33										
FAMILY PASIPHAEIDAE																														
Leptochela serratorbita																														
FAMILY PINNOTHERIDAE																														
Dissodactylus mellitae																											2	50	50	12.50

Table D-1. (continued)

	A1		A2		A3		A4		A5		Mean A		B1		B2		B3		Mean B		C1		C2		C3		C4		Mean C	
Species List	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density
CLASS OSTRACODA																														
Order MYODOCOPINA																														
FAMILY PHILOMEDIDAE																														
Philomedidae (LPIL)																														
Harbansus paucichelatus																														
FAMILY SARSIELLIDAE																														
Eusarsiella (LPIL)					1	25					.20	5.00																		
Eusarsiella radiicosta																														
Eusarsiella texana									1	25	.20	5.00											1	25			1	25	.50	12.50
Order PODOCOPIDA																														
Podocopida (LPIL)																											1	25	.25	6.25
BRYOZOA																														
Bryozoa (LPIL)																	1	25	.33	8.33										
CHORDATA																														
CLASS LEPTOCARDIA																														
Order AMPHIOXI																														
FAMILY BRANCHIOSTOMIDAE																														
Branchiostoma (LPIL)																														
CNIDARIA																														
CLASS HYDROZOA																														
Hydrozoa (LPIL)					1	25					.20	5.00																		
ECHINODERMATA																														
Echinodermata (LPIL)																														
CLASS ECHINOIDEA																														
Echinoidea (LPIL)																									2	50			.50	12.50
Order CLYPEASTEROIDA																														
FAMILY MELLITIDAE																														
Mellitidae (LPIL)																														
Mellita isometra																											1	25	.25	6.25
CLASS OPHIUROIDEA																														
Ophiuroidea (LPIL)													2	50	1	25	5	125					2	50	1	25			.75	18.75
Order OPHIURIDA																														
FAMILY AMPHIURIDAE																														
Amphiuridae (LPIL)													1	25					.33	8.33										
MOLLUSCA																														
CLASS BIVALVIA																														
Bivalvia (LPIL)	1	25					1	25			.40	10.00					1	25	.33	8.33										
Order OSTREOIDA																														
FAMILY ANOMIIDAE																														
Anomia simplex																														

Table D-1. (continued)

	A1		A2		A3		A4		A5		Mean A		B1		B2		B3		Mean B		C1		C2		C3		C4		Mean C	
Species List	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density
Order VENEROIDA																														
FAMILY CRASSATELLIDAE																														
Crassinella dupliniana																														
Crassinella lunulata													4	100			6	150	3.33	83.33										
FAMILY LUCINIDAE																														
Lucinidae (LPIL)			2	50							.40	10.00																		
Lucina (LPIL)																														
Lucina multilineata															1	25			.33	8.33										
FAMILY MESODESMATIDAE																														
Ervilia concentrica							1	25			.20	5.00																		
FAMILY MONTACUTIDAE																														
Montacutidae (LPIL)																														
FAMILY SEMELIDAE																														
Semelidae (LPIL)																	1	25	.33	8.33										
FAMILY TELLINIDAE																														
Strigilla mirabilis																														
Tellina (LPIL)			2	50					3	75	1.0	25.00			1	25			.33	8.33			4	100	5	125			2.25	56.25
Tellina iris			1	25							.20	5.00																		
CLASS GASTROPODA																														
Order CEPHALASPIDEA																														
FAMILY SCAPHANDRIDAE																														
Acteocina canaliculata					1	25					.20	5.00													1	25			.25	6.25
Cylichna alba			4	100	1	25					1.0	25.00									1	25					1	25	.50	12.50
Order MESOGASTROPODA																														
FAMILY CAECIDAE																														
Caecum pulchellum													1	25					.33	8.33			1	25	1	25	2	50	1.00	25.00
FAMILY EULIMIDAE																														
Strombiformis bilineatus																														
FAMILY NATICIDAE																														
Tectonatica pusilla																	1	25	.33	8.33										
Order NEOGASTROPODA																														
FAMILY OLIVIDAE																														
Oliva sayana							2	50	1	75	.60	25.00																		
Olivella dealbata																														
FAMILY TURRIDAE																														
Kurtziella atrostyla																														
Order PYRAMIDELLOIDA																														
FAMILY PYRAMIDELLIDAE																														
Odostomia weberi									1	25	.20	5.00																		
Turbonilla (LPIL)																														

Table D-1. (concluded)

	A1		A2		A3		A4		A5		Mean A		B1		B2		B3		Mean B		C1		C2		C3		C4		Mean C	
Species List	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density
PHORONIDA																														
FAMILY PHORONIDAE																														
Phoronis (LPIL)					1	25					.20	5.00					1	25	.33	8.33										
PLATYHELMINTHES																														
CLASS TURBELLARIA																														
Turbellaria (LPIL)													2	50	1	25	1	25	1.33	33.33										
RHYNCHOCOELA																														
Rhynchocoela (LPIL)					1	25					.20	5.00	2	50	1	25			1.00	25.00					1	25			.25	6.25
SIPUNCULA																														
FAMILY ASPIDOSIPHONIDAE																														
Aspidosiphon albus															1	25			.33	8.33										

Table D-2. Species abundance and density at sampling stations within borrow sites D, E, and F off Topsail Beach, NC.

	D1		D2		D3		D4		Mean D		E1		E2		E3		E4		Mean E		F1		F2		F3		F4		Mean F	
Species List	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density
ANNELIDA																														
CLASS OLIGOCHAETA																														
Order TUBIFICIDA																														
FAMILY ENCHYTRAEIDAE																														
Enchytraeidae (LPIL)																														
FAMILY TUBIFICIDAE																														
Tubificidae (LPIL)																														
CLASS POLYCHAETA																														
Order CAPITELLIDA																														
FAMILY CAPITELLIDAE																														
Capitellidae (LPIL)																														
Mediomastus (LPIL)													1	25					.25	6.25									.25	6.25
Mediomastus californiensis																														
FAMILY MALDANIDAE																														
Maldanidae (LPIL)															1	25			.25	6.25										
Order EUNICIDA																														
FAMILY DORVILLEIDAE																														
Schistomeringos pectinata																														
FAMILY LUMBRINERIDAE																														
Lumbrineris latreilli							1	25	.25	6.25																	1	25	.25	6.25
FAMILY OENONIDAE																														
Arabella multidentata																	1	25	.25	6.25										
FAMILY ONUPHIDAE																														
Onuphidae (LPIL)			1	25					.25	6.25															1	25	1	25	.50	12.50
Order OPHELIIDA																														
FAMILY OPHELIIDAE																														
Opheliidae (LPIL)													1	25			1	25	.50	12.50	1	25							.25	6.25
Armandia (LPIL)															1	25			.25	6.25										
Armandia maculata																	2	50	.50	12.50										
Ophelia denticulata																							1	25					.25	6.25
Order ORBINIIDA																														
FAMILY PARAONIDAE																														
Aricidea (LPIL)							1	25	.25	6.25			1	25					.25	6.25										
Aricidea catherinae																														
Aricidea suecica															1	25			.25	6.25										
Aricidea wassi							1	25	.25	6.25	1	25	2	50																
Cirrophorus (LPIL)															1	25			.25	6.25										
Order OWENIIDA																														
FAMILY OWENIIDAE																														
Owenia fusiformis	1	25																												

1457

Table D-2. (continued)

Species List	D1		D2		D3		D4		Mean D		E1		E2		E3		E4		Mean E		F1		F2		F3		F4		Mean F	
	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density
Order PHYLLODOCIDA																														
FAMILY CHRYSOPETALIDAE																														
Bhawania heteroseta																							1	25					.25	6.25
FAMILY GLYCERIDAE																														
Glyceridae (LPIL)											1	25							.25	6.25										
FAMILY GONIADIDAE																														
Goniada littorea			1	25	2	50	1	25	1.00	25.00	3	75			1	25			1.00	25.00					1	25	1	25	.50	12.50
Goniadides carolinae																							2	50					.50	12.50
FAMILY HESIONIDAE																														
Microphthalmus (LPIL)																							1	25					.25	6.25
FAMILY NEPHTYIDAE																														
Aglaophamus verrilli																														
Nephtys picta																											2	50	.50	12.50
Nephtys simoni																							1	25					.25	6.25
FAMILY NEREIDAE																														
Nereididae (LPIL)																														
Ceratocephale oculata																	1	25	.25	6.25					1	25	1	25	.50	12.50
FAMILY PHYLLODOCIDAE																														
Eumida sanguinea																														
FAMILY PILARGIIDAE																														
Ancistrosyllis (LPIL)											1	25							.25	6.25										
Ancistrosyllis hartmanae															1	25			.25	6.25										
Sigambra tentaculata																														
Order SPIONIDA																														
FAMILY CHAETOPTERIDAE																														
Spiochaetopterus oculatus																														
FAMILY CIRRATULIDAE																														
Cirratulidae (LPIL)																							1	25					.25	6.25
Caulleriella sp. J																					1	25							.25	6.25
FAMILY MAGELONIDAE																														
Magelona (LPIL)																														
Magelona papillicornis			3	75			1	25	1.00	25.00	1	25	2	50	2	50	2	50	1.75	43.75	1	25					1	25	.50	12.50
Magelona pettiboneae																					1	25							.25	6.25
FAMILY SPIONIDAE																														
Spionidae (LPIL)					1	25			.25	6.25	1	25							.25	6.25							1	25	.25	6.25
Paraprionospio pinnata																	1	25	.25	6.25					1	25			.25	6.25
Spiophanes bombyx			1	25					.25	6.25																				
Order TEREBELLIDA																														
FAMILY PECTINARIIDAE																														
Pectinaria gouldii																														
FAMILY TEREBELLIDAE																														
Terebellidae (LPIL)																														

Table D-2. (continued)

Species List	D1		D2		D3		D4		Mean D		E1		E2		E3		E4		Mean E		F1		F2		F3		F4		Mean F	
	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density
ARTHROPODA																														
CLASS MALACOSTRACA																														
Order AMPHIPODA																														
Amphipoda (LPIL)							1	25	.25	6.25																				
FAMILY AORIDAE																														
Rildardanus laminosa																														
Unciola serrata																														
FAMILY HAUSTORIIDAE																														
Acanthohaustorius intermedius																											2	50	.50	12.50
FAMILY ISAEIDAE																														
Microprotopus raneyi																														
FAMILY MELITIDAE																														
Maera caroliniana																							1	25					.25	6.25
FAMILY OEDICEROTIDAE																														
Oedicerotidae (LPIL)																														
Americhelidium americanum							1	25	.25	6.25	1	25							.25	6.25										
FAMILY PHOXOCEPHALIDAE																														
Metharpinia floridana															1	25			.25	6.25										
Rhepoxynius hudsoni							1	25	.25	6.25							1	25	.25	6.25							1	25	.25	6.25
FAMILY PLATYISCHNOPIDAE																														
Eudevenopus honduranus	1	25					3	75	.75	18.75	1	25	3	75	6	150	7	175	4.25	106.25					2	50	12	300	3.50	87.50
FAMILY SYNOPIIDAE																														
Metatiron (LPIL)																														
Metatiron triocellatus																														
Order CUMACEA																														
FAMILY DIASTYLIDAE																														
Oxyurostylis (LPIL)							1	25	.25	6.25					1	25			.25	6.25	1	25							.25	6.25
Order DECAPODA																														
FAMILY PAGURIDAE																														
Pagurus (LPIL)											1	25							.25	6.25										
FAMILY PASIPHAEIDAE																														
Leptochela serratorbita																														
FAMILY PINNOTHERIDAE																														
Dissodactylus mellitae																														
CLASS OSTRACODA																														
Order MYODOCOPINA																														
FAMILY PHILOMEDIDAE																														
Philomedidae (LPIL)							1	25	.25	6.25																				
Harbansus paucichelatus							1	25	.25	6.25																				
FAMILY SARSIELLIDAE																														
Eusarsiella (LPIL)																														
Eusarsiella radiicosta																											1	25	.25	6.25
Eusarsiella texana	1	25															1	25	.25	6.25	1	25							.25	6.25

Table D-2. (continued)

Species List	D1		D2		D3		D4		Mean D		E1		E2		E3		E4		Mean E		F1		F2		F3		F4		Mean F	
	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density
Order PODOCOPIDA																														
Podocopida (LPIL)																														
BRYOZOA																														
Bryozoa (LPIL)																														
CHORDATA																														
CLASS LEPTOCARDIA																														
Order AMPHIOXI																														
FAMILY BRANCHIOSTOMIDAE																														
Branchiostoma (LPIL)															2	50			.50	12.50	1	25	2	50					.75	18.75
CNIDARIA																														
CLASS HYDROZOA																														
Hydrozoa (LPIL)																														
ECHINODERMATA																														
Echinodermata (LPIL)															1	25			.25	6.25										
CLASS ECHINOIDEA																														
Echinoidea (LPIL)																														
Order CLYPEASTEROIDA																														
FAMILY MELLITIDAE																														
Mellitidae (LPIL)																											2	50	.50	12.50
Mellita isometra																														
CLASS OPHIUROIDEA																														
Ophiuroidea (LPIL)							1	25	.25	6.25			1	25					.25	6.25					2	50			.50	12.50
Order OPHIURIDA																														
FAMILY AMPHIURIDAE																														
Amphiuridae (LPIL)																														
MOLLUSCA																														
CLASS BIVALVIA																														
Bivalvia (LPIL)																														
Order OSTREOIDA																														
FAMILY ANOMIIDAE																														
Anomia simplex																							1	25					.25	6.25
Order VENEROIDA																														
FAMILY CRASSATELLIDAE																														
Crassinella dupliniana															3	75	1	25	1.00	25.00			4	100					1.00	25.00
Crassinella lunulata															2	50			.50	12.50	1	25	2	50					.75	18.75
FAMILY LUCINIDAE																														
Lucinidae (LPIL)			1	25					.25	6.25	1	25	2	50					.75	18.75					2	50	1	25	.75	18.75
Lucina (LPIL)							1	25	.25	6.25																				
Lucina multilineata																	3	75	.75	18.75										
FAMILY MESODESMATIDAE																														
Ervilia concentrica			1	25					.25	6.25																	1	25	.25	6.25

Table D-2. (concluded)

Species List	D1		D2		D3		D4		Mean D		E1		E2		E3		E4		Mean E		F1		F2		F3		F4		Mean F	
	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density
FAMILY MONTACUTIDAE																														
Montacutidae (LPIL)															1	25			.25	6.25										
FAMILY SEMELIDAE																														
Semelidae (LPIL)																														
FAMILY TELLINIDAE																														
Strigilla mirabilis															1	25	1	25	.50	12.50										
Tellina (LPIL)							1	25	.25	6.25			1	25	1	25	1	25	.75	18.75										
Tellina iris																														
CLASS GASTROPODA																														
Order CEPHALASPIDEA																														
FAMILY SCAPHANDRIDAE																														
Acteocina canaliculata					1	25			.25	6.25			2	50	1	25	1	25	1.00	25.00			1	25					.25	6.25
Cylichna alba	1	25																												
Order MESOGASTROPODA																														
FAMILY CAECIDAE																														
Caecum pulchellum			1	25	3	75	3	75	1.75	43.75	3	75	7	175	12	300	2	50	6.00	150.00			1	25	2	50			.75	18.75
FAMILY EULIMIDAE																														
Strombiformis bilineatus													1	25	1	25			.50	12.50										
FAMILY NATICIDAE																														
Tectonatica pusilla															1	25	1	25	.50	12.50										
Order NEOGASTROPODA																														
FAMILY OLIVIDAE																														
Oliva sayana																														
Olivella dealbata																									2	50			.50	12.50
FAMILY TURRIDAE																														
Kurtziella atrostyla																											1	25	.25	6.25
Order PYRAMIDELLOIDA																														
FAMILY PYRAMIDELLIDAE																														
Odostomia weberi																														
Turbonilla (LPIL)																							1	25					.25	6.25
PHORONIDA																														
FAMILY PHORONIDAE																														
Phoronis (LPIL)																														
PLATYHELMINTHES																														
CLASS TURBELLARIA																														
Turbellaria (LPIL)																					1	25							.25	6.25
RHYNCHOCOELA																														
Rhynchocoela (LPIL)			1	25					.25	6.25			2	50	1	25	1	25	1.00	25.00			3	75					.75	18.75
SIPUNCULA																														
FAMILY ASPIDOSIPHONIDAE																														
Aspidosiphon albus																														

Table D-3. Biomass for major taxa groups from Topsail Beach, NC, benthic sampling stations.

Station: A1	gm/04 m²	gm/m²
Annelida	0.5556	13.89
Mollusca	0.5544	13.86
Arthropoda	0.0000	0
Echinodermata	0.0000	0
Other Taxa	0.0000	0
Total	1.1100	27.75

Station: A2	gm/04 m²	gm/m²
Annelida	0.6517	16.2925
Mollusca	0.5792	14.48
Arthropoda	0.0000	0
Echinodermata	0.0000	0
Other Taxa	0.0000	0
Total	1.2309	30.7725

Station: A3	gm/04 m²	gm/m²
Annelida	0.5557	13.8925
Mollusca	0.5512	13.78
Arthropoda	0.5484	13.71
Echinodermata	0.0000	0
Other Taxa	0.5490	13.725
Total	2.2043	55.1075

Station: A4	gm/04 m²	gm/m²
Annelida	0.5620	14.05
Mollusca	0.5712	14.28
Arthropoda	0.5563	13.9075
Echinodermata	0.0000	0
Other Taxa	0.0000	0
Total	1.6895	42.2375

Station: A5	gm/04 m²	gm/m²
Annelida	0.5517	13.7925
Mollusca	0.5522	13.805
Arthropoda	0.0000	0
Echinodermata	0.0000	0
Other Taxa	0.0000	0
Total	1.1039	27.5975

Station: B1	gm/04 m²	gm/m²
Annelida	0.5519	13.7975
Mollusca	0.5513	13.7825
Arthropoda	0.5711	14.2775
Echinodermata	0.5760	14.4
Other Taxa	0.5654	14.135
Total	2.8157	70.3925

Station: B2	gm/04 m²	gm/m²
Annelida	0.5520	13.8
Mollusca	0.5520	13.8
Arthropoda	0.5481	13.7025
Echinodermata	0.5492	13.73
Other Taxa	0.5491	13.7275
Total	2.7504	68.76

Station: B3	gm/04 m²	gm/m²
Annelida	0.5665	14.1625
Mollusca	0.5511	13.7775
Arthropoda	0.5513	13.7825
Echinodermata	0.5490	13.725
Other Taxa	0.5595	13.9875
Total	2.7774	69.435

Station: C1	gm/04 m²	gm/m²
Annelida	0.5526	13.815
Mollusca	0.5490	13.725
Arthropoda	0.5520	13.8
Echinodermata	0.0000	0
Other Taxa	0.0000	0
Total	1.6536	41.34

Station: C2	gm/04 m²	gm/m²
Annelida	0.5526	13.815
Mollusca	0.5490	13.725
Arthropoda	0.5520	13.8
Echinodermata	0.0000	0
Other Taxa	0.0000	0
Total	1.6536	41.34

Station: C3	gm/04 m²	gm/m²
Annelida	0.5556	13.89
Mollusca	0.5555	13.8875
Arthropoda	0.5564	13.91
Echinodermata	0.5491	13.7275
Other Taxa	0.5496	13.74
Total	2.7662	69.155

Station: C4	gm/04 m²	gm/m²
Annelida	0.5539	13.8475
Mollusca	0.5496	13.74
Arthropoda	0.5533	13.8325
Echinodermata	21.4873	537.1825
Other Taxa	0.0000	0
Total	23.1441	578.6025

Table D-3. (concluded)

Station: D1	gm/04 m²	gm/m²
Annelida	0.5556	13.89
Mollusca	0.5494	13.735
Arthropoda	0.5483	13.7075
Echinodermata	0.0000	0
Other Taxa	0.0000	0
Total	1.6533	41.3325

Station: D2	gm/04 m²	gm/m²
Annelida	0.5659	14.1475
Mollusca	0.5491	13.7275
Arthropoda	0.0000	0
Echinodermata	0.0000	0
Other Taxa	0.5492	13.73
Total	1.6642	41.605

Station: D3	gm/04 m²	gm/m²
Annelida	0.5658	14.145
Mollusca	0.5493	13.7325
Arthropoda	0.0000	0
Echinodermata	0.0000	0
Other Taxa	0.0000	0
Total	1.1151	27.8775

Station: D4	gm/04 m²	gm/m²
Annelida	0.5743	14.3575
Mollusca	0.5495	13.7375
Arthropoda	0.5485	13.7125
Echinodermata	0.5492	13.73
Other Taxa	0.0000	0
Total	2.2215	55.5375

Station: E1	gm/04 m²	gm/m²
Annelida	0.5722	14.305
Mollusca	0.5526	13.815
Arthropoda	0.5766	14.415
Echinodermata	0.0000	0
Other Taxa	0.0000	0
Total	1.7014	42.535

Station: F1	gm/04 m²	gm/m²
Annelida	0.5520	13.8
Mollusca	0.5513	13.7825
Arthropoda	0.5520	13.8
Echinodermata	0.0000	0
Other Taxa	0.5491	13.7275
Total	2.2044	55.11

Station: E2	gm/04 m²	gm/m²
Annelida	0.5546	13.865
Mollusca	0.5545	13.8625
Arthropoda	0.5563	13.9075
Echinodermata	0.5492	13.73
Other Taxa	0.5490	13.725
Total	2.7636	69.09

Station: E3	gm/04 m²	gm/m²
Annelida	0.5622	14.055
Mollusca	0.5522	13.805
Arthropoda	0.5563	13.9075
Echinodermata	0.5491	13.7275
Other Taxa	0.5490	13.725
Total	2.7688	69.22

Station: E4	gm/04 m²	gm/m²
Annelida	0.5623	14.0575
Mollusca	0.5543	13.8575
Arthropoda	0.5524	13.81
Echinodermata	0.0000	0
Other Taxa	0.5492	13.73
Total	2.2182	55.455

Station: F2	gm/04 m²	gm/m²
Annelida	0.6508	16.27
Mollusca	0.5512	13.78
Arthropoda	0.5561	13.9025
Echinodermata	0.0000	0
Other Taxa	0.6559	16.3975
Total	2.4140	60.35

Station: F3	gm/04 m²	gm/m²
Annelida	0.6508	16.27
Mollusca	0.5512	13.78
Arthropoda	0.5561	13.9025
Echinodermata	0.0000	0
Other Taxa	0.6559	16.3975
Total	2.4140	60.35

Station: F4	gm/04 m²	gm/m²
Annelida	0.5513	13.7825
Mollusca	0.5740	14.35
Arthropoda	0.5490	13.725
Echinodermata	0.5496	13.74
Other Taxa	0.0000	0
Total	2.2239	55.5975

Feasibility Report
and
Environmental Impact Statement

on

Coastal Storm Damage Reduction

SURF CITY AND NORTH TOPSAIL BEACH, NORTH CAROLINA

Appendix T

Public Comments and USACE Responses

APPENDIX T

Comments and Responses

Comments received on the Feasibility Report and Environmental Impact Statement on Coastal Storm Damage Reduction, Surf City and North Topsail Beach, North Carolina, dated January 13, 2010 and the U. S. Army Corps of Engineers, Wilmington District response to each comment.

1.0 INTRODUCTION

This Appendix includes all comments received on the Feasibility Report and Environmental Impact Statement on Coastal Storm Damage Reduction, Surf City and North Topsail Beach, North Carolina and responses by the U. S. Army Corps of Engineers, (USACE) Wilmington District. These comments are listed in the following order: Federal agencies, State agencies, local agencies/municipalities, and conservation groups. No comments were received from interested businesses, groups, and individuals.

The Regulations for Implementing the Procedural Provisions of the National Environmental Policy Act (NEPA), 40 CFR Part 1503.4 Response to Comments (b), states, "All substantive comments received on the draft statement (or summaries thereof where the response has been exceptionally voluminous), should be attached to the final statement whether or not the comment is thought to merit individual discussion by the agency in the text of the statement." Additionally, the Environmental Quality; Procedures for Implementing the National Environmental Policy Act (NEPA); Final Rule, 33 CFR 230.19 (c) Comments Received on the Draft EIS, states, "District commanders will avoid lengthy or repetitive verbatim reporting of comments and will keep responses clear and concise."

In keeping with these regulations, the USACE will respond to summaries of lengthy written comments. Additionally, in order to reduce repetition, responses will be made once to a comment and a particular issue. If the issue appears again, in another letter, the reader will be referred to the initial comment and response. Detailed responses will not be given to comments which repeat information in the Feasibility Report/EIS or state opinions on the proposed action. Form letters and signed petitions with multiple signatures are not responded to individually. In some instances, our response to a comment may be indicated as "Noted." Noted means that the comment was evaluated and it will be considered in making the decision on whether to sign the Record of Decision.

2.0 PUBLIC AND AGENCY COORDINATION

On January 13, 2010 the Feasibility Report/EIS referenced above was mailed to Federal and State agencies and the interested public for a 45-day review and comment period. Responses to the Feasibility Report/EIS were received from the following:

Federal Agencies

- US Department of the Interior, Minerals Management Service
- US Department of Agriculture, Natural Resources Conservation Service
- US Department of Commerce, National Marine Fisheries Service
- US Department of the Interior, Fish and Wildlife Service
- US Environmental Protection Agency, Region IV

State Agencies

- NC Wildlife Resources Commission
- NC Division of Water Quality
- NC Department of Environment and Natural Resources
- NC Division of Marine Fisheries
- NC Division of Parks and Recreation
- NC Division of Land Resources
- NC Division of Coastal Management
- NC State Historic Preservation Office
- NC Department of Environment and Natural Resources, Shellfish Sanitation
- NC Coastal Reserve
- NC Division of Water Resources, Water Projects Section
- NC Natural Heritage Program

Local Agencies/Municipilities

- County of Pender

Copies of the actual correspondence received from these agencies are included at the end of the document.

MINERALS MANAGEMENT SERVICE (MMS)

1. COMMENT SOURCE: Public/Mineral Management Service

COMMENT: The Environmental Effects chapter (Chapter 8) offers a robust discussion of the potential environmental impacts related to the Tentatively Selected Plan. In contrast, the document offers a limited discussion of potential impacts associated with other alternatives, including the no action alternative. Chapter 5 presents a conceptual comparison of the environmental effects of beach fill, non-structural, and no action alternatives.

The MMS suggests the Corps clearly indicate which alternatives were dismissed and on what basis. Otherwise, the direct and indirect impacts of alternatives should be discussed in more detail and in context of their relative significance in the Environmental Effects chapter.

RESPONSE: Text will be added to section 5.06.4 to indicate why non-structural and no-action plans were screened out

REPORT CHANGE: Section 5.06.4 modified

Old Text: In addition to the economic comparison, the impacts of the major categories of plans on the resources described in Section 2.00, Affected Environment, are considered. Table 5.4 presents the comparative impacts on these resources. The "No Action" alternative is defined as no action by the Federal government on this particular proposed coastal storm damage reduction project.

New Text : In addition to the economic comparison, the impacts of the major categories of plans on the resources described in Section 2.00, Affected Environment, are considered. Table 5.4 presents the comparative impacts on these resources. The "No Action" alternative is defined as no action by the Federal government on this particular proposed coastal storm damage reduction project. It should be noted that categories of plans were not screened out based on environmental effects. As mentioned earlier in the report, the No Action plan was screened out because it does not provide any NED benefits, and the non-structural was screened out because the BC ratio was < 1. However, an environmental comparison of plans was still done to show if categories of plans are consistent with protecting the Nation's environment.

2. COMMENT SOURCE: Public/Mineral Management Service

COMMENT: Since most of the borrow areas identified for the proposed project are located on the Outer Continental Shelf (OCS), the MMS may need to authorize their use for initial and/or maintenance construction. The MMS, as a cooperating federal agency, may undertake a connected action (i.e., authorize use of the OCS borrow area) that is related, but unique from the Corps's proposed action (i.e., construction of the project). Consequently, the purpose and need of the MMS's proposed action is different. Ideally, the EIS should provide a more accurate description of the MMS's involvement under the Corps' proposed action.

The MMS's proposed action is the issuance of a negotiated agreement pursuant to its authority under the Outer Continental Shelf Lands Act. The purpose of that action is to authorize the use of OCS sand (or other sediment) resources in beach nourishment and coastal restoration projects undertaken by federal,

state or local government agencies, and/or in other federally authorized construction projects. The MMS's action will be needed because the Towns of Surf City and North Topsail Beach and the Corps submitted authorization requests to the MMS.

RESPONSE: Concur. Section 1.03 will be updated using the MMS provided text to more appropriately incorporate the purpose and need of MMS as a cooperating agency.

REPORT CHANGE: Section 1.03 "Purpose and Need for Action" will be replaced with the following:

"The purpose and need for the Corps' proposed coastal storm damage risk reduction project is to reduce both storm damages and beach erosion along the ocean shoreline of the Surf City and North Topsail Beach study area. There is a wide variety of possible measures that would reduce the impacts of erosion, flooding, and waves on commercial and residential structures and infrastructure of the island as well as provide incidental environmental and recreational benefits. Beach nourishment measures which include dredging of sediment from offshore borrow areas located on the Outer Continental Shelf (OCS) may require authorization by the Minerals Management Service (MMS) for use during initial and/or maintenance construction (See Section 10.11). The MMS Leasing Division is charged with environmentally responsible management of federal OCS sand and gravel resources. Public Law 102-426 (43 U.S.C. 1337(k)(2)), enacted 31 October 1994, gave MMS the authority to negotiate, on a noncompetitive basis, the rights to OCS sand, gravel, and shell resources for coastal storm damage reduction, beach or wetlands restoration projects, or for use in construction projects funded in whole or part by or authorized by the federal government. The MMS, as a cooperating federal agency, may undertake a connected action (i.e., authorize use of the OCS borrow area) that is related, but unique from the Corps's proposed action. The MMS's proposed action is the issuance of a negotiated agreement pursuant to its authority under the Outer Continental Shelf Lands Act. The purpose of that action is to authorize the use of OCS sand (or other sediment) resources in beach nourishment and coastal restoration projects undertaken by federal, state or local government agencies, and/or in other federally authorized construction projects."

3. COMMENT SOURCE: Public/Mineral Management Service

COMMENT: The feasibility study and proposed action should be presented in context of historical and proposed beach nourishment activities in the vicinity of Topsail Island. The Study Overview chapter should include a transparent and up-to-date discussion of historical and planned beneficial use projects (see 3.06), historical navigation and planned inlet management projects, as well as proposed Civil Works and Regulatory projects (see 7.04.2).

RESPONSE: Concur. Updates will include appropriate information.

REPORT CHANGE: Text added at end of section 1.09 (formerly 1.08)

New Text: Additionally, over the last 25 to 30 years, material resulting from maintenance dredging of New River, the AIWW and connecting channels has been placed on the northernmost mile of the study area in the vicinity of New River Inlet. Records from FY1998 through FY2007 show that this total placement of 680,000 cubic yards has occurred on an irregular basis, generally every 1 to 3 years, with dredging quantities varying from 70,000 to 170,000 cubic yards and averaging about 110,000 cubic yards per event.

The towns of North Topsail Beach and Topsail Beach are also currently proposing non-federally funded beach renourishment actions. North Topsail Beach has proposed putting 4 million cubic yards of material

in the CBRA zone, which is outside of the federal project study area. Topsail Beach has proposed putting about 1.3 million cubic yards of material as an "interim"

4. COMMENT SOURCE: Public/Mineral Management Service

COMMENT: The introductory text to the Affected Environment chapter should be revised to indicate that the footprint of the proposed action is not limited to the sub-aerial beach, but includes the marine environment offshore the barrier island.

RESPONSE: Concur.

REPORT CHANGE: Section 2.0 "Affected Environment" should be replaced with the following text:

"The project is located in Pender and Onslow Counties in the towns of Surf City and North Topsail Beach, NC. Topsail Island is a 22-mile long barrier island on North Carolina's south-central coast consisting of three communities, from south to north; Topsail Beach, Surf City, and North Topsail Beach. The footprint of the proposed action includes the sub-aerial beaches of Surf City and North Topsail Beach as well as the marine environment offshore of the barrier island. Significant Resources found within the vicinity of the project area, in both the marine and terrestrial environment, are described below. Physical resources, socioeconomic resources, recreation and aesthetic resources, cultural resources, Section 122, P.L. 91-611 Resources, and water quality conditions are also discussed in this section. Vertical datum for this report is NGVD29."

5. COMMENT SOURCE: Public/Mineral Management Service

COMMENT: Pelagic and benthic sargassum should be addressed as an important biological resource in the marine environment.

RESPONSE: Concur

REPORT CHANGE: The following paragraph will be included at the end of section 2.01:

"Sargassum is an abundant seaweed that occurs near the surface in warm waters of the western North Atlantic. With an exceptionally fast growth rate, floating rafts of Sargassum represent a highly renewable natural resource that can be harvested for various uses. Sargassum supports a wide range of marine organisms that include micro- and macro-epiphytes, fungi, more than 100 species of invertebrates, over 100 species of fishes, and four species of sea turtles. The SAFMC previously designated Sargassum as essential fish habitat for snappers, groupers, and coastal migratory pelagic fishes of the South Atlantic region (Coston-Clements *et al.*, 1991)."

The "References" section 15.0 should be updated to include the following:

Coston-Clements, L., L.R. Settle, D.E. Hoss and F.A. Cross. 1991. Utilization of the Sargassum habitat by marine invertebrates and vertebrates - a review. NOAA Technical Memorandum NMFS-SEFSC-296, 32 p.

6. COMMENT SOURCE: Public/Mineral Management Service

COMMENT: The narrative description of the location of both New Topsail and New River Inlets is unclear. The MMS suggests referring to a figure to clarify the narrative.

RESPONSE: Concur

REPORT CHANGE: The first and third sentence of Section 2.01.2 should be updated to include a reference to Figure 1.1.

7. COMMENT SOURCE: Public/Mineral Management Service

COMMENT: The biological assessment discusses protected species that are likely to occur in the proposed project area. However, the draft IFR/EIS does not address other marine mammals without protection status, such as dolphin species, that are likely to be present and may be affected by the proposed action.

RESPONSE: Concur

REPORT CHANGE: The last sentence of section 2.01.7 will be removed and replaced with the following:

"All marine mammals are protected by the Marine Mammal Protection Act (MMPA) of 1972, as amended, but the West Indian manatee and six large whales are also listed as endangered and, therefore, are afforded additional protection under the Endangered Species Act (ESA). The MMPA prohibits, with certain exceptions, the "take" of marine mammals in U.S. waters and by U.S. citizens on the high seas, and the importation of marine mammals and marine mammal products into the U.S. All marine mammals and reptiles that may be present within the project area and are federally listed as threatened or endangered under the ESA are addressed in the biological assessment (See Appendix I)."

The following additional paragraph will also be added at the end of Section 2.01.7:

"Several marine mammal species occur in the project which are not federally listed but are protected under the MMPA. The Navy uses the Marine Resource Assessment (MRA) program to develop a comprehensive data and literature compilation of protected and managed marine resources within its various operating areas. The document is used for planning purposes and for various types of environmental documentation, such as biological and environmental assessments, that must be prepared in accordance with the National Environmental Policy Act (NEPA), Marine Mammal Protection Act (MMPA), Endangered Species Act (ESA), and Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA). Thirty-eight marine mammal species have been recorded in or adjacent to the Surf City and North Topsail Beach project area. These species include 33 cetaceans (whales, dolphins, and porpoises), four pinnipeds (seals, sea lions, and fur seals), and one sirenian. Only 24 of those species are expected to regularly occur in the region (Table X.X). Some cetacean species occur in the project area year-round (e.g., bottlenose dolphin, beaked whales), while others (e.g., right whale, humpback whale) occur seasonally as they migrate through the area. Only rare occurrences of the West Indian manatee are anticipated. Although bottlenose dolphins are common in the project area, USACE has never documented a direct effect on bottlenose dolphins from dredging activities during its numerous dredging projects throughout the United States; therefore, an Incidental Harassment Authorization (IHA) in accordance with the MMPA is not anticipated for this project. In the April 25, 2005 notice in the Federal Register for the issuance of an IHA for blasting at the Port of Miami, NMFS concluded: "According to the Corps, bottlenose dolphins and other marine mammals have not been documented as being directly affected by dredging activities and, therefore, the Corps does not anticipate any incidental harassment of bottlenose dolphins. NMFS concurs." (NMFS, 2005)." Therefore, no further coordination under the MMPA is anticipated for this project."

The "References" Section 15.0 should be updated with the following:

"NMFS. 2005. Taking Marine Mammals Incidental to Specified Activities; Port of Miami Construction Project (Phase II). 70 FR 21174. April 25, 2005." and "Department of the Navy. 2008. Marine Resource Assessment Update for the Cherry Point Operating Area. Department of the Navy, U.S. Fleet Force Command, Norfolk, Virginia. Contract #N62470-02-D-9997, CTO 0056. Prepared by Geo-Marine, Inc., Hampton Virginia."

"Department of the Navy. 2008. Marine Resources Assessment Update for the Cherry Point Operating Area. Department of the Navy, U.S. Fleet Forces Command, Norfolk, Virginia. Contract #N62470-02-D-9997, CTO 0056. Prepared by Geo-Marine, Inc., Hampton, Virginia."

The following Table X.X. will be included in the report:

Table X. Marine mammal species found within the project area. Those species identified as endangered under the ESA are addressed in the biological assessment (Appendix I). (Source: Department of the Navy. 2008)

Order Cetacea
Suborder Mysticeti (baleen whales)
Family Balaenidae

North Atlantic right whale *Eubalaena glacialis* ENDANGERED
Family Balaenopteridae (rorquals)
Humpback whale *Megaptera novaeangliae* ENDANGERED
Minke whale *Balaenoptera acutorostrata*
Bryde's whale *Balaenoptera edeni*
Sei whale *Balaenoptera borealis* ENDANGERED
Fin whale *Balaenoptera physalus* ENDANGERED
Blue whale *Balaenoptera musculus* ENDANGERED

Suborder Odontoceti (toothed whales)
Family Physeteridae

Sperm whale *Physeter macrocephalus* ENDANGERED
Family Kogiidae
Pygmy sperm whale *Kogia breviceps*
Dwarf sperm whale *Kogia sima*

Family Ziphiidae (beaked whales)

Cuvier's beaked whale *Ziphius cavirostris*
True's beaked whale *Mesoplodon mirus*
Gervais' beaked whale *Mesoplodon europaeus*
Blainville's beaked whale *Mesoplodon densirostris*
Sowerby's beaked whale *Mesoplodon bidens*
Northern bottlenose whale *Hyperoodon ampullatus*

Family Delphinidae (dolphins)

Rough-toothed dolphin *Steno bredanensis*
Bottlenose dolphin *Tursiops truncatus*
Pantropical spotted dolphin *Stenella attenuata*
Atlantic spotted dolphin *Stenella frontalis*
Spinner dolphin *Stenella longirostris*
Striped dolphin *Stenella coeruleoalba*
Clymene dolphin *Stenella clymene*
Short-beaked common dolphin *Delphinus delphis*
Fraser's dolphin *Lagenodelphis hosei*
Risso's dolphin *Grampus griseus*
Melon-headed whale *Peponocephala electra*
Pygmy killer whale *Feresa attenuate*
False killer whale *Pseudorca crassidens*
Killer whale *Orcinus orca*
Long-finned pilot whale *Globicephala melas*
Short-finned pilot whale *Globicephala macrorhynchus*
Family Phocoenidae
Harbor porpoise *Phocoena phocoena*

Order Carnivora

Suborder Pinnipedia (seals, sea lions, walruses)
Family Phocidae (true seals)
Harbor seal *Phoca vitulina*
Gray seal *Halichoerus grypus*
Harp seal *Pagophilus groenlandicus*
Hooded seal *Cystophora cristata*

Order Sirenia
Family Trichechidae
West Indian manatee *Trichechus manatus*

8. COMMENT SOURCE: Public/Mineral Management Service

COMMENT: The description of and potential impacts to protected marine mammals and sea turtles are incorporated by reference to the biological assessment. The MMS recommends a brief summary be provided in the EIS, or, the biological assessment should be included as a physical attachment to the Final IFR/EIS.

RESPONSE: Concur

REPORT CHANGE: The biological assessment will be included as a physical attachment to the Final IFR/EIS.

9. COMMENT SOURCE: Public/Mineral Management Service

COMMENT: A detailed discussion of habitat association between benthic populations and habitat type (RSDs, hard bottom, sand and muddy substrate) should be provided. The benthic resources or hard bottom descriptions should include a detailed description of the occurrence and quality of benthic sargassum, corals, and sponges. The equivalent information requested is provided in 8.01.8.3 and 8.01.8.5 of the Environmental Effects chapter.

RESPONSE: Concur

REPORT CHANGE: Section 2.01.9 will be replaced with the following:

2.01.9 Benthic Resources – Nearshore Ocean

"Aquatic organisms that live in close association with the bottom, or substrate, of a body of water, are collectively called the benthos. Benthos communities provide a link between planktonic and benthic production and commercially important fish species (Posey, 1991). Benthic communities of the project area exhibit a wide range of organism composition and density, and community structure may vary considerably depending on substrate type, salinity regime, proximity to structural habitat, etc. Benthic substrate type and structural habitat within the project area range between fine to course grained sand, gravel and shell hash, and low, moderate and high relief hard bottom. Specifically, the nearshore "soft bottom" environment just offshore of the beach-face consists of transitioning regions of course gravel and shell hash and sand. These features, common to North Carolina, are defined in the literature as "rippled scour depressions, rippled channel depressions, and/or sorted bed forms." They are thought to be the result of a feedback mechanism whereby an existing deposit of course shell hash and gravel material is built upon and segregated from fine material due to wave motion interacting with the enhanced roughness of the seafloor bed around patches of course material (Cacchione *et al.*, 1984; Thieler *et al.*, 1999; Thieler *et al.*, 2001; Murray and Thieler, 2004) (See Section 8.01.8.2). The specific biological functions of these features have not been heavily studied; however, the benthic species composition, population, and community structure likely shift depending on the substrate type. Most nearshore benthic invertebrates in soft bottom substrates tend to be r-strategists, which are characteristically small-bodied, short-lived, and have high fecundity, efficient dispersal mechanisms, and rapid growth rates. Thus, re-colonization of a disturbed area is generally initiated by r-strategists (Bowen and Marsh, 1988).

As discussed in Section 2.01.10, "hard bottom" communities are located in the offshore environment of the project area and are found within the proposed borrow areas and consist of low, moderate, and high relief features (Moser and Taylor, 1995; Moser *et al.*, 1995). Benthic organisms and community structure associated with hard bottom features are unique from other "soft bottom" benthic communities. Section

2.01.10 and Appendix R4 discuss the specific organisms identified within representative hard bottom communities found within the study area. In summary, moderate to high relief hard bottom communities were more diverse and supported predominantly Oculina sp. colonies, tunicates, sponges, macro-algae (i.e. benthic sargassum), bryozoans, and hydrozoans; whereas, low relief communities were characterized by lower stony coral cover and higher cover by fast growing octocorals.

A myriad of benthic surveys of representative "soft bottom" nearshore ocean sites have been conducted throughout the Mid-Atlantic and South Atlantic regions, including within the vicinity of the proposed project area. Three nearshore ocean sites located off Virginia Beach were conducted for the USDOI Minerals Management Service (MMS) in 1996 and 1997 by Cutter and Diaz (1998). They collected a total of 119 taxa from 13 Smith-Macintyre grabs collected in 1996. Half of the top 14 taxa (occurrence and abundance) were polychaetes. The remainder included representatives from the amphipods, decapods, bivalves, nemerteans, tanaids, echinoderms, and chordates. They found the overall community composition to be typical for sandy shallow continental shelf habitats and with similar species composition for similar depths and sediment types reported by Day *et al.* (1971) for North Carolina (Table 2.1). Day *et al.* (1971) defines the nearshore ocean as the "turbulent zone", which includes ocean waters from below low tide to a depth of about 60 feet. According to Day et al., polychaete species are highly represented in this zone with pelecypods, decapods, amphipods, echinoderms, and cephalochordates also present. Biological characterization results from field surveys performed by MMS of offshore shallow shelf habitats in the Outer Banks, North Carolina identified members of the major invertebrate and vertebrate groups commonly found in the general area. Dominant infaunal groups consisted of crustaceans, echinoderms, mollusks, and polychaetes, while epifaunal taxa consisted primarily of decapods, sea stars, and squid. Dominant demersal fish species included clearnose skate (Raja eglanteria), flounder (Paralichthys sp.), scup (*Stenotomus chrysops*), and sea robin (*Prionotus scitulus*) (Byrnes *et al.,* 2003). Posey and Alphin (2000), collected offshore benthic infaunal samples at depths of 30-40 ft. from pre-borrow sites of Kure Beach, North Carolina. Results indicate that the benthic community was very diverse, with over 600 species, and largely dominated by polychaetes, with crustaceans and bivalves comprising most of the remaining taxa.

Benthic infaunal samples were collected by Dial Cordy and Associates Inc. within six borrow sites offshore of Topsail Beach in 2007 (USACE, 2009; USACE, 2007a). Benthic invertebrate abundance, species composition, and biomass were calculated and qualitative comparisons of the data were made to the results of other pertinent benthic studies in the Mid- and South-Atlantic regions. Results indicate that the benthic resources in the sampled borrow areas off of Topsail Beach are similar in composition and taxa dominance to those described in other studies along the North Carolina and South Carolina coasts (Table 2.1) (Byrnes *et al.*, 2003; Van Dolah *et al.*, 1984; Versar, 2002 and 2006; and Posey and Alphin 2000 and 2002). However, the benthic community found offshore of Topsail Beach was less diverse and abundant than baseline sampling performed for the Kure Beach restoration project (Posey and Alphin, 2000 and 2002) and for the Dare County beach coastal storm damage reduction project (Versar, 2006). It is likely that the differences between the benthic community off Topsail Beach and the two referenced studies are due to the more extensive sampling effort associated with baseline monitoring programs as compared to a less intensive sampling regime for a general characterization study (i.e. ten sampling stations per site off Dare County as compared to three to five stations per site for the Topsail Beach benthic characterization study). Of the 104 total taxa collected for the one-time sampling performed off Topsail Beach, polychaetes also dominated the community, comprising over 30% of the relative abundance at four of the six borrow sites (USACE, 2009; USACE, 2007a).

Though specific borrow areas identified for the Surf City and North Topsail Beach Coastal Storm Damage

Reduction Project have not been sampled, considering (1) the similarities in species composition and taxa dominance throughout all previously conducted benthic studies offshore of Virginia, North Carolina, and South Carolina, (2) the nearness of the Topsail Island sampled borrow areas (USACE, 2009; USACE, 2007a) to the proposed SCNTB project borrow areas, and (3) the similarity in sediment characteristics among the previous studies, it is expected the benthic infaunal communities within the borrow areas offshore of SCNTB will be similar to previous studies."

The following introduction in Section 2.01.10 Hard Bottoms page 27 should be updated to include an appendix reference as follows:

(3) USACE. 2008. Surf City/North Topsail Beach, NC Shore Protection Project, Hard Bottom Resource Confirmation and Characterization Study. Contract W912HN-08-C-0009. Submitted by ANAMAR Environmental Consulting Inc. and Coastal Planning and Engineering, Inc. (Appendix R; Attachment 4).

10. COMMENT SOURCE: Public/Mineral Management Service

COMMENT: The detailed narrative discussing the suite of investigations and the results of those investigations used to support assessment of hard bottom areas needs to be better synthesized. The synthesis should address the location, type, nature, and quality of hard bottom habitat and benthic communities in an integrated manner. The presentation of the chronological investigation is better suited for inclusion in another appendix. Likewise, the discussion of buffer requirements should be relegated to the Environmental Effects chapter in context of potential effects and effects-reducing mitigation measures. The MMS recommends the Corps provide a series of figures that clearly illustrate 1) the spatial extent of hard bottom areas and 2) the quality of habitat and diversity of supported biological communities. The description of nearshore hard bottom areas should not be limited to the offshore immediately east of the project area, but should include hard bottom areas identified offshore northern Topsail Island.

Also, the Corps should indicate that the calculated depth of closure is derived from "averaged" incident wave conditions, and/or a relative determination of nominal vertical change from a series of cross-shore beach profiles. Depth of closure is documented to be event-dependent (Nicholls et al., 1998). It should be stated that cross-shore sediment transport will likely occur beyond the depth of closure, but ultimately depends on the forcing conditions and the profile state at the time of the forcing event.

RESPONSE: Comment Acknowledged. The rationale for discussing the suite of investigations in Section 2.01.10 was to provide the historic context for how the selection and refinement of proposed borrow areas was based on screening effort utilizing data from each investigation to narrow from a macro to a micro scale. The hard bottom output from each investigation was not equally comprehensive; therefore, the intent of summarizing these investigations was to support how the hard bottom was avoided to the maximum extent practicable. The final diver ground truth hard bottom investigation (Appendix R; Attachment 4) was designed to confirm the presence of low, moderate, and high relief hard bottom resources within the borrow areas and characterize the biota along representative transects within a select number of borrow areas. These ground truth data confirmed the interpretation of the side scan sonar relative to relief categories and provided some representative species characterization so that impact evaluations could be made relative to potential sedimentation risk associated with the designated buffer distances. However, recognizing that all of the borrow areas and associated hard bottom features would not be characterized and mapped to the same level of detail, these ground truth and characterization data were interpolated across the rest of the study area to indicate representative

species for the relief categories. The discussion of buffer requirements were initiated in Section 2.0 because it was important to discuss that the PDT recommended ground truthing be done at select locations so that impacts could be better evaluated based on sedimentation risk from 400 ft. and 500 m. buffer differences. Considering that hard bottom communities are a significant resource within the study area and classified as HAPC, the Corps feels that it is important to clearly lay out in the main text, rather than an appendix, the processes that the PDT went through to identify borrow material while avoiding direct impacts to hard bottom resources.

Depth of closure (DoC) value is an engineering tool and is based upon average conditions. Wave forces can transport sediment cross-shore anytime above average conditions prevail.

REPORT CHANGE: Figure A-1 has been updated to indicate the spatial extent of high, moderate, and low relief hard bottom features throughout all borrow areas as well as associated buffers based on relief. Appendix R; attachment 4 contains all of the biological characterization data that is representative for each relief category. The additional nearshore hard bottom information within North Topsail Beach has been obtained from Coastal Planning and Engineering and is included in Figure A-1 as well.

11. COMMENT SOURCE: Public/Mineral Management Service

COMMENT: The draft IFR/EIS references a 2004 document as the source for information on federally managed fish species and their associated habitat. The fishery management plans are authoritative sources, and most plans have been updated and new information added since 2004. The MMS recommends that the Corps consult with the National Marine Fisheries Service on the completeness of the species and HAPCs lists.

Note that the Atlantic Highly Migratory Species Fishery Management Plan (2006) is implemented by the Secretarial Council.

RESPONSE: Comment Acknowledged. The Corps has consulted with the NMFS under the Essential Fish Habitat (EFH) provisions of the Magnuson-Stevens Act. In a letter dated 8 March 2010, NMFS provided comments and EFH recommendations pursuant to authorities of the FISH and Wildlife Coordination Act and the Magnuson-Stevens Fishery Conservation and Management Act. One of their provided comments states that "the DEIS provides an adequate overview of EFH and associated species managed by the South Atlantic Fishery Management Council, Mid-Atlantic Fishery Management Council, and NMFS. The discussion of impacts to EFH meets the information requirement of 50 CFR 600.920(e)." Based on this consultation, the Corps concludes that the species and HAPC list are complete.

REPORT CHANGE: No action required.

12. COMMENT SOURCE: Public/Mineral Management Service

COMMENT: The description of benthic seagrass, coral, and hard bottom HAPC in the project area is limited. The appropriate sections of the document concerning these sensitive resources should be cross-referenced.

RESPONSE: Concur

REPORT CHANGE: The last three sentences of Section 2.01.11 Essential Fish Habitat will be replaced with the following:

"Table 2.6 shows the categories of EFH and Habitat Areas of Particular Concern (HAPC) for managed species, which were identified in the Fishery Management Plan Amendments affecting the South Atlantic area. A description of specific HAPC resources (i.e. hard bottom, coral, artificial reef, and *sargassum*) within the project area can be found in Sections 2.01.9, 2.01.10, and Appendix R (Attachment 4). The fish species and habitats shown in these tables require special consideration to promote their viability and sustainability. The potential impacts of the proposed action on these fish and habitats are discussed in Section 8.01.8 of this report." Also, an introductory paragraph on report layout will explain that more detailed explanations of resources are contained in Chapters 7 and 8.

13. COMMENT SOURCE: Public/Mineral Management Service

COMMENT: The MMS recommends a more complete discussion of bird utilization of hard bottom areas and other offshore habitat.

RESPONSE: Concur

REPORT CHANGE: See USFWS Comment #2.

14. COMMENT SOURCE: Public/Mineral Management Service

COMMENT: The document should reference and include updated information from bird surveys completed in support of the North Topsail Shore Protection Project.

RESPONSE: Comment Acknowledged. This data is already included and referenced in Table 2.10

REPORT CHANGE: No action required.

15. COMMENT SOURCE: Public/Mineral Management Service

COMMENT: Table 2.7 should indicate the federal status (including candidate listing) for respective birds.

RESPONSE: Comment Acknowledged. As indicated in the table footnote for the "NC Status" column, Federal status is indicated in parentheses. Only the piping plover is federally listed as threatened and there are no species with candidate status.

REPORT CHANGE: Table 2.7 will be updated to indicate that the state status for both the Wilson's Plover and American Oystercatcher have been changed from "Significantly Rare (SR)" to "Special Concern (SC)." Text on page ? was also updated to and reflect the change from "Significantly Rare (SR)" to "Special Concern (SC)."

16. COMMENT SOURCE: Public/Mineral Management Service

COMMENT: It is recommended that physical resources be addressed prior to the biological resources to provide for appropriate environmental context.

The description of the geological and physical oceanographic environment should be presented prior to the discussion of shoreline and sand transport to provide for appropriate geological context. The description of the geological environment should be expanded referencing relevant material provided in the discussion of hard bottom habitat (USACE, 2003; USACE 2004a). The Corps should describe the

dominant physical processes occurring offshore, especially those processes responsible for the maintenance of sorted bed forms and the ephemeral exposure of hard bottom.

RESPONSE: Comment Acknowledged. The information requested is in the report. Though the recommended restructuring of the report may improve the biological context of section 2.0, the Corps does not believe that it will improve the overall content of the report to a level that warrants the time required to make the change.

17. COMMENT SOURCE: Public/Mineral Management Service

COMMENT: Ambient and anthropogenic noise in the marine environment is not described.

RESPONSE: Concur.

REPORT CHANGE: A third paragraph will be added to section 2.07.1 which will include the following:

"Within any harbor or open water coastal environment, there are a number of underwater ambient noise sources such as: commercial and recreational vessel traffic, dredges, wharf/dock construction (pile driving, etc.), natural sounds (storms, biological, etc.), etc. In order to better assess potential species impacts (i.e. disturbance of communication among marine mammals) associated with dredge specific noise from navigation maintenance, deepening, or borrow area dredging operations, Clarke *et al.* (2002) performed underwater field investigations to characterize sounds emitted by bucket, hydraulic cutterhead, and hopper dredge operations. A summary of results from this study are presented below and are a first step towards the development of a dredge sounds database which will encompass a range of dredge plant sizes and operational features:

Cutterhead Suction Dredge

Noise generated by a cutterhead suction dredge is continuous and muted and results from the cutterhead rotating within the bottom sediment and from the pumps used to transport the effluent to the placement area. The majority of the sound generated was from 70 to 1,000 Hz and peaked at 100 to 110 dB range. Though attenuation calculations were not completed, reported field observations indicate that the cutterhead suction dredge became almost inaudible at about 500 meters (Clarke *et al.*, 2002).

Hopper Dredge

The noise generated from a hopper dredge is similar to a cutterhead suction dredge except there is no rotating cutterhead. The majority of the noise is generated from the dragarm sliding along the bottom, the pumps filling the hopper, and operation of the ship engine/propeller. Similar to the cutterhead suction dredge, most of the produced sound energy fell within the 70 to 1,000 Hz range; however peak pressure levels were at 120 to 140 dB (Clarke *et al.*, 2002).

Bucket Dredge

Bucket dredges are relatively stationary and produce a repetitive sequence of sounds generated by winches, bucket impact with the substrate, bucket closing, and bucket emptying. The noise generated from a mechanical dredge entails lowering the open bucket through the water column, closing the bucket after impact on the bottom, lifting the closed bucket up through the water column, and emptying the bucket into an adjacent barge. Based on the data collected for this study, which included dredging of

coarse sands and gravel, the maximum noise spike occurs when the bucket hits the bottom (120 dB peak amplitude). A reduction of 30 dB re 1 µPa/m occurred between the 150 m and 5,000 m listening stations with faintly audible sounds at 7-km. All other noises from this operation (i.e., winch motor, spuds, etc.) were relatively insignificant (Clarke *et al.*, 2002).

The "References" Section 15.0 will be updated to include the following:

"Clarke, D, C. Dickerson, and K. Reine. 2002. Characterization of Underwater Sounds Produced by Dredges. Proceedings of the Third Specialty Conference on Dredging and Dredged Material Disposal. May 5-8 2002, Orlando, FL."

18. COMMENT SOURCE: Public/Mineral Management Service

COMMENT: Table 5.4 does not address the full suite of potential impacts from the range of beach fill and non-structural alternatives proposed, including potential impacts to physical processes, air quality, noise, etc.

RESPONSE: Concur

REPORT CHANGE: Section 5.06.4 was modified to read as follows:

New Text: In addition to the economic comparison, the impacts of the major categories of plans on the resources described in Section 2.00, Affected Environment, are considered. Table 5.4 presents the comparative impacts on these resources. Only impacts to areas that are of greater concern are listed in the table. The "No Action" alternative is defined as no action by the Federal government on this particular proposed coastal storm damage reduction project. It should be noted that categories of plans were not screened out based on environmental effects. As mentioned earlier in the report, the No Action plan was screened out because it does not provide any NED benefits, and the non-structural was screened out because the BC ratio was < 1. However, an environmental comparison of plans was still done to show if categories of plans are consistent with protecting the Nation's environment.

19. COMMENT SOURCE: Public/Mineral Management Service

COMMENT: The mitigation measures enumerated should be linked to the effects analysis. The requirement to monitor turbidity levels appears to have been excluded.

RESPONSE: Concur

REPORT CHANGE: Table 7.1 has been updated to include appropriate references following each enumerated commitment (This will be provided as a separate file). No commitment to turbidity monitoring was made in the report.

20. COMMENT SOURCE: Public/Mineral Management Service

COMMENT: The description mis-identifies the borrow areas proposed for the regulatory projects. The analysis of volume requirements across federal and non-federal projects is also inaccurate.

RESPONSE: Concur

REPORT CHANGE: The text and table in Section 7.04.2 "Regional Sand Requirements" have been replaced with the following.

New Text:

There are four beachfill projects planned or being planned for Topsail Island as shown schematically in Figure 7.3. These projects consist of the Surf City/North Topsail Beach Federal Coastal Storm Damage Reduction Project, the North Topsail Beach Non-Federal Project, the West Onslow Beach and New River Inlet (Topsail Beach) Federal Coastal Storm Damage Reduction Project, and the Topsail Beach Non-Federal Project. of the two federal projects and the North Topsail Beach Non-Federal project are planning to use material from offshore borrow areas identified for the Federal projects. However, the Topsail Beach Non-Federal project is not proposing to use material from these borrow areas. The estimated volume requirements for 50-year period of analysis of these projects are shown in Table 7.4.

By evaluating all Topsail Island offshore borrow areas together, the sixteen borrow areas contain approximately 50.5 million cubic yards of borrow material. The four Topsail Island project volume requirements are approximately 46.2 million cubic yards or about 91% of the available borrow material in all of the borrow areas evaluated for the Federal projects.

Project	Volume, Million CY
Surf City/North Topsail Beach Federal *	32.3
North Topsail Beach Non-Federal	0.34 #
Topsail Beach Federal	13.6
Topsail Beach Non-Federal	0^
Total, required	46.2
Total, available	50.5

* brought back from NED plan identification.

The amount estimated for the project is approximately 4 million cubic yards. However, only 340,000 cubic yards will be required from the borrow areas identified for the Federal project.

^ The amount estimated for the project is approximately 1.3 million cubic yards. However, none of this material is coming from the borrow areas identified for the Federal project.

21. COMMENT SOURCE: Public/Mineral Management Service

COMMENT: A plan for pump-out and pipeline conveyance operations is not well articulated. It is presumed that the hopper dredge will transfer dredged material through pump-outs located immediately offshore the placement site. Ideally, pump-out locations and pipeline corridors would be identified to illustrate the spatial relationship to any sensitive habitat, archaeological resources, etc.

RESPONSE: Comment Acknowledged. Details associated with hopper dredge pumpout locations and pipeline corridor locations will be identified during Pre-construction Engineering and Design (PED). As discussed in appendices R2-R4, a significant amount of remote sensing and ground truth diver survey efforts were conducted between the shore face and -23 ft. and no hard bottom resources were identified.

However, based on diver ground truth of two sites located about 500 to 600 feet offshore of the -23 ft Depth of Closure (DOC) line, low relief hard bottom and rock/gravel bottom was identified offshore of the -23 foot DOC. It is anticipated that any selected pipeline corridor for hopper dredge pumpout could extend from the shore face to approximately 2,500 to 3,000 feet offshore. Therefore, considering the ephemeral nature of the low relief hard bottom features in the nearshore environment and the identification of low lying outcrops located within the pipeline corridor distance requirements, the Corps intends to survey potential pipeline corridor routes prior to construction in order to develop a corridor that avoid hard bottom features. All existing remote sensing and ground truth data will be used in combination with the new survey data. All information associated with the surveys, data analysis, and identification and mapping of pipeline corridors, appropriate buffers, etc. and subsequent measures developed to avoid resource impacts will be coordinated with the resource agencies prior to construction. All necessary survey requirements for identifying and avoiding cultural resource targets will be incorporated.

REPORT CHANGE: Table 7.1 has been updated to reflect this commitment (To be provided as a separate attachment).

22. COMMENT SOURCE: Public/Mineral Management Service

COMMENT: The Corps' conclusion that offshore dredging and/or nearshore placement operations will not have any adverse physical impact on hard bottom areas may require clarification or re-phrasing. Based on its review of the substantial analyses undertaken by the Corps and affiliated contractors, the MMS prefers language that suggests impacts will occur but will not likely exceed natural sedimentation and burial, provided strict adherence to buffer requirements for all offshore activities. The dredging buffer should be applied consistently to all vessel activities, including anchoring and other bottom-disturbing activities by tugs and support vessels. The Corps should consider the potential effects of the proposed action on alongshore and across-shore sediment transport processes and any implications for hard bottom areas identified by Coastal Planning and Engineering immediately north of the project area.

Given the ephemeral exposure and burial of hard bottom areas, it is probable that the seafloor expression and configuration of hard bottom areas (as mapped from existing remote sensing / diver observations) will change prior to construction in 2018. Coastal Planning and Engineering's geophysical investigations and diver observations document a similar phenomena offshore the northern reaches of Topsail Island. The MMS recommends the Corps consider the appropriateness of additional mitigation that would require borrow area clearance via a geophysical survey immediately before dredging. Since a pre-dredge bathymetric survey is commonplace and typically required by the MMS, deploying side scan sonar would not constitute much of an additional cost to provide additional assurance that impacts to hard bottom areas would be avoided to the extent possible.

RESPONSE: Concur

REPORT CHANGE: The first sentence of the last paragraph on page 148 will be updated to read:

"As identified in Section 8.01.8.2, dredging in the selected borrow areas will not have an adverse physical impact on any hard bottoms in the area. Though secondary sedimentation impacts could occur from dredging operations, they will likely not exceed natural sedimentation and burial levels, provided strict adherence to buffer requirements for all offshore activities."

23. COMMENT SOURCE: Public/Mineral Management Service

COMMENT: The Corps' conclusion that there will be no impacts to benthic sargassum from dredging operations is not supported especially since benthic sargassum was documented to occur in most of the offshore borrow areas.

RESPONSE: Concur. As discussed in Section 2.01.10, and in more detail in Appendix R-4, benthic sargassum was identified as a dominant macroalgae in almost all surveyed transects. All dive transects in which benthic sargassum was identified were located on hard bottom communities, not within the sediments proposed for dredging. As discussed in Section 8.01.8.5, considering that no direct impacts will occur from dredging and no indirect impacts are anticipated from sedimentation considering the incorporation of buffers, the Corps believes that the conclusion of no impacts to benthic sargassum from the dredging activities is supported.

REPORT CHANGE: No action required.

24. COMMENT SOURCE: Public/Mineral Management Service

COMMENT: The Corps should discuss the potential benefits/costs of a borrow area management plan that requires the rotational use of borrow areas over initial and maintenance construction cycles as a means to mitigate cumulative effects to benthic communities and habitat.

RESPONSE: Comment Acknowledged. As discussed in Section 8.01.7 and in Appendix J "cumulative impacts," there are many possible sequences and methods for dredging available material for the project and a site specific borrow area use plan has yet to be defined. The economic optimization of the use of the borrow areas for the life of the project will be further evaluated when the final borrow area data has been collected and fully analyzed during the Plans and Specifications (P&S) phase. However, for a majority of the identified borrow sites to be utilized for this project, the depths of available sediment are relatively shallow with an average range of 2.6 to 6.4 ft for borrow areas G-T located offshore of Surf City and North Topsail Beach. Under the proposed plan, initial construction would require 11.8 mcy and each nourishment interval would require 2.6 mcy. Both initial construction and each nourishment interval will likely utilize multiple borrow areas with a sequence of temporary impacts to benthic resources over the life of the project. Considering the shallow average thickness of the borrow areas and the associated dredging operations and production capabilities to effectively dredge the sediment, it is anticipated that individual dredged areas within each borrow area will be fully utilized and will not be dredged again at consecutive dredging events. Therefore, once the dredged site recovers from the initial dredging impact, it will likely not be impacted again as all of the available sediment would be exhausted from the dredged area.

REPORT CHANGE: No action required.

25. COMMENT SOURCE: Public/Mineral Management Service

COMMENT: The emission inventory presented is based on the incorrect assumption that each of the four windows of initial construction will require 2 million cubic yards of sand. Since the initial fill requirement is approximately 12 million cubic yards, approximately 3 million cubic yards will be dredged during each cycle.

RESPONSE: Concur.

REPORT CHANGE: Section 8.08.1 will be updated with new emission numbers (Separate document will be provided by Hugh Heine containing replacement tables and text)

26. COMMENT SOURCE: Public/Mineral Management Service

COMMENT: The Environmental Effects chapter does not discuss the potential noise-related impacts of offshore dredging operations on marine mammals, sea turtles, and fish. The MMS refers the Corps to the following report: "A generic investigation into noise profiles of marine dredging in relation to the acoustic sensitivity of the marine fauna in UK waters with particular emphasis on aggregate dredging" (Thomsen et al., 2009).

RESPONSE: Concur

REPORT CHANGE: The following paragraph from Section 8.08.1 (page 182) should be removed:

"Noise from construction equipment is slightly out of .....evaluation included with this document Appendix G."

The following new paragraph should be added following Table 8.4 at the end of Section 8.08.1:

"Water quality impacts are discussed in Section 8.07.2 and in the Section 404(b)(1) (P.L. 95-217) evaluation included with this document as Appendix G. Noise in the outside environment associated with beach construction activities is expected to minimally exceed normal ambient noise within the project area; however, construction noise will be attenuated by background sounds from wind and surf. In water noise is expected in association with the dredging activities for this project. Specifically, noise associated with dredging may occur from (1) ship/machinery noise – noise associated with on-board machinery and propeller and thruster noise, (2) pump noise – noise associated with pump driving the suction through the pipe, (3) collection noise – noise associated with the operation and collection of material on the sea floor, (4) deposition noise – noise associated with the placement of the material within the barge or hopper, and (5) transport noise - noise associated with transport of material up the suction pipe. The limited available data indicate that dredging is not as noisy as seismic surveys, pile driving and sonar; but it is louder than for example most shipping, operating offshore wind turbines and drilling (Thomsen *et al.*, 2009).

Dredging produces broadband and continuous low frequency sound (below 1 kHz) and estimated source sound pressure levels range between 168 and 186 dB re 1 µPa at 1 m which can trigger avoidance reaction in marine mammals and marine fish. In some instances physical auditory damage may occur. Auditory damage is the physical reduction in hearing sensitivity due to exposure to high intensity sound and can be either temporary (temporary threshold shift – TSS) or permananent (permanent threshold Shift – PTS) depending on the exposure level and duration. Other than physical damage, the key auditory effect is the increase in background noise levels, such that the ability of an animal to detect a relevant sound signal is diminished, which is known as 'auditory masking'. Masking marine mammal vocalisations used for finding prey, navigation and social cohesion could compromise the ecological fitness of populations (Compton *et al.*, 2008).

According to Richardson *et al.* (1995) the following noise levels may be detrimental to marine mammals:

Prolonged Exposure of 140 dB re 1 µPa/m (continuous manmade noise), at 1 km may cause Permanent Hearing Loss

Prolonged Exposure of 195 to 225 dB re 1 µPa/m (intermittent noise), at a few meters or tens of meters, may cause Immediate Hearing Damage

According to Richardson et al. (1995), "Many marine mammals would avoid these noisy locations, although it is not certain that all would do so." In a study evaluating specific reaction of bowhead whales

to underwater drilling and dredge noise, Richardson *et al.* (1990) also noted that bowhead whales often move away when exposed to drillship and dredge sound; however, the reactions are quite variable and may be dependent on habituation and sensitivity of individual animals. According to Richardson *et al* (1995), received noise levels diminish by about 60 dB between the noise source and a radius of 1 km. For marine mammals to be exposed to a received level of 140 dB at 1 km radius, the source level would have to be about 200 dB re 1 micro Pa-m. Furthermore, few human activities emit continuous sounds at source levels greater than or equal to 200 dB re 1 micro Pa-m; however, supertankers and icebreakers may exceed the 195 dB noise levels.

According to Clarke et al. (2002), hopper dredge operations had the highest sustained pressure levels of 120-140 dB among the three measured dredge types; however, this measurement was taken at 40 m from the operating vessel and would likely attenuate significantly with increased distance from the dredge. Based on: (1) the predicted noise impact thresholds noted by Richardson et al. (1995), (2) the background noise that already exists within the marine environment, and (3) the ability of marine mammals and to move away from the immediate noise source, noise generated by bucket, cutterhead, and hopper dredge activities will not affect the migration, nursing/breeding, feeding/sheltering or communication of large whales. Although behavioral impacts are possible (i.e., a whale changing course to move away from a vessel), the number and frequency of vessels present within a given project area is small and any behavioral impacts would be expected to be minor. Furthermore, for hopper dredging activities, endangered species observers (ESOs) will be on board and will record all large whale sightings and note any potential behavioral impacts. As per the standard Corps specifications for all dredging projects, the Corps and the Contractor will keep the date, time, and approximate location of all marine mammal sightings. Care will be taken not to closely approach (within 300 feet) any whales, manatees, or other marine mammals during dredging operations or transportation of dredged material. An observer will serve as a lookout to alert the dredge operator and/or vessel pilot of the occurrence of these animals. If any marine mammals are observed during other dredging operations, including vessel movements and transit to the dredged material disposal site, collisions shall be avoided either through reduced vessel speed, course alteration, or both. During the evening hours, when there is limited visibility due to fog, or when there are sea states of greater than Beaufort 3, the dredge must slow down to 5 knots or less when transiting between areas if whales have been spotted within 15 nautical miles of the vessel's path within the previous 24 hours. Sightings of whales or manatees (alive, injured, or dead) in the work area shall be reported to NMFS Whale Stranding Network.

Similar to conclusions made regarding impacts of sound to marine mammals, non-injurious impacts to sea turtles may also occur due to acoustic annoyance or discomfort. It has been hypothesized, based on anatomical studies that sea turtle hearing range centers around low frequency sounds. Ridgeway *et al.* (1969 and 1970) evaluated the frequency sensitivity of green sea turtles and found that green turtles detected limited sound frequencies (200-700 Hz) and displayed high level of sensitivity at the low tone region (approx 400 Hz). According to Bartol *et al.* (1999), the most sensitive threshold for loggerhead sea turtles is 250 Hz to 750 Hz with the most sensitive threshold at 250 Hz. Though noise generated from dredging equipment is within the hearing range of sea turtles, no injurious impacts are anticipated considering that sea turtles can move from the area and the significance of the noise generated by the dredging equipment dissipates with an increasing distance from noise source."

The "References" Section 15.0 should be updated to include:

Richardson, W.J., C.R. Greene, Jr., C.I. Malme, D.H. Thomson with contributions by S.E. Moore and B. Wursig. 1995. Marine Mammals and Noise.

USACE. 2008. Regional Biological Assessment for Dredging Activities in the Coastal Waters, Navigation Channels (including designated Ocean Dredged Material Disposal Sites (ODMDS)), and Sand Mining Areas in the South Atlantic Ocean. USACE, Wilmington District. Submitted to NMFS on 12 September 2008.

Ridgway S.H., E.G. Wever, J.G. McCormick, J. Palin and J.H. Anderson. 1969. Hearing in the giant sea turtle, Chelonia mydas, Proc Natl Acad Sci 64 (1969), pp. 884–890.

Ridgway, S.H., E.G. Wever, J.G. McCormick, J. Palin and J. Anderson. 1970. Sensitivity of the green sea turtle's ear as shown by its electrical potentials, J Acoust Soc Am 47 (1970), p. 67.

Bartol, S.M., J.A. Musick and M.L. Lenhardt. 1999. Auditory evoked potentials of the loggerhead sea turtle (Caretta caretta), Copeia 3 (1999), pp. 836–840.

Compton, R., L. Goodwin, R. Handy, V. Abbott. 2008. A Critical Examination of Worldwide Guidelines for Minimising the Disturbance to Marine Mammals During Seismic Surveys. Marine Policy. 32; 255-262.

Thomsen, F. S. McCully, D. Wood, F. Pace, and P. White. 2009. A generic investigation into noise profiles of marine dredging in relation to the acoustic sensitivity of the marine fauna in UK waters with particular emphasis on aggregate dredging. Marine Aggregate Levy Sustainability Fund (MALSF). MEPF Ref No. MEPF/08/P21.

27. COMMENT SOURCE: Public/Mineral Management Service

COMMENT: Draghead screening may be necessary to reduce the risk of ordnance entrainment and any unintended consequences related to ordnance re-location onto the sub-aerial beach. Recent experiences with the dredging and placement of ordnance have occurred in Sandbridge Beach, VA, Bethany Beach, DE, and Long Beach Island, NJ. Placement of ordnance, or the risk of placement, can lead to serious public safety concerns and/or perception problems.

RESPONSE: Do not concur. No further work in regard to unexploded ordnance (UXO) is planned to be undertaken in the offshore borrow sites. Potential UXO in the area poses no risk and is too small to be detected by conventional survey techniques and deflector screening or to be identified by typical magnetometers. Furthermore, incorporation of draghead screening presents concerns with respect to Endangered Species Act compliance. Specifically, screening of dragheads for UXO minimizes or prevents the ability to detect sea turtles that may be incidentally taken by the dredging operation. However, to address the potential for encountering UXO during dredging, Section 8.08.3 of the report contains the following commitment: "To mitigate the very remote chance of encountering ordnance, the beach will be inspected on a daily basis and any ordnance discovered will be handled in accordance with the Military Munitions Rule, 40 CFR 260-270. The Marine Corps Base Explosive Ordnance Disposal Team will be available ("on call") during the dredging process. Additionally, the contract specifications for

the proposed project would direct the contractor to immediately stop dredging or disposal. At that time, additional measures will be implemented, as necessary, including inspection of dredged material on the beach and installation of outflow screens on the dredge pipeline. Any unexploded ordnance found on the beach would be promptly removed."

REPORT CHANGE: Table 7.1 will be updated to include the following language (updated table will be provided as a separate file):

"To mitigate the very remote chance of encountering ordnance, the beach will be inspected on a daily basis and any ordnance discovered will be handled in accordance with the Military Munitions Rule, 40 CFR 260-270. The Marine Corps Base Explosive Ordnance Disposal Team will be available ("on call") during the dredging process. Additionally, the contract specifications for the proposed project would direct the contractor to immediately stop dredging or disposal. At that time, additional measures will be implemented, as necessary, including inspection of dredged material on the beach and installation of outflow screens on the dredge pipeline. Any unexploded ordnance found on the beach would be promptly removed."

28. COMMENT SOURCE: Public/Mineral Management Service

COMMENT: The Corps has "lead agency" status for Section 7 and EFH consultations/coordination, and as "lead agency", the Corps should notify NMFS HCD, NMFS PRD, and FWS of MMS's involvement in the proposed action.

RESPONSE: Concur

REPORT CHANGE: As a component of consultation requirements associated with Section 7 and EFH consultations/coordination, the Corps has discussed within the respective consultation transmittal letters that the Corps is functioning as "lead agency" and MMS is functioning as a "cooperating agency."

29. COMMENT SOURCE: Public/Mineral Management Service

COMMENT: Appendix A-1 should be revised to accurately display all hard bottom habitat by relief type. Buffers should be indicated for each relief type on the map, not just high quality. If known, the pump-out locations and pipeline corridors should be identified. The hard bottom habitat identified immediately north of the project area should be added to the map.

RESPONSE: Comment Acknowledged. All hard bottom within the borrow areas that has been surveyed using both side scan sonar and diver ground truthing is depicted in Figure A-1 as high relief (Blue), moderate relief (purple), and low relief (grey). Also, 500 m buffer distances were also mapped (yellow) relative to the High Relief hard bottom sites.

REPORT CHANGE: Figure A-1 will be updated to reflect a 500 m buffer around moderate relief sites and a 400 ft. buffer for low relief sites. Additionally, locations of nearshore hard bottom identified by Coastal Planning and Engineering north of project will be added to figure (updated Figure will be provided as a separate file).

The pipeline corridor has not been identified at this point in time; however, additional hard bottom surveys will be completed within proposed corridor routes prior to construction in order to assure that potential hard bottom resources are avoided.

Table 7.1 will be updated to include the following commitment for "hard bottom":

"Considering the ephemeral nature of the low relief hard bottom features in the nearshore environment and the potential for low lying outcrops to occur within the pipeline corridor distance requirements and associated dredge and pipeline anchor points, the Corps intends to survey all areas associated with potential pumpout and pipeline corridor requirements prior to construction in order avoid potential impacts to hard bottom features. All information associated with the surveys, data analysis, identification and mapping of pipeline corridors, appropriate buffers, etc. and subsequent measures developed to avoid resource impacts will be coordinated with the resource agencies prior to construction."

30. COMMENT SOURCE: Public/Mineral Management Service

The Corps does not fully address the potential for prehistoric sites within the survey area. The MMS recommends that the following tasks relating to prehistoric site potential be addressed:

1. review current literature on late Pleistocene and Holocene geology, paleogeography, and sea level change in the area; marine and coastal prehistory; and previous archaeological resource reports in the area if available.
2. discuss relict geomorphic features and their archaeological potential that includes the type, age, and association of the mapped features; the acoustic characteristics of channels and their fill material; evidence for preservation or erosion of channel margins; evidence for more than one generation of fluvial downcutting; and the sea level curves used in the assessment.
3. discuss, based on the capabilities of current technology in relation to the thickness and composition of sediments overlying the area of a potential site, the potential for identification and evaluation of buried prehistoric sites.

The analysis for potential prehistoric sites was not included in the survey report, Archaeological Remote Sensing Survey of Topsail and West Onslow Beaches Offshore Borrow Areas (December 2004), used as the basis for the majority of the cultural resources material within the draft IFR/EIS. Furthermore, the cultural resource sections (2.05 and 8.06) do not adequately discuss the changes that occurred during the Holocene period with respect to exposed lands on the outer continental shelf (OCS) and sea level rise, and how prehistoric peoples might have interacted with the landscape that is now inundated.

The DEIS should incorporate information that summarizes the potential for prehistoric sites within the project area. There was geophysical data collected via sub-bottom profilers and vibracores within the project area (Appendices C0-C3 Geotechnical Analysis). With archaeological interpretation, this information could provide valuable insight into the paleogeography of the area, the effects of Holocene transgression on this landscape, and the potential for prehistoric site preservation.

Within Section 2.05 (Cultural Resources, p. 61), the following paragraph should be expanded to provide additional context and references to the scientific literature:
To date, there are few indications that Native American populations made significant use of ocean-side resources. Indeed, the intensive use of the sounds may indicate that resources there were so plentiful that an interest in exploiting the open-ocean never developed.

Within Section 8.06 (Cultural Resources, p. 178), the following sentences should be expanded to provide additional context and references to the scientific literature:
No prehistoric sites were specifically considered in the survey. While there has been some success developing upland-offshore site location correlations in Florida and perhaps elsewhere, the methodology is not very well developed for sites within the Carolinas region, nor are there a significant number of upland locations that could be used to model settlement in now inundated areas.

In Section 8.06 (Cultural Resources, p. 178-179), the Corps discusses the possibility of having UAB (specify acronym incidentally) archaeologists monitoring the dredging activities. The MMS suggests that

this might not be the most efficient use of UAB archaeologists' time and might create a burden on the State of North Carolina. MMS does request, however, that a monitoring protocol be implemented, with clear instructions on reporting and avoidance of prehistoric or historic sites that might be encountered during the dredging operations. This information, or reference to the applicable protocols, should be included in the DEIS (perhaps in Section 10.07). [Perhaps language similar to the Archaeological Discoveries clause in MMS' NTL No. 2008-G05 (http://www.gomr.mms.gov/homepg/regulate/regs/ntls/2008NTLs/08-g05.pdf)]

Repsonse: Concur. Additional information on prehistoric sites will be added to the appropriate sections.

REPORT CHANGE: Section 2.05 (Cultural Resources) and Section 8.06 (Cultural Resources) have been replaced with the following, and additional references added to the references section:

2.05 Cultural Resources

Recent archaeological findings in the Mid-Atlantic and Southeastern regions demonstrate that coastal areas were being exploited soon after human occupations began in North America. The most complete regional evidence of these early Americans comes from the Cactus Hill site, located on the coastal plain of the Nottaway River in Sussex County, Virginia. This site has abundant evidence of a Clovis occupation, which is so named after the distinctive fluted Clovis projectile point. This point is a marker for this nationally widespread horizon. The Clovis occupation at Cactus Hill is firmly dated and supports other dates from throughout North America, which place Clovis occupations around 13,000 B.P. (McAvoy 1997). Research at this and other sites throughout the Mid-Atlantic and Southeastern coasts of Virginia and North and South Carolina demonstrate that Paleoindian occupation of the coastal plain was widespread during these times of much lower sea level and cooler climate.

Glaciation during the late Pleistocene (ca. 18,000 to 14,000 B.P.) may have lowered sea level south of Cape Hatteras, North Carolina 60 or more meters below present level, exposing the entire continental shelf for settlement and exploitation (Boss and Hoffman 2001; Science Applications, Inc. 1981). Some exposed areas, however, lacked stabled land surfaces and mature estuaries due to down-cutting and other fluvial dynamics associated with lower stream base level (Sassaman 1996). Some research, particularly at Cactus Hill, suggests a pre-Clovis occupation going back to 18,000 B.P. Both archaeological and geological research suggest that the Paleoindians and the megafauna they hunted disappeared or became very scant in the archaeological record around 12,900 B.P., presumably as a result of a catastrophic event (Goodyear 2006).

Warming trends produced a major rise in sea level from water released from melting glaciers after 14,000 B.P. (Faught 2004). The rise in sea level was interrupted during the Younger Dryas (ca. 11.000 to 10,000 B.P.), as the climate returned to near glacial conditions. Sea levels were within a few meters of present levels by 9,000 B.P., and reached present sea level ca. 2,000 to 5,000 B.P. (Anderson et al. 1996; Haynes 2002; Lewis 2000).

After the demise of post-Pleistocene mega-fauna, Native Americans adapted with a new lifestyle and associated tool kit. These people, referred to by archaeologists as Archaic, focused on plant gathering and the hunting of modern game animals. Their tool kit remained limited but elegant, including a

variety of projectile points, ground stone tools, and basketry. Archaic populations appear in the archaeological record around 10,000 years ago and persist until the advent of agriculture around 3,000 years ago. Social organization probably still centered on extended families and bands, with possible larger seasonal gatherings; however, Russo (1996) proposes, based on analyses at a number of mid-Holocene coastal deposits, estuarine environments at this time were capable of supporting year-round occupation. The Archaic period was an extremely important foundation upon which later, more complex societies would grow. The early Woodland period, in particular, probably inhabited the same riverside locations and followed much the same lifestyle as their Archaic predecessors. However, regional subsistence specialization and incipient agriculture allowed for the development of a more settled lifestyle, support of larger permanent populations, and the establishment of defended territories.

While there are many scattered coastal Archaic and Early Woodland period sites and artifact finds, the most significant occupations tend to occur during Middle and Late Woodland periods (Ward and Davis 1999). This is a time of increasing reliance of agriculture, more settled village life, the development of pottery, and especially sophisticated political organization. Through time, many regional cultures appear along the coast with several cultural and language affiliations with groups to the north, west, and south (Phelps 1983; Ward and Davis 1999). Seasonal exploitation of sound-side resources is now full blown and some villages persisted long enough to establish large settlement, complete with ossuary pits (mass burials). The Colington phase of the Woodland Period is equated with the Carolina Algonkian culture, who greeted the first English explorers (Phelps 1983).

To date, there are few indications that Native American populations made significant use of ocean-side resources. Littoral zones, especially intertidal areas, appear to have been more important extractive locales than ocean-facing beaches (Phelps 1981; Science Applications, Inc. 1981). Inner and outer coast populations of North Carolina during the Middle Woodland period shared similar settlement and foraging strategies, with fish, shellfish, deer, rabbit, and raccoon being important food resources (Hargrove 1983; Hutchinson 2002). Indeed, the intensive use of the sounds may indicate that resources there were so plentiful that an interest in exploiting the open-ocean never developed.

The proposed borrow areas are located 1 to 6 miles offshore of the towns of Topsail Beach, Surf City and North Topsail Beach, and stretch from the New Topsail Inlet to the New River Inlet. This area has seen significant maritime activity since at least the early-eighteenth century when permanent settlement began. One of the earliest land grants included the inlet and area surrounding the sound, and by 1755 New Topsail Sound was designated as an official inspection point for export commodities in New Hanover County, along with counties Brunswick, Wilmington, and New Exeter (Angley 1984). Inspections were conducted for export commodities of fish, flour, butter, flax seed, beef, pork, rice, tar, pitch and turpentine, staves and headings, sawed lumber and shingles.

Throughout the Colonial Period, the inlet was relatively stable and was suitable for passage by schooners and small sloops. During the latter part of the eighteenth century and throughout most of the nineteenth century, New Topsail Inlet migrated significantly to the north. According to Wilson

Anglely's (1984) analysis, the Mouzon Map of 1775 and the Price-Strother Map of 1808, the inlet migrated northward some 2 miles. While the Mac Rae-Brazier Map of 1833 indicates no significant change, the U.S. Coast Survey Map of 1865 shows that an additional migration of 2 miles occurred during that period. The migration appears to have abated during the end of that century, as is suggested by review of the Kerr-Cain Map of 1882 and the Post Route Map of 1896. A detailed U.S. Coast Survey Map of 1885 indicates that the New Topsail Inlet was approximately 3,000 feet wide at that time.

Five miles northeast of North Topsail Beach lies New River, another important waterway in coastal North Carolina history. In 1705, three Englishmen established a settlement at Town Point, the first in Onslow County. Within 20 years, the population had grown to approximately 35 families with English, German, and French Huguenot ancestry. The Moseley map of 1733 indicates that settlement spread along the coast and up the rivers and streams, a pattern typical of the southern colonies. A county seat was platted at Mittam's Point on New River in 1742. The town, called "Johnston," was struck by a hurricane in 1752 that devastated much of the coastal southeast. In response to the destruction of the storm, the county seat was moved inland. Land was acquired from James Wantland, who operated a ferry and tavern at the site where the Boston–Charleston Post Road crossed the New River. This road was the precursor to US Highway 17, following nearly the same route as the present-day road. In 1775, a bill officially established a town at the ferry to be known as "Onslow Courthouse" but in 1842 the name of the town was changed to Jacksonville in honor of Andrew Jackson.

Production of turpentine and naval stores (tar and pitch) represented the primary occupation of small and large landholders in Onslow County. Substantial acres were planted in corn, with smaller investments in wheat, flax, and rice. In 1860, several military companies were formed. Hostilities were concentrated along the lower New River and Bear Inlet. Union raids, intended to quash blockade running and to demolish the coastal saltworks, occurred from 1862 to 1864. As was the case elsewhere in the South, the Civil War resulted in poverty, economic stagnation, and strained relations in Onslow County. Share-cropping and tenancy replaced plantation agriculture. In response to the gradual decline of the naval stores industry in southeastern North Carolina, local people turned to crop and livestock farming, mostly on the basis of relatively small-scale farms. Cotton began to emerge as a prominent market crop in the first postbellum decade, followed by tobacco in the 1890s, though neither became a dominant factor in the county's economy.

Eleven vessels are reported or believed to have been lost in the area of Topsail Inlet (Table 2.14), and an additional 19 recorded in the vicinity of New River Inlet. This number includes one of four vessels lost in 1750 as part of the Spanish Plate Fleet. That ship, the packet boat, *El Salvador*, was lost in the vicinity of Topsail Inlet on August 18, 1750. Due to the shifting sands, the surviving remains were buried in a matter of days, making salvaging operations difficult.

Table 2.14 NC Division of Archives and History,

Underwater Archaeology Section Shipwreck Files

1737	UNK, wrecked at mouth of New River with ten lives lost
1750	EL SALVADOR, wrecked at Topsail Inlet
1765	UNK, sloop lost in vicinity of New River
1769	UNK, brigantine lost below Topsail Inlet
1771	BETSY, merchant ship lost at Old Topsail Inlet
1799	SALLY, schooner lost east of New River Inlet bar channel
1815	UNK, vessel and cargo and crew (?) lost at mouth of New River
1837	SEAMAN, lost in or near New River Inlet
1838	PULASKI, wrecked off-shore of New River with 141 lives lost
1841	SUPERIOR, schooner driven ashore near Topsail Inlet
1858	ALBION, lost inside New River Inlet bar
1862	ADELAIDE, schooner wreck at mouth of New Topsail Inlet
1863	ALEXANDER COOPER, schooner wrecked at New Topsail
1863	INDUSTRY, schooner lost 5 miles north of Topsail Inlet
1863	PHANTOM, steamer sunk 200 yards off Topsail Inlet in 30 feet of water
1863	UNK, schooner lost west of Stump Inlet
1864	NUTFIELD, blockade runner, run ashore at New River Inlet
1867	ELLIS, federal gun boat lost 5 miles above New River Inlet, possibly salvaged
1871	HERTFORD, steamer aground inside New River Inlet bar, may have gotten off
1879	MARION GAGE, schooner lost in New River, total loss
1880	UNK, lost at mouth of New River
1881	N.W. DREW, schooner disabled and ashore 3 miles south of New River Inlet

1881	UNK, shipwreck at mouth of New River
1881	MARY BEAR, schooner wrecked 4 miles south of New River Inlet
1884	UNK, shipwreck at mouth of New River
1890	CHARLES, schooner aground on New River inlet bar, total loss
1892	LORENZO, schooner wrecked in New River Inlet, total loss
1894	UNK, lost in New River Inlet
1895	UNK, sharpie sunk at its mooring near Jacksonville
1919	WILLIAM H. SUMNER

Before the Civil War, the following vessels were lost in the vicinity: schooner *Superior*, driven ashore November 24, 1841; an unknown brig in September 1769, run ashore below Topsail Inlet; and English merchantman *Betsy* in 1771 at Old Topsail Inlet. The Civil War also resulted in a number of wrecks, including the schooner *Adelaide* of Halifax, an unidentified schooner west of Stump Inlet, the iron-hulled steamer *Phantom*, and the schooner *Industry*. During the late-nineteenth and early-twentieth centuries the following losses are recorded: the schooner *Mary Bear* on September 9, 1881, at New Topsail Inlet; and schooner *William H. Sumner* on September 7, 1919, grounded at Topsail Inlet.

As was indicated by the vessels seized, the inlet was active in salt production. An 1864 military map shows at least 2 Confederate salt works situated on either side of Holmes Landing. The presence of the salt works is further substantiated in a letter from November 1, 1862, written by USS Lieutenant William Cushing to his superior (Angley 1984).

In 1932, a 12-feet deep and 90-feet wide segment of the Intracoastal Waterway between Beaufort and the Cape Fear south of Wilmington was completed (USACE 1961). The channel allowed for an increase in vessel traffic from 33,710 tons in 1932 to 243,000 tons in 1939. As reported the previous year, the character of the vessel traffic – of around 9,000 vessel trips – consisted of approximately 8,500 motor vessels, 300 tugs, 200 barges, and a smattering of pleasure craft. Cargo vessels transported agricultural commodities, lumber, petroleum products, seafood, fertilizer, and general merchandise.

8.06 Cultural Resources

The Coastal Plain remains the least known archaeological region in North Carolina (Phelps 1983; Science Applications, Inc. 1981; Ward and Davis 1999). While there has been some success developing upland-offshore site location correlations in Florida and perhaps elsewhere, the methodology is not very well developed for sites within the Carolinas region. There are not a significant number of known upland locations that could be used to model settlement in now inundated areas (Ward and Davis 1999). Scientific Applications, Inc. (1981) noted the paucity of archaeological data in their study area along the Atlantic coast from North Carolina to Florida, and their need to use data from outside the study area to develop their model for predicting the location of archaeological sites on the submerged continental shelf. Anderson (1996) also found a low site incidence for Early, Middle and Late Archaic Period sites for the coastal area of North Carolina when examining Archaic settlement in the Southeast.

Five chronological cultural units, Pre-Paleoindian, Paleindian to Early Archaic (early), Early Archaic (late) to Middle Archaic, Late Archaic to Woodland, and Woodland were used for assembling the data for modeling. Pre-Paleoindian sites are assumed to date prior to 11,500 B.P. and represent transient camps of a low density population (Scientific Applications, Inc. 1981). Paleoindian and Early Archaic sites tend to be clustered along major drainages and sources of knappable stone (Anderson and Faught 2000; Ward and Davis 1999). These sites are likely to be associated with paleochannels; however, these sites are very rare in the North Carolina coastal region and consist only of single point (Science Applications, Inc. 1981). Terminal Early through Middle Archaic sites are also associated with riverine settings and upland swamps, with base camps located on terraces of major rivers, and specialized sites occurring in throughout interfluvial areas (Blanton 1996; Sassaman 1996; Scientific Applications, Inc. 1981; Ward and Davis 1999). Settlement during the Late Archaic and Early Woodland appears to have shifted to the mouths of major rivers, and by the Woodland period, sites are located in most estuarine settings (Scientific Applications, Inc. 1981; Ward and Davis 1999). Base camps, especially shell middens, tend to be in the most productive estuaries and adjacent landforms (Scientific Applications, Inc. 1981). However, Anderson (1996) noted the lower Coastal Plain and coastal areas of North Carolina appear to have been of limited use during the Late Archaic.

The Science Applications, Inc. model uses three sensitivity zones with zone 1 having the highest probability of containing archaeological sites, and zone 3 having the least probability. Zone 1 includes areas from the present day shoreline to the 8,000 B.P. shoreline (ca. the 39 foot depth contour). Zone 2 extends outward from the 8,000 B.P. shoreline to the 12,000 B.P. shoreline (ca. the 75 foot depth contour). Zone 3 continues outward from the 12,000 B.P. shoreline to the 16,000 B.P. shoreline (ca. 200 foot depth contour). The paleoshorelines for the above zones are based upon the sea level curve proposed in the same study (Science Applications, Inc. 1981).

The proposed borrow areas are located in water depths ranging from 28 feet to 52 feet. These depths would correlate to roughly the 9,000 B.P. to 6,000 B.P. shorelines proposed by Science Applications, Inc. (1981). Early to Middle Archaic base camps could occur along major inundated channels, with specialized sites in most riverine settings. Pump-out locations closer to shore may contain Late Archaic

and Woodland period sites. Significant sites of these periods tend to be larger than earlier base camps and contain shell middens in estuarine environments.

The proposed project is also located within Zone 1, the highest probability zone; however, the North Carolina coastline is considered a high-energy, wave-dominated zone because of the narrow and steep nature of the continental shelf. Most of the North Carolina continental shelf is believed to have been dominated by erosional transgression and have a low preservation potential (Scientific Applications, Inc. 1981).

Monitoring of renourished beach areas may be a way to determine if such sites were encountered during dredging, but the use of heavy equipment throughout the renourishment process might make precise relocation of sites very difficult. Inshore areas subject to pump-out activities will be identified and investigated for cultural resources in conjunction with hard bottom surveys. In addition, the District will discuss with archaeologists from the Underwater Archaeology Branch (UAB) of the North Carolina Office of State Archaeology the option of monitoring. In their reviews of the project, the UAB has not mentioned prehistoric sites or impacts to other types of sites; shipwrecks have been the major concern. The SHPO letter accepting the final report of investigations is dated March 1, 2005 and is included in Appendix H of the Draft Feasibility Report and EIS.

Whereas the Topsail Island vicinity is known to have had an active historical maritime trade, the Wilmington District, in consultation with the North Carolina Division of Archives and History, undertook contracted remote sensing survey designed to meet the intent of the National Historic Preservation Act and the Abandoned Shipwreck Act. During summer and fall of 2004, Mid-Atlantic Technology and Environmental Research, Inc. conducted a magnetometer and side-scan sonar survey of the ten proposed borrow areas. The results of that survey are reported in *Archaeological Remote Sensing Survey of Topsail and West Onslow Beaches Offshore Borrow Areas (*Contract DACW54-03-D-0002, Order 0003, Wes Hall, Principal Investigator, December 2004). Data was collected along parallel lines spaced at 65-foot (20-meter) intervals. Magnetic data, along with corresponding positioning data, was recorded at one-second sample intervals (or approximately every 8 feet along a track line at 5 knots).

It should be noted, originally seven potential offshore borrow areas (extending from the Topsail Beach/Surf City town limit to New River Inlet) were identified at the time the cultural resources survey was conducted. After completion of the survey, hard bottom was identified in several borrow areas, which required modification to the boundaries of several borrow areas and elimination of three borrow areas (currently identified as I, K, and M). Consequently, the remaining viable borrow areas were renamed and reconfigured into ten borrow areas. The boundaries of these reconfigured borrow areas are completely contained within the boundaries of the original seven borrow areas.

No single, isolated magnetic anomalies or acoustic targets were identified during the survey of the ten borrow areas. There is a low potential for encountering submerged prehistoric sites based upon proposed borrow areas and material type, preservation potential, and current data on North Carolina prehistoric sites in coastal/submerged settings. No further cultural resources studies are anticipated for the project within the proposed borrow areas. By letter of November 2, 2004, the North Carolina State

Historic Preservation Officer (NC SHPO) concurred with the reported findings. The USACE shall, pursuant to 36 CFR 800.13(b), immediately secure the jobsite, suspend work in the vicinity of the affected resource, and consult with the NC SHPO and MMS in the event previously unidentified culture resources are discovered during the execution of the project.

31. COMMENT SOURCE: Public/Mineral Management Service

COMMENT: Consistent with the Council on Environmental Quality's (CEQ) Regulations for Implementing the Procedural Provisions of the National Environmental Policy Act, the Corps has combined the preparation of an Environmental Impact Statement (EIS) with a planning instrument. The draft Integrated Feasibility Report (IFR) and EIS integrate alternative development, engineering and economic analyses, and environmental review in a single document. In the draft document, the elements required in an EIS are presented in an atypical order, and the re-organization presents some fundamental challenges to the reader. For example, the reader must first read the Tentatively Selected Plan chapter (Chapter 7), the practical description of the proposed action, to fully comprehend the site-specific discussion of resources (e.g., Hard Bottoms, Artificial Reefs, Birds, etc.) in the Affected Environment chapter (Chapter 2). Environmental commitments are enumerated in Table 7.1 (Chapter 7) before the presentation of the impact analyses in the Environmental Effects chapter (Chapter 8). Therefore, the reader must first read the effects analyses to fully appreciate the need and purpose of the proposed mitigation.

The MMS recommends the Corps prepare prefatory guidance to better orient the reader to the organization of the document. Alternatively, the Corps could insert the Affected Environment chapter after the Tentatively Selected Plan chapter and before the Environmental Effects chapter. Mitigation should be linked in a logical manner to the effects analysis.

RESPONSE: Concur.

REPORT CHANGE: New Section added after Study Organization

New Text:

1.01 Report Organization
This report is a combined feasibility study and Environmental Impact Statement (EIS), meaning it contains elements that are required for both a USACE planning feasibility report as well as an EIS as per the National Environmental Policy Act (NEPA). Chapter 1 of the report is an overview of the feasibility study. Chapter 2 contains background information on the environment that could potentially be affected by a USACE project resulting from the study. Chapters 3 to 6 discuss the plan formulation process that led to the selection of the final plan recommended in this report. Chapter 7 is a detailed description of the selected plan. Chapter 8 contains more expansive discussions on the resources that were discussed in Chapter 2, and describes in detail the environmental effects the selected plan will have on these resources. The chapter also contains briefer descriptions of the environmental effects of other major alternatives (No Action and Non-Structural) that were considered during the formulation process. Chapter 9 contains information on plan implementation such as schedule and cost-sharing. Chapter 10 lists the study's compliance with all applicable environmental laws and Executive Orders. Chapter 11 is a summary of agency and public involvement that has been undertaken throughout the course of the study. Chapters 12 to 16 contain, respectively, the report's conclusions, recommendations, main point of contact, literature references, and a list of report preparers.

32. COMMENT SOURCE: Public/Mineral Management Service

COMMENT: The study area description should more accurately describe the entire footprint of the proposed action, including the offshore borrow areas. Consider referencing Chapter 7 for a more complete description of the footprint of the proposed action. Similarly, the location map (Figure 1) should more clearly illustrate the footprint of proposed action, including the proposed borrow areas. Reference to Figure A-1 may be more appropriate. However, on Figure A-1, the beach fill zone should be clearly delineated. Inlets should be labeled. All figures and text references should use the same alongshore profile station or reach designations.

RESPONSE: Concur.

REPORT CHANGE: Figure 1 modified.

33. COMMENT SOURCE: Public/Mineral Management Service

COMMENT: Reference Figure A-1 to illustrate historical SEAMAP hard bottom observations.

RESPONSE: Concur.

REPORT CHANGE: Section 2.01.10 modified

Old Text: The location of the hard bottom communities offshore of Surf City, North Topsail Beach, and Onslow Beach, as identified in this study, are found in Table 2.2.

New Text: The location of the hard bottom communities offshore of Surf City, North Topsail Beach, and Onslow Beach, as identified in this study, are found in Table 2.2 and also shown in Figure A-1 in Appendix A.

34. COMMENT SOURCE: Public/Mineral Management Service

COMMENT: Figure A-7 does not show shoreline change as indicated in the narrative.

RESPONSE: Concur.

REPORT CHANGE: Text deleted in Section 3.02

Old Text (deleted): Refer to Figure A-7 in Appendix A for reach locations.

National Marine Fisheries Service

1. COMMENT SOURCE: Public/National Marine Fisheries Service

COMMENT: The DEIS adequately describes the project alternatives currently under consideration and the basis for selecting the NED plan as the preferred alternative. As noted earlier, NMFS assumes that the District would reinitiate EFH coordination with NMFS should any option other than the NED plan move forward.

RESPONSE: Concur. The Corps will reinitiate EFH coordination with NMFS should any option other than the NED plan move forward.

REPORT CHANGE: No Action Required

2. COMMENT SOURCE: Public/National Marine Fisheries Service

COMMENT: NMFS agrees with the District that use of the offshore borrow areas is more appropriate than using shoals associated with New River Inlet. In addition, The DEIS adequately describes the range of marine and estuarine habitats and associated fishery resources found in the project area.

RESPONSE: Concur

REPORT CHANGE: No Action Required.

3. COMMENT SOURCE: Public/National Marine Fisheries Service

COMMENT: While NMFS is pleased the DEIS addresses several environmental concerns, including potential impacts to nearshore hard bottom habitats, pipeline corridors and other key project details are unknown at this time. NMFS requests that the District continue to coordinate with us as construction-level detail is developed to ensure that any additional opportunities to avoid or minimize impacts to NOAA trust resources are fully considered.

RESPONSE: Concur. During Pre-construction Engineering and Design (PED), any impacts NOAA trust resources not previously addressed in this report relative to "construction level detail" will be coordinated to ensure that any additional opportunities to avoid or minimize impacts to NOAA trust resources are fully considered. As discussed in appendices R2-R4, a significant amount of remote sensing and ground truth diver survey efforts were conducted between the shoreface and -23 ft. and no hard bottom resources were identified. However, based on diver ground truth of two sites located about 500 to 600 feet offshore of the -23 ft Depth of Closure (DOC) line, low relief hard bottom and rock/gravel bottom was identified offshore of the -23 foot DOC. It is anticipated that any selected pipeline corridor for hopper dredge pumpout could extend from the shoreface to approximately 2,500 to 3,000 feet offshore. Therefore, considering the ephemeral nature of the low relief hard bottom features in the nearshore environment and the identification of low lying outcrops located within the pipeline corridor distance requirements, the Corps intends to survey potential pipeline corridor routes prior to construction in order to develop a corridor that avoid hard bottom features. All existing remote sensing and ground truth data will be used in combination with the new survey data. All information associated with the surveys, data analysis, identification and mapping of pipeline corridors, appropriate buffers, etc. and subsequent measures developed to avoid resource impacts will be coordinated with the NMFS prior to construction.

REPORT CHANGE: The hard bottom commitment section of Table 7.1 will be updated with the following:

"Considering the ephemeral nature of the low relief hard bottom features in the nearshore environment and the potential for low lying outcrops to occur within the pipeline corridor distance requirements and associated dredge and pipeline anchor points, the Corps intends to survey all areas associated with potential pumpout and pipeline corridor requirements prior to construction in order avoid potential impacts to hard bottom features. All information associated with the surveys, data analysis, identification and mapping of pipeline corridors, appropriate buffers, etc. and subsequent measures developed to avoid resource impacts will be coordinated with the resource agencies prior to construction (Section 8.01.8.2)"

4. COMMENT SOURCE: Public/National Marine Fisheries Service

COMMENT: The DEIS adequately describes the project alternatives currently under consideration and the basis for selecting the NED plan as the preferred alternative. As noted earlier, NMFS assumes that the District would reinitiate EFH coordination with NMFS should any option other than the NED plan move forward.

RESPONSE: Concur. The Corps will reinitiate EFH coordination with NMFS should any option other than the NED plan move forward.

REPORT CHANGE: No action required.

5. COMMENT SOURCE: Public/National Marine Fisheries Service

COMMENT: Table 7.1 lists 30 commitments to reduce environmental impacts. Three commitments, (18, 19, and 20) address benthic invertebrates, many of which serve as a forage base for fishery species. Commitments 19 and 20 deal with the timing of construction. NMFS agrees that limiting construction to the period between December 1 and March 31 would minimize impacts to fishery species by avoiding the peak recruitment and abundance times for surf zone fish and benthic invertebrates (commitment 18). However, we are concerned that other than the brief mention in Table 7.1 of this construction window being associated with minimizing impacts to fishery resources, the rationale for the window elsewhere in the DEIS is based on minimizing impacts to sea turtles, suggesting the window may be relaxed should alternate means to protect sea turtles be found (e.g., use of cutterhead pipeline dredge). From EFH and fisheries perspectives, deviating from a window of November 15 to March 31 would not be acceptable, and NMFS requests the District reinitiate EFH consultation with NMFS should any in-water work be proposed outside this time period.

Commitment 19 and corresponding text on page 106 briefly describe a monitoring program that would evaluate project impacts to benthic invertebrates. NMFS requests the District coordinate with us during the further develop of the monitoring program, and that this coordination occur well in advance of baseline sampling.

Three commitments (21, 22, and 23) address live/hard bottom habitat. The District proposes to implement a 122-meter (400 feet) dredging buffer around the low relief hard bottom (less than 0.5 meters [1.6 feet]) identified by MATER in the offshore borrow sites and 500-meter (1640 feet) buffer for high-relief hard bottom as defined within the state rule language (commitment 21 and page 27). NMFS requests the District coordinate with NMFS during development of the monitoring plan for sedimentation impacts (commitment 23).

RESPONSE: Concur

REPORT CHANGE: 1. The current plan for initial construction and each nourishment event is to complete the dredging and nourishment events within the least biologically productive months and the period when the risk of impacts to sea turtles from dredging is low. Any deviation from the selected plan would require the Corps reinitiate EFH consultation with NMFS.

2. Commitment number 19 has been updated to reflect the following:

"Prior to initiating any land disturbing activities related to the initial construction period, the Corps will develop Monitoring Plan, in coordination with the resource agencies, to assess project impacts on fisheries and fish prey habitat that outlines: (1) the methodologies for evaluating for hard bottom and intertidal beach habitat impacts, (2) the criteria for determining whether significant, adverse impacts to these habitats have occurred, (3) implementation of the monitoring plan. Though unlikely, based on the avoidance measures incorporated in the study design, should the Monitoring Plan document that a significant adverse impact to habitat has occurred, a Mitigation Plan will be developed outlining the appropriate actions that will be implemented in cooperation with state and federal agencies to rectify the adverse impacts to a level of insignificance."

As indicated in the commitment, the Corps will coordinate with NMFS during the further develop of the monitoring plan prior to any baseline sampling.

3. All sedimentation monitoring of offshore hard bottom habitats will be coordinated with NMFS.

6. COMMENT SOURCE: Public/National Marine Fisheries Service

COMMENT: NMFS agrees the District has taken significant steps towards avoiding and minimizing impacts to EFH and fishery species from this project. However, we do not agree that the cumulative effect of the several beach nourish projects currently underway or under review also is minimal. As noted in our comment letters on these projects, NMFS has concerns over borrow sites that are not the least damaging practicable alternative (e.g., Town of North Topsail Beach, Action ID No. 2005-00344-067) or dredging outside recommended seasonal restrictions solely for economic reasons (e.g., Town of Nags Head, Action ID No. 2006-40282).

RESPONSE: Concur. The Corps has taken significant planning steps towards avoiding and minimizing impacts to EFH and fishery species from this project. Based on the planning considerations of this study to avoid impacts, the Corps believes that the impacts associated with the proposed action will be minor. Not all projects throughout the state include similar consideration for adhering to seasonal restrictions and therefore, may sustain more significant impacts and longer recovery period. Multiple adjacent projects with extended recovery times due to the inability to adhere to environmental window restrictions may result in more significant cumulative impacts.

REPORT CHANGE: No action required.

7. COMMENT SOURCE: Public/National Marine Fisheries Service

COMMENT: EFH Conservation Recommendation 1: Before construction begins, the District shall provide NMFS with a map and description of the pipeline corridors relative to live/hard bottom habitats. The description shall include measures the District would take to ensure minimal impacts would occur to NOAA trust resources.

RESPONSE: Concur. During Pre-construction Engineering and Design (PED), any impacts NOAA trust resources not previously addressed in this report relative to "construction level detail" will be coordinated

to ensure that any additional opportunities to avoid or minimize impacts to NOAA trust resources are fully considered. As discussed in appendices R2-R4, a significant amount of remote sensing and ground truth diver survey efforts were conducted between the shoreface and -23 ft. and no hard bottom resources were identified. However, based on diver ground truth of two sites located about 500 to 600 feet offshore of the -23 ft Depth of Closure (DOC) line, low relief hard bottom and rock/gravel bottom was identified offshore of the -23 foot DOC. It is anticipated that any selected pipeline corridor for hopper dredge pumpout could extend from the shoreface to approximately 2,500 to 3,000 feet offshore. Therefore, considering the ephemeral nature of the low relief hard bottom features in the nearshore environment and the identification of low lying outcrops located within the pipeline corridor distance requirements, the Corps intends to survey potential pipeline corridor routes prior to construction in order to develop a corridor that avoid hard bottom features. All existing remote sensing and ground truth data will be used in combination with the new survey data. All information associated with the surveys, data analysis, identification and mapping of pipeline corridors, appropriate buffers, etc. and subsequent measures developed to avoid resource impacts will be coordinated with the NMFS prior to construction.

REPORT CHANGE: Section 8.01.8.2; paragraph titled "Monitoring" (pg. 164) will be updated with a new paragraph following the "Silent Inspector" paragraph. The new paragraph will be titled, "Nearshore Hard Bottom Monitoring - Pipeline Corridor." This paragraph will include the following:

"As discussed in Section 8.01.8.2 and Appendix R, Attachments 2-4, a significant amount of remote sensing and ground truth diver survey efforts were conducted between the shoreface and -23 ft. and no hard bottom resources were identified. It is anticipated that any selected pipeline corridor for hopper dredge pumpout during construction could extend from the shoreface to approximately 2,500 to 3,000 feet offshore. Considering the ephemeral nature of the low relief hard bottom features in the nearshore environment and the potential for low lying outcrops to occur within the pipeline corridor distance requirements and associated dredge and pipeline anchor points, the Corps intends to survey all areas associated with potential pumpout and pipeline corridor requirements prior to construction in order avoid impacts to hard bottom features. All existing remote sensing and ground truth data will be used in combination with the new survey data. All information associated with the surveys, data analysis, identification and mapping of pipeline corridors, appropriate buffers, etc. and subsequent measures developed to avoid resource impacts will be coordinated with the resource agencies prior to construction."

The last sentence within the last paragraph of the "Nearshore" section (pg. 156) of Section 8.01.8.2 should be removed and replaced with the following:

"Though surveys and diver ground truth efforts did not identify hard bottom within the -23 ft. depth contour, it is anticipated that any selected pipeline corridor and associated pumpout anchor point features could extend approximately 2,500 to 3,000 feet offshore into areas that were not surveyed. Therefore, considering the ephemeral nature of the low relief hard bottom features in the nearshore environment and that pipeline corridors and pumpout stations may be located outside of the surveyed areas, the Corps intends to survey all potential pipeline corridor routes prior to construction in order to avoid potential hard bottom features."

8. COMMENT SOURCE: Public/National Marine Fisheries Service

COMMENT: EFH Conservation Recommendation 2: The District shall coordinate with NMFS on the final design of the sampling programs for examining impacts to benthic invertebrate communities and sedimentation on live/hard bottom areas; this coordination shall occur well in advance of baseline sampling.

RESPONSE: Concur. The Corps will coordinate with NMFS on the final design of the sampling programs for examining impacts to benthic invertebrate communities and sedimentation on live/hard bottom areas; this coordination will occur well in advance of baseline sampling. As discussed in the report, a significant amount of monitoring for both dredging and beach placement impacts to benthic invertebrates has already been conducted with varying levels of impacts and associated recovery times ranging between 1 and 4 years depending on project specific design considerations. Management measures for reducing impacts to benthic invertebrates and associated recovery times (based on data analysis and recommendations from historic literature) from both dredging and beach placement related impacts have been incorporated into the design of this project and are discussed in detail in the report (see Section 8.01.6 and 8.01.7). Though a significant amount of data already exists regarding impacts and recovery rates of benthic invertebrates from dredging and beach placement of sediment, benthic invertebrate monitoring will be conducted during initial construction. Monitoring efforts will be based on a carefully developed plan, with input from NMFS and other appropriate regulatory agencies, which support improved future project planning by filling existing data gaps on benthic invertebrates. A monitoring consideration for this study may be to evaluate impacts and recovery rates of beach placement associated impacts to benthic invertebrates relative to the staggered construction event over the 4 year initial construction period. Other federal and non-federal beach nourishment projects under study or already authorized/permitted throughout the state will be considered in development of the final monitoring plan in order to develop a comprehensive, inter-related, cumulative approach to how information gained from each project can be used to build upon one another in order to achieve long term goals.

During Pre-Construction Engineering and Design (PED) of this project, prior to initial construction, the final monitoring plan will be coordinated with NMFS and other appropriate regulatory agencies. Information gained from this monitoring will be used to support a long term strategy for understanding dredging and beach placement impacts. Identifying management measures for improved project planning and implementation of future dredging and beach nourishment projects will be a goal of this plan.

As discussed in section 8.01.8.2 under the "monitoring" paragraph as well as within Table 7.1 of the report, the Corps has committed to sedimentation monitoring of offshore hard bottom communities relative to dredging activities. The monitoring plan has already been reviewed by state and federal agencies as a part of the permitted non-federal North Topsail Beach Shore Protection Project; however, prior to implementation as a component of the this federal project, the monitoring plan will be coordinated again. Details associated with this plan are provided in the report.

REPORT CHANGE: No action required.

9. COMMENT SOURCE: Public/National Marine Fisheries Service

COMMENT: EFH Conservation Recommendation 3: The District shall reinitiate EFH consultation with the NMFS Habitat Conservation Division should any in-water work be proposed outside the period of November 15 to March 31.

RESPONSE: Concur. The Corp will reinitiate EFH consultation with the NMFS Habitat Conservation Division should any in-water work be proposed outside the period of November 15 to March 31.

REPORT CHANGE: No action required.

10. COMMENT SOURCE: Public/National Marine Fisheries Service

COMMENT: EFH Conservation Recommendation 4: Section 305(b)(4)(B) of the Magnuson-Stevens Act and its implementing regulations at 50 CFR 600.920(k), requires your office to provide a written response to our EFH recommendations within 30 days of receipt. If it is not possible to provide a substantive response within 30 days, in accordance with our "findings' with your Planning Functions Branch, an interim response should be provided to NMFS. A detail response must then be provided prior to final approval of the action. Your detail response must include a description of measures proposed by your agency to avoid, mitigate, or offset the adverse impacts of the activity. If your response is inconsistent with our EFH conservation recommendations, your must provide a substantive discussion justifying the reasons for not following the recommendation. The detail response should be received by the NMFS at least ten days prior to final approval of the action.

RESPONSE: Concur. In accordance with Section 305(b)(4)(B) of the Magnuson-Stevens Act and its implementing regulations at 50 CFR 600.920(k), the Corps provided a written response letter (dated 5 April 2010) indicating our concurrence with the EFH recommendations provided by NMFS.

REPORT CHANGE: No action required.

11. COMMENT SOURCE: Public/National Marine Fisheries Service

COMMENT: These comments do not satisfy your consultation responsibilities under Section 7 of the Endangered Species Act of 1973, as amended. If any activity "may effect" listed sea turtles and marine mammals and their habitats under NMFS purview, consultation should be initiated with our Protected Species Division at the letterhead address.

RESPONSE: Concur. In accordance with Section 7 of the Endangered Species Act of 1973, a letter (dated 13 January 2010) was provided to the Protected Species Division containing our effect determination for all listed species and their habitats within the study area under NMFS purview. In an email response (dated 19 January 2010) provided by Eric Hawk of the NMFS Southeast Regional Office (SERO) for protected resources, NMFS provided the following determination: "NMFS agreed with the COE's determination that the proposed beach renourishment action, consisting (in part) of utilizing hopper dredges to mine offshore sand sources for deposition of sand onto North Carolina beaches (a 17-mile section extending from Topsail Beach/Surf City town limits to the northern end of Topsail Island) falls under the authority of the current NMFS South Atlantic regional biological opinion on hopper dredging of navigation channels and borrow areas in the southeastern United States, dated September 25, 1997 (i.e., SARBO). The SARBO is in the process of being revised and will eventually supersede the current opinion. The COE will abide by the revised SARBO when it is ultimately issued. Sea turtle or shortnose sturgeon takes resulting from the proposed dredging action when conducted under the RPMs and T&Cs of the SARBO are authorized and will be counted against the ITS take limit as set forth in the SARBO."

REPORT CHANGE: No action required.

US Department of Interior (DOI) & US Fish and Wildlife Service (FWS)

1. COMMENT SOURCE: Public/US DOI & FWS

COMMENT: Most of the references utilized in the draft document (67%) are over ten years old, and 47% are over fifteen years old. These include several references used for discussions on biological impacts. The discussion on sea level rise, for instance, includes a 1987 National Research Council reference (page 130, discussion on risk and uncertainty in sea level rise assumptions). It is suggested that the authors insure that the final EIS include the most recently available references in its discussions and in its assessments

RESPONSE: Environmental: Comment Acknowledged. The Corps believes that appropriate literature pertaining to the resources of interest was utilized in order to develop appropriate impact determinations relative to the proposed action. Though in some cases, the literature appears to be dated, they may still be significant studies that support conclusions made in the report. In the event that more recent literature exists for a specific species or resource which provided significant new information that could change an impact evaluation, those literature sources were utilized and cited in the report. If additional specific literature sources are recommended by USFWS that could be reviewed and incorporated into the report where appropriate, the Corps would be interested in reviewing them. Specific studies referenced in subsequent USFWS comments will be reviewed and cited where appropriate.

REPORT CHANGE: No action required.

2. COMMENT SOURCE: Public/US DOI & FWS

COMMENT: The DEIS identifies several species that may be impacted from proposed activities, but does not address available scientific information that could be utilized for an impact assessment or provide a discussion of proposed mitigation options. For instance, the document identifies several species of birds that may be impacted from proposed activities and provides tables with summary of surveys, stating that (page 48) "Annual shorebird surveys conducted by the NCWRC within the project vicinity are limited and complete surveys for American oystercatchers and Wilson's plovers have only been conducted in 2004 and 2007....". The DEIS also lists several threatened and endangered species that have been documented to inhabit the project area, but does not discuss in any detail potential mitigation options for the alternatives identified, such as for the loggerhead and green sea turtles (page 75) or the Florida manatee (page 192). The public would benefit from having recent available scientific information and surveys that could be used for conducting an impact assessment and discussing mitigation options in the final EIS. Suggested recent scientific references include the Sauer et al, 2008 reference for status and trends of bird populations, the Douglas and Dechant-Shaffer 2002 reference that provides a discussion of the effects of management practices on wetland birds, and the Adimey et al, 2009 and Lefebvre et al. 2009 references that provide important information on factors affecting Florida manatee survival.

RESPONSE: Comment Acknowledged. The Corps believes that all available scientific information pertaining to existing literature and survey data for bird resources within the project area was incorporated into the report, including waterbird survey data collected at North Topsail beach in 2007. However, the recommended citations will be incorporated into the report where appropriate. Furthermore, recognizing all of the avoidance and minimization measures incorporated into the project planning and design, the Corps does not believe that mitigation for impacts to bird resources is warranted. Section 8.02.3 discusses the rationale for this conclusion in more detail. Specifically, the last paragraph of section 8.02.3 concludes: "Based on the following considerations, the proposed construction activities will not

8.02.3 concludes: "Based on the following considerations, the proposed construction activities will not significantly impact breeding and nesting shorebirds or colonial waterbirds within the project area: 1.) timing of the initial construction activities and periodic renourishments will adhere to the 1 April to 31 August bird nesting window, 2) beach nourishment and construction activities will not occur within the New River and New Topsail Inlet complexes, which most likely to support foraging, loafing, roosting, and nesting shorebirds, and 3) project construction timing and planning will allow for rapid recovery of intertidal foraging habitat in the project area."

REPORT CHANGE:

First 3 paragraphs of Section 2.02.3 "Birds" were replaced with the following replaced with the following:

New Text:

Birds common to the nearshore ocean in the project area include loons, grebes, gannets, cormorants, scoters, red-breasted mergansers, gulls, and terns (LeGrand, 1983, USACE 2007b, and Sauer et al., 2008). The habitat and food source of these seabirds is the marine environment, whether coastal, offshore or pelagic. They can be divided into four groups by their feeding strategies, which are reflected in their anatomy, physiology and habitat niche: surface feeders, surface swimmers/pursuit divers, plunge-divers, and scavengers and pirates (i.e. steal from other birds). The waters off of Topsail Island are very important to migrating and wintering northern gannets, loons and grebes because of the abundant hard bottom habitat located offshore of Surf City and North Topsail Beach (See Section 2.01.10) (Sue Cameron, pers. comm.). These hard bottom communities support a rich diversity of invertebrates which are refuges and food sources for fish and other marine life. These diverse communities support a variety of reef and pelagic fish species which in-turn provide a forage base for migrating and wintering sea birds. The USFWS indicate that sea ducks raft in large numbers in the nearshore ocean waters of the project area during spring and fall migrations. Ducks, geese, and many kinds of shorebirds may also be found here during the spring and fall (Sauer et al., 2008).

The beaches and inlets of the project vicinity are heavily used by migrating shorebirds. However, dense development and high public use of project area ocean front beaches may reduce their value to shorebirds. Along the ocean beach, black-bellied plovers, ruddy turnstones, whimbrels, willets, red knots, semi-palmated sandpipers, and sanderlings may be found (LeGrand, 1983, USACE 2007b, and Sauer et al., 2008). Table 2.7 provides a more complete list of waterbirds found in the project area. The dunes of the project area support fewer numbers of birds but can be very important habitats for resident species and for other species of songbirds during periods of migration. The maritime forest along Topsail Island is important for painted buntings and in the herbaceous dune areas, the American kestrel, merlin, bald eagle, peregrine falcon, northern harrier, and other raptors may be found during migration. Other birds occurring in this area are mourning doves, swallows, fish crows, starlings, meadowlarks, redwinged blackbirds, boat tailed grackles, and savannah sparrows (Douglas and Dechant-Shaffer, 2002 and Sauer et al., 2008).

The black skimmer, least tern, and common tern are State listed species of concern for Pender and Onslow counties, North Carolina and are found on Topsail Island year round during both the breeding season and during migration, with peak abundance occurring in the summer months. Terns feed by diving from the air upon insects and small fish and the black skimmer feeds on shrimp or small fish by flying just above the water with the tip of the long lower mandible shearing the surface. All of these bird species may use Topsail Island for roosting, foraging, breeding, and nesting (Potter et al., 1980).

Section 15.0 "References" of the report should be updated to include the following citations:

Sauer, J.R., J.E. Hines, and J. Fallon. 2008. The North American Breeding Bird Survey, results and analysis 1966-2007. Version 5.15.2008. Patuxent Wildlife Research Center, Laurel, MD.

Dechant, J. A., M. L. Sondreal, D. H. Johnson, L. D. Igl, C. M. Goldade, B. D. Parkin, and B. R. Euliss. 2003. Effects of management practices on grassland birds: Willet. Northern Prairie Wildlife Research Center, Jamestown, ND. Northern Prairie Wildlife Research Center Online. http://www.npwrc.usgs.gov/resource/literatr/grasbird/will/will.htm (Version 12DEC2003).

3. COMMENT SOURCE: Public/US DOI & FWS

COMMENT: The DEIS includes several incomplete citations in the References section, such as the Coastal Science Associates, Inc. 2002 and the North Carolina Division of Coastal Management The final EIS should provide complete references.

RESPONSE: Concur

REPORT CHANGE: The "References" section 15.0 of the report will be updated with the following citations:

Coastal Science Associates (CSA), Inc. 2002. Bogue Banks Beach Nourishment Second Post-Dredge Environmental Monitoring Study. Prepared for Carteret County , Town of Pine Knoll Shores, Town of Indian Beach, and Town of Emerald Isle, NC.

USACE Permit #200000325 and NC CAMA Permit #124001. NCAC 07H. 0208 (Use Standards) (b) (12)(A)(iv)). North Carolina Division of Coastal Management. CAMA Rules and Policies. Effective October 1 2009. http://dcm2.enr.state.nc.us/Rules/rules.htm.

4. COMMENT SOURCE: Public/US DOI & FWS

COMMENT: Several important conservation measures incorporated in the plan are provided (USACE 2009b, pp. 192-194) in Section 10.06.1. These commitments to reduce impacts to listed species include limiting hopper dredging to the period from December 1 through March 31, but only to the "maximum extent practicable." There would also be a commitment to use sediment compatible with the existing beach along with measures to assess and rectify any sediment compaction or escarpment formation.

RESPONSE: Concur

REPORT CHANGE: No Action Required.

5. COMMENT SOURCE: Public/US DOI & FWS

COMMENT: Section 8 of the DEIS provides (USACE 2009b, pp. 139 - 185) a detailed discussion of the anticipated environmental effects of implementing the tentatively selected plan. In general, all the major resources are considered and the likely impacts of initial construction and the early reconstruction events are considered. However, the discussion seems based on the assumption that present environmental conditions will continue throughout the 50 years of the authorized project. The DEIS appears to lack a

consideration of adverse environmental impacts that could occur in the final decades of the project if sea level rise is greater than currently predicted. For example, the plan assumes a consistent four-year reconstruction cycle throughout the project (USACE 2009b, p. 103). Plans for initial construction (USACE 2009b, pp. 100-101) indicate that a portion of the beachfill would be below mean low water, approximately -1.9 feet NGVD. Placing beachfill below the low tide line is essentially putting sand in the ocean. As sea level rises over the decades of the project, efforts to save the existing ocean front structures would result in a greater portion of imported sediment for each reconstruction event being placed in an area that would be open ocean under natural conditions. Sediment placed below the natural low tide line is likely to be less stable than that placed on an intertidal or dry beach. Any accelerated loss of imported material is very likely to result in a reduction of the reconstruction interval. Such a reduction could pose a risk to beach macro invertebrates that form an important base on the coastal food chain. Literature dating back to the early 1970's along the southeast coast indicates that opportunistic infauna species (ex. Emerita and Donax) found in the beachfill areas are subject to direct mortality from burial; but recovery often occurs within one year (USACE 2009b, p. 143 and references therein). More frequent reconstruction operations along with post-storm, emergency sand placements would provide less time for these organism to recover and maintain healthy population levels.

RESPONSE: Comment Acknowledged. Beach projects place beachfill below the low tide elevation as part of construction of the required template that provides the storm protection. The renourishment interval was analyzed as part of the coastal studies and it was found that net benefits were relatively equal at intervals between 4 and 7 years. Accelerated SLR would likely result in larger renourishment volumes which could still be placed using the 6-year renourishment interval. Annual surveys will be used to monitor the project performance and will also reveal increases in renourishment volume requirements, so changes will be noted and any required adjustments will be recommended as part of the adaptive management plan. Based on the conclusion that SLR will not result in a reduction in the renourishment interval, but rather a potential increase in renourishment volume, the Corps does not believe that beach macro-invertebrates will be impacted by a more frequent renourishment interval.

REPORT CHANGE: No action required.

6. COMMENT SOURCE: Public/US DOI & FWS

COMMENT: Over time, beach reconstruction at intervals less than four years would pose a risk to sea turtle reproductive success. Overall, the historical literature indicates that there are inherent changes in beach characteristics as a result of mechanically placing sediment on a beach from alternate sources. The change in beach characteristics often results in short-term decreases in nest success and/or alterations in nesting processes. Any decrease in the reconstruction interval on Topsail Island could result in less time for the imported material to assume the natural characteristics of beaches necessary for successful sea turtle reproduction.

RESPONSE: Comment Acknowledged. See response to comment 5 above. The Corps does not believe that there will be reduction in the proposed 6 year nourishment interval over the duration of the project but rather a potential for increased renourishment volumes. Therefore, sea turtle reproductive success will not be impacted by a presumed reduction in the renourishment interval over the 50 year project life as a result of potential sea level rise scenarios.

REPORT CHANGE: No action required.

7. **COMMENT SOURCE**: Public/US DOI & FWS

COMMENT: Overall, based on the information provided in the DEIS and BA, the USFWS believes that the proposed action is not likely to adversely affect federally listed species or their critical habitat as defined by the Endangered Species Act (ESA) of 1973, as amended (16 U.S.C. 1531-1543). Therefore, the requirements of section 7 (a)(2) of the ESA have been satisfied for this project. However, the Corps' obligations under the ESA must be reconsidered if: (1) new information identifies impacts of this action that may affect listed species or critical habitat in a manner not previously considered; (2) this action is modified in a manner that was not considered in this review; or, (3) a new species is listed or critical habitat determined that may be affected by the identified action. With regard to project modification, the Corps should contact the USFWS if beachfill must be extended outside the proposed schedule of December 1 through March 31 or the material to be used for the beachfill deviates significantly from the standards proposed in the DEIS. Furthermore, significant placements of beachfill between the scheduled reconstruction operations given in Table 7.11 (USACE 2009b, p. 126) would represent modification of the proposed effort. The Corps should contact the USFWS if more than 1.6 million cubic yards of material, the standard reconstruction volume, are placed on project area beaches between established reconstruction events.

RESPONSE: Concur. The Corps' obligations under the ESA will be reconsidered if: (1) new information identifies impacts of this action that may affect listed species or critical habitat in a manner not previously considered; (2) this action is modified in a manner that was not considered in this review; or, (3) a new species is listed or critical habitat determined that may be affected by the identified action. Furthermore, the Corps will contact the USFWS if beachfill must be extended outside the proposed schedule of December 1 through March 31, the material to be used for the beachfill deviates significantly from the standards proposed in the DEIS, and/or more than 1.6 million cubic yards of material, the standard reconstruction volume, are placed on project area beaches between established reconstruction events.

REPORT CHANGE: No action required.

Environmental Protection Agency (EPA)

1. **COMMENT SOURCE**: Public/EPA

COMMENT: We are currently reviewing the Final Environmental Impact Statement (FEIS) for the proposed project adjacent to this one, known officially as the "Relocation of New River Inlet Ebb Tide Channel Between North Topsail Beach and Onslow Beach, and the Placement of the Dredged Material Along the Ocean Shoreline of North Topsail Beach in Onslow County, NC."

RESPONSE: Comment Acknowledged.

REPORT CHANGE: No change required.

2. **COMMENT SOURCE**: Public/EPA

COMMENT: Based upon the recommendations regarding use of public funds for the reduction of damages along this shoreline, the Sponsors have reportedly agreed to provide public access and parking in accordance with Corps guidelines, at "intervals of no more than a half mile, throughout Surf City and the reach of North Topsail Beach benefitted by the cost-shared project." EPA recommends that the FEIS include an excerpt(s) from the Corps guidelines about public access and parking to ensure that the project interval "of no more than a half mile" meets these guidelines.

RESPONSE: The Corps Guidance simply states that parking should be available within a "reasonable walking distance of the beach" and should be sufficient to "accommodate the lesser of the peak hour demand or the beach capacity". The "half mile" guidelines were established by Wilmington District in coordination with the South Atlantic Division.

REPORT CHANGE: No action required.

3. **COMMENT SOURCE**: Public/EPA

COMMENT: Council on Environmental Quality (CEQ) regulations (40 CFR 1502.15) require an EIS to describe the environment of the areas to be affected (or created) by the alternatives under consideration. The data and analysis in the draft report were found to be commensurate with the importance of the impacts, although EPA still has some general concerns about the potential impacts from use of a hopper dredge on marine threatened and endangered resources (e.g., such as the potential for entrainment of sea turtles associated with hopper dredges). EPA's specific concerns are the project's impacts to the green sea turtle, loggerhead sea turtle, Kemp's ridley sea turtle, and the leatherback sea turtle, which are all known to nest in the project vicinity. These species could be affected by initial project construction and periodic renourishment, and the sea turtles that occur in offshore waters may be affected by hopper dredges. EPA strongly recommends initial construction and periodic renourishment activities not be conducted during the sea turtle nesting season. EPA further recommends that hopper dredging not be conducted during months when water temperatures are warm and the various turtle species may be present.

RESPONSE: Comment Acknowledged. Section 3.02.4 of Appendix I (Biological Assessment) discusses in detail the potential impacts of the proposed action on nesting and in-water sea turtles, proposed commitments to reduce impacts, and subsequent effect determination. Section 4.00 (commitments to reduce impacts to listed species) includes specific commitments to avoid the sea turtle nesting season

during initial construction and periodic re-nourishment activities (commitment #4). Additionally, hopper dredging will be conducted during the winter months (1 December to 31 March) to avoid warm water periods when sea turtles may be present (commitment #1).

REPORT CHANGE: No action required.

4. **COMMENT SOURCE**: Public/EPA

COMMENT: EPA continues to have concerns about the project's impacts to the piping plover, which has been documented to feed along the 10-mile project reach. During the winter months the piping plover has been documented to be found in the surf zone. EPA strongly recommends the development and implementation of stringent construction criteria to ensure that the project does not affect the piping plover's foraging activities on the beach. EPA is particularly concerned that the piping plover's beach food resources may be affected by beach fill operations.

RESPONSE: Comment Acknowledged. Section 3.02.8 of Appendix I (Biological Assessment) discusses in detail the potential impacts of the proposed action on piping plovers and their foraging activities and subsequent effect determination. Beach placement of sand for this project during initial construction and each periodic nourishment interval is scheduled to avoid the breeding and nesting season as well as peak recruitment periods for benthic invertebrate forage base; however, short term impacts to foraging may occur. In summary, the long-term effects of the project may restore lost roosting and nesting habitat through the addition of beach fill; however, short-term impacts to foraging, sheltering, roosting habitat may occur during project construction.

REPORT CHANGE: No action required.

5. **COMMENT SOURCE**: Public/EPA

COMMENT: EPA recommends that the U.S. Fish and Wildlife Service and the National Marine Fisheries Service review and provide recent concurrence letters (to be included in the FEIS) regarding the adequacy of the Biological Assessment developed for this project pursuant to Section 7 (of the Endangered Species Act of 1973) and presented with the draft report.

RESPONSE: Concur. The USFWS and NMFS have reviewed the draft report and have provided there concurrence letters regarding the adequacy of the Biological Assessment pursuant to Section 7 of the ESA. Specifically, the USFWS has indicated that "overall, based on the information provided in the DEIS and BA, the USFWS believes that the proposed action is not likely to adversely affect federally listed species or their critical habitat as defined by the ESA of 1973, as amended. Therefore, the requirements of Section 7 (a)(2) of the ESA have been satisfied." The NMFS indicated the following: "NMFS agrees with the COE's determination that the proposed beach renourishment action, consisting (in part) of utilizing hopper dredges to mine offshore sand sources for deposition of sand onto North Carolina beaches (a 17-mile section extending from Topsail Beach/Surf City town limits to the northern end of Topsail Island) falls under the authority of the current NMFS South Atlantic regional biological opinion on hopper dredging of navigation channels and borrow areas in the southeastern United States, dated September 25, 1997 (i.e., SARBO). The SARBO is in the process of being revised and will eventually supersede the current opinion. The COE will abide by the revised SARBO when it is ultimately issued. Sea turtle or shortnose sturgeon takes resulting from the proposed dredging action when conducted under the RPMs and T&Cs of the SARBO are authorized and will be counted against the ITS take limit as set forth in the SARBO."

REPORT CHANGE: No action required.

6. **COMMENT SOURCE**: Public/EPA

COMMENT: As mentioned previously, we are also currently reviewing the FEIS for the adjacent project known as the "Relocation of New River Inlet Ebb Tide Channel Between North Topsail Beach and Onslow Beach, and the Placement of the Dredged Material Along the Ocean Shoreline of North Topsail Beach in Onslow County, NC." This FEIS describes a plan by the Town of North Topsail Beach to develop a non-Federal coastal storm damage reduction project for the parts of the town that lie within the Coastal Barrier Resources System (Topsail Unit, L06). EPA recommends careful coordination between the two projects to ensure that there are no conflicts between the Federal and non-Federal projects, either on the shoreline or in the borrow areas. Your draft report states that in the event that the non-Federal project is not in place when the Federal project begins, then the northern 2,000 ft of the dune and berm system will be replaced with a transition section. Your FEIS should include specific engineering details about what this 2,000 ft transition section would look like and how it may affect the overall NED Plan.

RESPONSE: Concur. Coordination between the two projects continues to occur to ensure that there are no conflicts between the Federal and non-Federal projects, either on the shoreline or in the borrow areas. Specific engineering and design details are not done until the PED (Pre-Construction Engineering and Design) phase of the study.

REPORT CHANGE: No action required.

7. **COMMENT SOURCE**: Public/EPA

COMMENT: We understand that the Agency Technical Review (ATR) was conducted in accordance with the Corps' "Peer Review of Decision Documents" process, and this means the proposed project "has been reviewed by Corps staff outside the originating office, conducted by a regional and national team of experts in the field, and coordinated by the National Planning Center of Expertise in Coastal Storm Damage Reduction, North Atlantic Division, U.S. Army Corps of Engineers." EPA recommends that the FEIS include all comments and responses developed as part of the ATR process.

RESPONSE: ATR occurs at several stages during the development of the feasibility report, and the report undergoes revisions at each stage, based on the comments. The final FEIS reflects all changes that were made in response to these comments. The Corps does not believe it will add to the report to include these comments with the report.

REPORT CHANGE: No action required.

8. **COMMENT SOURCE**: Public/EPA

COMMENT: We further understand that an "Independent External Peer Review" (IEPR) will be conducted (following the ATR) by a "non-USACE national team of experts in the field, and coordinated by the National Planning Center of Expertise in Coastal Storm Damage Reduction, North Atlantic Division, U.S. Army Corps of Engineers." EPA recommends that the FEIS include all comments and responses developed as part of the IEPR process.

RESPONSE: IEPR comments and USACE responses are made public separately from the publication of the FEIS.

REPORT CHANGE: No action required.

9. **COMMENT SOURCE**: Public/EPA

COMMENT: CEQ regulations (40 CFR 1502.14(a)) require that an EIS is to "rigorously explore and objectively evaluate all reasonable alternatives" for a proposed action. The regulations (40 CFR 1502.14(b)) further require that substantial treatment be made of each alternative considered in detail, including the proposed action. The draft report appropriately notes that study team considered both structural and non-structural measures. EPA recommends that the FEIS include complete details on the nonstructural measures that were considered, such as removal and relocation, as well as final summaries of the economic analyses (using recent economic data) that found these nonstructural measures to have greater costs than benefits.

RESPONSE: Concur. Details on the non-structural analysis were provided in Appendix P of the FEIS.

REPORT CHANGE: No action required.

10. **COMMENT SOURCE**: Public/EPA

COMMENT: The draft report appropriately assesses project risk, uncertainty, and consequences, and generally describes these with sufficient detail so that that "decisions can be made with knowledge of the degree of reliability of the estimated benefits and costs and of the effectiveness of alternative plans." EPA concurs that all recommendations made in the FEIS should be capable of being implemented through adaptive management, should future conditions warrant such. The draft report appropriately notes that "renourishment may be needed more often or less often, depending on the occurrence of large storms and accompanying erosion."

RESPONSE: Comment Acknowledged.

REPORT CHANGE: No action required.

11. **COMMENT SOURCE**: Public/EPA

COMMENT: To avoid conflicts, the project should be coordinated with monitoring efforts led by the North Carolina Recreational Water Quality Program (NCRWQ), which regularly tests these coastal waters in order to protect public health by monitoring and notifying the public when bacteriological standards for safe bodily contact are exceeded. Also, the project should be coordinated with the North Carolina Department of Environmental and Natural Resources, Division of Environmental Health, Shellfish Sanitation Section, which is also continually monitoring and classifying these coastal waters as to their suitability for shellfish harvesting for human consumption.

RESPONSE: Comment Acknowledged. Prior to commencement of construction activities, the Corps will coordinate with the NCWRQ as well as the NCDENR, shellfish sanitation section. Appropriate requirements will be incorporated into the project plans and specifications.

REPORT CHANGE: No action required.

12. **COMMENT SOURCE**: Public/EPA

COMMENT: The main channel of the Atlantic Intracoastal Waterway (AIWW) in North Carolina has been maintained by dredging for over 70 years to remove shoals that periodically develop. Some of the dredged material removed during maintenance activities is reported to be high quality beach sand. This material has been placed directly on nearby ocean beaches, or stockpiled in confined disposal areas near the shoreline of the AIWW. Other area sand sources are from dredging activities in the New Topsail Inlet and Connecting Channels, as well as the New River Inlet. EPA recommends that these sand sources be considered for renourishment activities for the 10-mile long project reach.

RESPONSE: Material available from the AIWW would be a very small amount compared to the size of the project, and would not be cost-effective for placement on Surf City/North Topsail Beach. This information has been added to section 5.06.3 of the FEIS.

REPORT CHANGE: No action required.

13. **COMMENT SOURCE**: Public/EPA

COMMENT: The FEIS should include complete supporting geotechnical information, especially representative boring logs and/or grain size analysis plots from soil borings conducted in the finalized borrow areas.

RESPONSE: Concur. Details on geotechnical information were included in Appendix C of the FEIS

REPORT CHANGE: No action required.

14. **COMMENT SOURCE**: Public/EPA

COMMENT: EPA recommends that areas with extensive hard bottom area and/or relatively low volumes of beach compatible material be ruled out as potential sources of borrow material for this project. Final selection of borrow areas should be based upon high volumes of accessible, beach quality sands. We recommend rigorous delineation of all hard bottom resources within each prospective borrow area before commencement of work in order to avoid potential impacts to hard bottom resources (particularly from hopper dredging activities). The State of North Carolina's hard bottom buffer rule language requires that dredging should not be conducted "on or within 500 meters of significant biological communities, such as high relief hard bottom areas." EPA supports the Corps' efforts to use divers to conduct ground truth confirmation in the potential borrow areas, as well as collecting sediment samples, conducting video documentation, and employing sidescan technology, all for the purpose of assisting with hard bottom avoidance.

RESPONSE: Concur. During the planning process borrow areas with extensive hard bottom and/or relatively low volumes of beach compatible material were ruled out as potential sources of borrow material for this project. Specifically, borrow areas I, K, M, and R were excluded as noted in Figure A-1 of the report. Additional borrow area refinement will occur during the PED stage of the study. Specific discussion of hard bottom within the proposed borrow areas as well as potential impacts and associated buffers and avoidance measures are discussed in Sections 2.01.10 and 8.01.8.2 of the report.

REPORT CHANGE: No action required.

15. **COMMENT SOURCE**: Public/EPA

COMMENT: EPA supports the on-going characterization of potential borrow areas during all 4 seasons in order to determine if there are significant differences in species composition and diversity for each sampling period.

RESPONSE: Comment Acknowledged.

REPORT CHANGE: No action required.

16. **COMMENT SOURCE**: Public/EPA

COMMENT: The FEIS should cite North Carolina Division of Marine Fisheries (NCDMF) commercial finfish and shellfish updated data (from 2009).

RESPONSE: Section 2.04.3 of the report has been updated to include the North Carolina Division of Marine Fisheries (NCDMF) commercial finfish and shellfish updated data (from 2009).

REPORT CHANGE: The beginning of the first paragraph of Section 2.04.3 of the report will be updated to include the following:

"According to the North Carolina commercial fish landings report produced annually by the North Carolina Division of Marine Fisheries (NCDMF), the commercial finfish harvest was up 17 percent from 2008-2009. However, the commercial shellfish harvest was down 7.3 million pounds in 2009 mostly due to a 43 percent decrease in shrimp harvest from 2009. Total commercial landings in 2009 were 68.6 million pounds which is about 2.5 million pounds lower than in 2008 (NCDMF, 2009). The NCDMF report approximately 136,000 pounds of commercial.....

Section 15.00 References should be updated to include:

North Carolina Division of Marine Fisheries. 2009. Annual Fisheries Bulletin – 2009 Commercial and Recreational Statistics. License and Statistics Section, Morehead City, NC. April 2010. http://www.ncfisheries.net/download/2009AnnualNC_FisheriesBulletin.pdf.

17. **COMMENT SOURCE**: Public/EPA

COMMENT: The FEIS should discuss efforts to protect the 937-foot long Surf City Ocean Pier during construction, as it is apparently located within the proposed beach fill area.

RESPONSE: During Planning Engineering and Design (PED) and prior to construction, the Corps will evaluate potential construction related concerns associated with placement of beach fill within the vicinity of the Surf City Ocean Pier.

REPORT CHANGE: No action required.

18. **COMMENT SOURCE**: Public/EPA

COMMENT: The draft report has a section reporting on the Administration's position on funding of coastal storm damage reduction projects. As this report was under development in 2008, this should be clarified (e.g., the current Administration?). We understand that the Office of Management and Budget (OMB) advises that "while the Water Resources Development Act of 1999 (WRDA 99) changed the cost-sharing formula for the long-term sand renourishment component of certain future shore protection projects," these changes did not go far enough considering the long-term cost of most of these projects. Further, because WRDA 99 delayed the effect of the change in cost sharing for up to a decade or more, it reportedly "did not address current constraints on Federal spending," and therefore the Administration intends to work with Congress to address these problems. However, EPA understands that until these issues are satisfactorily resolved, there will be no authorization of new shore protection projects "that involve significant long-term Federal investments beyond the initial construction of these projects, and will give new shore protection projects that are already authorized low priority for funding."

RESPONSE: Language regarding the "Administration's position" has been removed from the report.

REPORT CHANGE: No action required.

19. **COMMENT SOURCE**: Public/EPA

COMMENT: Finalized mitigation measures should be presented in the FEIS, to include specific measures recommended by U.S. Fish and Wildlife Service (USFWS) and National Marine Fisheries Service (NMFS) for protection of all threatened and endangered species. The finalized mitigation plan should include specific finalized protocols to be employed should any sea turtles be encountered during the dredging activity.

RESPONSE: Concur. All planning considerations and final mitigation measures recommended by the Corps and other state and federal resource agencies, including measures recommended by the USFWS and NMFS for protection of threatened and endangered species, have been included in Table 7.2 and Section 10.06.1 of the main report as well as Section 4.00 of Appendix I. The development of specific monitoring plans (i.e. hard bottom sedimentation monitoring and benthic invertebrate monitoring), as identified in the list of commitments to reduce environmental impacts, will be coordinated with the EPA and other state and federal resource agencies prior to implementation.

REPORT CHANGE: No action required.

NC Wildlife Resources Commission (NCWRC)

1. COMMENT SOURCE: Public/NC Wildlife Resources Commission (NCWRC)

COMMENT: The NCWRC recommends that all work to be conducted outside of the established moratoriums for nesting shorebirds (01 April-31 Aug) and nesting sea turtles (01 May - 15 Nov or until the last known nest hatches). Any encroachment in these time frames will increase the chances for significant, adverse impacts to important wildlife species and would require further consultation with NCWRC biologists before the project can proceed.

RESPONSE: Concur. The proposed 1 December through 31 March schedule for initial construction and each periodic nourishment events was planned around avoidance of resource impacts. Specifically, work will be conducted outside of the established moratoriums for nesting shorebirds (01 April-31 Aug) and nesting sea turtles (01 May - 15 November). Though not anticipated, in the event that these construction schedules are modified and encroach in these time frames, further consultation with NCWRC biologists will be initiated before the project can proceed.

REPORT CHANGE: No action required.

2. COMMENT SOURCE: Public/National Marine Fisheries Service

COMMENT: To reduce impacts to benthic invertebrates, the NCWRC supports staggering the renourishment areas so that the first renourishment event would start at the section or the project area where initial construction began; avoiding the most recent beach disposal area. Staggering these areas will allow a greater time for benthic invertebrates to adequately recover to sustainable levels.

RESPONSE: Concur. As discussed in the report, in order to allow a greater time for benthic invertebrates to adequately recover to sustainable levels, the proposed initial construction plan is to stagger the intervals of the initial construction beach fill template over the course of four years. Additionally, the first renourishment event would start at the section of the project where initial construction began.

REPORT CHANGE: No action required.

3. COMMENT SOURCE: Public/NC Wildlife Resources Commission (NCWRC)

COMMENT: The NCWRC requests that our recommendations be considered throughout the 50 years of this project and that any alterations to this plan be reviewed by NCWRC staff.

RESPONSE: Concur. All recommendations are considered throughout the 50 year life of this project. Though not anticipated, any alterations to this plan will be appropriately coordinated with NCWRC staff.

REPORT CHANGE: No action required.

NC Division of Water Quality

1. COMMENT SOURCE: Public/NC Division of Water Quality

COMMENT: The Division of Water Quality (DWQ) has no objections to the project as proposed as long as they comply with the dredging moratoriums and environmental monitoring discussed in the document.

RESPONSE: Concur

REPORT CHANGE: No Action Required.

NC Natural Heritage Program

1. COMMENT SOURCE: Public/NC Natural Heritage Program

COMMENT: The Federal and State Threatened sea beach amaranth (Amaranthus pumulus) is typically an annual that grows on accreting sand beaches, and thus is found mostly on ends of islands. As long as the dredging and beach renourishment can be done/completed within the December I to March 31 period, the impacts to the amaranth should be negligible.

RESPONSE: Concur

REPORT CHANGE: No action Required.

NC State Consistency Concurrence

NC Department of Environment and Natural Resources (NCDENR): NCWRC, DMF, Division of Parks and Recreation, Natural Heritage Program, DWQ, Division of Land Resources, DCM, SHPO, Shellfish Sanitation, Coastal Reserve, DWR (Water Projects Section), and County of Pender

1. COMMENT SOURCE: Public/State Consistency

COMMENT: The Applicant, prior to initiating any land or water disturbing activities, shall obtain a Section 401 Water Quality Certification from the NC Division of Water Quality for the proposed project. The Applicant shall comply with the requirements of the Section 401 Water Quality Certification. A copy of the certification shall be forwarded to DCM.

RESPONSE: Concur

REPORT CHANGE: Table 7.1 will be updated with the following:

"Prior to initiating any land or water disturbing activities, the Corps will obtain a Section 401 Water Quality Certification from the NC Division of Water Quality for the proposed project. The Corps will comply with the requirements of the Section 401 Water Quality Certification and will provide a copy of the certification to DCM"

2. COMMENT SOURCE: Public/State Consistency

COMMENT: The Applicant, prior to initiating any land disturbing activities, shall obtain the approval of the NC Division of Land Resources of an erosion and sedimentation control plan. The Applicant shall comply with the requirements of the approved erosion and sedimentation control plan. A copy of the plan approval shall be forwarded to DCM.

RESPONSE: Concur

REPORT CHANGE: Table 7.1 will be updated with the following:

"Prior to initiating any land disturbing activities, the Corps will obtain the approval of the NC Division of Land Resources of an erosion and sedimentation control plan. The Corps will comply with the requirements of the approved erosion and sedimentation control plan and a copy of the plan will be provided to DCM."

3. COMMENT SOURCE: Public/State Consistency

COMMENT: In order to protect nesting shorebirds, work will not be allowed from April 1st through August 31st of any year without the prior approval of the Division of Coastal Management, in consultation with the North Carolina Wildlife Resources Commission.

RESPONSE: Concur. The proposed 1 December through 31 March schedule for initial construction and each periodic nourishment events was planned around avoidance of resource impacts. Specifically, work will be conducted outside of the established moratoriums for nesting shorebirds (01 April-31 Aug). Though not anticipated, in the event that these construction schedules are modified and encroach in these time frames, the Corps will seek approval from the NC Division of Coastal Management in consultation with NCWRC biologists.

REPORT CHANGE: No action required.

4. COMMENT SOURCE: Public/State Consistency

COMMENT: In order to protect nesting sea turtles and their hatchlings, work will not be allowed from May 1st through November 15th (or until the last known nest hatches) of any year without the prior approval of the Division of Coastal Management, in consultation with the North Carolina Wildlife Resources Commission.

RESPONSE: Concur. The proposed 1 December through 31 March schedule for initial construction and each periodic nourishment events was planned around avoidance of resource impacts. Specifically, work will be conducted outside of the established moratoriums for nesting sea turtles (01 May - 15 November). Though not anticipated, in the event that these construction schedules are modified and encroach in these time frames, the Corps will seek approval from the NC Division of Coastal Management in consultation with NCWRC biologists.

REPORT CHANGE: No action required.

5. COMMENT SOURCE: Public/State Consistency

COMMENT: Only beach quality sand shall be used for this project. Should the dredging operations encounter sand deemed non-compatible with native grain size or sorting characteristics of the native beach, the dredge operator shall immediately cease operation and contact the DCM. Dredge operations will resume only after resolution of the issue of sand compatibility is achieved.

RESPONSE: Concur. Table 7.1 (Project Commitments) incorporates these commitments for assurance of sediment compatibility.

REPORT CHANGE: No action required.

6. COMMENT SOURCE: Public/State Consistency

COMMENT: The Applicant shall adhere to any mitigation measures described in the consistency submission and the *Draft Integrated Feasibility Report and Environmental Impact Statement, Coastal Storm Damage Reduction, Surf City and North Topsail Beach, North Carolina*" (August 2009) to the extent that they do not conflict with any of the conditions of concurrence stated above.

RESPONSE: Concur

REPORT CHANGE: No action required.

7. COMMENT SOURCE: Public/State Consistency

COMMENT: The North Carolina Wildlife Resources Commission (NCWRC) and the North Carolina Division of Marine Fisheries (NCDMF) are concerned about the impact of proposed dredging operations on benthic habitat. NCWRC recommend that during the four year initial construction event that beach nourishment activities be staggered to minimize the adverse effects on benthic invertebrates. Benthic invertebrates are an important food source for foraging shorebirds and many species of fish. To assure the availability of this food source, DCM recommends that the Corps, to the extent practical, implement the recommendations of the NCWRC and the NCDMF

RESPONSE: Concur. The proposed project, as currently written, incorporates these recommended measures in order minimize impacts to benthic invertebrates.

REPORT CHANGE: No action required.

United States Department of the Interior

MINERALS MANAGEMENT SERVICE
Washington, DC 20240

Colonel Jefferson Ryscavage
U.S. Army Corps of Engineers, Wilmington District
District Command
69 Darlington Avenue
Wilmington, North Carolina 28403-1343

MAR 5 - 2010

Dear Colonel Ryscavage:

The Minerals Management Service (MMS) appreciates the opportunity to review the U.S. Army Corps of Engineers' Draft Integrated Feasibility Report /Environmental Impact Statement (IFR/EIS), Coastal Storm Damage Reduction, Surf City and North Topsail Beach, North Carolina.

The draft IFR/EIS describes the Corps' proposal to construct a berm and dune along approximately 10 miles of oceanfront between Surf City and North Topsail Beach. The draft IFR/EIS identifies several borrow areas on the Outer Continental Shelf (OCS) that may be used to obtain sand for the proposed project. Since the MMS has jurisdiction over borrow areas located on the OCS, the MMS was designated as a cooperating agency for the environmental review of the proposed project. As a cooperating agency, the MMS may adopt and use the Final IFR/EIS to support future leasing decisions.

Please find our comments on the draft IFR/EIS enclosed. If you have any questions, please contact Geoffrey Wikel at (703) 787-1283 or by e-mail at Geoffrey.Wikel@mms.gov.

Sincerely,

James F. Bennett
Chief, Branch of Environmental Assessment

Enclosure

cc: Doug Piatkowski, Corps-SAW

TAKE PRIDE IN AMERICA

Draft Integrated Feasibility Report / Environmental Impact Statement Coastal Storm Damage Reduction, Surf City and North Topsail Beach, North Carolina (August 2009)		
Section No.	**Page No.**	**MMS Comment or Recommended Change**
		Consistent with the Council on Environmental Quality's (CEQ) Regulations for Implementing the Procedural Provisions of the National Environmental Policy Act, the Corps has combined the preparation of an Environmental Impact Statement (EIS) with a planning instrument. The draft Integrated Feasibility Report (IFR) and EIS integrate alternative development, engineering and economic analyses, and environmental review in a single document. In the draft document, the elements required in an EIS are presented in an atypical order, and the re-organization presents some fundamental challenges to the reader. For example, the reader must first read the Tentatively Selected Plan chapter (Chapter 7), the practical description of the proposed action, to fully comprehend the site-specific discussion of resources (e.g., *Hard Bottoms, Artificial Reefs, Birds*, etc.) in the Affected Environment chapter (Chapter 2). Environmental commitments are enumerated in Table 7.1 (Chapter 7) before the presentation of the impact analyses in the Environmental Effects chapter (Chapter 8). Therefore, the reader must first read the effects analyses to fully appreciate the need and purpose of the proposed mitigation. The MMS recommends the Corps prepare prefatory guidance to better orient the reader to the organization of the document. Alternatively, the Corps could insert the Affected Environment chapter after the Tentatively Selected Plan chapter and before the Environmental Effects chapter. Mitigation should be linked in a logical manner to the effects analysis.
		The MMS assumes the "without project" and "with project" engineering and economic analyses were prepared without consideration of the potential impacts of the proposed inlet management and beach fill proposals currently being considered under the Corps' Regulatory purview. The Corps should address if the proposed interim projects change any assumptions used as the basis for the existing engineering analyses (i.e., sediment transport and budget, beach profile and plan form design, fill equilibration, longevity, volume requirements, etc). If there are potential implications for "without project" and "with project" engineering considerations, the cascading effect to project economics and environmental effects should also be considered.

1525

Draft Integrated Feasibility Report / Environmental Impact Statement Coastal Storm Damage Reduction, Surf City and North Topsail Beach, North Carolina (August 2009)		
Section No.	**Page No.**	**MMS Comment or Recommended Change**
		The Environmental Effects chapter (Chapter 8) offers a robust discussion of the potential environmental impacts related to the Tentatively Selected Plan. In contrast, the document offers a limited discussion of potential impacts associated with other alternatives, including the no action alternative. Chapter 5 presents a conceptual comparison of the environmental effects of beach fill, non-structural, and no action alternatives. The MMS suggests the Corps clearly indicate which alternatives were dismissed and on what basis. Otherwise, the direct and indirect impacts of alternatives should be discussed in more detail and in context of their relative significance in the Environmental Effects chapter.
		Since most of the borrow areas identified for the proposed project are located on the Outer Continental Shelf (OCS), the MMS may need to authorize their use for initial and/or maintenance construction. The MMS, as a cooperating federal agency, may undertake a *connected action* (i.e., authorize use of the OCS borrow area) that is related, but unique from the Corps's proposed action (i.e., construction of the project). Consequently, the purpose and need of the MMS's proposed action is different. Ideally, the EIS should provide a more accurate description of the MMS's involvement under the Corps' proposed action. The MMS's proposed action is the issuance of a negotiated agreement pursuant to its authority under the Outer Continental Shelf Lands Act. The purpose of that action is to authorize the use of OCS sand (or other sediment) resources in beach nourishment and coastal restoration projects undertaken by federal, state or local government agencies, and/or in other federally authorized construction projects. The MMS's action will be needed because the Towns of Surf City and North Topsail Beach and the Corps submitted authorization requests to the MMS.
1.02	5	The study area description should more accurately describe the entire footprint of the proposed action, including the offshore borrow areas. Consider referencing Chapter 7 for a more complete description of the footprint of the proposed action. Similarly, the location map (Figure 1) should more clearly

1526

Draft Integrated Feasibility Report / Environmental Impact Statement Coastal Storm Damage Reduction, Surf City and North Topsail Beach, North Carolina (August 2009)		
Section No.	**Page No.**	**MMS Comment or Recommended Change**
		illustrate the footprint of proposed action, including the proposed borrow areas. Reference to Figure A-1 may be more appropriate. However, on Figure A-1, the beach fill zone should be clearly delineated. Inlets should be labeled. All figures and text references should use the same alongshore profile station or reach designations.
1.08		The feasibility study and proposed action should be presented in context of historical and proposed beach nourishment activities in the vicinity of Topsail Island. The Study Overview chapter should include a transparent and up-to-date discussion of historical and planned beneficial use projects (see 3.06), historical navigation and planned inlet management projects, as well as proposed Civil Works and Regulatory projects (see 7.04.2).
2.0	10	The introductory text to the Affected Environment chapter should be revised to indicate that the footprint of the proposed action is not limited to the sub-aerial beach, but includes the marine environment offshore the barrier island.
2.01	10	Pelagic and benthic sargassum should be addressed as an important biological resource in the marine environment.
2.0.2	12	The narrative description of the location of both New Topsail and New River Inlets is unclear. The MMS suggests referring to a figure to clarify the narrative.
2.01.7	16	The biological assessment discusses protected species that are likely to occur in the proposed project area. However, the draft IFR/EIS does not address other marine mammals without protection status, such as dolphin species, that are likely to be present and may be affected by the proposed action.
2.01.7 / 2.02.4 / 8.01.5		The description of and potential impacts to protected marine mammals and sea turtles are incorporated by reference to the biological assessment. The MMS recommends a brief summary be provided in the EIS, or, the biological assessment should be included as a physical attachment to the Final IFR/EIS.
2.01.9	17-18	A detailed discussion of habitat association between benthic populations and habitat type (RSDs, hard bottom, sand and muddy substrate) should be provided. The benthic resources or hard bottom descriptions should include a detailed description of the occurrence and quality of benthic sargassum,

Draft Integrated Feasibility Report / Environmental Impact Statement Coastal Storm Damage Reduction, Surf City and North Topsail Beach, North Carolina (August 2009)		
Section No.	**Page No.**	**MMS Comment or Recommended Change**
		corals, and sponges. The equivalent information requested is provided in 8.01.8.3 and 8.01.8.5 of the Environmental Effects chapter.
2.01.10	20	Reference Figure A-1 to illustrate historical SEAMAP hard bottom observations.
2.01.10	23-30	The detailed narrative discussing the suite of investigations and the results of those investigations used to support assessment of hard bottom areas needs to be better synthesized. The synthesis should address the location, type, nature, and quality of hard bottom habitat and benthic communities in an integrated manner. The presentation of the chronological investigation is better suited for inclusion in another appendix. Likewise, the discussion of buffer requirements should be relegated to the Environmental Effects chapter in context of potential effects and effects-reducing mitigation measures. The MMS recommends the Corps provide a series of figures that clearly illustrate 1) the spatial extent of hard bottom areas and 2) the quality of habitat and diversity of supported biological communities. The description of nearshore hard bottom areas should not be limited to the offshore immediately east of the project area, but should include hard bottom areas identified offshore northern Topsail Island. Also, the Corps should indicate that the calculated depth of closure is derived from "averaged" incident wave conditions, and/or a relative determination of nominal vertical change from a series of cross-shore beach profiles. Depth of closure is documented to be event-dependent (Nicholls et al., 1998). It should be stated that cross-shore sediment transport will likely occur beyond the depth of closure, but ultimately depends on the forcing conditions and the profile state at the time of the forcing event.
2.01.11	34	The draft IFR/EIS references a 2004 document as the source for information on federally managed fish species and their associated habitat. The fishery management plans are authoritative sources, and most plans have been updated and new information added since 2004. The MMS recommends that the Corps consult with the National Marine Fisheries Service on the completeness of the species and HAPCs lists. Note that the Atlantic Highly Migratory Species Fishery Management Plan (2006) is implemented by

1528

Draft Integrated Feasibility Report / Environmental Impact Statement Coastal Storm Damage Reduction, Surf City and North Topsail Beach, North Carolina (August 2009)		
Section No.	**Page No.**	**MMS Comment or Recommended Change**
		the Secretarial Council.
2.01.11	34	The description of benthic seagrass, coral, and hard bottom HAPC in the project area is limited. The appropriate sections of the document concerning these sensitive resources should be cross-referenced.
2.02.3	47	The MMS recommends a more complete discussion of bird utilization of hard bottom areas and other offshore habitat.
2.02.3	51	The document should reference and include updated information from bird surveys completed in support of the North Topsail Shore Protection Project.
2.02.3	47	Table 2.7 should indicate the federal status (including candidate listing) for respective birds.
2.03	55-57	It is recommended that physical resources be addressed prior to the biological resources to provide for appropriate environmental context. The description of the geological and physical oceanographic environment should be presented prior to the discussion of shoreline and sand transport to provide for appropriate geological context. The description of the geological environment should be expanded referencing relevant material provided in the discussion of hard bottom habitat (USACE, 2003; USACE 2004a). The Corps should describe the dominant physical processes occurring offshore, especially those processes responsible for the maintenance of sorted bed forms and the ephemeral exposure of hard bottom.
2.05 / 8.06	60-64 / 178-179	The Corps does not fully address the potential for prehistoric sites within the survey area. The MMS recommends that the following tasks relating to prehistoric site potential be addressed: 1. review current literature on late Pleistocene and Holocene geology, paleogeography, and sea level change in the area; marine and coastal prehistory; and previous archaeological resource reports in the area if available. 2. discuss relict geomorphic features and their archaeological potential that includes the type, age, and association of the mapped features; the acoustic characteristics of channels and their

1529

Draft Integrated Feasibility Report / Environmental Impact Statement Coastal Storm Damage Reduction, Surf City and North Topsail Beach, North Carolina (August 2009)		
Section No.	**Page No.**	**MMS Comment or Recommended Change**
		fill material; evidence for preservation or erosion of channel margins; evidence for more than one generation of fluvial downcutting; and the sea level curves used in the assessment. 3. discuss, based on the capabilities of current technology in relation to the thickness and composition of sediments overlying the area of a potential site, the potential for identification and evaluation of buried prehistoric sites. The analysis for potential prehistoric sites was not included in the survey report, *Archaeological Remote Sensing Survey of Topsail and West Onslow Beaches Offshore Borrow Areas* (December 2004), used as the basis for the majority of the cultural resources material within the draft IFR/EIS. Furthermore, the cultural resource sections (2.05 and 8.06) do not adequately discuss the changes that occurred during the Holocene period with respect to exposed lands on the outer continental shelf (OCS) and sea level rise, and how prehistoric peoples might have interacted with the landscape that is now inundated. The DEIS should incorporate information that summarizes the potential for prehistoric sites within the project area. There was geophysical data collected via sub-bottom profilers and vibracores within the project area (Appendices C0-C3 Geotechnical Analysis). With archaeological interpretation, this information could provide valuable insight into the paleogeography of the area, the effects of Holocene transgression on this landscape, and the potential for prehistoric site preservation. Within Section 2.05 (Cultural Resources, p. 61), the following paragraph should be expanded to provide additional context and references to the scientific literature: To date, there are few indications that Native American populations made significant use of ocean-side resources. Indeed, the intensive use of the sounds may indicate that resources there were so plentiful that an interest in exploiting the open-ocean never developed.

1530

Draft Integrated Feasibility Report / Environmental Impact Statement Coastal Storm Damage Reduction, Surf City and North Topsail Beach, North Carolina (August 2009)		
Section No.	**Page No.**	**MMS Comment or Recommended Change**
		Within Section 8.06 (Cultural Resources, p. 178), the following sentences should be expanded to provide additional context and references to the scientific literature: No prehistoric sites were specifically considered in the survey. While there has been some success developing upland-offshore site location correlations in Florida and perhaps elsewhere, the methodology is not very well developed for sites within the Carolinas region, nor are there a significant number of upland locations that could be used to model settlement in now inundated areas. In Section 8.06 (Cultural Resources, p. 178-179), the Corps discusses the possibility of having UAB (specify acronym incidentally) archaeologists monitoring the dredging activities. The MMS suggests that this might not be the most efficient use of UAB archaeologists' time and might create a burden on the State of North Carolina. MMS does request, however, that a monitoring protocol be implemented, with clear instructions on reporting and avoidance of prehistoric or historic sites that might be encountered during the dredging operations. This information, or reference to the applicable protocols, should be included in the DEIS (perhaps in Section 10.07). [Perhaps language similar to the Archaeological Discoveries clause in MMS' NTL No. 2008-G05 (http://www.gomr.mms.gov/homepg/regulate/regs/ntls/2008NTLs/08-g05.pdf)]
2.05	60-64	There is no discussion of the potential for archaeological resources in the vicinity of pump-out locations and pipeline corridors, and the likely areas for those operations are not identified. Consideration of these areas may be important as they are subject to bottom disturbing activities such as anchoring, anchor drag, and pipeline emplacement.
2.07		Ambient and anthropogenic noise in the marine environment is not described.
3.02	69	Figure A-7 does not show shoreline change as indicated in the narrative.
5.04	87-88	The assertion that the "no action plan" or "no action alternative" has no implication for welfare economics (i.e., costs and benefits are zero) may need to be clarified. Since the economic analysis did

Draft Integrated Feasibility Report / Environmental Impact Statement Coastal Storm Damage Reduction, Surf City and North Topsail Beach, North Carolina (August 2009)		
Section No.	**Page No.**	**MMS Comment or Recommended Change**
		not address non-use or non-market valuation of benefits (e.g., improved or reduced ecosystem services), this may not be an accurate statement. The CEQ has proposed systematic changes to the *Principles and Guidelines* for such water resource projects, suggesting that both monetary (use and non-use) and non-monetary benefits should be considered in cost benefit analyses. The assertion in question should also be revised to indicate that the no action alternative was evaluated for environmental purposes, but not for engineering or economic purposes.
5.06.4	97	Table 5.4 does not address the full suite of potential impacts from the range of beach fill and non-structural alternatives proposed, including potential impacts to physical processes, air quality, noise, etc.
7.03.6	106-112	The mitigation measures enumerated should be linked to the effects analysis. The requirement to monitor turbidity levels appears to have been excluded.
7.04.2	117	The description mis-identifies the borrow areas proposed for the regulatory projects. The analysis of volume requirements across federal and non-federal projects is also inaccurate.
7.06.2	120	A plan for pump-out and pipeline conveyance operations is not well articulated. It is presumed that the hopper dredge will transfer dredged material through pump-outs located immediately offshore the placement site. Ideally, pump-out locations and pipeline corridors would be identified to illustrate the spatial relationship to any sensitive habitat, archaeological resources, etc.
8.01.7	148	The Corps' conclusion that offshore dredging and/or nearshore placement operations will not have any adverse physical impact on hard bottom areas may require clarification or re-phrasing. Based on its review of the substantial analyses undertaken by the Corps and affiliated contractors, the MMS prefers language that suggests impacts will occur but will not likely exceed natural sedimentation and burial, provided strict adherence to buffer requirements for all offshore activities. The dredging buffer should be applied consistently to all vessel activities, including anchoring and other bottom-disturbing activities by tugs and support vessels. The Corps should consider the potential effects of the proposed action on alongshore and across-shore sediment transport processes and any implications for hard

Draft Integrated Feasibility Report / Environmental Impact Statement Coastal Storm Damage Reduction, Surf City and North Topsail Beach, North Carolina (August 2009)		
Section No.	**Page No.**	**MMS Comment or Recommended Change**
		bottom areas identified by Coastal Planning and Engineering immediately north of the project area. Given the ephemeral exposure and burial of hard bottom areas, it is probable that the seafloor expression and configuration of hard bottom areas (as mapped from existing remote sensing / diver observations) will change prior to construction in 2018. Coastal Planning and Engineering's geophysical investigations and diver observations document a similar phenomena offshore the northern reaches of Topsail Island. The MMS recommends the Corps consider the appropriateness of additional mitigation that would require borrow area clearance via a geophysical survey immediately before dredging. Since a pre-dredge bathymetric survey is commonplace and typically required by the MMS, deploying side scan sonar would not constitute much of an additional cost to provide additional assurance that impacts to hard bottom areas would be avoided to the extent possible.
8.01.8.5	168	The Corps' conclusion that there will be no impacts to benthic sargassum from dredging operations is not supported especially since benthic sargassum was documented to occur in most of the offshore borrow areas.
8.01	145-167	The Corps should discuss the potential benefits/costs of a borrow area management plan that requires the rotational use of borrow areas over initial and maintenance construction cycles as a means to mitigate cumulative effects to benthic communities and habitat.
8.03	174	Section 8.03 presents a limited discussion of the potential impacts to physical processes resulting from offshore bathymetric modification, including wave transformation, changes in flow regime, and changes in sediment transport processes. The assertion that incident waves will not be substantively transformed when propagating over the modified seafloor should be supported by appropriate reference(s).
8.08.1	181	The emission inventory presented is based on the incorrect assumption that each of the four windows of initial construction will require 2 million cubic yards of sand. Since the initial fill requirement is approximately 12 million cubic yards, approximately 3 million cubic yards will be dredged during each

Draft Integrated Feasibility Report / Environmental Impact Statement Coastal Storm Damage Reduction, Surf City and North Topsail Beach, North Carolina (August 2009)		
Section No.	**Page No.**	**MMS Comment or Recommended Change**
		cycle.
8.08.1	182	The Environmental Effects chapter does not discuss the potential noise-related impacts of offshore dredging operations on marine mammals, sea turtles, and fish. The MMS refers the Corps to the following report: "A generic investigation into noise profiles of marine dredging in relation to the acoustic sensitivity of the marine fauna in UK waters with particular emphasis on aggregate dredging" (Thomsen et al., 2009).
8.08.3	183-184	Draghead screening may be necessary to reduce the risk of ordnance entrainment and any unintended consequences related to ordnance re-location onto the sub-aerial beach. Recent experiences with the dredging and placement of ordnance have occurred in Sandbridge Beach, VA, Bethany Beach, DE, and Long Beach Island, NJ. Placement of ordnance, or the risk of placement, can lead to serious public safety concerns and/or perception problems.
10	191-192	The Corps has "lead agency" status for Section 7 and EFH consultations/coordination, and as "lead agency", the Corps should notify NMFS HCD, NMFS PRD, and FWS of MMS's involvement in the proposed action.
	A-1	Appendix A-1 should be revised to accurately display all hard bottom habitat by relief type. Buffers should be indicated for each relief type on the map, not just high quality. If known, the pump-out locations and pipeline corridors should be identified. The hard bottom habitat identified immediately north of the project area should be added to the map.

1534

UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL MARINE FISHERIES SERVICE

Southeast Regional Office
263 13th Avenue South
St. Petersburg, Florida 33701-5511
(727) 824-5317; FAX (727) 824-5300

March 8, 2010 F/SER4:RS/pw

(Sent via Electronic Mail)

Colonel Jefferson Ryscavage
District Engineer, Wilmington District
Department of the Army, Corps of Engineers
P.O. Box 1890
Wilmington, North Carolina 28402-1890

Attention: Ms Jan Brodmerkel, Project Manager

Dear Colonel Ryscavage:

NOAA's National Marine Fisheries Service (NMFS) reviewed the *Draft Feasibility Integrated Report and Environment Impact Statement for Coastal Damage Reduction, Surf City and North Topsail Beach, North Carolina* (DEIS), dated August 2009, prepared by the Wilmington District, and the accompanying letter dated January 13, 2010, requesting consultation under the essential fish habitat (EFH) provisions of the Magnuson-Stevens Act. The Wilmington District is the lead agency in development of the DEIS and EFH consultation, and the US Minerals Management Services (MMS) is a cooperating agency due to the inclusion of borrow areas within federal waters. The DEIS examines options for reducing erosion along the shoreline of the Town of Surf City and the Town of North Topsail Beach (collectively Towns) on Topsail Island, Pender and Onslow Counties, North Carolina. The DEIS includes a preferred plan and discussion of potential impacts to EFH, and the Wilmington District and MMS tentatively conclude in DEIS section 8.01.8.11 that impacts from the project to EFH and federally managed fishery species are expected to be minor on an individual and cumulative effects basis. As the nation's federal trustee for the conservation and management of marine, estuarine, and anadromous fishery resources, the following comments and recommendations are provided pursuant to authorities of the Fish and Wildlife Coordination Act and the Magnuson-Stevens Fishery Conservation and Management Act (Magnuson-Stevens Act).

Project Description
The principle purpose of the project would be to reduce damages associated with coastal storms and beach erosion; the analysis period is 50 years. Alternatives considered include various combinations of dunes and berms and the "no-action" alternative. After consideration of the costs, benefits, and environmental consequences, the District proposes to construct the plan they

believe has the greatest net National Economic Development (NED) benefit. At this time, the Towns have not identified their preferred plan; therefore, the NED plan is currently the recommended plan; NMFS assumes that the District would coordinate with the agencies should any option other than the NED plan move forward.

The NED plan requires about 11.5 million cubic yards of borrow material during initial construction, averaging 220 cubic yards per linear foot over approximately 10 miles of ocean front beach (including the Town of Surf City and the southern section of the Town of North Topsail Beach) and consists of a sand dune constructed to an elevation of 15 feet NGVD (National Geodetic Vertical Datum), fronted by a 50-foot wide beach berm constructed to an elevation of 7 feet NGVD. The northern portion of the Town of North Topsail Beach is separated from the southern section by an area designated as a Coastal Barrier Resource Area (CBRA); the CBRA section, in principle, would not be directly affected by the proposed federal project. At the project's terminal ends, the beach fill sections would gradually transition to join with the unaltered beach.

Volume requirements for the 4-year nourishment cycle are about 1.6 million cubic yards of borrow material; in total, about 31.1 million cubic yards of borrow material would be required for the 50-year project. These estimated volumes are 12 percent greater than the in-place volumes to account for losses during construction. The material would be pumped to the beach from hopper dredges and shaped on the beach by earth moving equipment. The construction profile would extend seaward of the design (equilibrium) profile by 100 to 200 feet to cover anticipated sand movement during and immediately following construction. The anticipated construction plan is to use two hopper dredges during four separate construction seasons to complete the initial project; maintenance of the berm on a 4-year cycles is expected to require two hopper dredges in one construction season. Environmental windows to protect sea turtles from limit the construction season to December 1 to March 31.

Sixteen borrow areas have been identified for the project. These borrow areas include 10 identified for the Surf City/North Topsail Beach project and six borrow areas identified for the Topsail Beach federal project. These areas are typically between 1 and 6 miles offshore and have pre-dredge bottom depths between 35 and 50 feet. Extensive geophysical investigations were conducted to identify live/hardbottom in and near the borrow areas. Buffers of 500 meters (1,640 feet) would be established for high- and moderate-relief live/hardbottom and 122 meters (400 feet) would be established for low-relief hard bottom.

General Comments on the DEIS
The DEIS adequately describes the project alternatives currently under consideration and the basis for selecting the NED plan as the preferred alternative. As noted earlier, NMFS assumes that the District would reinitiate EFH coordination with NMFS should any option other than the NED plan move forward.

The DEIS examines a range of alternative borrow sites and beach fill configurations, addressing both their benefits and problematic issues. NMFS agrees with the District that use of the offshore borrow areas is more appropriate than using shoals associated with New River Inlet. In addition, the DEIS adequately describes the range of marine and estuarine habitats and

associated fishery resources found in the project area. The project would be located in highly productive marine and estuarine environments that support commercial and recreational fisheries, some recognized as aquatic resources of national importance. While NMFS is pleased the DEIS addresses several environmental concerns, including potential impacts to nearshore hardbottom habitats, pipeline corridors and other key project details are unknown at this time. NMFS requests that the District continue to coordinate with us as construction-level detail is developed to ensure that any additional opportunities to avoid or minimize impacts to NOAA trust resources are fully considered.

Specific Comments

Section 2.01.11 – [Affeeted Environment] Essential Fish Habitat

The DEIS provides an adequate overview of EFH and associated species managed by the South Atlantic Fishery Management Council, Mid-Atlantic Fishery Management Council, and NMFS. The discussion of impacts to EFH meets the information requirement of 50 CFR 600.920(e).

Section 7.03.6 – Environmental Monitoring and Other Commitments

Table 7.1 lists 30 commitments to reduce environmental impacts. Three commitments, (18, 19, and 20) address benthic invertebrates, many of which serve as a forage base for fishery species. Commitments 19 and 20 deal with the timing of construction. NMFS agrees that limiting construction to the period between December 1 and March 31 would minimize impacts to fishery species by avoiding the peak recruitment and abundance times for surf zone fish and benthic invertebrates (commitment 18). However, we are concerned that other than the brief mention in Table 7.1 of this construction window being associated with minimizing impacts to fishery resources, the rationale for the window elsewhere in the DEIS is based on minimizing impacts to sea turtles, suggesting the window may be relaxed should alternate means to protect sea turtles be found (e.g., use of cutterhead pipeline dredge). From EFH and fisheries perspectives, deviating from a window of November 15 to March 31 would not be acceptable, and NMFS requests the District reinitiate EFH consultation with NMFS should any in-water work be proposed outside this time period.

Commitment 19 and corresponding text on page 106 briefly describe a monitoring program that would evaluate project impacts to benthic invertebrates. NMFS requests the District coordinate with us during the further develop of the monitoring program, and that this coordination occur well in advance of baseline sampling.

Three commitments (21, 22, and 23) address live/hardbottom habitat. The District proposes to implement a 122-meter (400 feet) dredging buffer around the low relief hard bottom (less than 0.5 meters [1.6 feet]) identified by MATER in the offshore borrow sites and 500-meter (1640 feet) buffer for high-relief hard bottom as defined within the state rule language (commitment 21 and page 27). NMFS requests the District coordinate with NMFS during development of the monitoring plan for sedimentation impacts (commitment 23).

Section 7.10.4 – [The Tentatively Selected Plan] Risk and Uncertainty in the Sea Level Rise Assumptions

The second paragraph in the section addresses recommendations by the National Research Council in their 1987 report *Responding to Changes in Sea Level.* The DEIS should be revised

to reflect the latest scientific consensus on expected rates of sea level rise for the project area. In January 2010, the North Carolina Division of Coastal Management accepted the recommendations of the state's Science Advisory Panel and is planning for a 1 meter (3.3 feet) increase in sea level by 2100. A similar rate has been adopted for planning purposes by the states of Florida, Maine, and Maryland. This is a substantial increase in the rate of sea level rise experienced over the last 25 to 30 years, upon which the conclusions of the DEIS are based. In addition, in February 2010, a group of scientists from the federal government and academia that had previously disagreed about the effect of global warming on hurricanes published a paper agreeing that there will likely be fewer, but stronger, hurricanes in the future[1]. Given the frequency and scope of impact which North Topsail Island has experienced from past hurricanes, it seems likely that the area will experience stronger storms in the next few decades.

Section 8.01.8.11 – [Environmental Effects] Impact Summary for Essential Fish Habitat and 8.09 Summary of Cumulative Effects

In section 8.01.8.11, the District indicates the "impacts [from the project] are expected to be minor on an individual and cumulative effects basis"; a determination by the District is required by 50 CFR 600920(e)(3)(iii). NMFS agrees the District has taken significant steps towards avoiding and minimizing impacts to EFH and fishery species from this project. However, we do not agree that the cumulative effect of the several beach nourish projects currently underway or under review also is minimal. As noted in our comment letters on these projects, NMFS has concerns over borrow sites that are not the least damaging practicable alternative (e.g., Town of North Topsail Beach, Action ID No. 2005-00344-067) or dredging outside recommended seasonal restrictions solely for economic reasons (e.g., Town of Nags Head, Action ID No. 2006-40282).

Conservation Recommendation

NMFS appreciates that the plans described in the DEIS include substantive measures to avoid and minimize impacts to EFH and federally managed fishery species. Beach nourishment, however, is an inherently disruptive action to EFH. Section 305(b)(4)(A) of the Magnuson-Stevens Act requires NMFS to provide EFH conservation recommendations when an activity is expected to adversely impact EFH. Based on this requirement, NMFS provides the following:

EFH Conservation Recommendations

- Before construction begins, the District shall provide NMFS with a map and description of the pipeline corridors relative to live/hardbottom habitats. The description shall include measures the District would take to ensure minimal impacts would occur to NOAA trust resources.
- The District shall coordinate with NMFS on the final design of the sampling programs for examining impacts to benthic invertebrate communities and sedimentation on live/hardbottom areas; this coordination shall occur well in advance of baseline sampling.
- The District shall reinitiate EFH consultation with the NMFS Habitat Conservation Division should any in-water work be proposed outside the period of November 15 to March 31.

[1] Thomas R. Knutson, John L. McBride, Johnny Chan, Kerry Emanuel, Greg Holland, Chris Landsea, Isaac Held, James P. Kossin, A. K. Srivastava, and Masato Sugi. 2010. Tropical cyclones and climate change. Nature Geoscience 3: 157-163

Section 305(b)(4)(B) of the Magnuson-Stevens Act and its implementing regulations at 50 CFR 600.920(k), requires your office to provide a written response to our EFH recommendations within 30 days of receipt. If it is not possible to provide a substantive response within 30 days, in accordance with our "findings' with your Planning Functions Branch, an interim response should be provided to NMFS. A detail response must then be provided prior to final approval of the action. Your detail response must include a description of measures proposed by your agency to avoid, mitigate, or offset the adverse impacts of the activity. If your response is inconsistent with our EFH conservation recommendations, your must provide a substantive discussion justifying the reasons for not following the recommendation. The detail response should be received by the NMFS at least ten days prior to final approval of the action.

These comments do not satisfy your consultation responsibilities under Section 7 of the Endangered Species Act of 1973, as amended. If any activity "may effect" listed sea turtles and marine mammals and their habitats under NMFS purview, consultation should be initiated with our Protected Species Division at the letterhead address.

Thank you for the opportunity to provide these comments. Related questions or comments should be directed to the attention of Mr. Ronald Sechler at our Beaufort Field Office, 101 Pivers Island Road, Beaufort, North Carolina 28516-9722, or at (252) 728-5090.

Sincerely,



/ for

Miles M. Croom
Assistant Regional Administrator
Habitat Conservation Division

COE, Jan.P.Brodmerkel@usace.army.mil
USFWS, Howard Hall@fws.gov
SAFMC, Roger.Pugiliese@samfc.net
NCDCM, Doug.Huggett@ncmail.net
EPA, Fox.Rebecca@epa.gov
NOAA PPI, PPI.Nepa@noaa.gov
F, nmfs.hq.nepa@noaa.gov
F/SER, nmfs.ser.eis@noaa.gov
F/SER47, Ron.Sechler@noaa.gov

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION 4
ATLANTA FEDERAL CENTER
61 FORSYTH STREET
ATLANTA, GEORGIA 30303-8960

February 24, 2010

Mr. Glenn McIntosh
Project Manager
U.S. Army Corps of Engineers
Post Office Box 1890
Wilmington, North Carolina 28402-1890

Subject: **Comments on the Draft Integrated Feasibility Report and Environmental Impact Statement (EIS) for Coastal Storm Damage Reduction for Surf City and North Topsail Beach, North Carolina (report dated August 2009; received January 14, 2010) CEQ Number: 20100010; ERP Number: COE-E39079-NC**

Dear Mr. McIntosh:

Pursuant to Section 309 of the Clean Air Act (CAA) and Section 102(2)(C) of the National Environmental Policy Act (NEPA), the U.S. Environmental Protection Agency (EPA) Region 4 has reviewed the combined Draft Integrated Feasibility Report and Environmental Impact Statement (EIS) for Coastal Storm Damage Reduction for Surf City and North Topsail Beach, North Carolina, which we received on January 14, 2010. The draft combined report was issued by the Wilmington District of the US Army Corps of Engineers (Corps), and was intended to comply with the National Environmental Policy Act (NEPA), and therefore a separate EIS has not been provided. The draft document that we were provided has been termed "a fully-integrated report" that is intended to comply with all NEPA requirements, as well as the requirements of the Corps (and Federal) water resources planning process.

We understand that the purpose of the combined Draft Integrated Feasibility Report and EIS is to evaluate coastal storm damage reduction for the Towns of Surf City and North Topsail Beach, NC, and then "develop the most suitable plan of damage reduction for the present and future conditions" for the selected 50-year period of analysis. Topsail Island is on the southeastern North Carolina coast, and (from south to north) the three towns on the island are Topsail Beach, Surf City and North Topsail Beach. The primary study area for the report we reviewed includes the towns of Surf City and North Topsail Beach and the associated nearby borrow sites. We understand that this report was authorized by two U.S. House Committee on Transportation and Infrastructure resolutions dated February 16, 2000 and April 11, 2000, and that a General Reevaluation Report is also currently being completed for the Town of Topsail Beach under a separate authority.

The Wilmington District study team appropriately included representatives of Federal, State, and local governments, in an effort "to identify cost-effective and

environmentally- and technically-sound alternatives to reduce damages within the two towns, and to the adjacent shoreline." The process reportedly integrated the Corps' "Twelve Actions for Change", in all aspects of the NEPA process. The study effort appropriately identified a "National Economic Development" (NED) Plan, which is formulated to "maximize net benefits through reduction of future storm damages." No Locally Preferred Plan was reportedly suggested, and construction of the NED Plan is the Corps' tentatively recommended plan of improvement. The study we reviewed concluded that "the most practicable plan" of damage reduction for the primary study area is a "berm and dune project extending along approximately 10 miles of the oceanfront." The southern limit of the project is the boundary between Topsail Beach and Surf City, while the northern limit is within North Topsail Beach at the southern edge of the Coastal Barrier Resources System (Topsail Unit, L06).

The draft report appropriately included a stated "purpose and need" for the project, to include the "reduction of damages associated with coastal storm events and beach erosion," as well as "enhancing the beach strand available for recreation use and providing needed habitat for a variety of plants and animals." The draft report also appropriately included an analysis of various measures and plans, and then recommended selection of the plan with the highest net benefits while determining that the improvement is justified under current planning criteria and policies. The tentatively selected NED Plan consists of a sand dune system constructed to an elevation of 15 feet above the National Geodetic Vertical Datum (NGVD), fronted by a 50-foot wide beach berm constructed to an elevation of 7 feet above NGVD, with the berm and dune extending along a reach of 52,150 feet in length (about 10 miles). This plan is identified among the other alternatives as "Plan 1550."

The draft report appropriately followed detailed guidance provided in the U.S. Army Corps of Engineers Planning Guidance Notebook (Engineer Regulation 1105-2-100) for studies of water and related land resources. This guidance is "based upon the Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies that were developed pursuant to Section 103 of the Water Resources Planning Act (P.L. 89-80) and Executive Order 11747, which were approved by the U.S. Water Resources Council in 1982 and by the President in 1983." The draft report also appropriately references a number of prior studies conducted in the Topsail Island area, including engineering, planning, and environmental reports. These studies have addressed coastal storm damage reduction as well as navigational needs.

An economic analysis was appropriately conducted as part of the study, and a Benefit/Cost Ratio has been calculated (BCR = 3.7) for the tentatively recommended plan (based upon October 2008 price levels). First costs of the project are currently estimated at $118,000,000, and renourishment costs at 4-year intervals are estimated to be $17,600,000. Expected annual costs are estimated at $10,900,000, with expected annual benefits estimated at $40,000,000 ($16,900,000 of these annual benefits are coastal storm damage reduction benefits, $20,000,000 are recreation benefits and $3,100,000 are benefits during construction). The baseline cost estimate for construction in FY2015 is reported to be $126,000,000.

The following are EPA's comments on the Draft Integrated Feasibility Report and the EIS:

- We are currently reviewing the Final Environmental Impact Statement (FEIS) for the proposed project adjacent to this one, known officially as the "Relocation of New River Inlet Ebb Tide Channel Between North Topsail Beach and Onslow Beach, and the Placement of the Dredged Material Along the Ocean Shoreline of North Topsail Beach in Onslow County, NC."
- Based upon the recommendations regarding use of public funds for the reduction of damages along this shoreline, the Sponsors have reportedly agreed to provide public access and parking in accordance with Corps guidelines, at "intervals of no more than a half mile, throughout Surf City and the reach of North Topsail Beach benefitted by the cost-shared project." EPA recommends that the FEIS include an excerpt(s) from the Corps guidelines about public access and parking to ensure that the project interval "of no more than a half mile" meets these guidelines.
- Council on Environmental Quality (CEQ) regulations (40 CFR 1502.15) require an EIS to describe the environment of the areas to be affected (or created) by the alternatives under consideration. The data and analysis in the draft report were found to be commensurate with the importance of the impacts, although EPA still has some general concerns about the potential impacts from use of a hopper dredge on marine threatened and endangered resources (e.g., such as the potential for entrainment of sea turtles associated with hopper dredges). EPA's specific concerns are the project's impacts to the green sea turtle, loggerhead sea turtle, Kemp's ridley sea turtle, and the leatherback sea turtle, which are all known to nest in the project vicinity. These species could be affected by initial project construction and periodic renourishment, and the sea turtles that occur in offshore waters may be affected by hopper dredges. EPA strongly recommends initial construction and periodic renourishment activities not be conducted during the sea turtle nesting season. EPA further recommends that hopper dredging not be conducted during months when water temperatures are warm and the various turtle species may be present.
- EPA continues to have concerns about the project's impacts to the piping plover, which has been documented to feed along the 10-mile project reach. During the winter months the piping plover has been documented to be found in the surf zone. EPA strongly recommends the development and implementation of stringent construction criteria to ensure that the project does not affect the piping plover's foraging activities on the beach. EPA is particularly concerned that the piping plover's beach food resources may be affected by beachfill operations.
- EPA recommends that the U.S. Fish and Wildlife Service and the National Marine Fisheries Service review and provide recent concurrence letters (to be included in the FEIS) regarding the adequacy of the Biological Assessment developed for this project pursuant to Section 7 (of the Endangered Species Act of 1973) and presented with the draft report.
- As mentioned previously, we are also currently reviewing the FEIS for the adjacent project known as the "Relocation of New River Inlet Ebb Tide Channel Between North Topsail Beach and Onslow Beach, and the Placement of the

Dredged Material Along the Ocean Shoreline of North Topsail Beach in Onslow County, NC." This FEIS describes a plan by the Town of North Topsail Beach to develop a non-Federal coastal storm damage reduction project for the parts of the town that lie within the Coastal Barrier Resources System (Topsail Unit, L06). EPA recommends careful coordination between the two projects to ensure that there are no conflicts between the Federal and non-Federal projects, either on the shoreline or in the borrow areas. Your draft report states that in the event that the non-Federal project is not in place when the Federal project begins, then the northern 2,000 ft of the dune and berm system will be replaced with a transition section. Your FEIS should include specific engineering details about what this 2,000 ft transition section would look like and how it may affect the overall NED Plan.

- We understand that the Agency Technical Review (ATR) was conducted in accordance with the Corps' "Peer Review of Decision Documents" process, and this means the proposed project "has been reviewed by Corps staff outside the originating office, conducted by a regional and national team of experts in the field, and coordinated by the National Planning Center of Expertise in Coastal Storm Damage Reduction, North Atlantic Division, U.S. Army Corps of Engineers." EPA recommends that the FEIS include all comments and responses developed as part of the ATR process.
- We further understand that an "Independent External Peer Review" (IEPR) will be conducted (following the ATR) by a "non-USACE national team of experts in the field, and coordinated by the National Planning Center of Expertise in Coastal Storm Damage Reduction, North Atlantic Division, U.S. Army Corps of Engineers." EPA recommends that the FEIS include all comments and responses developed as part of the IEPR process.
- CEQ regulations (40 CFR 1502.14(a)) require that an EIS is to "rigorously explore and objectively evaluate all reasonable alternatives" for a proposed action. The regulations (40 CFR 1502.14(b)) further require that substantial treatment be made of each alternative considered in detail, including the proposed action. The draft report appropriately notes that study team considered both structural and non-structural measures. EPA recommends that the FEIS include complete details on the nonstructural measures that were considered, such as removal and relocation, as well as final summaries of the economic analyses (using recent economic data) that found these nonstructural measures to have greater costs than benefits.
- The draft report appropriately assesses project risk, uncertainty, and consequences, and generally describes these with sufficient detail so that that "decisions can be made with knowledge of the degree of reliability of the estimated benefits and costs and of the effectiveness of alternative plans." EPA concurs that all recommendations made in the FEIS should be capable of being implemented through adaptive management, should future conditions warrant such. The draft report appropriately notes that "renourishment may be needed more often or less often, depending on the occurrence of large storms and accompanying erosion."

- To avoid conflicts, the project should be coordinated with monitoring efforts led by the North Carolina Recreational Water Quality Program (NCRWQ), which regularly tests these coastal waters in order to protect public health by monitoring and notifying the public when bacteriological standards for safe bodily contact are exceeded. Also, the project should be coordinated with the North Carolina Department of Environmental and Natural Resources, Division of Environmental Health, Shellfish Sanitation Section, which is also continually monitoring and classifying these coastal waters as to their suitability for shellfish harvesting for human consumption.
- The main channel of the Atlantic Intracoastal Waterway (AIWW) in North Carolina has been maintained by dredging for over 70 years to remove shoals that periodically develop. Some of the dredged material removed during maintenance activities is reported to be a high quality beach sand. This material has been placed directly on nearby ocean beaches, or stockpiled in confined disposal areas near the shoreline of the AIWW. Other area sand sources are from dredging activities in the New Topsail Inlet and Connecting Channels, as well as the New River Inlet. EPA recommends that these sand sources be considered for renourishment activities for the 10-mile long project reach.
- The FEIS should include complete supporting geotechnical information, especially representative boring logs and/or grain size analysis plots from soil borings conducted in the finalized borrow areas.
- EPA recommends that areas with extensive hard bottom area and/or relatively low volumes of beach compatible material be ruled out as potential sources of borrow material for this project. Final selection of borrow areas should be based upon high volumes of accessible, beach quality sands. We recommend rigorous delineation of all hard bottom resources within each prospective borrow area before commencement of work in order to avoid potential impacts to hard bottom resources (particularly from hopper dredging activities). The State of North Carolina's hard bottom buffer rule language requires that dredging should not be conducted "on or within 500 meters of significant biological communities, such as high relief hard bottom areas." EPA supports the Corps' efforts to use divers to conduct ground truth confirmation in the potential borrow areas, as well as collecting sediment samples, conducting video documentation, and employing sidescan technology, all for the purpose of assisting with hardbottom avoidance.
- EPA supports the on-going characterization of potential borrow areas during all 4 seasons in order to determine if there are significant differences in species composition and diversity for each sampling period.
- The FEIS should cite North Carolina Division of Marine Fisheries (NCDMF) commercial finfish and shellfish updated data (from 2009).
- The FEIS should discuss efforts to protect the 937-foot long Surf City Ocean Pier during construction, as it is apparently located within the proposed beach fill area.
- The draft report has a section reporting on the Administration's position on funding of coastal storm damage reduction projects. As this report was under development in 2008, this should be clarified (e.g., the current Administration?). We understand that the Office of Management and Budget (OMB) advises that "while the Water Resources Development Act of 1999 (WRDA 99) changed the

cost-sharing formula for the long-term sand renourishment component of certain future shore protection projects," these changes did not go far enough considering the long-term cost of most of these projects. Further, because WRDA 99 delayed the effect of the change in cost sharing for up to a decade or more, it reportedly "did not address current constraints on Federal spending," and therefore the Administration intends to work with Congress to address these problems. However, EPA understands that until these issues are satisfactorily resolved, there will be no authorization of new shore protection projects "that involve significant long-term Federal investments beyond the initial construction of these projects, and will give new shore protection projects that are already authorized low priority for funding."

- Finalized mitigation measures should be presented in the FEIS, to include specific measures recommended by U.S. Fish and Wildlife Service (USFWS) and National Marine Fisheries Service (NMFS) for protection of all threatened and endangered species. The finalized mitigation plan should include specific finalized protocols to be employed should any sea turtles be encountered during the dredging activity.

Thank you for the opportunity to provide comments on this draft report. Because of our concerns about the use of hopper dredges and the potential effects on marine and threatened and endangered resources, we rate this DEIS as EC-2, meaning we have some environmental concerns and have requested that information be provided in the FEIS (the finalized mitigation plan, the finalized sea turtle protocol, and a map of the final selected borrow areas). If you wish to discuss these comments or have any other questions, please contact me at (404) 562-9611 (mueller.heinz@epa.gov) or Paul Gagliano, P.E., of my staff at (404) 562-9373 (gagliano.paul@.epa.gov).

Sincerely,

Christine M. Hoberg /for

Heinz J. Mueller, Chief
NEPA Program Office
Office of Policy and Management

United States Department of Agriculture

NRCS

Natural Resources Conservation Service
4407 Bland Road, Suite 117
Raleigh, North Carolina 27609

Phone: (919) 873-2103
Fax: (919) 873-2156
Email: mike.hinton@nc.usda.gov

February 22, 2010

Ms. Jan Brodmerkel
Project Manager
Wilmington District-COE
69 Darlington Ave
Wilmington, NC 28403

Dear Ms. Brodmerkel:

Thank you for the opportunity to provide comments on the Draft Integrated Feasibility Report and EIS, Coastal Storm Damage Reduction, Surf City and North Topsoil Beach, Onslow, County, North Carolina.

The Natural Resources Conservation Service does not have any comments at this time.

If you need additional information, please feel free to contact me at (919) 873-2103.

Sincerely,

Michael J. Hinton
Assistant State Conservationist for Water Resources

North Carolina Department of Environment and Natural Resources
Division of Coastal Management

Beverly Eaves Perdue
Governor

James H. Gregson
Director

Dee Freeman
Secretary

January 20, 2010

W. Coleman Long, Chief
Planning and Environmental Branch
Wilmington District Office
US Army Corps of Engineers
69 Darlington Avenue
Wilmington, NC 28403-1343

SUBJECT: Status of Consistency Determination for Proposed Implementation of the Integrated Feasibility Report and EIS Regarding Coastal Storm Damage Reduction at Surf City and North Topsail Beach, Onslow and Pender Counties, North Carolina (DCM#20100006)

Dear Mr. Long:

We received your consistency determination on January 14, 2010 for proposed implementation of the Integrated Feasibility Report and EIS regarding coastal storm damage reduction at Surf City and North Topsail Beach, Onslow and Pender Counties, North Carolina. On January 20, 2010 we initiated the public review period. The project has been distributed to State agencies that would have a regulatory interest in the proposed activity for review and comment. The public review period will close on February 5, 2010. Please be aware that as we continue to review this submission that we may request additional information. We intend to make a decision regarding whether the proposed activity would be consistent with the State's coastal program soon after.

Pursuant to 15 CFR 930.35 the State of North Carolina has sixty (60) days from the receipt of the consistency determination to either *"concur"* or *"object"* to your consistency determination unless an extension is agreed to. The sixtieth day is March 15, 2010.

The State is entitled, pursuant to 15 CFR 930.41(b), to an extension of up to fifteen (15) days if additional review time is necessary. Furthermore, final Federal agency action cannot be taken sooner than ninety (90) days from the State's receipt of the consistency determination unless State concurrence is obtained. Please feel free to contact me at 252-808-2808 if you have any questions. Thank you for your consideration of the North Carolina Coastal Management Program.

Sincerely,

Stephen Rynas, AICP
Federal Consistency Coordinator
Cc: Doug Huggett, Division of Coastal Management
Steve Everhart, Division of Coastal Management
Jeff Richter, US Army Corps of Engineers
Doug Piatkowski, US Army Corps of Engineers

400 Commerce Ave., Morehead City, NC 28557-3421
Phone: 252-808-2808 \ FAX: 252-247-3330 Internet: www.nccoastalmanagement.net

An Equal Opportunity \ Affirmative Action Employer

One North Carolina Naturally

North Carolina
Department of Administration

Beverly Eaves Perdue, Governor

Moses Carey, Jr., Secretary

March 9, 2010

Mr. Doug Piatkowski
Department of the Army
Wilmington Dristrict
Corps of Engineers
69 Darlington Avenue
Wilmington, NC 28403-1343

Re: SCH File # 10-E-0000-0249; DEIS; Develop Coastal Storm Damage Reduction plan for Surf City and North Topsail Beach

Dear Mr. Piatkowski:

The above referenced environmental impact information has been submitted to the State Clearinghouse under the provisions of the National Environmental Policy Act. According to G.S. 113A-10, when a state agency is required to prepare an environmental document under the provisions of federal law, the environmental document meets the provisions of the State Environmental Policy Act. Attached to this letter for your consideration are the comments made by agencies in the course of this review.

If any further environmental review documents are prepared for this project, they should be forwarded to this office for intergovernmental review.

Should you have any questions, please do not hesitate to call.

Sincerely,

Chrys Baggett (S74)

Ms. Chrys Baggett
State Environmental Review Clearinghouse

Attachments

cc: Region O
Region P

Mailing Address:
1301 Mail Service Center
Raleigh, NC 27699-1301

Telephone: (919)807-2425
Fax (919)733-9571
State Courier #51-01-00
e-mail state.clearinghouse@doa.nc.gov

Location Address:
116 West Jones Street
Raleigh, North Carolina

An Equal Opportunity/Affirmative Action Employer



North Carolina Department of Environment and Natural Resources

Beverly Eaves Perdue
Governor

Dee Freeman
Secretary

MEMORANDUM

TO: Valerie McMillan
State Clearinghouse

FROM: Melba McGee
Environmental Review Coordinator

RE: 10-0249 DEIS for the Storm Damage Reduction Plan for Surf City and North Topsail Beach in Onslow and Pender Counties

DATE: March 8, 2010

The Department of Environment and Natural Resources has reviewed the proposed information. The attached comments are for the applicant's information.

Thank you for the opportunity to review.

Attachments

1601 Mail Service Center, Raleigh, North Carolina 27699-1601
Phone: 919-733-4984 \ FAX: 919-715-3060 Internet: www.enr.state.nc.us
An Equal Opportunity \ Affirmative Action Employer – 50% Recycled \ 10% Post Consumer Paper

One NorthCarolina Naturally



North Carolina Wildlife Resources Commission

Gordon Myers, Executive Director

MEMORANDUM

TO: Melba McGee
Office of Legislative & Intergovernmental Affairs

And

Stephen Rynas
Federal Consistency Coordinator
Division of Coastal Management

FROM: Molly Ellwood
Southeastern Permit Coordinator
North Carolina Wildlife Resources Commission

DATE: March 5, 2010

SUBJECT: Comments for the Draft Environmental Impact Statement for the Storm Damage Reduction Plan for Surf City and North Topsail Beach, Onslow and Pender Counties OLIA 10-0249

Biologists from the N. C. Wildlife Resources Commission (NCWRC) have reviewed the proposed project description. Our comments are provided in accordance with certain provisions of the North Carolina Environmental Policy Act (G.S. 113A-1 through 113A-10; 1 NCAC 25), certain provisions of the Coastal Area Management Act (G.S. 113A-100 through 113A-128), as amended, and the Fish and Wildlife Coordination Act (48 Stat. 401, as amended; 16 U.S.C. 661et seq.).

The United States Army Corps of Engineers is assessing the feasibility of Federal coastal storm damage risk reduction for the Towns of Surf City and North Topsail Beach, which are located on Topsail Island in Pender and Onslow Counties. The preferred alternative as described in the draft Environmental Impact Statement (DEIS) will be to dispose 11.5 mcy of beach compatible material from acceptable offshore sand sources to nourish approximately 52,150 lf in length of ocean front beach with a long dune a berm design constructed to a height of 15 ft NGVD fronted by a 7 ft NGVD (50 ft wide) beach berm. As proposed, the renourishment cycle would be every 4 years after the initial construction phases for a 50 year project.

Mailing Address: Division of Inland Fisheries • 1721 Mail Service Center • Raleigh, NC 27699-1721
Telephone: (919) 707-0220 • **Fax:** (919) 707-0028

The NCWRC have the following concerns and recommendations:

- The NCWRC recommends that all work to be conducted outside of the established moratoriums for nesting shorebirds (01 April-31 Aug) and nesting sea turtles (01 May – 15 Nov or until the lat known nest hatches). Any encroachment in these time frames will increase the chances for significant, adverse impacts to important wildlife species and would require further consultation with NCWRC biologists before the project can proceed.

- The NCWRC is continually concerned with the impacts of beach nourishment on benthic invertebrates. Benthic invertebrates are important food sources for foraging shorebirds and continued, frequent nourishment events can potentially have significant adverse impacts on these populations if they are not provided enough time to recover their populations to sustainable numbers.

  The DEIS discusses the proposed 4 year renourishment cycle that would start 1 year after the initial nourishment event. To reduce impacts to benthic invertebrates, the NCWRC supports staggering the renourishment areas so that the first renourishment event would start at the section of the project area where initial construction began; avoiding the most recent beach disposal area. Staggering these areas will allow a greater time for benthic invertebrates to adequately recover to sustainable levels.

Thank you for the opportunity to review and comment on this project. The NCWRC requests that our recommendations be considered throughout the 50 years of this project and that any alterations to this plan be reviewed by NCWRC staff. Moratorium windows are important for the protection of our state and federally listed wildlife species and we recommend that the project avoid any encroachment into these time frames. Please feel free to contact me at (910) 796-7240 if you have any additional questions or concerns pertaining to this project.

Cc: Matthew Godfrey, NCWRC
David Allen, NCWRC
Joanne Steenhuis, NCDWQ
Jessi O'Neal, NCDMF
Dave Timpy, USACE

North Carolina Department of Environment and Natural Resources

Beverly Eaves Perdue
Governor

Dee Freeman
Secretary

January 29, 2010

MEMORANDUM

TO: Stephen Rynas, Federal Consistency Coordinator
NC Division of Coastal Management

FROM: Harry LeGrand, Natural Heritage Program

SUBJECT: Proposed Implementation of a Coastal Storm Damage Reduction Program for Surf City and North Topsail Beach; Onslow and Pender counties

REFERENCE: DCM#20100006

The Natural Heritage Program has no record of significant natural communities, significant natural heritage areas, or conservation/managed areas at the site. However, the beachfront is the site for nesting by the Federal and State Threatened loggerhead seaturtle (*Caretta caretta*). The Biological Assessment (Appendix I) provides considerable information on nesting by seaturtles. Our Program concurs with the proposed hopper dredging window of December 1 to March 31. We also strongly hope that all placement of sediment on the beach can be done within this window, as well.

The Federal and State Threatened seabeach amaranth (*Amaranthus pumilus*) is typically an annual that grows on accreting sand beaches, and thus is found mostly on ends of islands. As long as the dredging and beach renourishment can be done/completed within the December 1 to March 31 period, the impacts to the amaranth should be negligible. Both the northeastern and southwestern ends of Topsail Island are used by birds for nesting. Appendix I discusses these species. In general, increasing the amount of sand on the middle portion of an island, through ocean dredging and sand renourishment, will favor build-up of sand on the downdrift end of the island and be favorable to nesting by birds (by providing more extensive habitat), though this might take several years. Impacts to the "updrift" end of an island are probably not clear. Nonetheless, it might be too speculative to comment on the positive or negative impacts to birds nesting on either end of the island, in regard to this project.

Please do not hesitate to contact me at 919-715-8697 if you have questions or need further information.

1601 Mail Service Center, Raleigh, North Carolina 27699-1601
Phone: 919-733-4984 \ FAX: 919-715-3060 Internet: www.enr.state.nc.us

An Equal Opportunity \ Affirmative Action Employer – 50% Recycled \ 10% Post Consumer Paper

One North Carolina Naturally

RECEIVED
JAN 26 2010

Project Number
10-0249

County
Pender, Onslow

DEPARTMENT OF ENVIRONMENT AND NATURAL RESOURCES
DIVISION OF ENVIRONMENTAL HEALTH

Inter-Agency Project Review Response

Project Name **Dept of the Army, Wilmington District Corps of Engineers**

Type of Project **Draft Environmental Impact Statement - Develop Coastal Storm Damage Reduction Plan for Surf City & North Topsail Beach**

Comments provided by:

☐ Regional Program Person

☒ Regional Supervisor for Public Water Supply Section

☐ Central Office program person

RECEIVED
JAN 22 2010
BY:_____

Name **Debra Benoy-Wilmington RO** Date **01/20/2010**

Telephone number: _____

Program within Division of Environmental Health:

☐ Public Water Supply

☐ Other, Name of Program: _____

Response (check all applicable):

☐ No objection to project as proposed

☐ No comment

☐ Insufficient information to complete review

☐ Comments attached

☐ See comments below

There should not be any impact on any public water supplies. EJ

Return to:
Public Water Supply Section
Environmental Review Coordinator for the
Division of Environmental Health

DEPARTMENT OF ENVIRONMENT AND NATURAL RESOURCES
DIVISION OF ENVIRONMENTAL HEALTH

Project Number
10-0249
County
Pender, Onslow

RECEIVED

JAN 22 2010

Inter-Agency Project Review Response

Project Name **Dept of the Army, Wilmington District Corps of Engineers**

Type of Project **Draft Environmental Impact Statement - Develop Coastal Storm Damage Reduction Plan for Surf City & North Topsail Beach**

☐ The applicant should be advised that plans and specifications for all water system improvements must be approved by the Division of Environmental Health prior to the award of a contract or the initiation of construction (as required by 15A NCAC 18C .0300et. seq.). For information, contact the Public Water Supply Section, (919) 733-2321.

☐ This project will be classified as a non-community public water supply and must comply with state and federal drinking water monitoring requirements. For more information the applicant should contact the Public Water Supply Section, (919) 733-2321.

☐ If this project is constructed as proposed, we will recommend closure of _____ feet of adjacent waters to the harvest of shellfish. For information regarding the shellfish sanitation program, the applicant should contact the Shellfish Sanitation Section at (252) 726-6827.

☐ The soil disposal area(s) proposed for this project may produce a mosquito breeding problem. For information concerning appropriate mosquito control measures, the applicant should contact the Public Health Pest Management Section at (919) 733-6407.

☐ The applicant should be advised that prior to the removal or demolition of dilapidated structures, an extensive rodent control program may be necessary in order to prevent the migration of the rodents to adjacent areas. For information concerning rodent control, contact the local health department or the Public Health Pest Management Section at (919) 733-6407.

☐ The applicant should be advised to contact the local health department regarding their requirements for septic tank installations (as required under 15A NCAC 18A. 1900 et. sep.). For information concerning septic tank and other on-site waste disposal methods, contact the On-Site Wastewater Section at (919) 733-2895.

☐ The applicant should be advised to contact the local health department regarding the sanitary facilities required for this project.

☐ If existing water lines will be relocated during the construction, plans for the water line relocation must be submitted to the Division of Environmental Health, Public Water Supply Section, Technical Services Branch, 1634 Mail Service Center, Raleigh, North Carolina 27699-1634, (919) 733-2321.

☒ For Regional and Central Office comments, see the reverse side of this form.

Jim McRight	PWSS	01/20/2010
Reviewer	Section/Branch	Date

State of North Carolina
Department of Environment and Natural Resources

Reviewing Office: Wilm

INTERGOVERNMENTAL REVIEW - PROJECT COMMENTS

Project Number: 10-0249 Due Date: 3/3/10

After review of this project it has been determined that the ENR permit(s) and/or approvals indicated may need to be obtained in order for this project to comply with North Carolina Law. Questions regarding these permits should be addressed to the Regional Office indicated on the reverse of the form. All applications, information and guidelines relative to these plans and permits are available from the same Regional Office.

	PERMITS	SPECIAL APPLICATION PROCEDURES or REQUIREMENTS	Normal Process Time (statutory time limit)
☐	Permit to construct & operate wastewater treatment facilities, sewer system extensions & sewer systems not discharging into state surface waters.	Application 90 days before begin construction or award of construction contracts. On-site inspection. Post-application technical conference usual.	30 days (90 days)
☐	NPDES - permit to discharge into surface water and/or permit to operate and construct wastewater facilities discharging into state surface waters.	Application 180 days before begin activity. On-site inspection. Pre-application conference usual. Additionally, obtain permit to construct wastewater treatment facility-granted after NPDES. Reply time, 30 days after receipt of plans or issue of NPDES permit-whichever is later.	90-120 days (N/A)
☐	Water Use Permit	Pre-application technical conference usually necessary	30 days (N/A)
☐	Well Construction Permit	Complete application must be received and permit issued prior to the installation of a well.	7 days (15 days)
☐	Dredge and Fill Permit	Application copy must be served on each adjacent riparian property owner. On-site inspection. Pre-application conference usual. Filling may require Easement to Fill from N.C. Department of Administration and Federal Dredge and Fill Permit.	55 days (90 days)
☐	Permit to construct & operate Air Pollution Abatement facilities and/or Emission Sources as per 15 A NCAC (2Q.0100 thru 2Q.0300)	Application must be submitted and permit received prior to construction and operation of the source. If a permit is required in an area without local zoning, then there are additional requirements and timelines (2Q.0113).	90 days
☐	Permit to construct & operate Transportation Facility as per 15 A NCAC (2D.0800, 2Q.0601)	Application must be submitted at least 90 days prior to construction or modification of the source.	90 days
☐	Any open burning associated with subject proposal must be in compliance with 15 A NCAC 2D.1900	N/A	60 days (90 days)
☐	Demolition or renovations of structures containing asbestos material must be in compliance with 15 A NCAC 2D.1110 (a) (1) which requires notification and removal prior to demolition. Contact Asbestos Control Group 919-707-5950.		
☐	Complex Source Permit required under 15 A NCAC 2D.0800		
☐	The Sedimentation Pollution Control Act of 1973 must be properly addressed for any land disturbing activity. An erosion & sedimentation control plan will be required if one or more acres to be disturbed. Plan filed with proper Regional Office (Land Quality Section) At least 30 days before beginning activity. A fee of $65 for the first acre or any part of an acre. An express review option is available with additional fees.		20 days (30 days)
☐	Sedimentation and erosion control must be addressed in accordance with NCDOT's approved program. Particular attention should be given to design and installation of appropriate perimeter sediment trapping devices as well as stable stormwater conveyances and outlets.		(30 days)
☐	Mining Permit	On-site inspection usual. Surety bond filed with ENR Bond amount varies with type mine and number of acres of affected land. Any arc mined greater than one acre must be permited. The appropriate bond must be received before the permit can be issued.	30 days (60 days)
☐	North Carolina Burning permit	On-site inspection by N.C. Division Forest Resources if permit exceeds 4 days	1 day (N/A)
☐	Special Ground Clearance Burning Permit - 22 counties in coastal N.C. with organic soils	On-site inspection by N.C. Division Forest Resources required "if more than five acres of ground clearing activities are involved. Inspections should be requested at least ten days before actual burn is planned."	1 day (N/A)
☐	Oil Refining Facilities	N/A	> 0-120 days (N/A)
☐	Dam Safety Permit	If permit required, application 60 days before begin construction. Applicant must hire N.C. qualified engineer to prepare plans, inspect construction, certify construction is according to ENR approved plans. May also require permit under mosquito control program. And a 404 permit from Corps of	

	PERMITS	SPECIAL APPLICATION PROCEDURES or REQUIREMENTS	Normal Process Time (statutory time limit)
☐	Permit to drill exploratory oil or gas well	File surety bond of $5,000 with ENR running to State of NC conditional that any well opened by drill operator shall, upon abandonment, be plugged according to ENR rules and regulations.	10 days N/A
☐	Geophysical Exploration Permit	Application filed with ENR at least 10 days prior to issue of permit. Application by letter. No standard application form	10 days N/A
☐	State Lakes Construction Permit	Application fees based on structure size is charged. Must include descriptions & drawings of structure & proof of ownership of riparian property.	15-20 days N/A
☑	401 Water Quality Certification	N/A	60 days (130 days)
☐	CAMA Permit for MAJOR development	$250.00 fee must accompany application	55 days (150 days)
☐	CAMA Permit for MINOR development	$50.00 fee must accompany application	22 days (25 days)
☐	Several geodetic monuments are located in or near the project area. If any monument needs to be moved or destroyed, please notify: N.C. Geodetic Survey, Box 27687 Raleigh, NC 27611		
☐	Abandonment of any wells, if required must be in accordance with Title 15A. Subchapter 2C.0100.		
☐	Notification of the proper regional office is requested if "orphan" underground storage tanks (USTS) are discovered during any excavation operation.		
☐	Compliance with 15A NCAC 2H 1000 (Coastal Stormwater Rules) is required.		45 days (N/A)
☐	Tar Pamlico or Neuse Riparian Buffer Rules required.		

x Other comments (attach additional pages as necessary, being certain to cite comment authority)

REGIONAL OFFICES

Questions regarding these permits should be addressed to the Regional Office marked below.

☐ **Asheville Regional Office**
2090 US Highway 70
Swannanoa, NC 28778
(828) 296-4500

☐ **Mooresville Regional Office**
610 East Center Avenue, Suite 301
Mooresville, NC 28115
(704) 663-1699

☐ **Wilmington Regional Office**
127 Cardinal Drive Extension
Wilmington, NC 28405
(910) 796-7215

☐ **Fayetteville Regional Office**
225 North Green Street, Suite 714
Fayetteville, NC 28301-5043
(910) 433-3300

☐ **Raleigh Regional Office**
3800 Barrett Drive, Suite 101
Raleigh, NC 27609
(919) 791-4200

☐ **Winston-Salem Regional Office**
585 Waughtown Street
Winston-Salem, NC 27 107
(336) 771-5000

☐ **Washington Regional Office**

MEMORANDUM

DIVISION OF WATER QUALITY

TO: Melba McGee, Environmental Coordinator

FROM: Joanne Steenhuis, Senior Environmental Specialist JHS

THROUGH: Rick Shiver, Surface Water Protection Regional Supervisor

DATE: February 26, 2010

SUBJECT: EIS Develop Coastal Storm Damage Reduction Plan for Surf City and North Topsail Beach

PROJECT: Implementation of a Coastal Storm Damage Reduction Plan for Surf City and North Topsail Beach

Project No. 10-0249

COUNTY: Pender and Onslow Counties

The Wilmington Regional Office has reviewed the Environmental Impact Statement for the implementation of a coastal storm damage reduction plan for Surf City and North Topsail Beach. The Division of Water Quality (DWQ) has no objections to the project as proposed as long as they comply with the dredging moratoriums and environmental monitoring as discussed in the document.

WiRO

NORTH CAROLINA STATE CLEARINGHOUSE
DEPARTMENT OF ADMINISTRATION
INTERGOVERNMENTAL REVIEW

COUNTY: PENDER
ONSLOW

H05: IRRIGATION/DRAINAGE/FLOOD CONTROL

STATE NUMBER: 10-E-0000-0249
DATE RECEIVED: 01/14/2010
AGENCY RESPONSE: 03/03/2010
REVIEW CLOSED: 03/08/2010

RECEIVED
JAN 15 2010
HISTORIC PRESERVATION OFFICE

MS RENEE GLEDHILL-EARLEY
CLEARINGHOUSE COORDINATOR
DEPT OF CULTURAL RESOURCES
STATE HISTORIC PRESERVATION OFFICE
MSC 4617 - ARCHIVES BUILDING
RALEIGH NC

CH-01-0497
~~E 10-0249~~
A - Cultural resources addressed 1/19/10
2-3-10

REVIEW DISTRIBUTION

CAPE FEAR COG
CC&PS - DIV OF EMERGENCY MANAGEMENT
DENR - COASTAL MGT
DENR LEGISLATIVE AFFAIRS
DEPT OF AGRICULTURE
DEPT OF CULTURAL RESOURCES
DEPT OF TRANSPORTATION
EASTERN CAROLINA COUNCIL

FEB 2010

Due 2/1/10

PROJECT INFORMATION

APPLICANT: Department of the Army
TYPE: National Environmental Policy Act
Draft Environmental Impact Statement

DESC: Develop Coastal Storm Damage Reduction plan for Surf City and North Topsail Beach

The attached project has been submitted to the N. C. State Clearinghouse for intergovernmental review. Please review and submit your response by the above indicated date to 1301 Mail Service Center, Raleigh NC 27699-1301.

If additional review time is needed, please contact this office at (919)807-2425.

AS A RESULT OF THIS REVIEW THE FOLLOWING IS SUBMITTED: ☒ NO COMMENT ☐ COMMENTS ATTACHED

SIGNED BY: Renee Gledhill-Earley DATE: 2.5.10

JAN 19 10

NCDENR
North Carolina Department of Environment and Natural Resources
Division of Coastal Management

Beverly Eaves Perdue
Governor

James H. Gregson
Director

Dee Freeman
Secretary

April 16, 2010

RECEIVED
APR 20 2010
REG. WILM. FLD. OFC.

Col. Jefferson M. Ryscavage, District Commander
Wilmington District Office
US Army Corps of Engineers
69 Darlington Avenue
Wilmington, NC 28403-1343

SUBJECT: **CD10-017** – Consistency Concurrence for Proposed Implementation of the Integrated Feasibility Report and EIS Regarding Coastal Storm Damage Reduction at Surf City and North Topsail Beach, Onslow and Pender Counties, North Carolina (DCM#20100006)

Dear Col. Ryscavage:

We received your consistency determination on January 14, 2010 for proposed implementation of the Integrated Feasibility Report and EIS regarding coastal storm damage reduction at Surf City and North Topsail Beach, Onslow and Pender Counties, North Carolina. The consistency review deadline was extended, by mutual agreement, to April 16, 2010. The submitted National Economic Development (NED) plan consists of a sand dune constructed to an elevation of 15 feet above the National Geodetic Vertical Datum (NGVD), fronted by a 50-foot wide beach berm constructed to an elevation of 7 feet above NGVD. The berm and dune project extends along a reach of 52,150 feet. This plan is identified among other alternatives in the "*Draft Integrated Feasibility Report and Environmental Impact Statement, Coastal Strom Damage Reduction, Surf City and North Topsail Beach, North Carolina*" (August 2009) as "*Plan 1550*".

North Carolina's coastal zone management program consists of, but is not limited to, the Coastal Area Management Act, the State's Dredge and Fill Law, Chapter 7 of Title 15A of North Carolina's Administrative Code, and the land use plan of the County and/or local municipality in which the proposed project is located. It is the objective of the Division of Coastal Management (DCM) to manage the State's coastal resources to ensure that proposed Federal activities would be compatible with safeguarding and perpetuating the biological, social, economic, and aesthetic values of the State's coastal waters.

400 Commerce Ave., Morehead City, NC 28557-3421
Phone: 252-808-2808 \ FAX: 252-247-3330 Internet: www.nccoastalmanagement.net

An Equal Opportunity \ Affirmative Action Employer

One NorthCarolina Naturally

To solicit public comments, DCM circulated a description of the proposed project to State agencies that would have a regulatory interest. No comments asserting that the proposed activity would be inconsistent with the State's coastal management program were received. Nevertheless, comments were received concerning the necessity to minimize adverse environmental effects resulting from dredging. A copy of the responses received has been attached for reference.

DCM has reviewed the submitted information pursuant to the management objectives and enforceable policies of Subchapters 7H and 7M of Chapter 7 of Title 15A of North Carolina's Administrative Code which are a part of the State's certified coastal management program and concurs, as conditioned below, that the proposed Federal activity is consistent, to the maximum extent practicable, with the enforceable policies of North Carolina's coastal management program.

In order to be found consistent with North Carolina's coastal management, the US Army Corps of Engineers (Applicant) shall comply with the following conditions of concurrence.

- The Applicant, prior to initiating any land or water disturbing activities, shall obtain a Section 401 Water Quality Certification from the NC Division of Water Quality for the proposed project. The Applicant shall comply with the requirements of the Section 401 Water Quality Certification. A copy of the certification shall be forwarded to DCM.
- The Applicant, prior to initiating any land disturbing activities, shall obtain the approval of the NC Division of Land Resources of an erosion and sedimentation control plan. The Applicant shall comply with the requirements of the approved erosion and sedimentation control plan. A copy of the plan approval shall be forwarded to DCM.
- In order to protect nesting shorebirds, work will not be allowed from April 1st through August 31st of any year without the prior approval of the Division of Coastal Management, in consultation with the North Carolina Wildlife Resources Commission.
- In order to protect nesting sea turtles and their hatchlings, work will not be allowed from May 1st through November 15th of any year without the prior approval of the Division of Coastal Management, in consultation with the North Carolina Wildlife Resources Commission.
- The Applicant, prior to initiating any land disturbing activities related to the initial construction period, shall submit to DCM a Monitoring Plan to assess project impacts on fisheries and fish prey habitat that outlines: (1) the methodologies for evaluating for hard bottom and intertidal beach habitat impacts, (2) the criteria for determining whether significant, adverse impacts to these habitats have occurred, (3) implementation of the monitoring plan. Though unlikely, based on the avoidance measures incorporated in the study design, should the Monitoring Plan document that a significant adverse impact to habitat has occurred, a Mitigation Plan will be submitted to DCM, in consultation with the NCDMF, for supplementary consistency review. The Mitigation Plan will outline the appropriate actions that will be implemented in cooperation with state and federal agencies to rectify the adverse impacts to a level of insignificance.
- Only beach quality sand shall be used for this project. Should the dredging operations encounter sand deemed non-compatible with native grain size or sorting characteristics of the native beach, the dredge operator shall immediately cease operation and contact the DCM. Dredge operations will resume only after the issue of sand compatibility is resolved.

- Sand excavation activities shall not be conducted on or within 400 feet of significant biological communities, such as high relief hard bottom areas.
- Prior to the initiation of any beach nourishment activity above the normal high water contour (NHW) within the limits of the authorized project, easements or similar legal instruments shall be obtained from all impacted property owners.
- Prior to the initiation of any beach nourishment activity, the Applicant shall coordinate with DCM to determine the static vegetation line that shall be used as the reference point for measuring future oceanfront setbacks. This static vegetation line shall then be marked and a survey depicting this static vegetation line shall be submitted to DCM prior to any beach nourishment activities.
- Temporary dikes shall be used to retain and direct flow of material parallel to the shoreline to minimize surf zone turbidities. The temporary dikes shall be removed and the beach graded in accordance with approved profiles upon completion of pumping activities in that particular section of beach.
- In order to prevent leakage, dredge pipes shall be routinely inspected. If leakage is found and repairs cannot be made immediately, pumping of material shall stop until such leaks are fixed.
- Land-based equipment necessary for beach nourishment work shall be brought to the site through existing accesses. Should the work result in any damage to existing accesses, the accesses shall be restored to pre-project conditions immediately upon project completion in that specific area.
- Where oceanfront development exists at elevations nearly equal to that of the native beach, a low protective dune shall be pushed up along the backwash to prevent slurry from draining towards the development.
- Dune disturbance shall be kept to a minimum. Any alteration of existing dunes shall be coordinated with DCM as well as the appropriate property owner(s). All disturbed areas shall be restored to original contours and configuration with reference to the surveyed normal high water line and shall be revegetated immediately following project completion in that specific area.
- No sand shall be placed on any sandbags that have been determined by DCM to be subject to removal under 15A NCAC 07H .0308(a)(2). In order to ensure compliance with this condition, DCM shall be contacted at 910-796-7215 prior to project initiation so that Division staff may meet on-site with the permittee and/or contractor.
- The Applicant shall adhere to any mitigation measures described in the consistency submission and the *Draft Integrated Feasibility Report and Environmental Impact Statement, Coastal Storm Damage Reduction, Surf City and North Topsail Beach, North Carolina*" (August 2009) to the extent that they do not conflict with any of the conditions of concurrence stated above.

This letter of concurrence is contingent on the Federal agency agreeing with the conditions stated above. In the event that the Federal agency does not agree with the conditions of concurrence, this letter effectively becomes a letter of State "*Objection*". Should the Federal agency not agree with the conditions stated above, a letter of non-agreement should be sent to DCM. The procedures of 15 CFR 930.43 would then need to be followed.

The North Carolina Wildlife Resources Commission (NCWRC) and the North Carolina Division of Marine Fisheries (NCDMF) are concerned about the impact of proposed dredging operations on benthic habitat. NCWRC recommend that during the four year initial construction event that beach nourishment activities be staggered to minimize the adverse effects on benthic invertebrates. Benthic invertebrates are an important food source for foraging shorebirds and many species of fish. To assure the availability of this food source, DCM recommends that the Corps, to the extent practical, implement the recommendations of the NCWRC and the NCDMF.

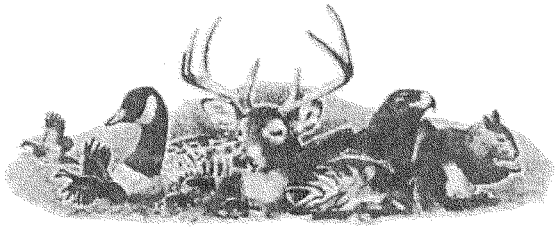
Should the proposed action be modified a revised consistency determination could be necessary. This might take the form of either a supplemental consistency determination pursuant to 15 CFR 930.46, or a new consistency determination pursuant to 15 CFR 930.36. Likewise, if further project assessments reveal environmental effects not previously considered by the proposed development, a supplemental consistency certification may be required. If you have any questions, please contact Stephen Rynas at 252-808-2808. Thank you for your consideration of the North Carolina Coastal Management Program.

Sincerely,

Doug Huggett

Doug Huggett
Manager, Major Permits and Consistency Unit

Cc: Steve Everheart, Division of Coastal Management
Doug Piatkowski, US Army Corps of Engineers



North Carolina Wildlife Resources Commission

Gordon Myers, Executive Director

MEMORANDUM

TO: Melba McGee
Office of Legislative & Intergovernmental Affairs

And

Stephen Rynas
Federal Consistency Coordinator
Division of Coastal Management

FROM: Molly Ellwood
Southeastern Permit Coordinator
North Carolina Wildlife Resources Commission

DATE: March 5, 2010

SUBJECT: Comments for the Draft Environmental Impact Statement for the Storm Damage Reduction Plan for Surf City and North Topsail Beach, Onslow and Pender Counties
OLIA 10-0249

Biologists from the N. C. Wildlife Resources Commission (NCWRC) have reviewed the proposed project description. Our comments are provided in accordance with certain provisions of the North Carolina Environmental Policy Act (G.S. 113A-1 through 113A-10; 1 NCAC 25), certain provisions of the Coastal Area Management Act (G.S. 113A-100 through 113A-128), as amended, and the Fish and Wildlife Coordination Act (48 Stat. 401, as amended; 16 U.S.C. 661et seq.).

The United States Army Corps of Engineers is assessing the feasibility of Federal coastal storm damage risk reduction for the Towns of Surf City and North Topsail Beach, which are located on Topsail Island in Pender and Onslow Counties. The preferred alternative as described in the draft Environmental Impact Statement (DEIS) will be to dispose 11.5 mcy of beach compatible material from acceptable offshore sand sources to nourish approximately 52,150 lf in length of ocean front beach with a long dune a berm design constructed to a height of 15 ft NGVD fronted by a 7 ft NGVD (50 ft wide) beach berm. As proposed, the renourishment cycle would be every 4 years after the initial construction phases for a 50 year project.

Mailing Address: Division of Inland Fisheries • 1721 Mail Service Center • Raleigh, NC 27699-1721
Telephone: (919) 707-0220 • **Fax:** (919) 707-0028

The NCWRC have the following concerns and recommendations:

- The NCWRC recommends that all work to be conducted outside of the established moratoriums for nesting shorebirds (01 April-31 Aug) and nesting sea turtles (01 May – 15 Nov or until the lat known nest hatches). Any encroachment in these time frames will increase the chances for significant, adverse impacts to important wildlife species and would require further consultation with NCWRC biologists before the project can proceed.

- The NCWRC is continually concerned with the impacts of beach nourishment on benthic invertebrates. Benthic invertebrates are important food sources for foraging shorebirds and continued, frequent nourishment events can potentially have significant adverse impacts on these populations if they are not provided enough time to recover their populations to sustainable numbers.

  The DEIS discusses the proposed 4 year renourishment cycle that would start 1 year after the initial nourishment event. To reduce impacts to benthic invertebrates, the NCWRC supports staggering the renourishment areas so that the first renourishment event would start at the section of the project area where initial construction began; avoiding the most recent beach disposal area. Staggering these areas will allow a greater time for benthic invertebrates to adequately recover to sustainable levels.

Thank you for the opportunity to review and comment on this project. The NCWRC requests that our recommendations be considered throughout the 50 years of this project and that any alterations to this plan be reviewed by NCWRC staff. Moratorium windows are important for the protection of our state and federally listed wildlife species and we recommend that the project avoid any encroachment into these time frames. Please feel free to contact me at (910) 796-7240 if you have any additional questions or concerns pertaining to this project.

Cc: Matthew Godfrey, NCWRC
David Allen, NCWRC
Joanne Steenhuis, NCDWQ
Jessi O'Neal, NCDMF
Dave Timpy, USACE

RECEIVED
JAN 2 1 2010
DMF - HABITAT PROTECTION

Jessi

North Carolina Department of Environment and Natural Resources
Division of Coastal Management

Beverly Eaves Perdue
Governor

James H. Gregson
Director

Dee Freeman
Secretary

RECEIVED
MAR 2 2010
Morehead City DCM

MEMORANDUM

January 20, 2010

RECEIVED
MAR - 1 2010
DMF - HABITAT PROTECTION

TO: Anne Deaton
NCDENR - Division of Marine Fisheries
PO Box 769
Morehead City, NC 28557-0769

FROM: Stephen Rynas, AICP; Federal Consistency Coordinator

SUBJECT: Proposed Implementation of a Coastal Storm Damage Reduction Program (DCM#20100006)

LOCATION: Surf City and North Topsail Beach, Onslow and Pender Counties, North Carolina

This document is being circulated for **consistency** review and comment by **February 5, 2010**. The US Army Corps of Engineers is proposing to implement a coastal storm damage reduction program at Surf City and North Topsail Beach. Your responses will assist us in determining whether the proposed project would be consistent with the State's Coastal Management Program. If the proposed project does not conform to your requirements, please identify the measures that would be necessary to bring the proposed project into conformance. If you have any additional questions regarding the proposed project you may contact me at 252-808-2808 or email me at stephen.rynas@ncdenr.gov.

REPLY:

____ No Comment.

____ This office supports the project as proposed.

_✓_ Comments to this project are attached.

____ This office objects to the project as proposed.

Signed: Jessi O'Neal Anne Deaton Date: 2/26/10 2/25/10

CORRECTIONS: Please identify any corrections, additions, or deletions that should be made in terms of contact information.

RETURN COMPLETED FORM TO:

Stephen Rynas, Federal Consistency Coordinator
NC Division of Coastal Management
400 Commerce Avenue
Morehead City, NC 28557-3421

North Carolina Department of Environment and Natural Resources
Division of Marine Fisheries

Beverly Eaves Perdue
Governor

Dr. Louis B. Daniel III
Director

Dee Freeman
Secretary

MEMORANDUM:

TO: Melba McGee, DENR Environmental Coordinator
Stephen Rynas, DCM Federal Consistency Coordinator

THROUGH: Anne Deaton, DMF Habitat Section Chief AD

FROM: Jessi O'Neal, DMF Marine Biologist JO

SUBJECT: DEIS for the Surf City -North Topsail Beach (SCNTB) Coastal Storm Damage Reduction program

DATE: February 26, 2010

The North Carolina Division of Marine Fisheries (DMF) submits the following comments pursuant to General Statute 113-131. USACE DMF has reviewed the US Army Corps of Engineers (USACE) EIS for the Surf City -North Topsail Beach (SCNTB) Coastal Storm Damage Reduction project which includes a portion of North Topsail Beach shoreline and the entirety of Surf City shoreline. The fill area will be approximately 10 miles (52,150 feet) in length and material for initial construction will total 11,500,000 cubic yards. Initial construction will take four seasons with an estimated production rate of 14,000 cubic yards per day to construct a 15-foot tall (above msl) dune and 7-foot tall berm. All sand for this project will come from one of 16 offshore borrow sites that are 1 - 6 miles offshore and are 35 - 50 feet deep.

The Division is very concerned about the potential adverse impacts to hard bottom habitat and shoreline benthic populations. Impacts to these communities through dredging of the existing tidal delta and borrow area, in addition to burying the existing surf and swash zones, could impact the most productive forage locations in the project area. The absence of a large quantity of prey organisms could disrupt the local food web. We are also concerned about potential impacts to unidentified near-shore hard bottom due to the erosion of the construction berm. We are concerned that the schedules for construction, renourishment, and monitoring activities could result in adverse impacts to fisheries and fisheries prey.

Construction and sand volumes

The construction sequence is unclear. Please discuss the stages of construction discussed on page 145 including the length and location of each stage in each of the four construction seasons. It is also unclear what the potential construction and design beach widths are from the text or profiles. For example, Figure 7.1 could be updated to assign a more defined width or range of widths to each component of the profile, especially the additional beach width provided by achieving the design profile.

On page 117, it is explained that the total sand required for the life of the project is 86% of the total amount available in the surveyed area. Because of this DMF questions the necessity for the sand volumes proposed in for initial construction and renourishment. The North Topsail Beach nourishment

5285 Hwy 70 West, Morehead City, North Carolina 28557
Phone: 252-808-8066\ FAX: 252-727-5127\ Internet: www.ncdmf.net
An Equal Opportunity \ Affirmative Action Employer

One NorthCarolina Naturally

project that will tie into this project has a design profile of a 14-foot tall dune with a 6-foot berm. Considering the relative lack of sand resources, explain the reason for the additional foot of height on each feature.

Renourishment

On page 104 of the EIS, the Renourishment Interval section, reads as follows.

> 7.03.4 Renourishment Interval
> An analysis of various renourishment intervals from 2 to 7 years determined that a 6-year periodic nourishment interval results in slightly higher net benefits. Net benefits increase as a function of renourishment interval from 2 to 4 years, beyond which net benefits fluctuate about 1 percent as the interval increases. Longer renourishment intervals increase the risks between renourishment events of allowing accumulated erosion to create escarpments, narrow the non-dune portion of the beachfill, erode the toe of the dune, and damage dune vegetation. The potential reduction in the project's ability to sustain recreational uses and to provide a suitable habitat for sea turtles and other species on the beach outweigh the slight gain in net storm damage reduction benefits. Therefore the recommended renourishment interval is 4 years which captures over 99% of the maximum economic benefits and better sustains other benefits.

Although a long interval does increase the risks between renourishment events, it appears that risk is already a factor in the net benefit analysis (as described in Section 5) but environmental factors are not included. Considering the absence of environmental costs to important fisheries habitats in the net benefit analysis, DMF maintains that a renourishment interval of six years should be utilized. The 6-year periodic nourishment interval has the highest net benefit (as described in the scope of the study on page 4) based on the US ACE's calculations and would allow a longer recovery time between disturbances for the beach, surf zone, near-shore, and off-shore habitats.

Mitigation and Monitoring

DMF is very concerned about monitoring for changes in the benthic community in intertidal and hard bottom communities. In addition to the proposed monitoring for impacts to hard bottom habitat, impacts to the beach and borrow areas should be monitored. Please provide a detailed description of proposed biological monitoring protocols including pre- and post-construction monitoring of benthic invertebrates in the intertidal zone and the recovery of grade, substrate, and benthic invertebrates in the borrow areas.

As a part of any good monitoring program, a baseline must be established and then comparisons to that baseline can be made throughout the life of the project. On page 218 USFWS recommends annual monitoring for beach and sub-tidal benthic invertebrate monitoring with a pre-project assessment. The Corps responded that because of the historical data base and since Dare County is already conducting pre- and post- construction benthic invertebrate assessment, there is no need for the data. Below is a

table from the 2010 Coastal Habitat Protection Plan (*in review*) that summarizes several pertinent studies on the topic.

Locaton	Biological recovery following beach nourishment	Reference
North Topsail, N.C.	After 1 year, mole crab, coquina clam, and amphipod abundance remained significantly less than at control sites and body size was significantly smaller. Polychaetes increased in abundance.	Lindquist and Manning 2001
Bogue Banks, NC	Mole crabs recovered within months, coquina clams and amphipods failed to initiate recovery after one growing season. No follow up sampling.	Peterson et al. 2006
Bogue Banks, NC	On ebb tide delta, where sediment deposited, significant coarsening of sediment, and reductions in spinoind polychaetes after 8 mo.	Bishop et al. 2006
Atlantic Beach, N.C.	Densities of mole crabs and coquina clams were 86 – 99% lower than control sites, 5 – 10 weeks post-nourishment, during mid-summer.	Peterson et al. 2000b
Atlantic Beach, N.C.	More than 3 months. Coquina clams in nearshore overwintering bottom killed initially by turbidity; delayed recruitment and repopulation; Haustoriid amphipods had not recovered after 3 months. Polychaete *S. squamata* recovered 15 – 30 days post nourishment.	Reilly and Bellis 1983
Bald Head Island, Caswell Beach, Oak Island, NC	Coquina clams, mole crabs - > 1 year. Abundance declined 1 – 10 times from control. Most severe reductions and longest times of recovery due to season of project – greatest in spring and summer, except Oak Island coquina clams recovered within 1 year - timing of sand deposition allowed summer recruitment.	Versar 2003
Pea Island N.W.R., N.C.	2 – 9 months for coquina clams and mole crabs.	Donoghue 1999
Hilton Head, S.C.	Density and diversity returned to levels similar to control sites in 6 months.	Van Dolah et al. 1992
Folly Beach, S.C.	2 – 5 months, depending on benthic group and site, polychaetes recruiting earlier than mollusks.	Jutte et al. 1999
Panama City, F.L.	Large reductions in abundance and diversity remained after 2 years.	Rakocinski et al. 1993
Manasquan, N.J.	Abundance, biomass, and diversity completely recovered after 6.5 months. Recovery quickest when filling completed before low point in seasonal infaunal abundance and where grain size of fill material matched natural beach.	COE 2001

Based on the inconclusive results of this research and the unique character of this project using multiple borrow areas around hard bottom, DMF believes that benthic shoreline monitoring remains necessary. Since benthic recovery is site specific and highly dependent on timing and magnitude of disturbance, monitoring results from other sites cannot be substituted.

DMF is very concerned about the monitoring of beach substrate during and after construction activities. Further explanation will be necessary to outline the methodologies, standards, and protocols to follow when standards are surpassed.

Please describe any proposed mitigation for potential impacts revealed by monitoring. Provide information about potential mitigation strategies and who will be responsible for completing the mitigation project.

In addition to concerns about schedules of construction, renourishment, and monitoring, DMF has these additional comments about the EIS.

At two locations in the EIS (Table 7.1 (23) page 111 and p166), the following phrase appears: "...then the Corps will direct the contractor to stop dredging within the 122m buffer and move to another area located 500m from the identified hard bottom site." This phrase may imply that dredge activities occurring within the 122m buffer around hard bottom habitat. Perhaps it needs to be re-phrased.

DMF is very concerned about turbidity, caused by dredging of the borrow areas and construction of the beach areas. High turbidity levels can clog larval fish gills and gills of many surf–zone prey species, smother sessile organisms and bury important hard bottom habitat. Please provide a more detailed description of the proposed method of pumping sand onto the beach and how near-shore turbidity impacts will be reduced (ex. Utilizing a sand catchment basin to control run-off into the surf zone).

DMF is very concerned about secondary and cumulative impacts to offshore fisheries (especially shrimp, snapper and grouper species, and black sea bass) and surf fisheries including surf fishing and pier fishing (especially pompano, red drum, kingfish, spot, and croaker). On page 177, Section 8.04.1 Commercial and Recreational Fisheries, states that "Impacts on shore fishing would be limited to the area where material is being placed on the beach. This localized temporary impact can easily be avoided by anglers in the area. Nearshore fishing boats can operate around the dredging equipment operating in the area." This implies that the only impact to fishing will be the actual physical location of ongoing construction and the dredge itself. In addition to the potential impacts to fish habitats by depletion of the food base, it has been shown that fish react to noise and vibrations caused by in-water work. This should be addressed in the DEIS.

In conclusion, additional information is needed as described above, regarding design, construction schedule, renourishment interval, monitoring types and methodologies, and details on sand placement.

Federal Consistency

The NC Marine Fisheries Commission adopted "Policies for the Protection and Restoration of Marine and Estuarine Resources from Beach Dredging and Filling and Large Scale Coastal Engineering" on November 16, 2000 (see attached). Policy 6 states that projects "..should include compensatory mitigation for all reasonably predictable impacts to the marine and estuarine resources of North Carolina.." and Policy 7 continues that "Projects should include baseline and project-related monitoring adequate to document pre-project conditions and impacts of the projects on the marine and estuarine resources of North Carolina;". Unless this project includes an outline of proposed mitigation for possible impacts and includes documentation of pre- and post-project conditions of marine resources to include common swash zone benthic invertebrates, this project will be inconsistent with the policies of the Division of Marine Fisheries.

North Carolina Department of Environment and Natural Resources
Division of Coastal Management

Beverly Eaves Perdue
Governor

James H. Gregson
Director

Dee Freeman
Secretary

MEMORANDUM

January 20, 2010

RECEIVED
FEB 2 2010
Morehead City DCM

TO: Brian Strong
NCDENR - Division of Parks and Recreation
512 North Salisbury Street, Seventh Floor
Raleigh, NC 27604-1170

FROM: Stephen Rynas, AICP; Federal Consistency Coordinator

SUBJECT: Proposed Implementation of a Coastal Storm Damage Reduction Program (DCM#20100006)

LOCATION: Surf City and North Topsail Beach, Onslow and Pender Counties, North Carolina

This document is being circulated for **consistency** review and comment by **February 5, 2010**. The US Army Corps of Engineers is proposing to implement a coastal storm damage reduction program at Surf City and North Topsail Beach. Your responses will assist us in determining whether the proposed project would be consistent with the State's Coastal Management Program. If the proposed project does not conform to your requirements, please identify the measures that would be necessary to bring the proposed project into conformance. If you have any additional questions regarding the proposed project you may contact me at 252-808-2808 or email me at stephen.rynas@ncdenr.gov.

REPLY:

____ No Comment.

____ This office supports the project as proposed.

✓ Comments to this project are attached.

____ This office objects to the project as proposed.

Signed: Harry E. Latham, Jr Date: Jan. 29, 2010

CORRECTIONS: Please identify any corrections, additions, or deletions that should be made in terms of contact information.

RETURN COMPLETED FORM TO:

Stephen Rynas, Federal Consistency Coordinator
NC Division of Coastal Management
400 Commerce Avenue
Morehead City, NC 28557-3421

North Carolina Department of Environment and Natural Resources

Beverly Eaves Perdue
Governor

Dee Freeman
Secretary

January 29, 2010

MEMORANDUM

TO: Stephen Rynas, Federal Consistency Coordinator
NC Division of Coastal Management

FROM: Harry LeGrand, Natural Heritage Program

SUBJECT: Proposed Implementation of a Coastal Storm Damage Reduction Program for Surf City and North Topsail Beach; Onslow and Pender counties

REFERENCE: DCM#20100006

The Natural Heritage Program has no record of significant natural communities, significant natural heritage areas, or conservation/managed areas at the site. However, the beachfront is the site for nesting by the Federal and State Threatened loggerhead seaturtle (*Caretta caretta*). The Biological Assessment (Appendix I) provides considerable information on nesting by seaturtles. Our Program concurs with the proposed hopper dredging window of December 1 to March 31. We also strongly hope that all placement of sediment on the beach can be done within this window, as well.

The Federal and State Threatened seabeach amaranth (*Amaranthus pumilus*) is typically an annual that grows on accreting sand beaches, and thus is found mostly on ends of islands. As long as the dredging and beach renourishment can be done/completed within the December 1 to March 31 period, the impacts to the amaranth should be negligible. Both the northeastern and southwestern ends of Topsail Island are used by birds for nesting. Appendix I discusses these species. In general, increasing the amount of sand on the middle portion of an island, through ocean dredging and sand renourishment, will favor build-up of sand on the downdrift end of the island and be favorable to nesting by birds (by providing more extensive habitat), though this might take several years. Impacts to the "updrift" end of an island are probably not clear. Nonetheless, it might be too speculative to comment on the positive or negative impacts to birds nesting on either end of the island, in regard to this project.

Please do not hesitate to contact me at 919-715-8697 if you have questions or need further information.

1601 Mail Service Center, Raleigh, North Carolina 27699-1601
Phone: 919-733-4984 \ FAX: 919-715-3060 Internet: www.enr.state.nc.us

An Equal Opportunity \ Affirmative Action Employer – 50% Recycled \ 10% Post Consumer Paper

One NorthCarolina Naturally



North Carolina Department of Environment and Natural Resources
Division of Coastal Management

Beverly Eaves Perdue
Governor

James H. Gregson
Director

Dee Freeman
Secretary

RECEIVED
MAR 3 2010
Morehead City DCM

RECEIVED
JAN 22 2010
BY:

MEMORANDUM

January 20, 2010

TO: Joanne Steenhuis (401 Water Quality)
DWQ - 401 Water Quality Certification (Wilmington)
NCDENR - Division of Water Quality
127 Cardinal Drive Extension
Wilmington, NC 28405-5406

FROM: Stephen Rynas, AICP; Federal Consistency Coordinator

SUBJECT: Proposed Implementation of a Coastal Storm Damage Reduction Program (DCM#20100006)

LOCATION: Surf City and North Topsail Beach, Onslow and Pender Counties, North Carolina

This document is being circulated for **consistency** review and comment by **February 5, 2010**. The US Army Corps of Engineers is proposing to implement a coastal storm damage reduction program at Surf City and North Topsail Beach. Your responses will assist us in determining whether the proposed project would be consistent with the State's Coastal Management Program. If the proposed project does not conform to your requirements, please identify the measures that would be necessary to bring the proposed project into conformance. If you have any additional questions regarding the proposed project you may contact me at 252-808-2808 or email me at stephen.rynas@ncdenr.gov.

REPLY:

_____ No Comment.

_____ This office supports the project as proposed.

_X_ Comments to this project are attached. JHS

_____ This office objects to the project as proposed.

Signed: Dick Shiner Date: 02.26.10

CORRECTIONS: Please identify any corrections, additions, or deletions that should be made in terms of contact information.

RETURN COMPLETED FORM TO:

Stephen Rynas, Federal Consistency Coordinator
NC Division of Coastal Management
400 Commerce Avenue
Morehead City, NC 28557-3421

MEMORANDUM

DIVISION OF WATER QUALITY

TO: Stephen Rynas, Division of Coastal Management Federal Consistency Coordinator

FROM: Joanne Steenhuis, Senior Environmental Specialist JHS

THROUGH: Rick Shiver, Surface Water Protection Regional Supervisor

DATE: February 26, 2010

SUBJECT: EIS Develop Coastal Storm Damage Reduction Plan for Surf City and North Topsail Beach

PROJECT: Implementation of a Coastal Storm Damage Reduction Plan for Surf City and North Topsail Beach
DCM Project No. 10-0006

COUNTY: Pender and Onslow Counties

The Wilmington Regional Office has reviewed the Environmental Impact Statement for the implementation of a coastal storm damage reduction plan document for Surf City and North Topsail Beach. The Division of Water Quality (DWQ) has no objections to the project as proposed as long as they comply with the dredging moratoriums and environmental monitoring as discussed in the document.

Thank You

WiRO

RECEIVED
JAN 2 2 2010
DCM

North Carolina Department of Environment and Natural Resources
Division of Coastal Management

Beverly Eaves Perdue
Governor

James H. Gregson
Director

Dee Freeman
Secretary

RECEIVED
JAN 2 9 2010
Morehead City DCM

MEMORANDUM

January 20, 2010

TO: Dan Sams
NCDENR - Division of Land Resources
127 Cardinal Drive Extension
Wilmington, NC 28405-5406

FROM: Stephen Rynas, AICP; Federal Consistency Coordinator

SUBJECT: Proposed Implementation of a Coastal Storm Damage Reduction Program (DCM#20100006)

LOCATION: Surf City and North Topsail Beach, Onslow and Pender Counties, North Carolina

This document is being circulated for **consistency** review and comment by **February 5, 2010**. The US Army Corps of Engineers is proposing to implement a coastal storm damage reduction program at Surf City and North Topsail Beach. Your responses will assist us in determining whether the proposed project would be consistent with the State's Coastal Management Program. If the proposed project does not conform to your requirements, please identify the measures that would be necessary to bring the proposed project into conformance. If you have any additional questions regarding the proposed project you may contact me at 252-808-2808 or email me at stephen.rynas@ncdenr.gov.

REPLY:

_____ No Comment.

_____ This office supports the project as proposed.

_X_ Comments to this project are attached. Activity over one acre in size requires erosion and sediment plan application and approval.

_____ This office objects to the project as proposed.

Signed: Daniel Sams Date: JAN. 25, 2010

CORRECTIONS: Please identify any corrections, additions, or deletions that should be made in terms of contact information.

RETURN COMPLETED FORM TO:

Stephen Rynas, Federal Consistency Coordinator
NC Division of Coastal Management
400 Commerce Avenue
Morehead City, NC 28557-3421



North Carolina Department of Environment and Natural Resources
Division of Coastal Management

Beverly Eaves Perdue
Governor

James H. Gregson
Director

Dee Freeman
Secretary

MEMORANDUM

January 20, 2010

TO: John Giles
Division of Coastal Management - Wilmington
127 Cardinal Drive Extension
Wilmington, NC 28405-5406

FROM: Stephen Rynas, AICP; Federal Consistency Coordinator

SUBJECT: Proposed Implementation of a Coastal Storm Damage Reduction Program (DCM#20100006)

LOCATION: Surf City and North Topsail Beach, Onslow and Pender Counties, North Carolina

This document is being circulated for **consistency** review and comment by **February 5, 2010**. The US Army Corps of Engineers is proposing to implement a coastal storm damage reduction program at Surf City and North Topsail Beach. Your responses will assist us in determining whether the proposed project would be consistent with the State's Coastal Management Program. If the proposed project does not conform to your requirements, please identify the measures that would be necessary to bring the proposed project into conformance. If you have any additional questions regarding the proposed project you may contact me at 252-808-2808 or email me at stephen.rynas@ncdenr.gov.

REPLY:

✓ No Comment.

____ This office supports the project as proposed.

____ Comments to this project are attached.

____ This office objects to the project as proposed.

Signed: [signature] Date: 2/12/10

CORRECTIONS: Please identify any corrections, additions, or deletions that should be made in terms of contact information.

RETURN COMPLETED FORM TO:

Stephen Rynas, Federal Consistency Coordinator
NC Division of Coastal Management
400 Commerce Avenue
Morehead City, NC 28557-3421

RECEIVED
DCM WILMINGTON, NC
JAN 29 2010

RECEIVED
JAN 22 2010
HISTORIC PRESERVATION OFFICE

North Carolina Department of Environment and Natural Resources
Division of Coastal Management

Beverly Eaves Perdue
Governor

James H. Gregson
Director

Dee Freeman
Secretary

MEMORANDUM

January 20, 2010 RECEIVED

CH 01-0417
ER ~~10-0121~~

FEB 11 2010
Morehead City DCM

A - Cultural resources prev. addressed with ltr 2-3-10

TO: Renee Gledhill-Early
State Historic Preservation Office
4617 Mail Service Center
Raleigh, NC 27699-4617

FROM: Stephen Rynas, AICP; Federal Consistency Coordinator

Due 2/11/10

SUBJECT: Proposed Implementation of a Coastal Storm Damage Reduction Program (DCM#20100006)

LOCATION: Surf City and North Topsail Beach, Onslow and Pender Counties, North Carolina

This document is being circulated for **consistency** review and comment by **February 5, 2010**. The US Army Corps of Engineers is proposing to implement a coastal storm damage reduction program at Surf City and North Topsail Beach. Your responses will assist us in determining whether the proposed project would be consistent with the State's Coastal Management Program. If the proposed project does not conform to your requirements, please identify the measures that would be necessary to bring the proposed project into conformance. If you have any additional questions regarding the proposed project you may contact me at 252-808-2808 or email me at stephen.rynas@ncdenr.gov.

REPLY:

____ No Comment.

X This office supports the project as proposed.

____ Comments to this project are attached.

____ This office objects to the project as proposed.

Signed: Renee Gledhill-Early Date: 2·5·10

CORRECTIONS: Please identify any corrections, additions, or deletions that should be made in terms of contact information.

RETURN COMPLETED FORM TO:

Stephen Rynas, Federal Consistency Coordinator
NC Division of Coastal Management
400 Commerce Avenue
Morehead City, NC 28557-3421

1-25-10

5J

RECEIVED
JAN 25 2010
Shellfish Sanitation & Recreational
Water Quality Section

RECEIVED
JAN 26 2010
Morehead City DCM

RECEIVED
JAN 20 2010
Shellfish Sanitation & Recreational
Water Quality Section

NCDENR
North Carolina Department of Environment and Natural Resources
Division of Coastal Management
James H. Gregson
Director

Beverly Eaves Perdue
Governor

Ben Greeman
Secretary

MEMORANDUM

January 20, 2010

TO: Patti Fowler
Shellfish Sanitation and Recreational Water Quality Section
NCDENR - Division of Environmental Health
PO Box 769
Morehead City, NC 28557-0769

FROM: Stephen Rynas, AICP; Federal Consistency Coordinator

SUBJECT: Proposed Implementation of a Coastal Storm Damage Reduction Program (DCM#20100006)

LOCATION: Surf City and North Topsail Beach, Onslow and Pender Counties, North Carolina

This document is being circulated for **consistency** review and comment by **February 5, 2010**. The US Army Corps of Engineers is proposing to implement a coastal storm damage reduction program at Surf City and North Topsail Beach. Your responses will assist us in determining whether the proposed project would be consistent with the State's Coastal Management Program. If the proposed project does not conform to your requirements, please identify the measures that would be necessary to bring the proposed project into conformance. If you have any additional questions regarding the proposed project you may contact me at 252-808-2808 or email me at stephen.rynas@ncdenr.gov.

REPLY:

X No Comment.

____ This office supports the project as proposed.

____ Comments to this project are attached.

____ This office objects to the project as proposed.

Signed: [signature] Re Patti Fowler Date: 1/22/10

CORRECTIONS: Please identify any corrections, additions, or deletions that should be made in terms of contact information.

RETURN COMPLETED FORM TO:

Stephen Rynas, Federal Consistency Coordinator
NC Division of Coastal Management
400 Commerce Avenue
Morehead City, NC 28557-3421

RECEIVED
JAN 21 2010
Shellfish Sanitation & Recreational
Water Quality Section

North Carolina Department of Environment and Natural Resources
Division of Coastal Management

Beverly Eaves Perdue
Governor

James H. Gregson
Director

Dee Freeman
Secretary

MEMORANDUM

January 20, 2010

TO: John Fear
Coastal Reserve Program - Beaufort
101 Pivers Island Road
Beaufort, NC 28516-9701

FROM: Stephen Rynas, AICP; Federal Consistency Coordinator

SUBJECT: Proposed Implementation of a Coastal Storm Damage Reduction Program (DCM#20100006)

LOCATION: Surf City and North Topsail Beach, Onslow and Pender Counties, North Carolina

This document is being circulated for **consistency** review and comment by **February 5, 2010**. The US Army Corps of Engineers is proposing to implement a coastal storm damage reduction program at Surf City and North Topsail Beach. Your responses will assist us in determining whether the proposed project would be consistent with the State's Coastal Management Program. If the proposed project does not conform to your requirements, please identify the measures that would be necessary to bring the proposed project into conformance. If you have any additional questions regarding the proposed project you may contact me at 252-808-2808 or email me at stephen.rynas@ncdenr.gov.

REPLY:

X No Comment.

____ This office supports the project as proposed.

____ Comments to this project are attached.

____ This office objects to the project as proposed.

Signed: John Fear Date: 2-3-10

CORRECTIONS: Please identify any corrections, additions, or deletions that should be made in terms of contact information.

RETURN COMPLETED FORM TO:

Stephen Rynas, Federal Consistency Coordinator
NC Division of Coastal Management
400 Commerce Avenue
Morehead City, NC 28557-3421

North Carolina Department of Environment and Natural Resources
Division of Coastal Management

Beverly Eaves Perdue
Governor

James H. Gregson
Director

Dee Freeman
Secretary

MEMORANDUM

January 20, 2010

TO: Jim Mead
DWR - Water Projects Section
NCDENR - Division of Water Resources
1611 Mail Service Center
Raleigh, NC 27699-1611

FROM: Stephen Rynas, AICP; Federal Consistency Coordinator

SUBJECT: Proposed Implementation of a Coastal Storm Damage Reduction Program (DCM#20100006)

LOCATION: Surf City and North Topsail Beach, Onslow and Pender Counties, North Carolina

This document is being circulated for **consistency** review and comment by **February 5, 2010**. The US Army Corps of Engineers is proposing to implement a coastal storm damage reduction program at Surf City and North Topsail Beach. Your responses will assist us in determining whether the proposed project would be consistent with the State's Coastal Management Program. If the proposed project does not conform to your requirements, please identify the measures that would be necessary to bring the proposed project into conformance. If you have any additional questions regarding the proposed project you may contact me at 252-808-2808 or email me at stephen.rynas@ncdenr.gov.

REPLY:

X No Comment.

____ This office supports the project as proposed.

____ Comments to this project are attached.

____ This office objects to the project as proposed.

Signed: Jim Mead Date: 2/4/10

CORRECTIONS: Please identify any corrections, additions, or deletions that should be made in terms of contact information.

RETURN COMPLETED FORM TO:

Stephen Rynas, Federal Consistency Coordinator
NC Division of Coastal Management
400 Commerce Avenue
Morehead City, NC 28557-3421

RECEIVED
JAN 21 2010
DIVISION OF WATER RESOURCES

North Carolina Department of Environment and Natural Resources
Division of Coastal Management

Beverly Eaves Perdue
Governor

James H. Gregson
Director

Dee Freeman
Secretary

MEMORANDUM

January 20, 2010

RECEIVED
FEB 8 2010
Morehead City DCM

TO: County of Pender
PO Box 444
Burgaw, NC 28425-0444

FROM: Stephen Rynas, AICP; Federal Consistency Coordinator

SUBJECT: Proposed Implementation of a Coastal Storm Damage Reduction Program (DCM#20100006)

LOCATION: Surf City and North Topsail Beach, Onslow and Pender Counties, North Carolina

This document is being circulated for **consistency** review and comment by **February 5, 2010.** The US Army Corps of Engineers is proposing to implement a coastal storm damage reduction program at Surf City and North Topsail Beach. Your responses will assist us in determining whether the proposed project would be consistent with the State's Coastal Management Program. If the proposed project does not conform to your requirements, please identify the measures that would be necessary to bring the proposed project into conformance. If you have any additional questions regarding the proposed project you may contact me at 252-808-2808 or email me at stephen.rynas@ncdenr.gov.

REPLY:

X No Comment.

____ This office supports the project as proposed.

____ Comments to this project are attached.

____ This office objects to the project as proposed.

Signed: [signature] Date: 2/3/10

CORRECTIONS: Please identify any corrections, additions, or deletions that should be made in terms of contact information.

RETURN COMPLETED FORM TO:

Stephen Rynas, Federal Consistency Coordinator
NC Division of Coastal Management
400 Commerce Avenue
Morehead City, NC 28557-3421

From: Eric G. Hawk [Eric.Hawk@noaa.gov]
Sent: Tuesday, January 19, 2010 9:31 AM
To: Piatkowski, Douglas SAW
Cc: David Bernhart; Robert Hoffman; Michael Barnette
Subject: August 2009 Draft Integrated Feasibility Report and EIS,
Coastal Storm Damage Reduction, Surf City and North Topsail Beach, North
Carolina

Attachments: eric_hawk.vcf

Hi Doug,

We received and reviewed Colonel Ryscavages's January 13, 2010, letter and attached Draft Integrated Feasibility Report and EIS, Coastal Storm Damage Reduction, Surf City and North Topsail Beach, North Carolina, dated August 2009.
NMFS agrees with the COE's determination that the proposed beach renourishment action, consisting (in part) of utilizing hopper dredges to mine offshore sand sources for deposition of sand onto North Carolina beaches (a 17-mile section extending from Topsail Beach/Suf City town limits to the northern end of Topsail Island) falls under the authority of the current NMFS South Atlantic regional biological opinion on hopper dredging of navigation channels and borrow areas in the southeastern United States, dated September 25, 1997 (i.e., SARBO). The SARBO is in the process of being revised and will eventually supersede the current opinion. The COE will abide by the revised SARBO when it is ultimately issued. Sea turtle or shortnose sturgeon takes resulting from the proposed dredging action when conducted under the RPMs and T&Cs of the SARBO are authorized and will be counted against the ITS take limit as set forth in the SARBO. If you have any questions, please contact me or Mike Barnette.

Best Regards,

Eric Hawk

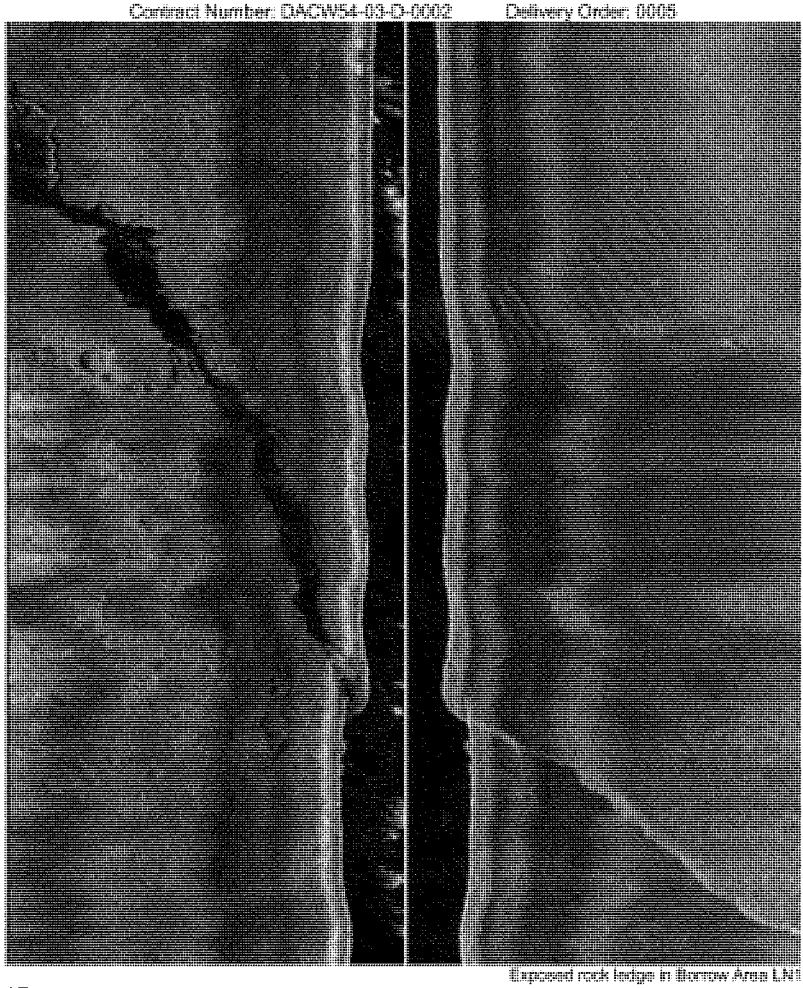
INTEGRATED
FEASIBILITY REPORT
AND
ENVIRONMENTAL IMPACT STATEMENT

COASTAL STORM DAMAGE REDUCTION PROJECT
SURF CITY AND NORTH TOPSAIL BEACH
NORTH CAROLINA

Appendix U
Archaeological Appendix

An Archaeological Remote Sensing Survey of Surf City-North Topsail Beaches Offshore Borrow Areas

Contract Number: DACW54-03-D-0002 Delivery Order: 0005



Exposed rock ledge in Borrow Area LN1

Submitted To:
U.S. Army Corps of Engineers
Wilmington District

Submitted By:
Mid-Atlantic Technology and Environmental Research, Inc.
Principal Investigator:

Wes Hall
23 September 2005

An Archaeological Remote Sensing Survey of Surf City-North Topsail Beaches Offshore Borrow Areas

Contract Number: DACW54-03-D-0002 Delivery Order Number: 0005

Submitted To:

U.S. Army Corps of Engineers
Wilmington District
69 Darlington Avenue
Wilmington, North Carolina 28403

Submitted By:

Mid-Atlantic Technology and Environmental Research, Inc.
441 Blossom Ferry Road
Castle Hayne, North Carolina 28429

Principal Investigator:

_____

Wes Hall

23 September 2005

ABSTRACT

The U.S. Army Corps of Engineers Wilmington District (USACE) is conducting preliminary investigations of seven proposed sand borrow areas totaling +/- 12,000 acres, for a beach re-nourishment project at Surf City-North Topsail Beaches, in Pender and Onslow Counties, North Carolina. As a part of these investigations, Mid-Atlantic Technology and Environmental Research, Inc. (M-AT/ER) of Castle Hayne, North Carolina, conduct marine magnetometer and side-scan sonar surveys of the proposed borrow areas for the purpose of identifying any potential archaeological resources that might be impacted by the offshore dredging activities during the sand mining process.

In addition to archaeological resources, M-AT/ER conducted a search to identify hard bottom/marine habitat areas, using side-scan sonar record analysis as part of the remote sensing investigations. M-AT/ER conducted historical research and field investigations for the project between 14 October 2004 and May 10 2005.

The remote sensing survey identified no magnetic anomalies or the acoustic targets related to cultural resources within any of the seven proposed sand borrow areas. No additional archaeological investigations or actions are recommended.

Hard bottom ranging from low to high relief was found in each proposed borrow area. Appropriate action to avoid or mitigate sand mining impacts to these areas should be exercised.

TABLE OF CONTENTS

Page

Abstract i
List of Figures iii
Introduction 1
Project Location 1
Historical Background 10
  Settlement 10
  Environment 11
  Shipwrecks 11
  New River Inlet, Surf City and North Topsail Beach 12
  Maritime Commerce 13
  Twentieth Century Activity 13
Previous Investigations 14
Pre-survey Consultation and Documentation 15
Description of Investigations 15
  Data Analysis 16
  Data Assessment (General) 17
Description of Findings 19
  Shipwreck List 19
  Remote Sensing Survey Findings 19
Identification of Hard Bottom Areas 28
Conclusions and Recommendations 50
References 51

LIST OF FIGURES

Page
Figure 1. Project Location Map. 2
Figure 2. Relative Position of Project Areas 2
Figure 3. Area H 3
Figure 4. Area K. 4
Figure 5. Area LN1 5
Figure 6. Area M. 6
Figure 7. Area N2 7
Figure 8. Area N3 8
Figure 9. Area P. 9
Figure 10. Area H Magnetic Contour Map. 21
Figure 11. Area K Magnetic Contour Map 22
Figure 12. Area LN1 Magnetic Contour Map. 23
Figure 13. Area M Magnetic Contour Map. 24
Figure 14. Area N2 Magnetic Contour Map. 25
Figure 15. Area N3 Magnetic Contour Map. 26
Figure 16. Area P Magnetic Contour Map 27
Figure 17. Sonar image of typical hard bottom in Area H. 29
Figure 18. Hard Bottom Map – Area H 30
Figure 19. Sonar Imagine of Moderate Relief Hard Bottom in Area K 31
Figure 20. Example Sonar Image of Moderate to High Relief in Area K. 32
Figure 21. Hard Bottom Map of Area K. 33
Figure 22. Example Sonar Image of Low Relief in Area LN1. 34
Figure 23. Example Sonar Image of Moderate Relief in Area LN1. 35
Figure 24. Example Sonar Image of High Relief in Area LN1. 36
Figure 25. Hard Bottom Map of Area LN1 37
Figure 26. Example Sonar Image of Low Relief Area M. 38
Figure 27. Example Sonar Image of Moderate Relief Area M. 39
Figure 28. Example Sonar Image of High Relief in Area M. 40
Figure 29. Hard Bottom Map of Area M. 41
Figure 30. Example Sonar Image Low Relief in Area N2. 42
Figure 31. Hard Bottom Map of Area N2 43
Figure 32. Example Sonar Image of Low to Moderate Relief in Area N3. 44
Figure 33. Example Sonar Image of Moderate to High Relief in Area N3. 45
Figure 34. Hard Bottom Map of Area N3 46
Figure 35. Example of Sonar Image of Low Relief in Area P. 47
Figure 36. Example Sonar Image of Moderate Relief in Area P. 48
Figure 37. Hard Bottom Map of Area P. 49

INTRODUCTION

The U.S. Army Corps of Engineers Wilmington District (USACE) is conducting preliminary investigations of seven proposed sand borrow areas totaling +/- 12,000 acres, for a beach re-nourishment project at Surf City-North Topsail Beaches, in Pender and Onslow Counties, North Carolina. As a part of these investigations, Mid-Atlantic Technology and Environmental Research, Inc. (M-AT/ER) of Castle Hayne, North Carolina, was contracted to conduct marine magnetometer[1] and side-scan sonar[2] surveys of the proposed borrow areas for the purpose of identifying any potential archaeological resources that might be impacted by the offshore dredging activities during the sand mining process. This work was conducted pursuant to provisions of Section 106 of the National Preservation Act of 1966 (36 CFR 800, Protection of Historic Properties) and the Abandon Shipwreck Act of 1987 (Abandon Shipwreck Guidelines, National Park Service, Federal Register, Vol. 55, No. 3, 4 December 1990, pages 50116-50145)[3].

In addition to archaeological resources, M-AT/ER was required to search for and identify hard bottom/marine habitat areas using side-scan sonar record analysis as part of the remote sensing investigations. M-AT/ER conducted historical research and field investigations for the project between 14 October 2004 and May 10 2005.

PROJECT LOCATION

The seven survey areas are located between 2 and 4 nautical miles offshore of Surf City and North Topsail Beach. The survey areas were located 7 to 19 nautical miles northeast of New Topsail Inlet. Figures 1 and 2 show the project location and the relative position of each borrow area, followed by Figures 3 through 10 that provide detail of each survey area. North Carolina State Plane coordinates (NAD 83) are included for reference. The combined acreage for the seven borrow areas is +/- 12,000 acres.

---

[1] A magnetometer is an electronic instrument that measures localized changes in the earth's magnetic field. By using a magnetometer in a controlled survey, the presence of ferrous materials can be detected. Since most historically significant shipwrecks contain relatively large amounts of iron or steel in the form of fasteners, anchors, cannons, or engines, etc., their presence can frequently be detected by a magnetometer survey.

[2] Side-scan sonar is an underwater acoustic instrument that by electronic means generates a graphic representation of the bottom surface. By interpretation of these graphic records, the user can identify geographic changes in the bottom or man-made objects protruding above the bottom surface.

[3] A national policy for historic preservation has been established in accordance with authorization contained in Sections 106 and 110 (formerly E.O. 11593) of the National Historic Preservation Act of 1966, as amended following the Advisory Council on Historic Preservation Regulations (36 CFR 800). Executive Order 11593 and the Historic Preservation Act Amendments of 1980 specified that the Federal Government shall provide leadership in preserving, restoring, and maintaining the historic and cultural environment of the nation. In 1988, the Abandoned Shipwreck Act (Public Law 100-298) declared that the states (or territories of the U.S.) are to manage shipwrecks in state waters. As a result of these acts and other legislation, state and federal agencies are required to administer cultural properties under their control in a spirit of stewardship and trusteeship. Each agency is required to initiate such measures as are necessary to insure that policies, plans, and programs will preserve sites, structures, and objects of historical or archaeological significance that exist on properties owned by the Federal Government or that are subject to federal regulation.

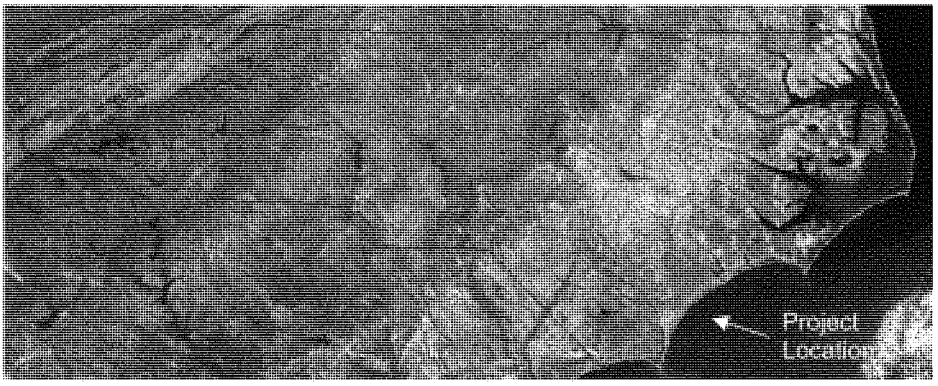


Figure 1. Project Location Map.

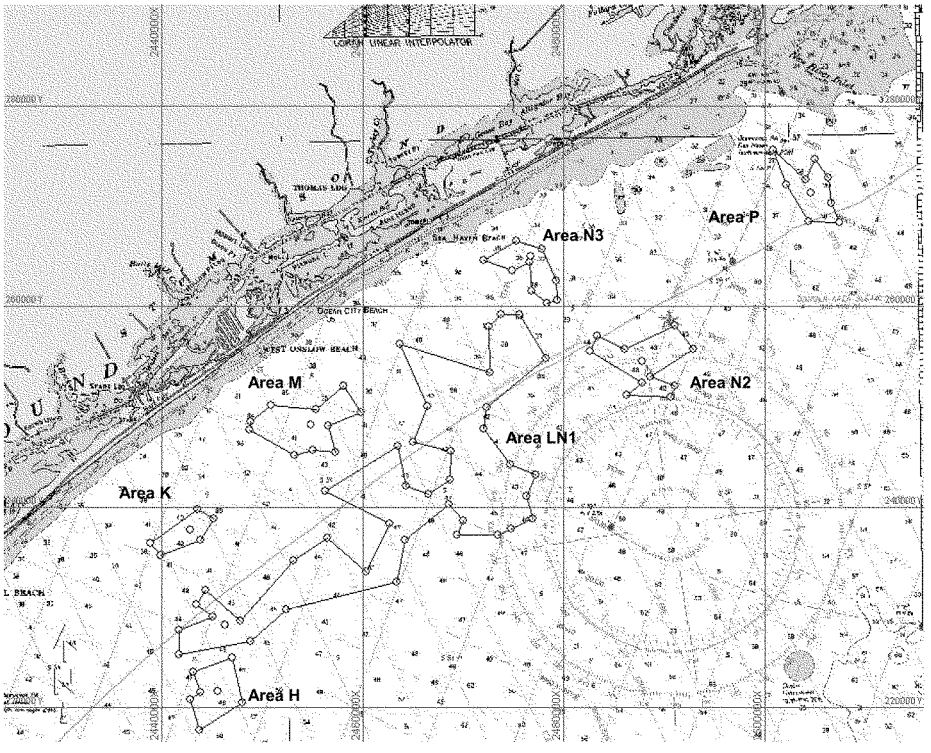


Figure 2. Relative Position of Project Areas

North Carolina State Plane Coordinates (NAD 83) for the proposed sand borrow areas:

Area H

x	y
2446987	225033
2443172	223555
2443846	221546
2442825	220884
2443731	217786
2448013	220552

Area K

x	y
2438842	236368
2439815	235165
2443837	236712
2445157	238873
2443553	239793

Area M

x	y
2450899	250165
2448779	248565
2448738	247715
2453215	245142
2455020	245723
2457285	245475
2456551	248114
2459851	249423
2458040	252130
2455385	249735

Area N2

x	y
2482642	255512
2487788	252443
2486319	251215
2490652	250949
2491103	252084
2488659	253055
2492875	255758
2491058	258142
2486120	255781
2483302	257062

Area N3

X	y
2474907	263606
2476566	264404
2476786	261508
2478342	260354
2479315	260660
2479301	262586
2477793	265729
2475308	266532
2472011	264594

Area P

X	y
2507494	268362
2506613	270356
2506334	272832
2505053	274732
2504144	272680
2500861	275609
2502188	272115
2504376	268450

Area LN1

x	y
2443402	230301
2445092	229129
2441682	227807
2441717	225316
2448825	226655
2452400	229839
2463352	232513
2464183	236746
2468532	240243
2469994	238637
2469420	237181
2473432	237267
2474819	237834
2476898	238870
2476328	241108
2477191	243211
2474670	244234
2472049	247782
2472292	249978
2478220	254870
2475639	259219
2473736	259234
2472581	258025
2472660	253466
2463732	256238
2466388	250055
2465042	246504
2468781	245543
2468626	242696
2466522	241309
2464316	242167
2463481	246095
2456232	241586
2462665	238303
2460354	233551
2456478	236939
2453090	234734
2447804	228664
2444323	231783

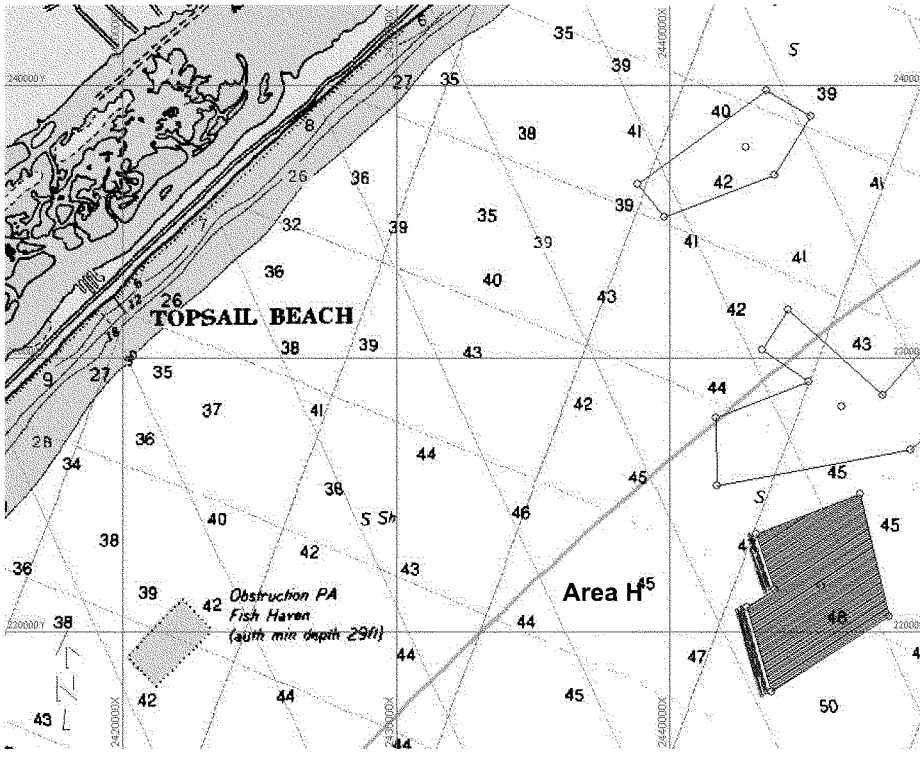


Figure 3. Area H.

The Area H survey consisted of 80 lines @ 65ft/20m spacing, totaling more than 354,771 linear ft/59 nautical miles with water depths of 45 to 47 ft.

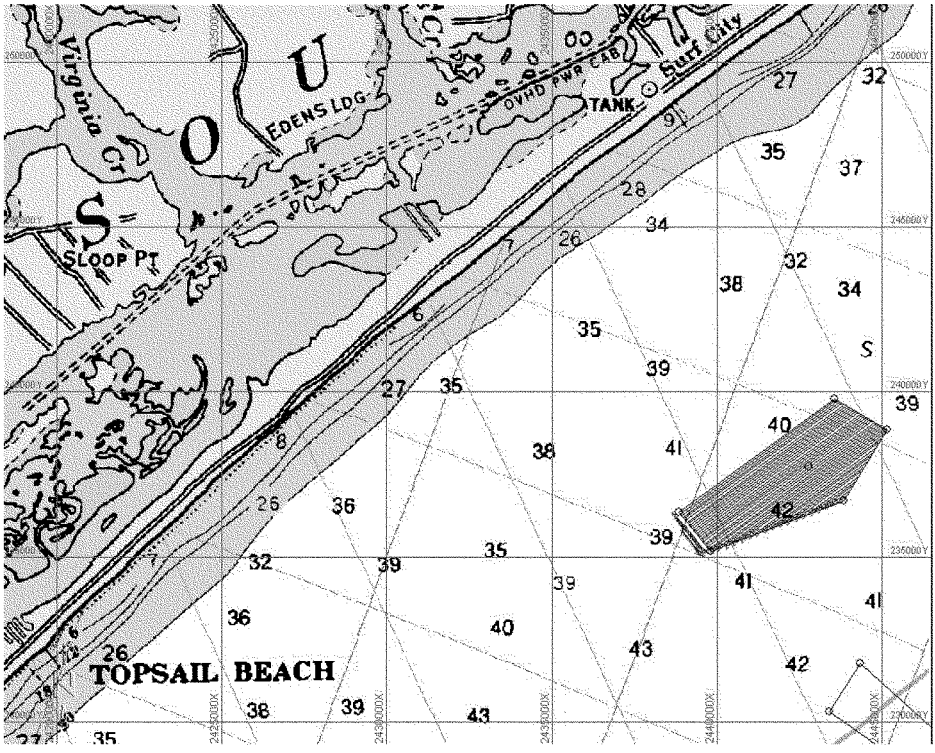


Figure 4. Area K.

The Area K survey consisted of 41 lines @ 65ft/20m spacing, totaling 201,806 linear ft/33 nautical miles with water depths of 39 to 42 ft.

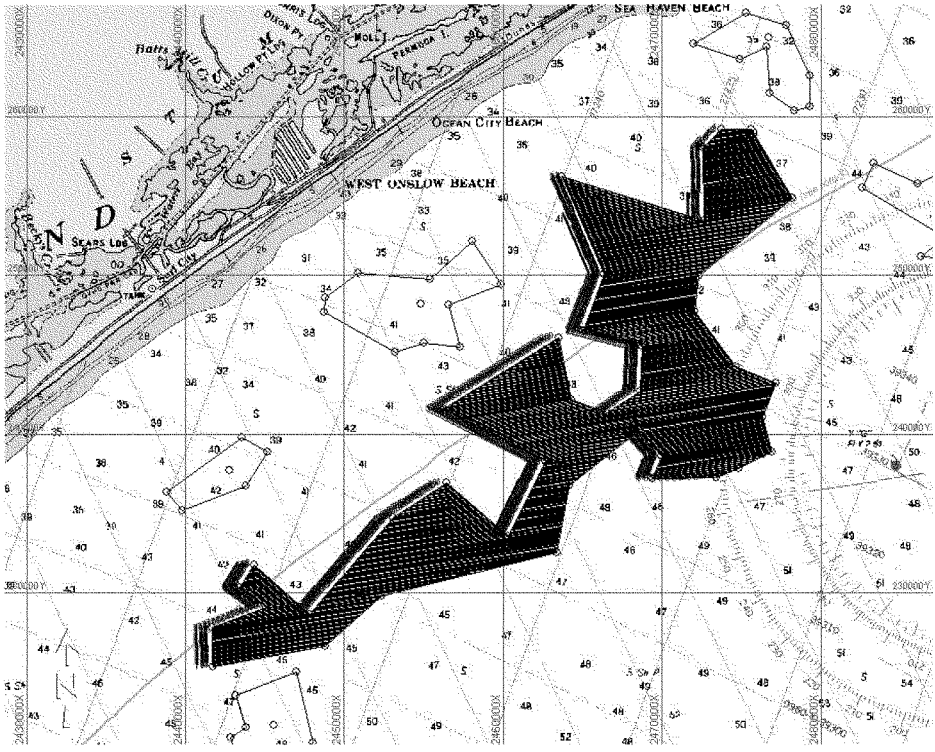


Figure 5. Area LN1.

The Area LN1 survey consisted of 753 lines @ 65ft/20m spacing, totaling 4,496,068 linear ft/740 nautical miles with water depths of 38 to 47 ft.

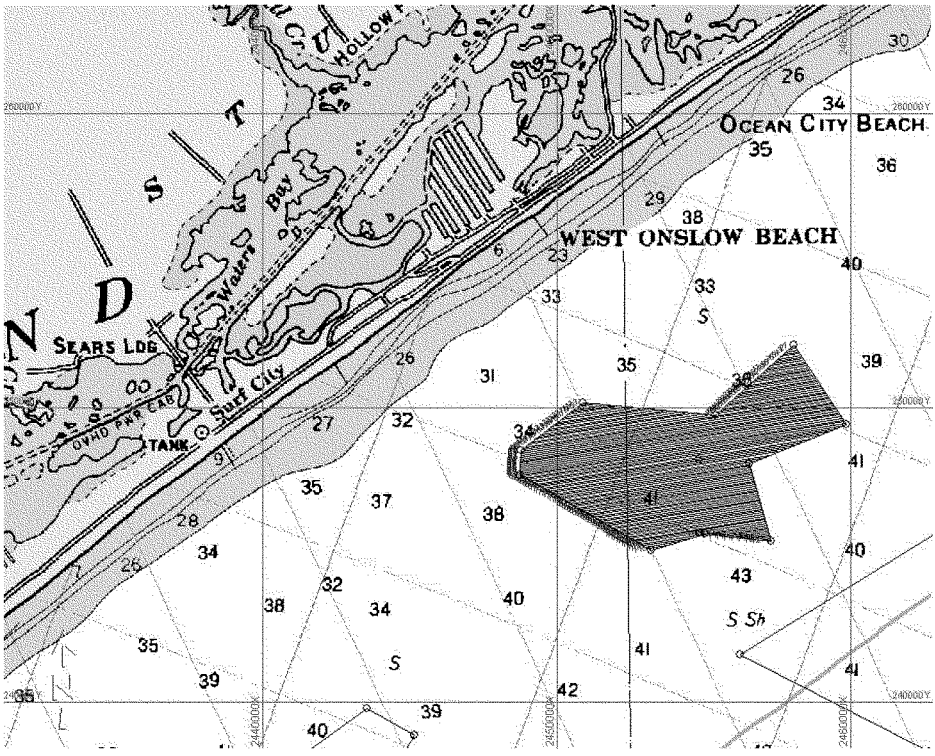


Figure 6. Area M.

The Area M survey consisted of 121 lines @ 65ft/20m spacing, totaling 587,018 linear ft/97 nautical miles with water depths of 32 to 47 ft.

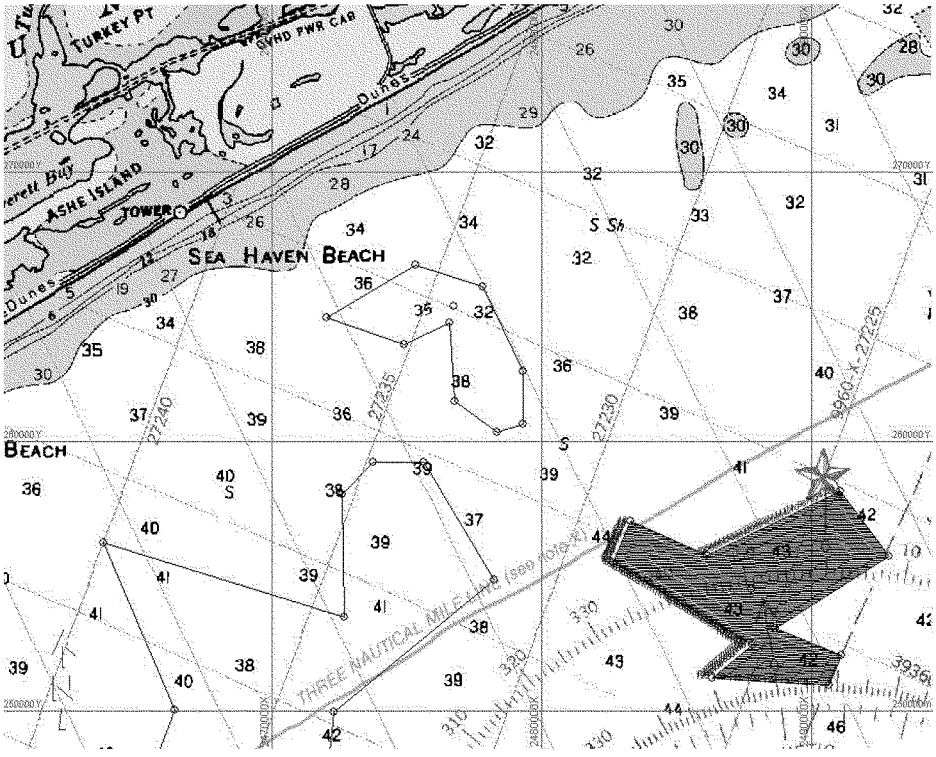


Figure 7. Area N2.

The Area N2 survey consisted of 131 lines @ 65ft/20m spacing, totaling 519,939 linear ft/86 nautical miles with water depths of 41 to 43 ft.

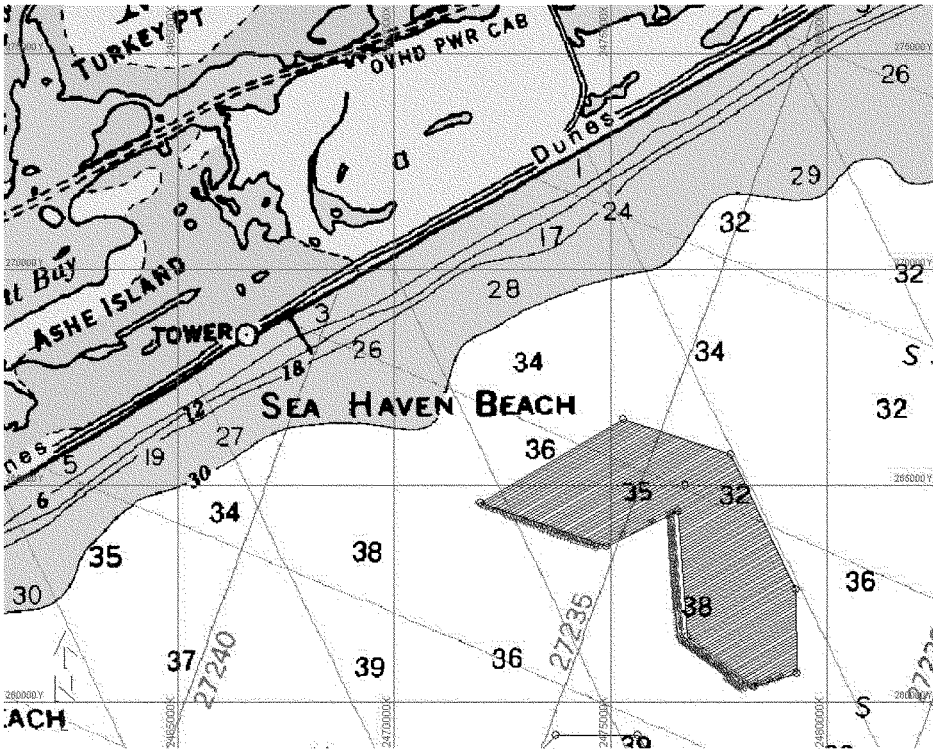


Figure 8. Area N3.

The Area N3 survey consisted of 109 lines @ 65ft/20m spacing, totaling 288,492 linear ft/47 nautical miles with water depths of 32 to 38 ft.

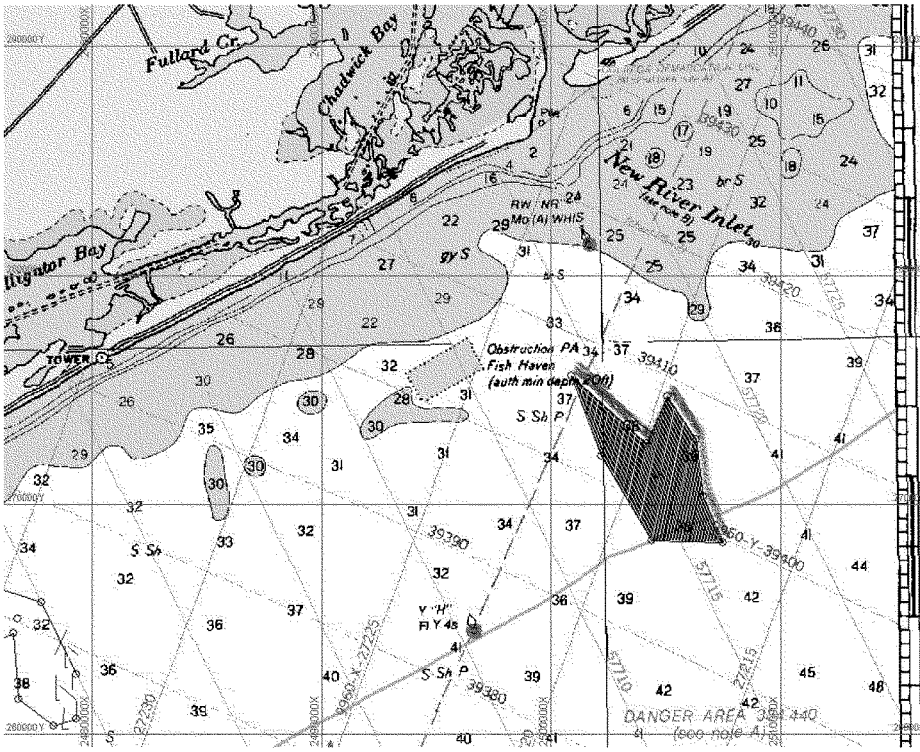


Figure 9. Area P.

The Area P survey consisted of 123 lines @ 65ft/20m spacing, totaling 321,952 linear ft/53 nautical miles with water depths of 37 to 41 ft.

HISTORICAL BACKGROUND

North Carolina's barrier islands formed nearly 18,000 years ago when coastal areas submerged during the Holocene epoch. High sand ridges built up along the mainland beaches by wind and water action, during the last period of glaciations. As the sea level rose, the ridge system failed, causing low-lying areas behind to flood. As a result, lagoons and shallow sounds were formed, leaving the existing dune ridges as barrier islands.

Inlets are formed by the wave action and shifting sands. Most of the inlets are temporary, either migrating along the coast or closing altogether as near shore currents transport sand parallel to the coastline. Permanent inlets occur along the southern coast where the mouths of significant rivers provide enough force to maintain stable inlets (Tubby 2000:59).

New Topsail Inlet is located at the lower end of Topsail Beach and connects the waters of the Atlantic Ocean with those of Topsail Sound, in Pender County. New River Inlet is to the north and Old Topsail Inlet to the south. The city of Wilmington is approximately 20 miles to the southwest.

Settlement

Permanent settlement of the Topsail Sound shoreline began in the early eighteenth century. One of the earliest land grants was issued in 1726 to John Baptista Ashe and was comprised of 800 acres "being the banks between Stumpy Sound and New Topsail Inlet" (Angley 1984:1).

Around this same time, the Nixon family began to settle along Topsail Sound, evidenced by the label "Nixon" opposite the inlet on the Moseley Map of 1733. The Wimble Map of 1738 notes several plantations near the inlet as well as an anchorage point just inside the inlet, indicating its use as an artery of coastal trade. By the time of the American Revolution, several other families had settled along the nearby shoreline of Topsail Sound, including the families of Bishop, Price, Morris, and Harrison (Angley 1984:1).

As early as 1755, New Topsail Sound was designated as an official inspection point for export commodities in New Hanover County, along with counties Brunswick, Wilmington, and New Exeter. In the following years of 1758, 1764, and 1770, the legislature again issued the designation. The New Topsail Inlet itself was made the point of inspection for the Topsail Sound area, in 1784. Inspections were conducted for export commodities of fish, flour, butter, flax seed, beef, pork, rice, tar, pitch and turpentine, staves and headings, sawed lumber and shingles (Angley 1984:1).

Settlement continued in the area. By the mid-nineteenth century, new families had established residency. In 1845, in addition to existing sound property, Charles H. Alexander acquired some 75 acres of beach property on both sides of the inlet.

Owen Holmes was granted 76 acres on the upper side of the inlet and 361 acres between New Topsail and Old Topsail inlets, in 1859. Holmes Landing was established directly opposite New Topsail Inlet as a local shipping point, by the time of the Civil War (Angley 1984:2).

Environment

With a depth of 10 feet (presumably at high tide), the inlet was suitable for passage by schooners and small sloops. It appears that the position of the inlet remained relatively stable throughout the Colonial Period. However, the volume of trade was limited by the shallowness of adjoining sounds and a lack of direct communication with the mouth of a large navigable stream (Angley 1984:2).

During the latter part of the eighteenth century and throughout most of the nineteenth century, New Topsail Inlet migrated significantly to the north. According to the Mouzon Map of 1775 and the Price-Strother Map of 1808, the inlet migrated northward some two miles. While the Mac Rae-Brazier Map of 1833 indicates no significant change, the U.S. Coast Survey Map of 1865 shows that an additional migration of two miles occurred during that period. The migration appears to have abated during the end of that century, as is suggested by review of the Kerr-Cain Map of 1882 and the Post Route Map of 1896 (Angley 1984:7).

A detailed U.S Coast Survey Map of 1885 indicates that the New Topsail Inlet was approximately 3,000 feet wide at that time.

Shipwrecks

Eleven vessels were reported or believed to have been lost in the area of Topsail Inlet (see also Shipwreck List).

In 1750, a hurricane struck the mid-Atlantic region, causing the loss of four vessels of the 1750 Spanish Plate Fleet. One of those ships, packet boat *El Salvador* was lost in the vicinity of Topsail Inlet on 18 August 1750 (Stick 1952:244). Due to the shifting sands, the surviving remains were buried in a matter of days, making salvaging operations difficult. The exact position of the vessel has been uncertain, although two locations have been suggested: modern New Topsail Inlet or Beaufort Inlet, which also was known as Old Topsail Inlet during that period (Tubby 2000:51).

Before the Civil War, the following vessels were lost in the vicinity: schooner *Superior*, driven ashore 24 November 1841 (Angley 1984:6); an unknown brig in September 1769, run ashore below Topsail Inlet (Tubby 2000:173); English merchantman *Betsy* in 1771 at Old Topsail Inlet (Tubby 2000:173); schooner *Mary Bear* on 9 September 1881 at New Topsail Inlet (Stick 1952:249); and schooner *William H. Sumner* on 7 September 1919, grounded at Topsail Inlet.

The Civil War activity in the area resulted in a number of wrecks. On 22 October 1862, sailing aboard the USS *Ellis*, Lieutenant William B. Cushing reported the seizure and scuttling of schooner *Adelaide* of Halifax. Abandoned about a mile from the mouth of New Topsail Inlet, the ship was loaded with about 600 barrels of turpentine, 36 bales of cotton, and tobacco. Unable to be floated to sea, the vessel was burned (Angley 1984:4).

Eight days later, en route from Hampton Roads to its Wilmington station, the USS *Daylight* seized the blockade-runner *Racer* near New Topsail Inlet. The vessel, loaded primarily with salt, had been abandoned by her crew along Topsail Beach in order to avoid capture. The USS *Daylight* crew was able to refloat the vessel, which was later taken to New York (Angley 1984:4). (*Graveyard of the Atlantic* lists this vessel as having wrecked at Diamond Shoals (Stick 1952:246)).

The USS *Daylight* again was successful in thwarting Confederate shipping, when they chased ashore and destroyed an unidentified schooner, westward of Stump Inlet (Angley 1984:4).

On 23 September 1863, iron-hulled steamer *Phantom* ran aground and was burned near Rich Inlet. She carried a cargo of government stores including arms, medicine, lead ingots, and sundry items (Tubby 2000:173). It was later confirmed the Phantom actually ran aground in Topsail Inlet (Personal communication, Richard Lawrence, NC Division of Archives and History, Underwater Archaeology Unit, Fort Fisher).

About 5 miles to the northward of New Topsail Inlet, on 2 February 1863, the USS *Mount Vernon* destroyed an abandoned blockade runner loaded with salt (Angley 1984:4), believed to be schooner *Industry* (Tubby 2000:173).

On 25 August 1863, Lieutenant Cushing, aboard USS *Shokokon*, captured the *Alexander Cooper*, which is believed to be the last vessel sunk or captured in the New Topsail Inlet vicinity during the Civil War (Angley 1984:4).

Other vessels lost in the Topsail Inlet vicinity during the Civil War include an unknown schooner that ran ashore westward of Stump Inlet on 22 January 1863; and *Wild Dayrell* (or *Wild Darryl*), a side-wheel steamer that was grounded and burned near Rich Inlet (mistakenly placed in New Topsail Inlet Tubby's thesis). She carried a cargo of shoes, blankets, and valuable merchandise (Tubby 2000:173).

New River Inlet, Surf City and North Topsail Beach

No shipwrecks have been record in New River inlet or offshore of Surf City or North Topsail Beach.

Maritime Commerce

As was indicative of vessels seized, the inlet was active with salt production. A 1864 military map shows at least 2 Confederate salt works situated on either side of Holmes Landing. The presence of the salt works is further substantiated in a letter of 1 November 1862 written by USS Lieutenant William Cushing to his superior.

The following year, on 22 August, Lieutenant Cushing and his men destroyed the second salt works on Topsail Sound, which apparently had been rebuilt later to the east of Holmes Landing (Angley 1984:3).

Twentieth Century Activity

As reported on a detailed map by surveyor Eric Norden in the mid-1920s, New Topsail Inlet had narrowed to a width of 2,550 feet.

In 1932, a 12-feet deep and ninety-feet wide segment of the Intracoastal Waterway between Beaufort and the Cape Fear south of Wilmington was completed. The channel allowed for an increase in vessel traffic from 33,710 tons in 1932 to 243,000 tons in 1939. As reported the previous year, the character of the vessel traffic – of around 9,000 vessel trips – consisted of approximately 8,500 motor vessels, 300 tugs, 200 barges, and a smattering of pleasure craft. Cargo vessels transported agricultural commodities, lumber, petroleum products, seafood, fertilizer, and general merchandise (Angley 1984:8).

No subsequent improvements of any kind were made to the New Topsail Inlet vicinity, or along Topsail Beach, according to a Pender County highway map of 1938. Although a few structures existed near the mouth of the Old Topsail Creek, other structures were located in the Sloop Point area, well to the northeast.

However, by 1947, development of Topsail Beach began. A bridge had been built across the sound (at the upper end of beach), and a road had been constructed along the beach to the mouth of the New Topsail Inlet. Between 1947 and 1970, considerable growth occurred on Topsail Beach, resulting in hundreds of cottages, other structures, a network of streets, and docking facilities at the lower end of the beach adjoining the mouth of New Topsail Inlet. Additionally, a new marked channel provided direct communication between the inlet and the Intracoastal Waterway, besides the associated old Banks and Howard channels.

By the mid-1970s, the New Topsail Inlet had narrowed considerably more – to a width of 1,250 feet from a mid-1920s width of 2,550 feet. During 1938 and 1972, the inlet moved southward some 2,680 feet, reversing the migration of the late eighteenth and early nineteenth centuries. Most of the migration occurred between 1948 and 1956 (Angley 1984:8).

Whereas the earlier maritime activity within the New Topsail Inlet vicinity was related to settlement and expansion, modern-day vessel traffic primarily consists of

pleasure craft, sporting fishing boats, and some commercial vessels. Today, the inlet is maintained by the U.S. Army Corps of Engineers.

PREVIOUS INVESTIGATIONS

During 1963 and 1964, the United States Navy, at the request of the North Carolina Division of Archives and History, conducted salvage and exploration activities in the area. Location and preliminary examination was made of a Civil War period steam vessel in the immediate vicinity of either Rich or Topsail Inlet. Limited surviving records of this investigation do not confirm the site's location or describe the extent or nature of the work undertaken (Watts et al. 1975:57).

In 1975, the North Carolina Underwater Archaeology Unit (Fort Fisher) conducted a summer field school that included a general magnetometer survey of portions of the areas north of Carolina Beach to Topsail Island. The magnetometer survey identified four magnetic anomalies in the vicinity of New Topsail and Old Topsail Inlets. Data collected indicates that the two targets were low intensity, multi-component anomalies. These targets were not examined further because of poor weather conditions. The report recommended further magnetic remote sensing.

The third target ("The Phantom Site") was found at a location originally called the Colorado Site, which is located approximately 200 yards south of the southern end of New Topsail Inlet and in 16 to 18 feet of water. Only the boilers, steam machinery, and small portion of the hull were exposed. However, given the intense magnetic signature of 7,000 gammas, it is believed that more of the vessel lies below the bottom. The target was identified as the remains of a mid-nineteenth century iron hull, double screw steamer – possibly the remains of blockade-runner *Phantom*. Additional investigations were recommended in order to positively identify the specific vessel found (Watts et al. 1975:115).

The forth anomaly indicated a target with "a considerable amount of material below the bottom", which was located 1.2 miles east of New Topsail Inlet. This target was deemed most worthy of additional investigation. Dive investigations failed to reveal any materials above the bottom (Kimmel 1998:2).

Prior to this survey, no previous attempts to locate submerged cultural resources were undertaken in this area.

Later, in 1988, the USACOE performed a magnetic survey inside New Topsail Inlet for a proposed borrow area. The survey reported no anomalies within the survey area. However, there is mention of a large object (250 feet in length), located offshore of the borrow area and visible from an aerial photo taken in 1963. The object is not visible on more recent photos.

In 2000, in an effort to locate the 1750 Spanish Plate Fleet *El Salvador,* a magnetometer and side-scan sonar survey was conducted around New Topsail Inlet in a 6-square-mile area centered on the inlet. Two sites were found, and dive

investigations of these sites revealed the remains of a late nineteenth to early twentieth century sailing vessel. The other site did not represent the remains of a broken up wreck. The *El Salvador* was not located.

PRE-SURVEY CONSULTATION AND DOCUMENTATION

As part of the investigative effort, M-AT/ER first conducted a literature search to help document man's activities in the vicinity and to provide a historical context for the assessment of potential cultural resources discovered offshore. The search helped to determine the extent and type of commercial and naval activity offshore, which further assisted in the assessment of targets identified during field investigations. This research focused on primary and secondary materials, as compiled by environmental and archeological agencies responsible for managing the State's cultural resources and depositories, such as libraries and museums. In addition, research included consultation with local historians and the State Underwater Archaeologist at Fort Fisher.

The following offices and/or institutions were contacted:

- Underwater Archaeology Unit, Division of Archives and History, Fort Fisher, NC
- North Carolina Maritime Museum, Beaufort, NC
- NC State Archives
- Office of the Historian, U.S. Coast Guard, Washington, D.C.
- Marine Casualty Branch, U.S. Coast Guard
- Maritime Historian, Sanctuaries and Reserves Division, National Oceanic and Atmospheric Administration

Preliminary secondary sources examined:

- The Encyclopedia of American Shipwrecks
- Merchant Steam Vessels of the United States 1807 - 1868
- Shipwrecks of the Western Hemisphere
- Shipwrecks of the Civil War
- Official Records of the Union and Confederate Navies in the War of the Rebellion
- Automated Wreck and Obstruction Information System of the National Oceanic and Atmospheric Administration
- Web Site Review of http://anchor.ncd.noaa.gov/awois/search.cfm
- Historical Maps and Charts

Researchers reviewed source materials at each institution and conducted interviews with librarians/technical staff to determine the best potential sources for background information. A list of known or potential shipwrecks has been developed for the vicinity.

DESCRIPTION OF INVESTIGATIONS

Using a 25-foot survey vessel, M-AT/ER's underwater archaeology team conducted a remote sensing survey of the seven proposed borrow areas. Two remote sensing devices were used: a Geometrics 881 cesium marine magnetometer, and a Marine Sonic 600-kHz side-scan sonar. Each instrument was interfaced with a Starlink

Differential Global Positioning System. HYPACK MAX™ navigation software also was interfaced with the DGPS system, being used to develop the survey lines and maintain vessel track during data collection.

Data was collected along parallel lines spaced at 65-foot (20-meter) intervals. Magnetic data, along with corresponding positioning data, was recorded at one-second sample intervals (or approximately every 8 feet along a track line at 5 knots) using MAGSEA and HYPACK data acquisition software. Since depths in each of the proposed borrow areas ranged from 38 to 45 feet, a 65-pound tri-fin stabilizer/depressor was used to keep the magnetometer sensor at an average depth of 18 to 22 feet above the bottom surface. Acoustic data was recorded with Sea Scan PC acoustic data acquisition software using an onboard PC computer system. At the end of each day, acoustic data was stored on 700 mb CDs. The side-scan sonar fish was maintained at an altitude (generally 20 to 30 feet) above the bottom, which provided the most detailed records.

To assist in data analysis, hydrographic data also was recorded entirely in HYPACK.

Data Analysis

During field investigations, data being produced by the magnetometer and side-scan sonar was closely monitored. Targets (magnetic or acoustic) were identified and recorded as they were generated. Also noted on field records was information about the local environment, which included man-made features such as pipelines, channel markers, crab traps, and conditions that could influence magnetic or acoustic data.

After a survey area had been completed, archaeologists edited the magnetic data for detailed analysis and comparison to acoustic data. Editing was performed in three phases. The initial phase consisted of using HYPACK's single-beam editing program to review raw data (of individual survey lines) and to delete any artificially induced noise or data spikes. While editing survey lines, a preliminary target table was developed to include individual target coordinates, signature characteristics, intensity, and duration. Once all survey line data for an area was edited, that data was converted to an XYZ file (Easting and Northing State Plane Coordinates, and magnetometer data measured in nanoteslas), also using HYPACK. Next, the XYZ files were imported into a Triangular Irregular Network (TIN) modeling program (HYPACK) that was used to contour the data in five-nanoTesla intervals. Once the data was contoured, the contour graphic was converted to a DXF file and imported into AutoCAD in order to clearly view individual magnetic anomalies and their association with acoustic target signatures. Once in AutoCAD, additional editing of the total magnetic intensity was performed without effecting individual magnetic anomalies. For example, dramatic or pronounced diurnal changes that frequently will create a "striped," "zigzag," or "herring bone" pattern in the contour lines can be edited out and averaged across a survey area to create a more realistic and accurate contour map.

A second major analytical technique employed was the subtraction of general background from each successive data sample to develop the actual field gradient. The gradient is the vertical difference (z) among samples. By subtracting successive data samples one from the other, the effects of diurnal changes are completely eliminated. The resulting data represents only the localized changes in the magnetic background created by ferrous object(s), i.e., anomalies. When graphically represented by contouring (using the same method described above), only the intensity of variation is represented.

During the analysis process, magnetic anomalies were categorized using the anomaly intensity, duration and/or extent, and signature characteristics. In addition, the anomaly's geographic location was taken into consideration, as well as its association with acoustic target signatures.

After magnetic data was developed into a target list, acoustic data was examined using SeaScan™ acoustic data review software to identify any unnatural or man-made features in the records. Once identified, acoustic features were described using visible length, width, and height from the bottom surface. The coordinates of the acoustic features also were recorded.

Data Assessment (General)

Target signatures are evaluated using the National Register of Historic Places criteria as a basis for the assessment. Determining the significance of an historic vessel depends on whether the wreck site or vessel is:

1) the sole, best, or a good representative of a specific vessel type; or
2) is associated with a significant designer or builder; or
3) was involved in important maritime trade, naval, recreational, government, or commercial activities.

In order for a target to be eligible for nomination to the national register, it must meet one or more of the following criteria:

A. be associated with events that have made a significant contribution to the broad patterns of our history; or

B. be associated with the lives of persons significant in our past; or

C. embody the distinctive characteristics of a type, period, or method of construction, or that represent the work of a master, or that possess high artistic values, or that represent a significant and distinguishable entity whose components may lack individual distinction; or

D. have yielded, or may be likely to yield, information important in prehistory or history.

(National Register Bulletin, U.S. Department of the Interior, National Park Service, Interagency Resources Division)

Target assessment for this project was based primarily on the nature and characteristics of the acoustic and magnetic signatures. Shipwrecks — large or small — often have distinctive acoustic signatures, which are characterized by geometrical features typically found only in a floating craft. Often, modern debris near docks, bridges, or an anchorage is easily identified based solely on the characteristics of its acoustic signature. Most geometrical features identified on the bottom (in open water) are man-made objects — modern debris such as wire rope, chain, or other ferrous material.

Often an acoustic signature will have an associated magnetic signature. Generally, if the acoustic signature demonstrates geometric forms or intersecting lines with some relief above the bottom surface and has a magnetic signature of any sort, it can be categorized as a potentially significant target.

Magnetic target signatures alone are more difficult to assess. Without any supporting sonogram record, the nature of the bottom sediments and the water currents become more important to the assessment process. Soft migrating sand or mud can bury large wrecks, leaving little or no indication of their presence on the bottom surface. A shipwreck that occurs in a region with a hard bottom, with little migrating sand, tends to remain exposed and is often visible on sonogram records. However, a magnetic anomaly that is identified in a hard bottom area but has no associated acoustic signature often is discounted as an historic shipwreck. Physical examination is necessary to make a more definitive determination.

The type of magnetic signature that a boat or ship might produce is infinite because of the large number of variables including location, position, chemical environment, other metals, vessel type, cargo, sea state, etc. This dynamic environment is subject to constant change. Thus, in making an assessment of a magnetic anomaly's potential to represent a significant cultural resource, investigators must be circumspect in their predictions.

A small, single-source magnetic signature has the least potential to be a significant cultural resource. Although it might represent a single cannon ball or historic anchor, this type of signature has little potential to meet the above referenced National Register criteria. Conversely, a more complex magnetic anomaly, represented by a broad or intense, multi-component signature, which is particularly if found in soft sand and low-velocity currents, has the greatest potential of representing a shipwreck. A high-intensity, multi-component magnetic signature without an accompanying acoustic signature in an area of relatively high-velocity currents often can frequently be discounted as an historic resource. Eddies created by high-velocity currents most often keep some portion of a wreck exposed. Generally, wire rope or some other low-profile ferrous debris produces this type of signature in these circumstances.

Many types of magnetic anomalies display characteristics that are not easily interpreted. Frequently, these objects produce a record that clearly indicates a man-made object; however, based solely on the magnetic signature, the object is impossible to identify or date. The only definitive method of determining the nature of the object creating these anomalies is by physical examination.

In making an archaeological assessment, the historical and modern use of the waterway must be taken into consideration. Obviously, historically active areas tend to have greater potential for submerged cultural resources. This information — along with environmental variables, magnetic and acoustic signatures, shape the assessment process. The assessment process is meant to prioritize targets for further underwater archaeological investigations.

DESCRIPTION OF FINDINGS

Investigations to identify documented shipwrecks near the project area revealed that 11 ships have wrecked in the Topsail Inlet and Topsail Beach vicinities. No shipwrecks have been recorded offshore of Surf City, North Topsail Beach or New River Inlet. Most of the shipwrecks occurred during the nineteenth century.

Shipwreck List

Reported Shipwrecks are as follows:

Wreck Name	Date Lost	Type Vessel	Location
El Salvador	18 Aug 1750	Nao	Topsail Inlet (suspected)
Unknown Brig	Sep 1769	Brigantine	Below Topsail Inlet
Betsy	1771	Merchantman	Old Topsail Inlet
Adelaide	22 Oct 1862	Schooner	Mouth of New Topsail Inlet
Alexander Cooper	22 Aug 1863	Schooner	New Topsail Inlet
Industry	2 Feb 1863	Schooner	5 miles north of Topsail Inlet
Phantom	23 Sep 1863	Steamer	200 yards offshore in 30 feet of water, Topsail Inlet
Unknown Schooner	22 Jan 1863	Schooner	Westward of Stump Inlet
Wild Dayrell	3 Feb 1864	Side-wheel Steamer	Rich Inlet
Mary Bear	9 Sep 1881	Schooner	New Topsail Inlet
William H. Sumner	7 Sep 1919	Schooner	Topsail Inlet

Remote Sensing Survey Findings

No single isolated magnetic or acoustic targets or anomalies were identified during the survey of all seven borrow areas. A general geologically generated change in the magnetic background was noted in some areas. There were no indications that these gradual changes in gradient were associated with bottom features or sand.

Many small "false anomalies" created by the contouring of pole data seems to be a product of a combination of factors including change in gradient, line spacing, diurnal change, and the TIN analysis modeling program used to contour data. Most of the false anomalies were monopolar with less than 10 nanotesla in amplitude.

BORROW AREA H

No magnetic or acoustic targets were identified in Borrow Area H (Figure 10).

BORROW AREA K

No magnetic or acoustic targets were identified in Borrow Area K (Figure 11).

BORROW AREA LN1

No magnetic or acoustic targets were identified in Borrow Area LN1 (Figure 12).

BORROW AREA M

No magnetic or acoustic targets were identified in Borrow Area M (Figure 13).

BORROW AREA N2

No magnetic or acoustic targets were identified in Borrow Area N2 (Figure 14).

BORROW AREA N3

No magnetic or acoustic targets were identified in Borrow Area N3 (Figure 15).

BORROW AREA P

No magnetic or acoustic targets were identified in Borrow Area P (Figure 16).

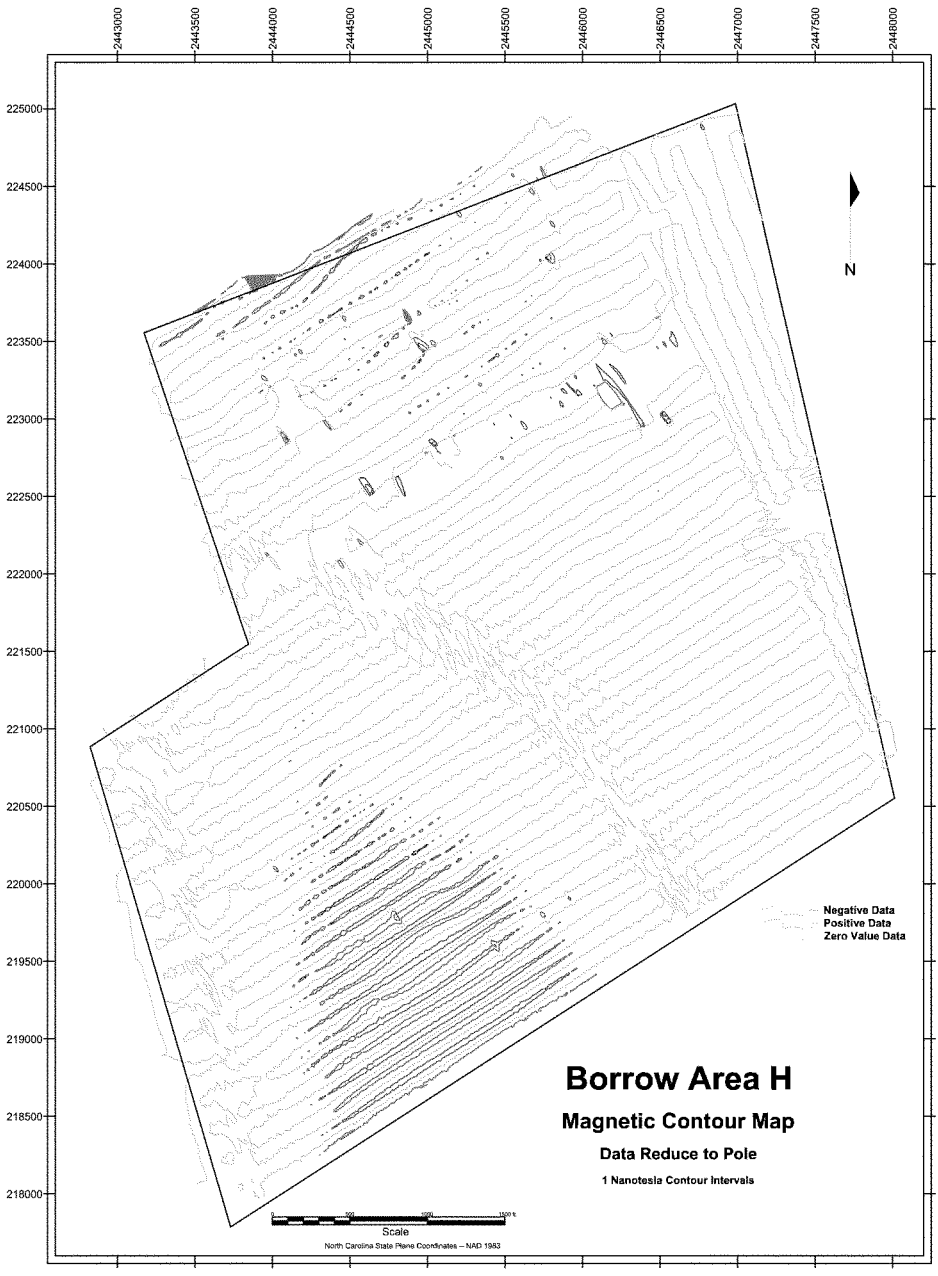


Figure 10. Area H Magnetic Contour Map.

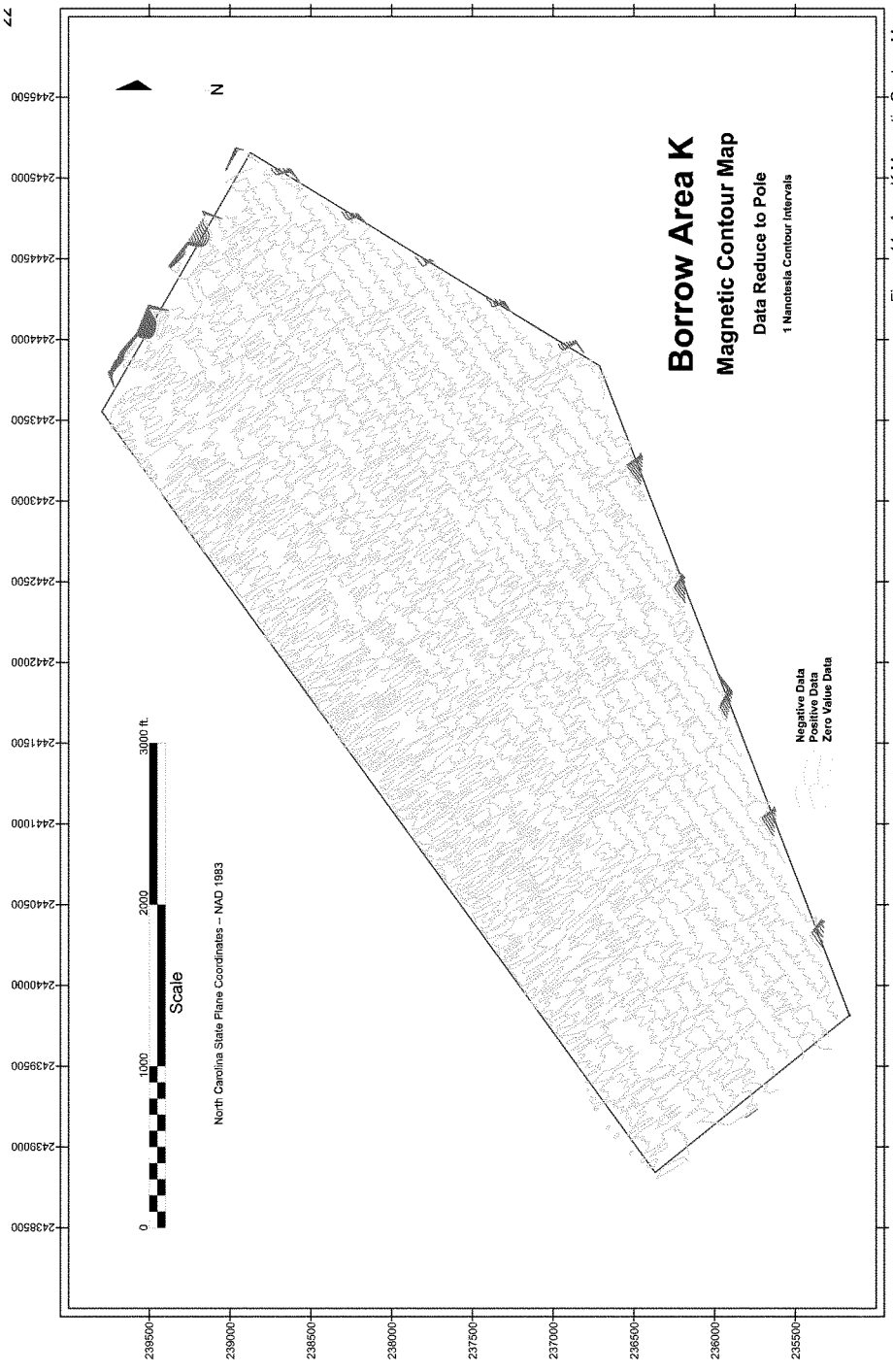


Figure 11. Area K Magnetic Contour Map.

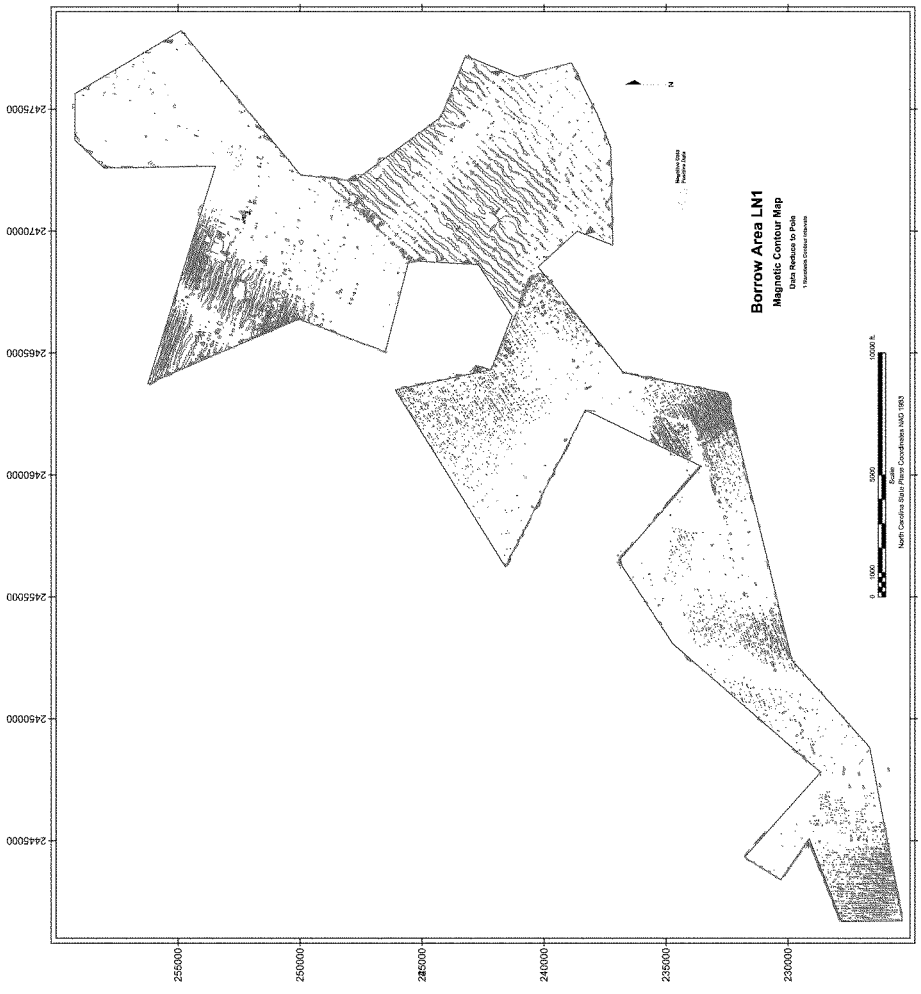


Figure 12. Area LN1 Magnetic Contour Map.

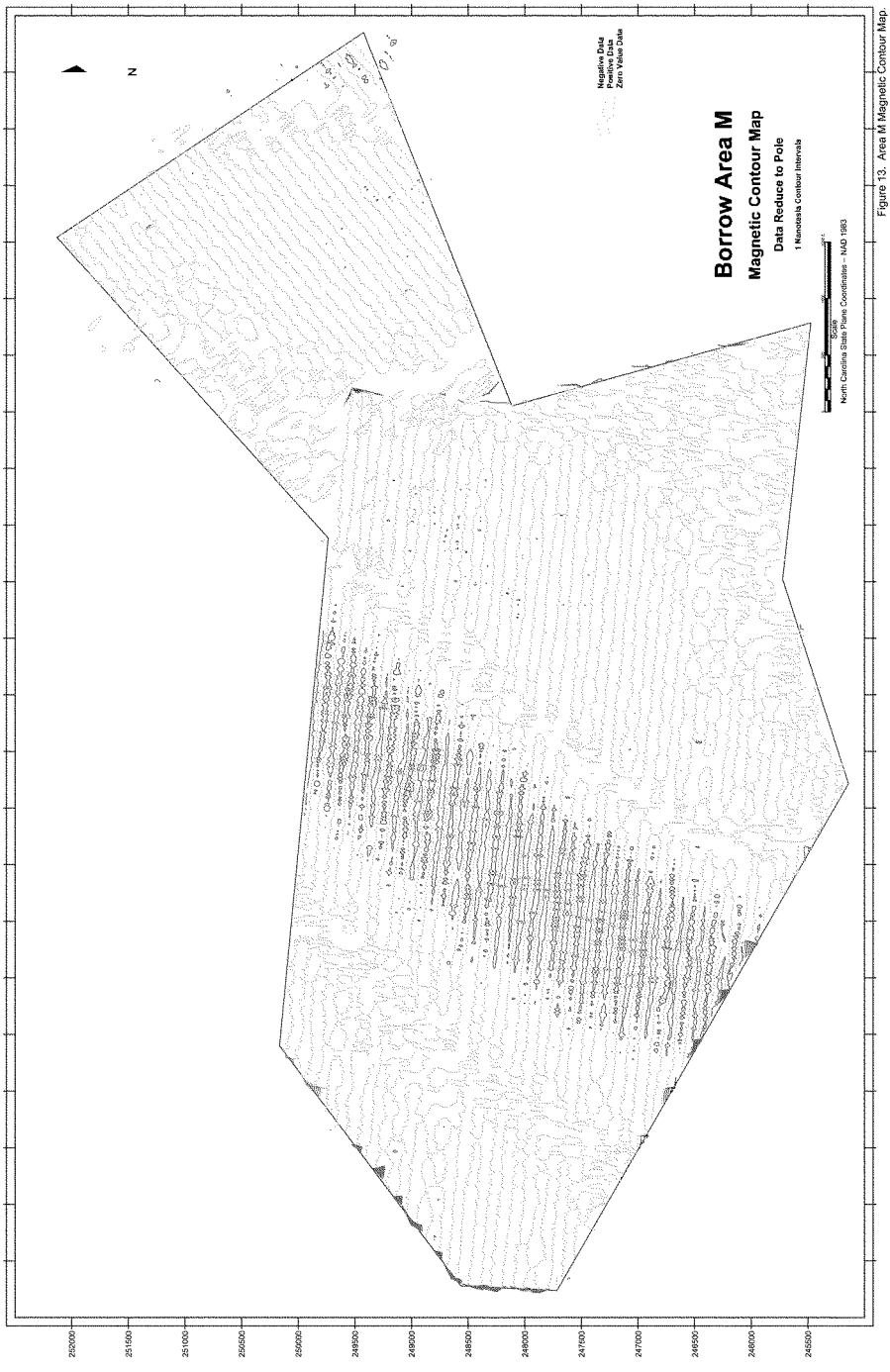


Figure 13. Area M Magnetic Contour Map.

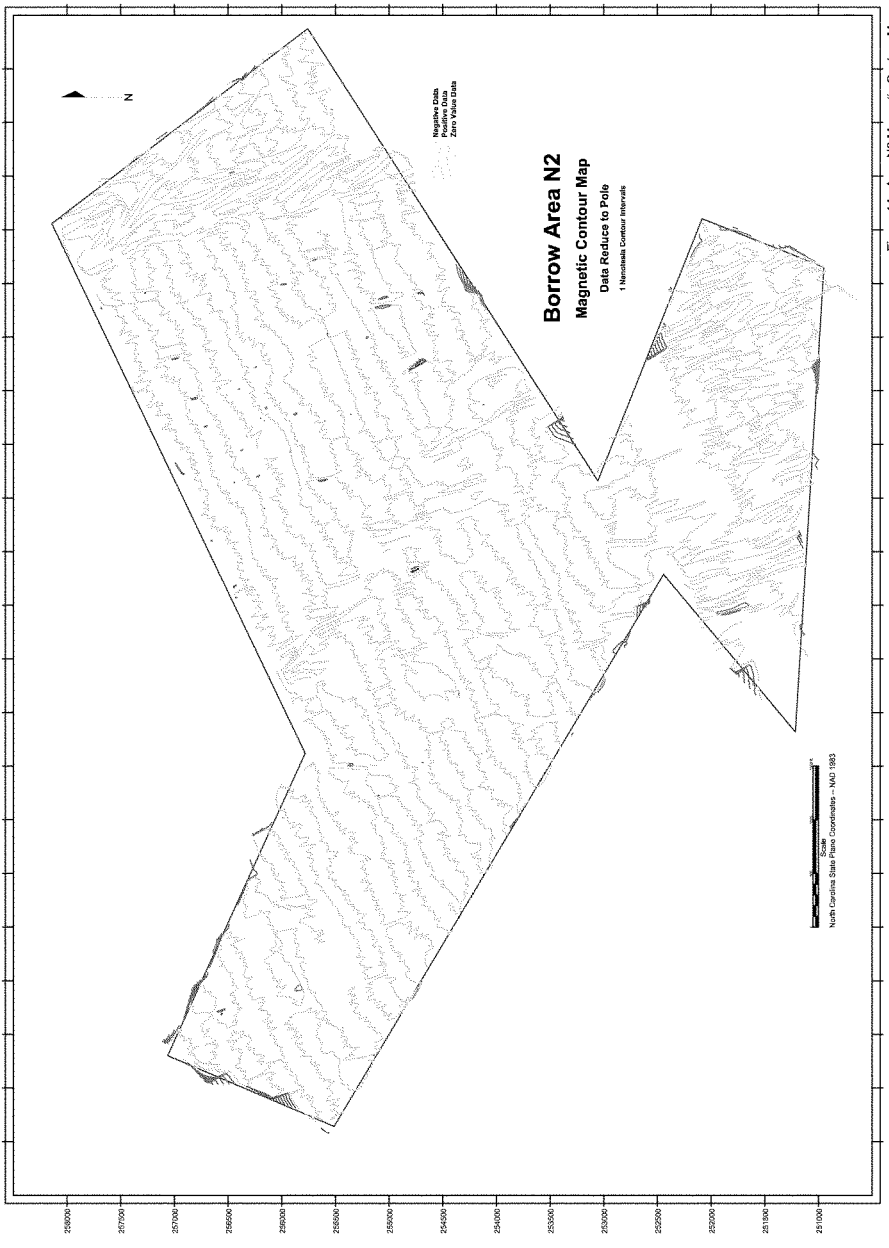


Figure 14. Area N2 Magnetic Contour Map.

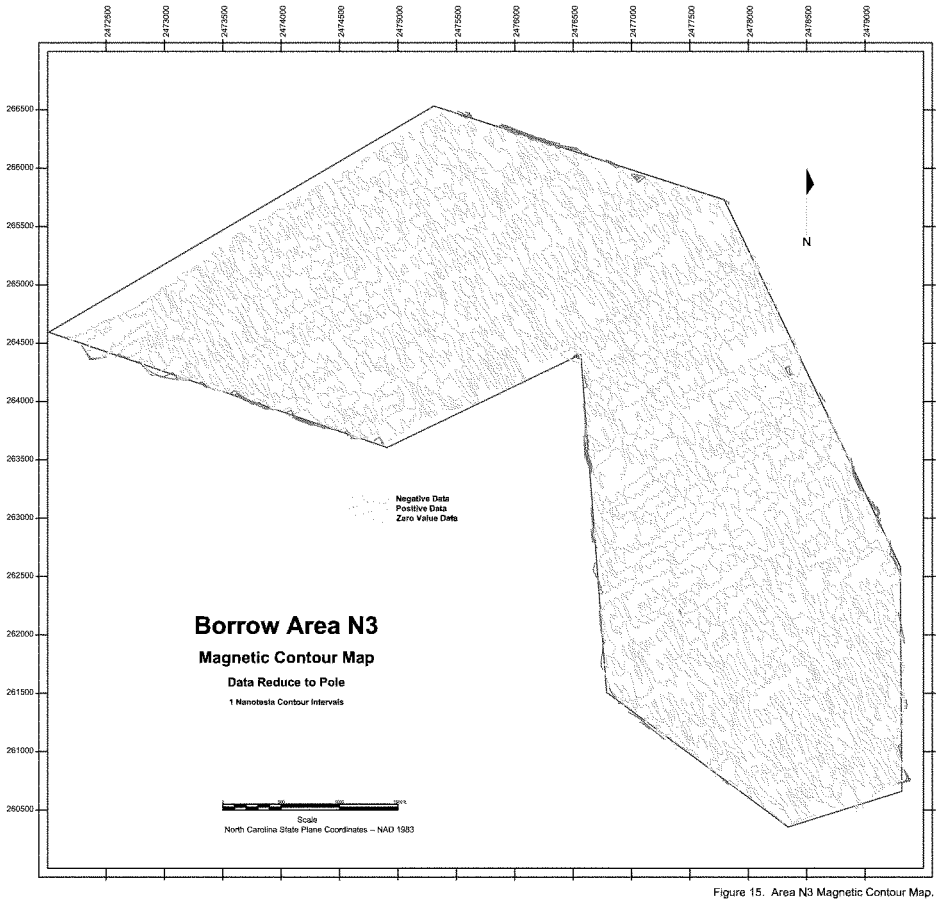


Figure 15. Area N3 Magnetic Contour Map.

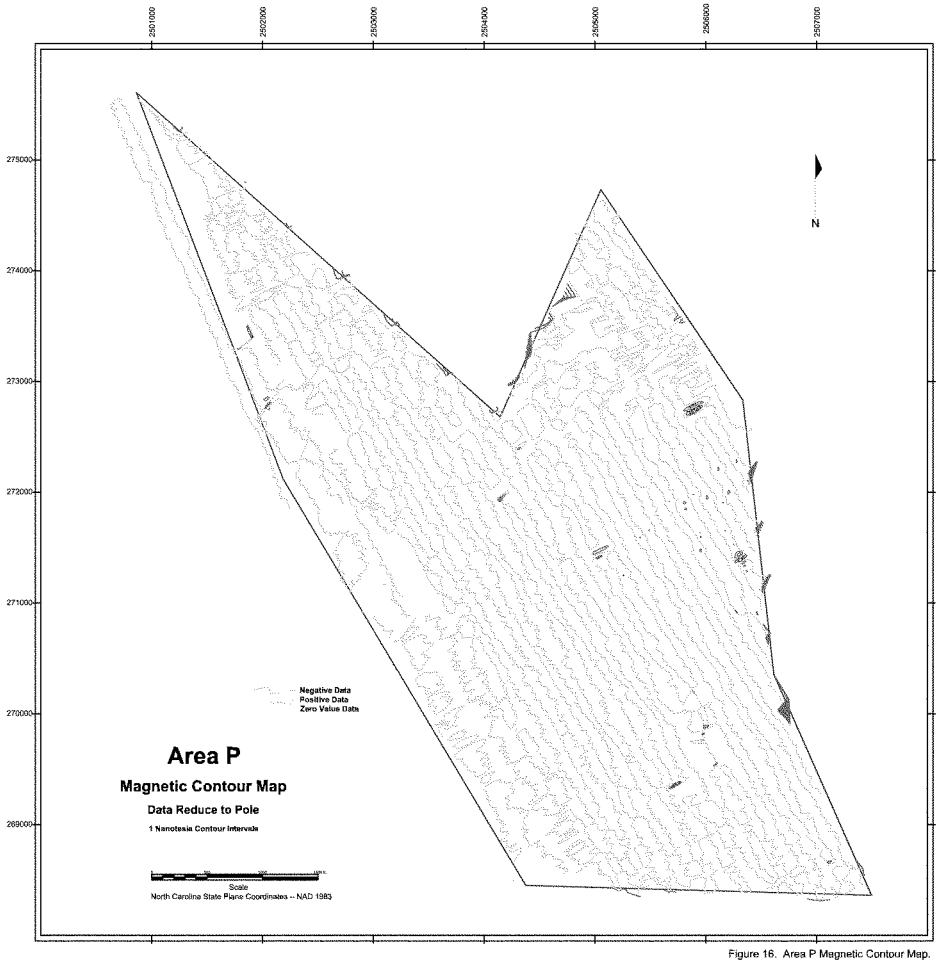


Figure 16. Area P Magnetic Contour Map.

IDENTIFICATION OF HARD BOTTOM AREAS

M-AT/ER reviewed acoustic records (side-scan sonar and depth) to identify and define areas that were "hard bottom" or habitat for marine animals. Hard bottom areas were defined as areas larger than 1,800 square meters. Other characteristics include "low" protrusions – the majority of the area less than .5-meters above the bottom; "moderate" protrusions – the majority of the area 1 to 2 meters above the bottom; and "high" protrusions – more than 2 meters above the bottom.

Hard bottom was identified to some degree in each proposed borrow area. Using AutoCAD's area calculation program M-AT/ER calculated the approximate percentage of hard bottom or exposed bottom in each proposed borrow area:

Borrow Area H = 2% hard bottom all low relief.

Borrow Area K = 73% hard bottom with mix of low, moderate and high relief.

Borrow Area LN1 = 13% hard bottom with mix of low, moderate and high relief.

Borrow Area M = 48% hard bottom with mix of low, moderate and high relief.

Borrow Area N2 = 19% hard bottom all low relief.

Borrow Area N3 = 20% hard bottom with mix of low and moderate relief.

Borrow Area P = 46% hard bottom with mix of low to moderate relief.

The following are example imagines and maps of each borrow area defining hard bottom in three levels low, moderate and high as described above.

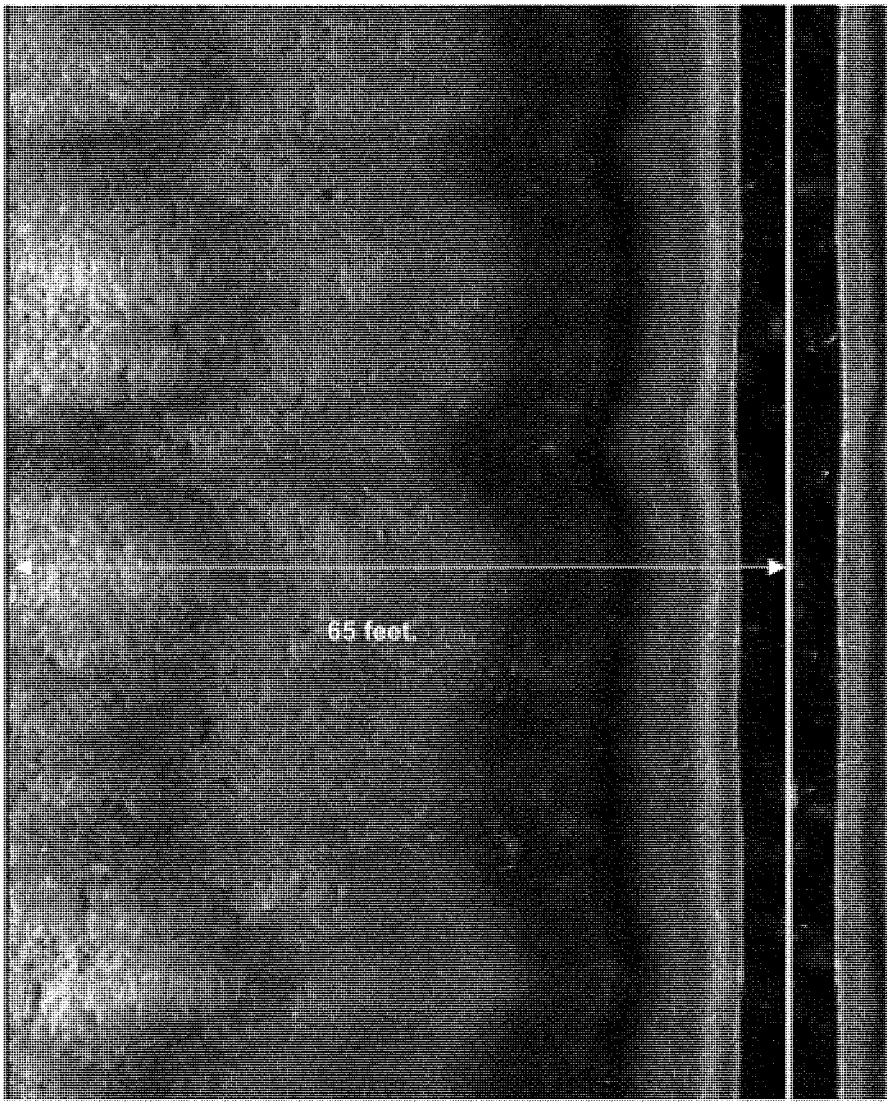


Figure 17. Sonar image of typical hard bottom in Area H.

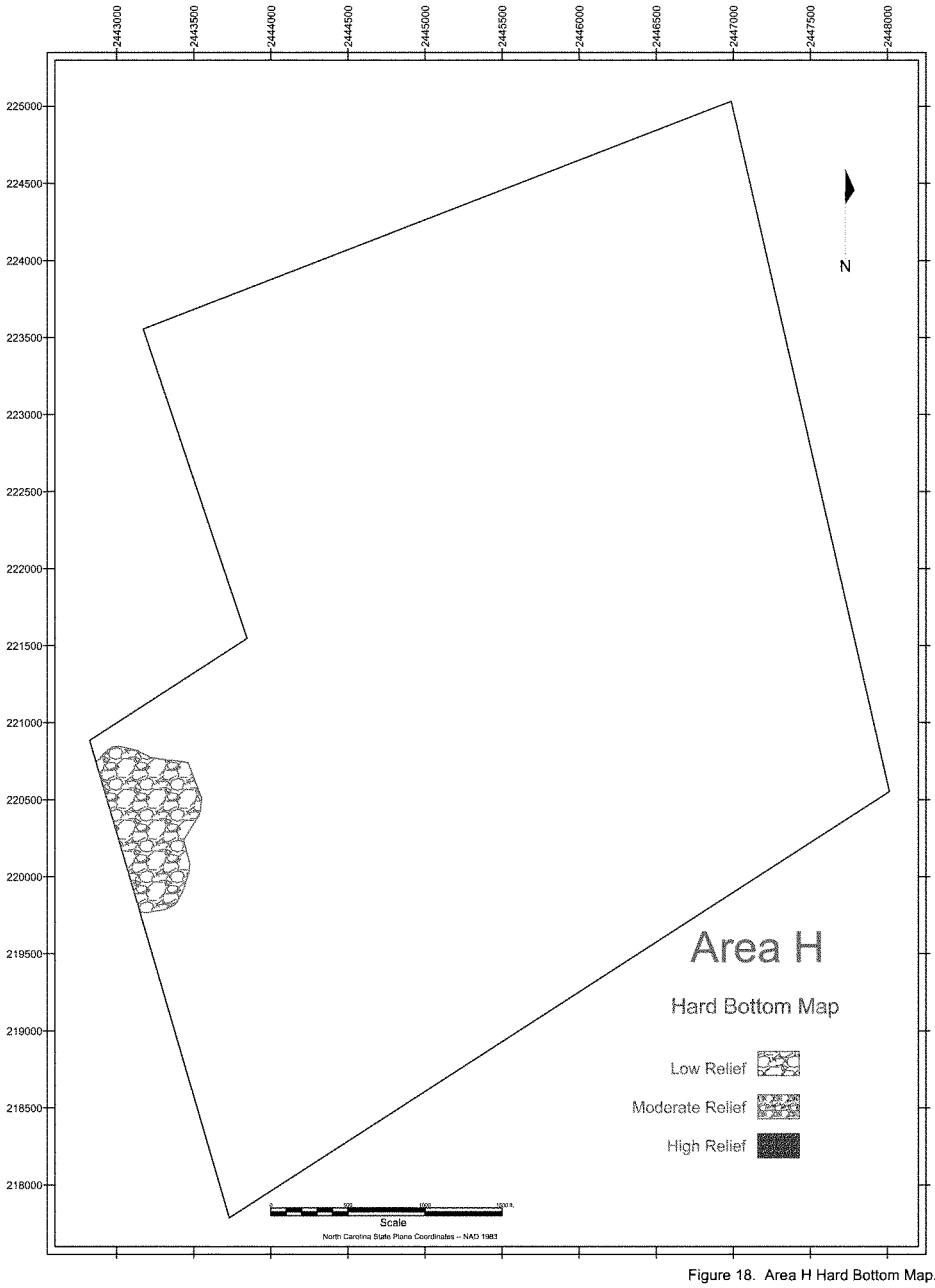


Figure 18. Area H Hard Bottom Map.

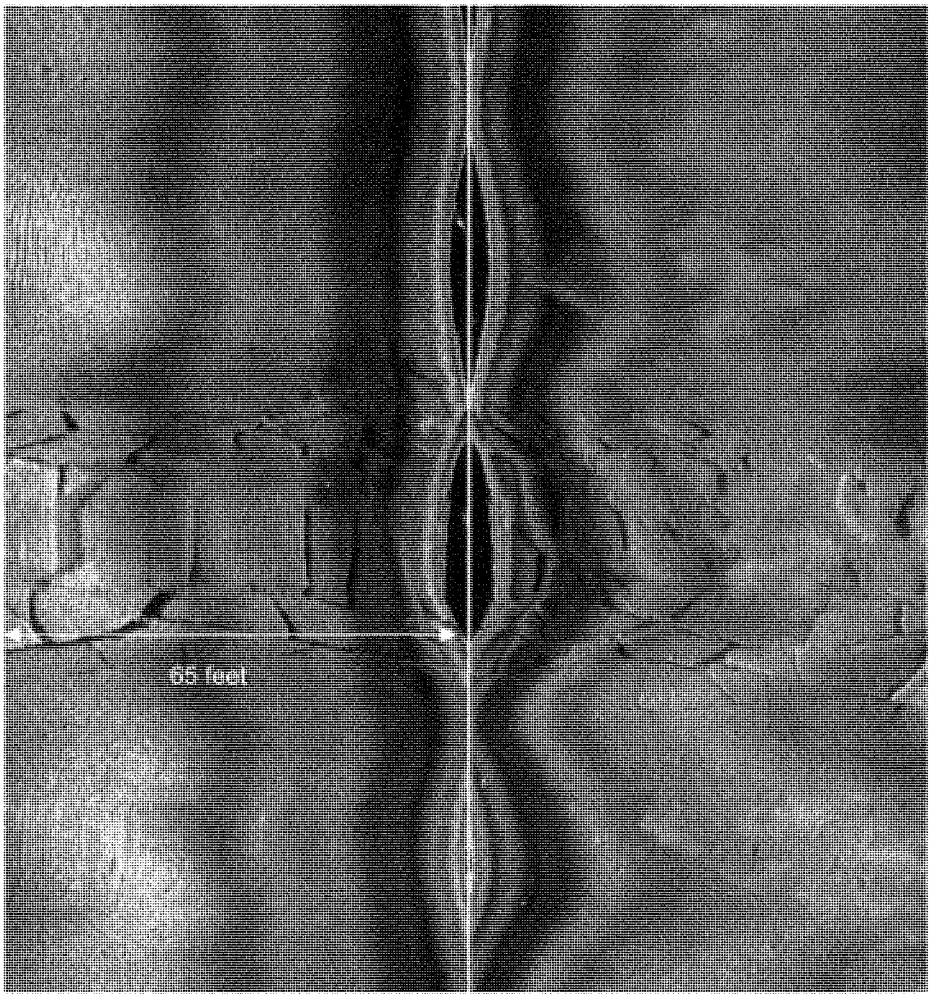


Figure 19. Sonar Imagine of Moderate Relief Hard Bottom in Area K.

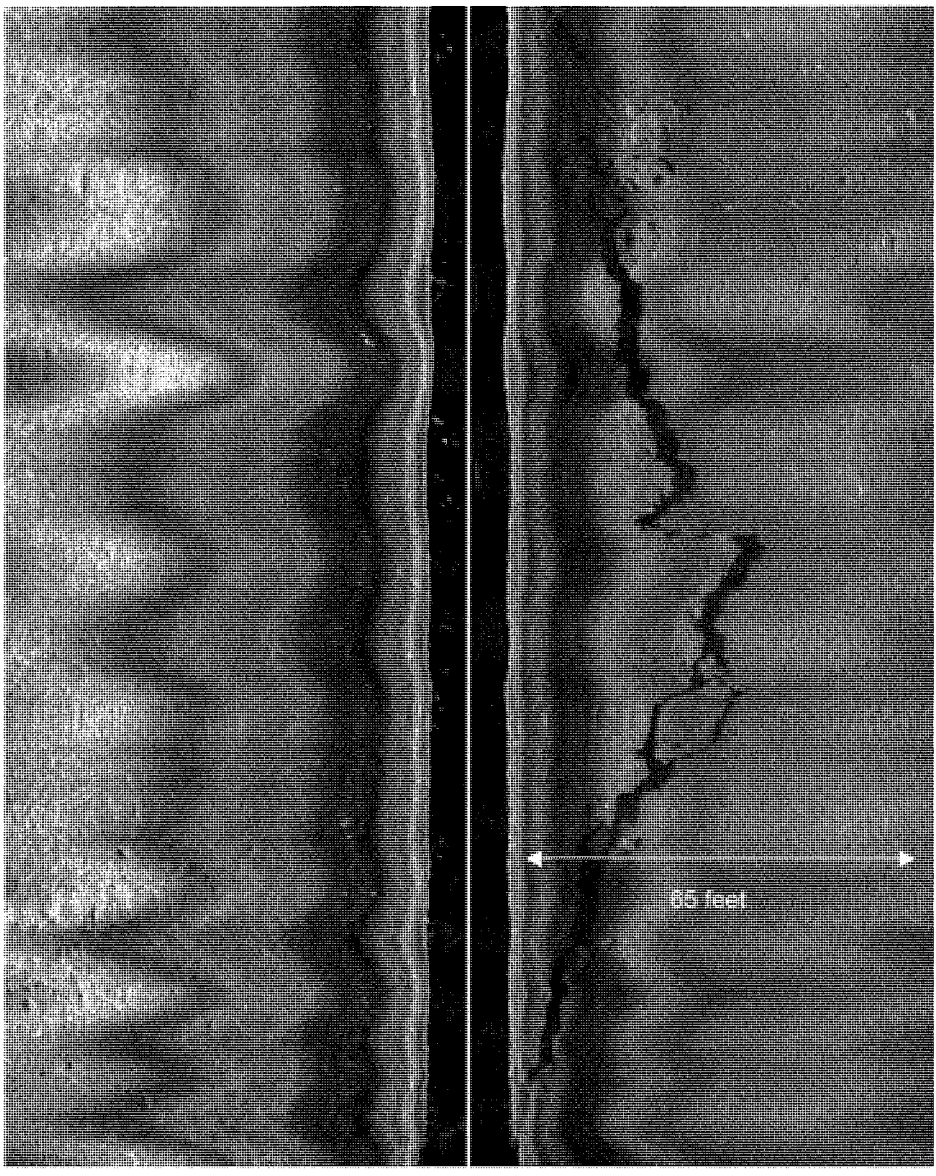


Figure 20. Example Sonar Image of Moderate to High Relief in Area K.

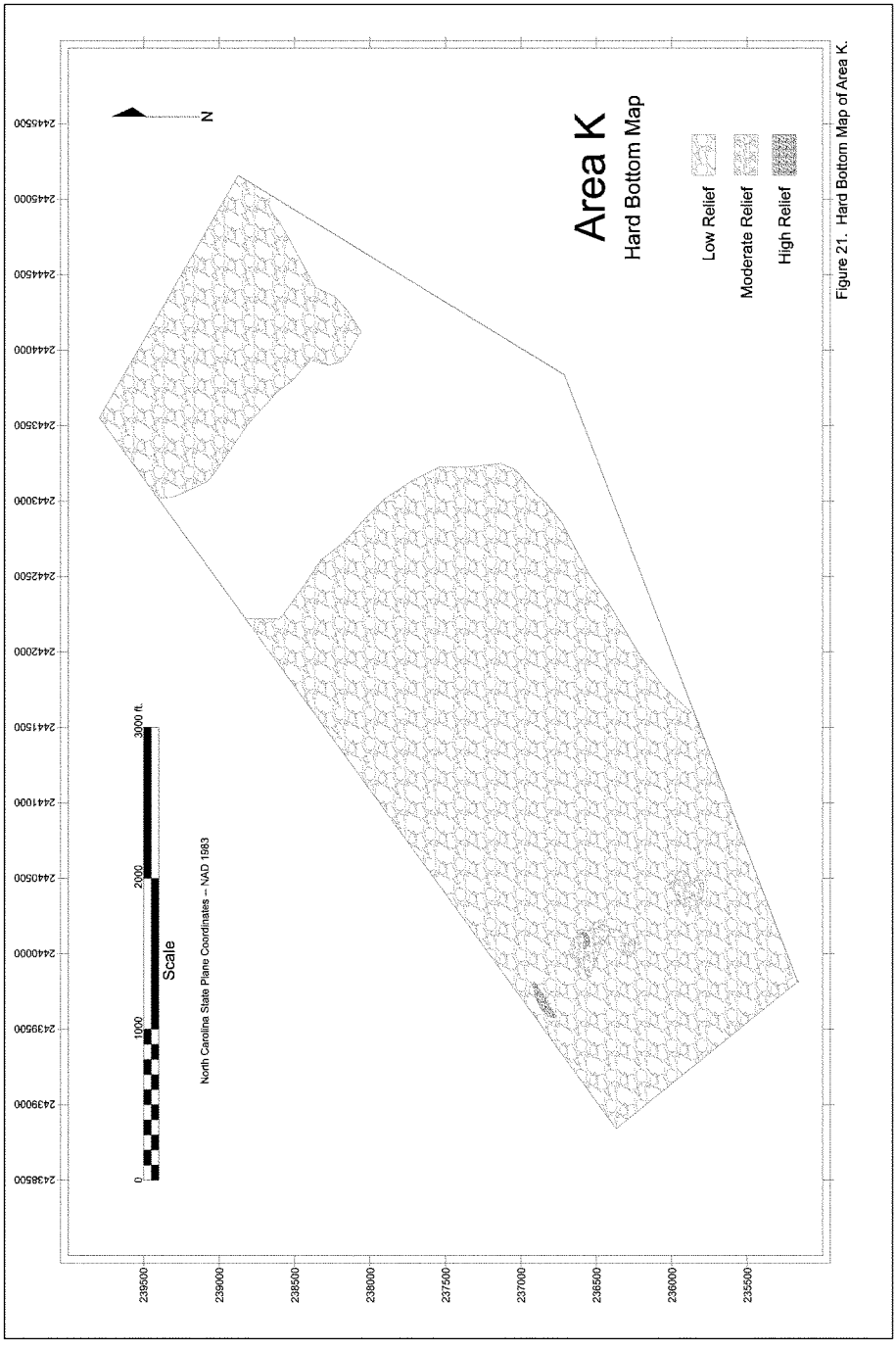


Figure 21. Hard Bottom Map of Area K.

E:\Fig11&21.dwg 11/24/2008 3:51:15 PM

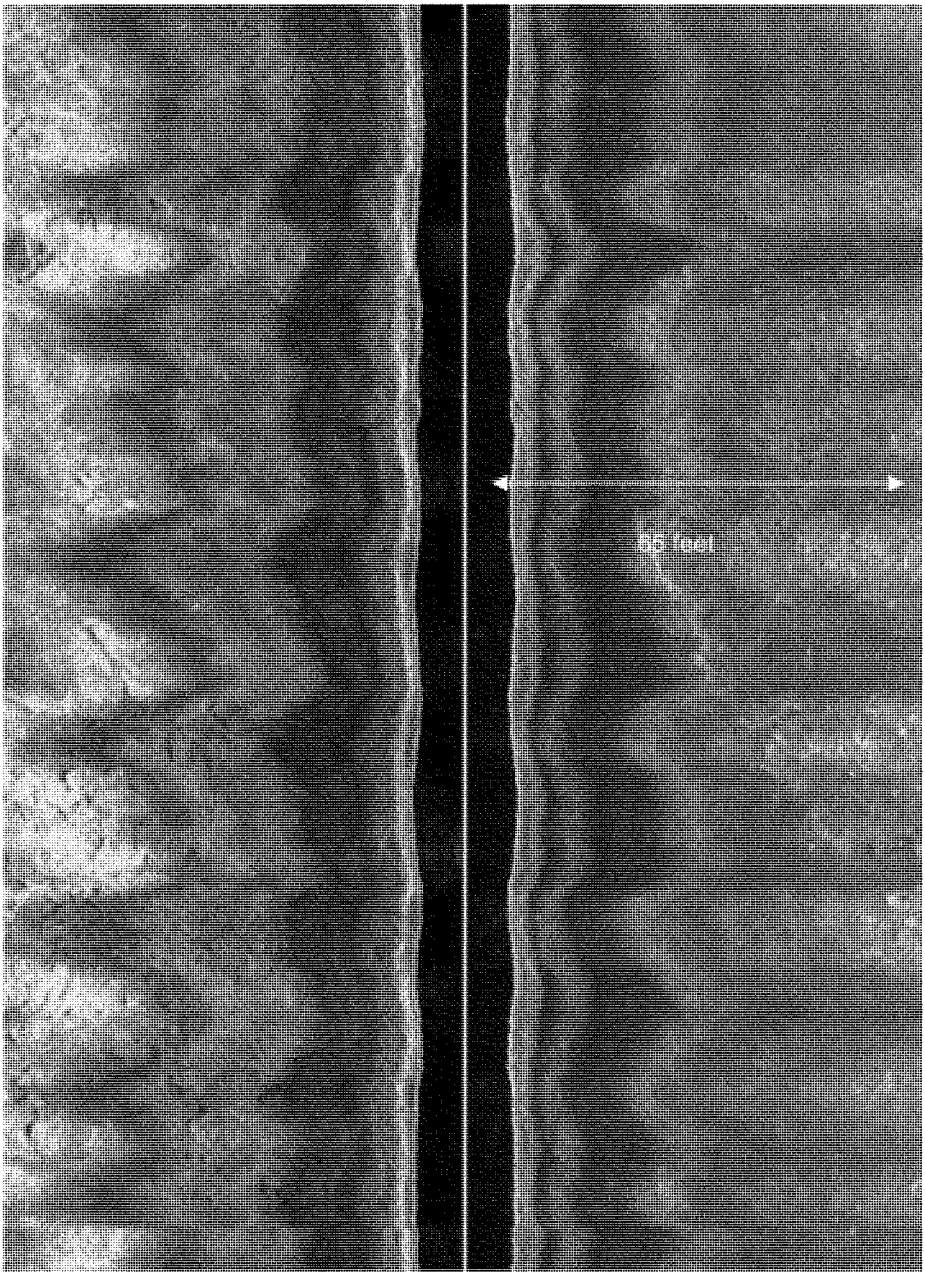


Figure 22. Example Sonar Image of Low Relief in Area LN1.

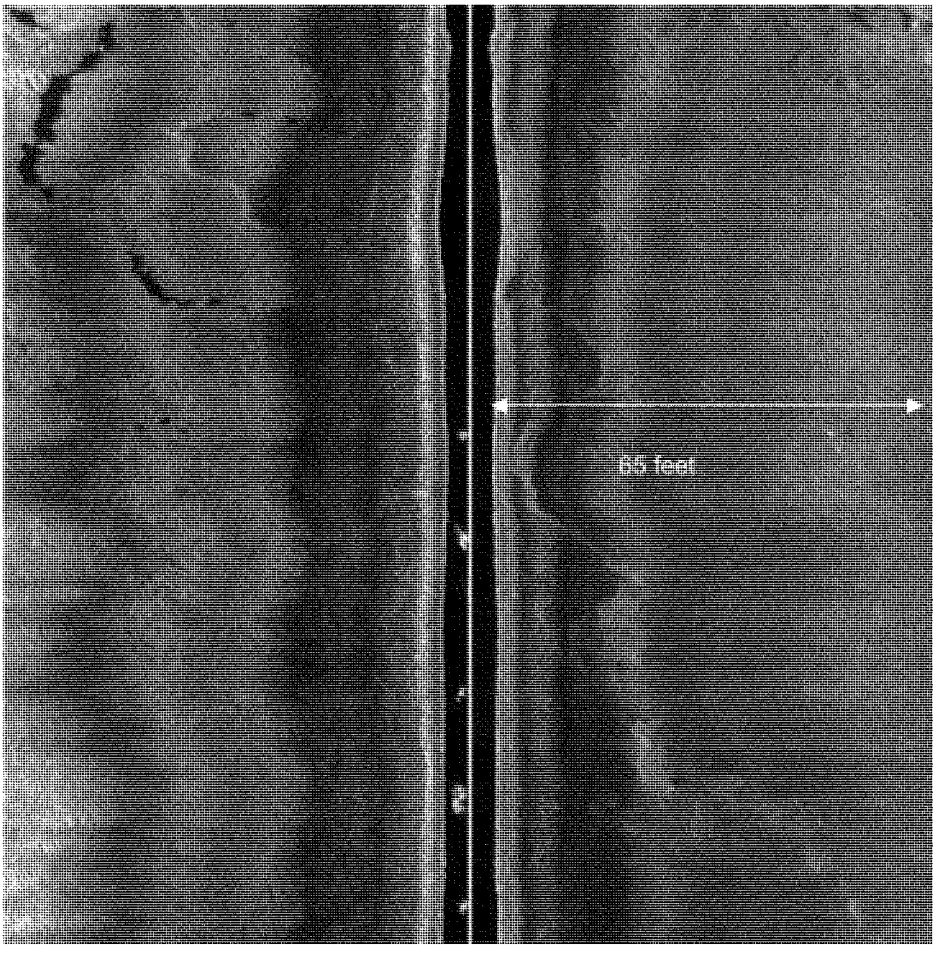


Figure 23. Example Sonar Image of Moderate Relief in Area LN1.

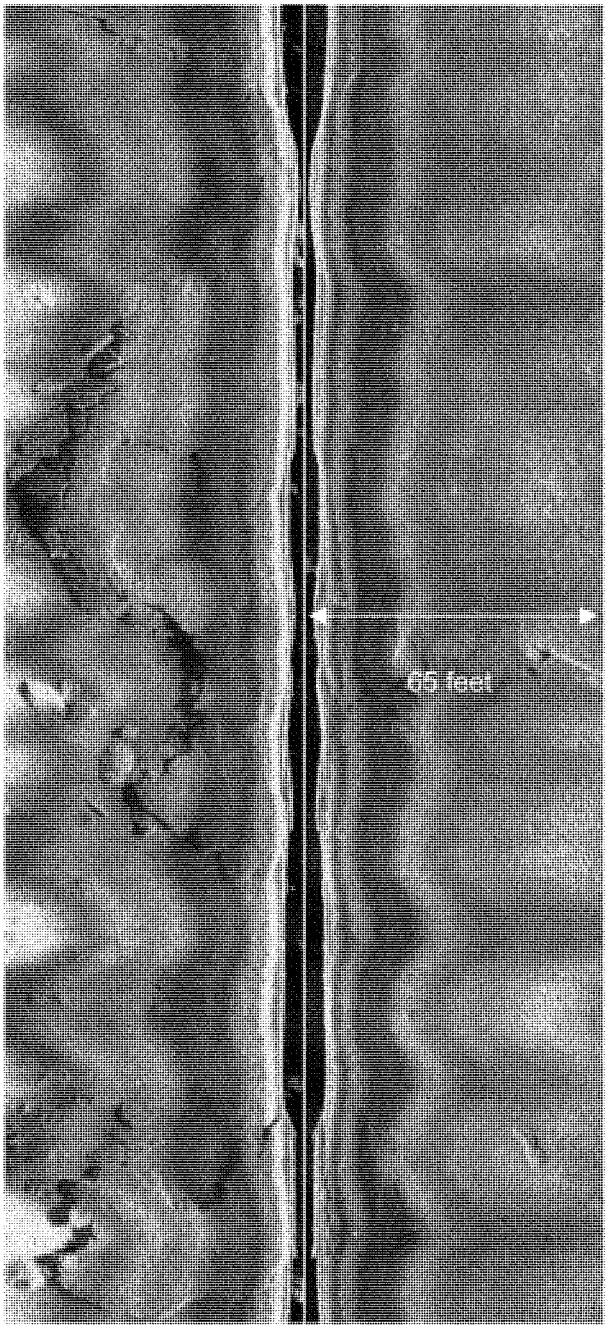


Figure 24. Example Sonar Image of High Relief in Area LN1.

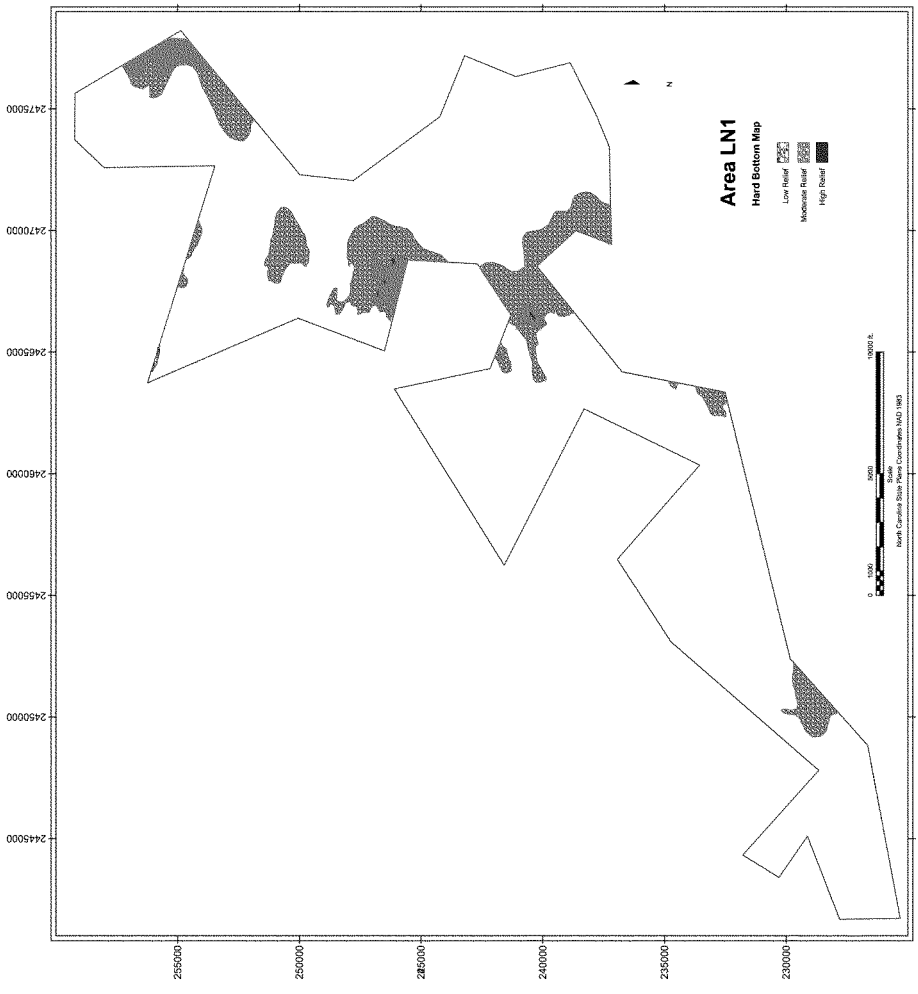


Figure 25. Hard Bottom Map of Area LN1.

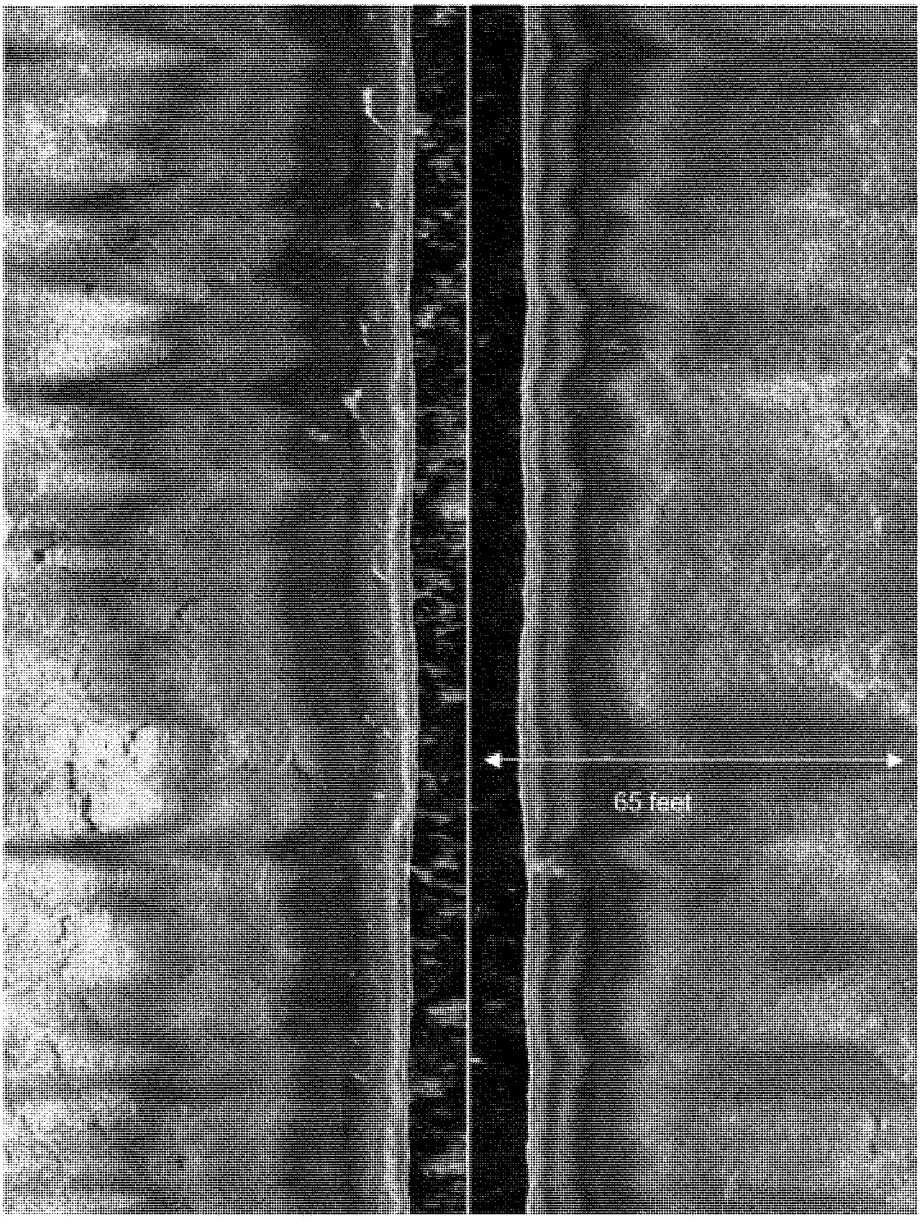


Figure 26. Example Sonar Image of Low Relief Area M.

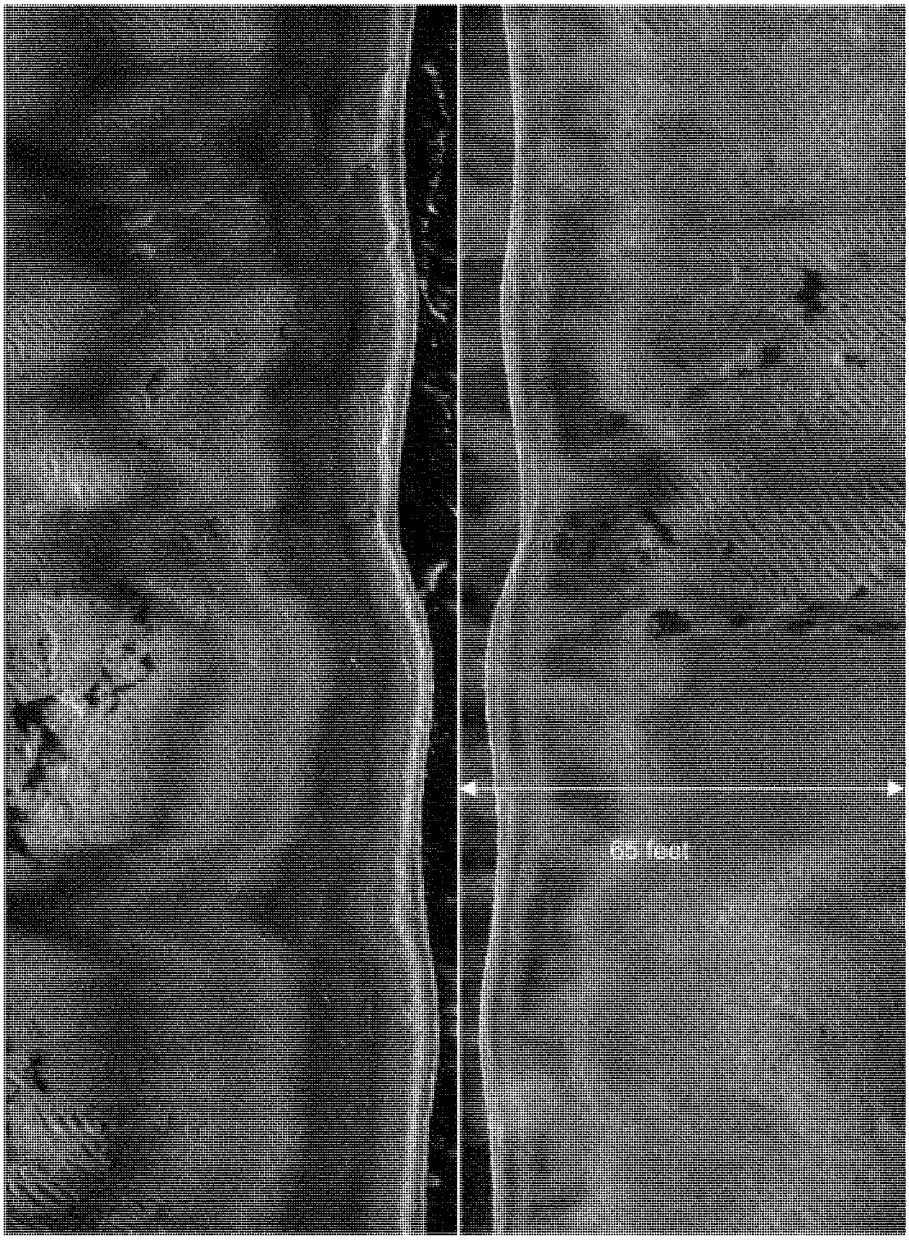


Figure 27. Example Sonar Image of Moderate Relief Area M.

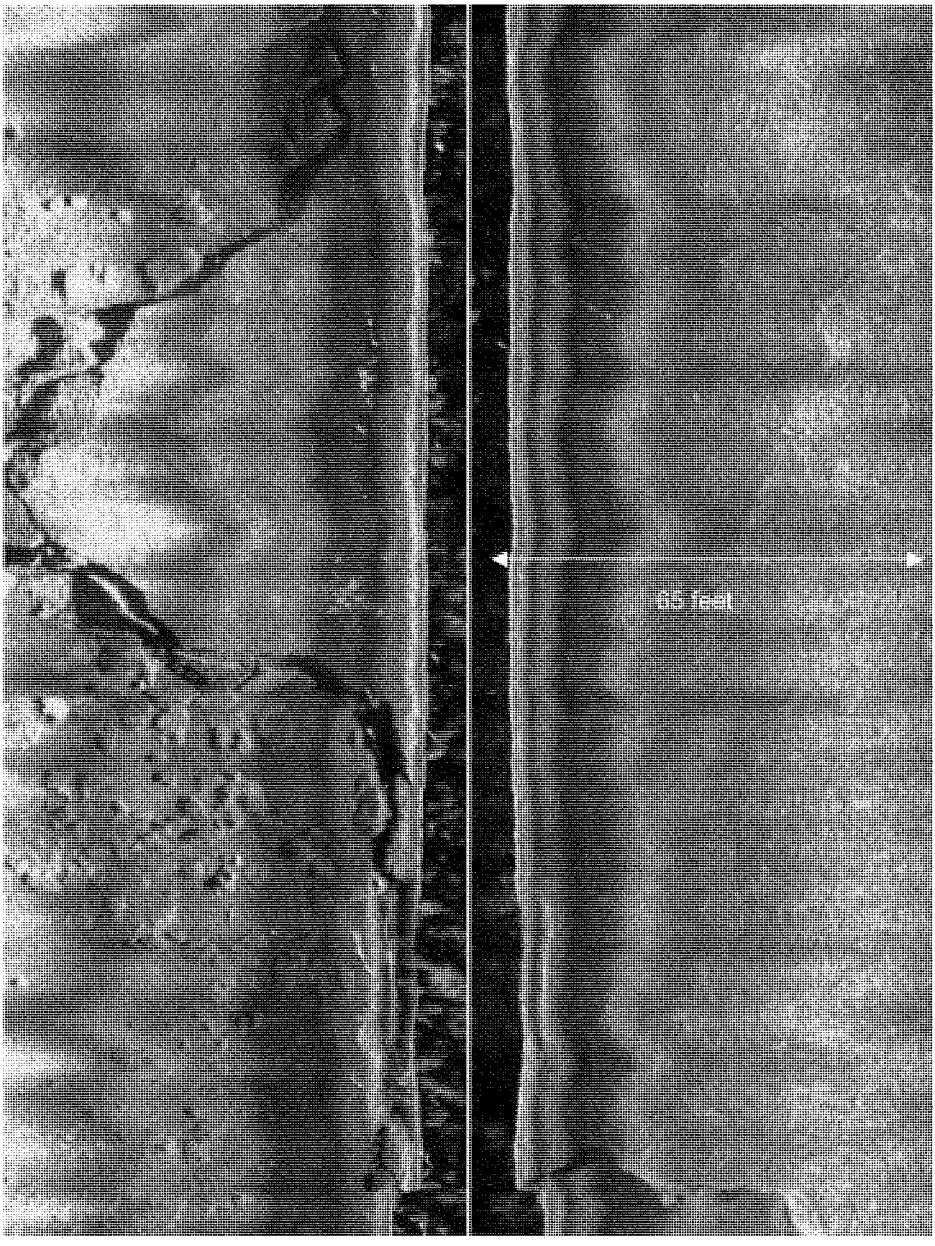


Figure 28. Example Sonar Image of High Relief in Area M.

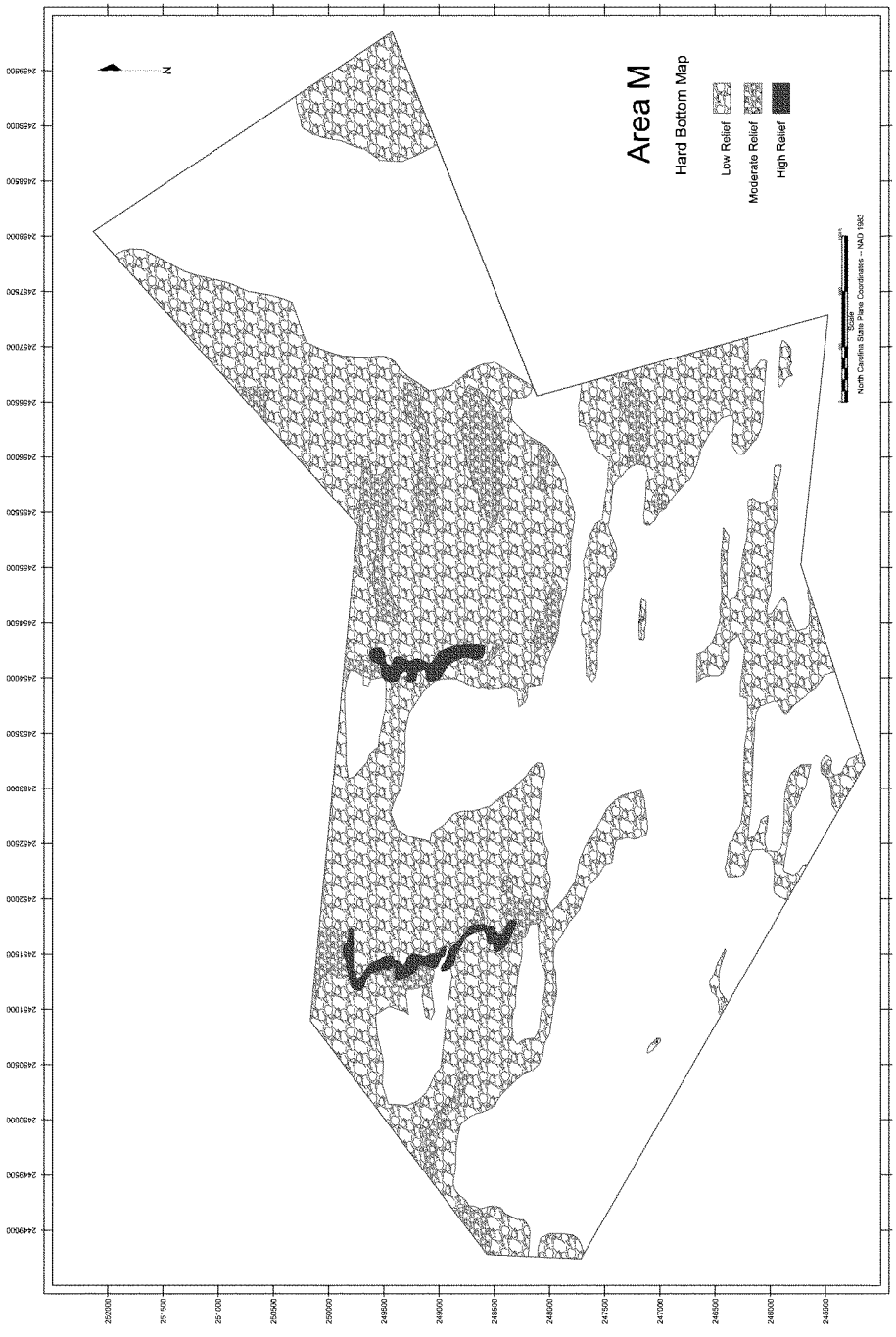


Figure 29. Area M Hard Bottom Map.

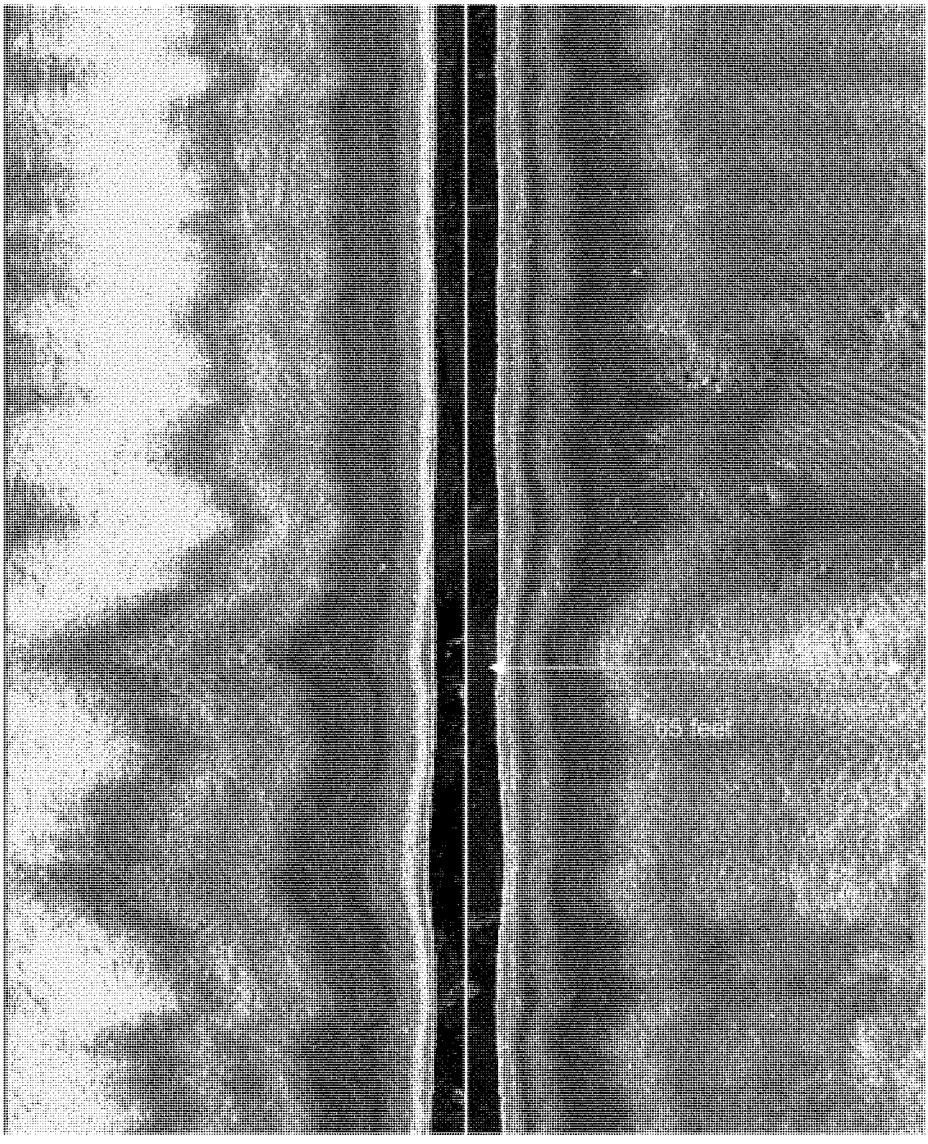


Figure 30. Example Sonar Image Low Relief in Area N2.

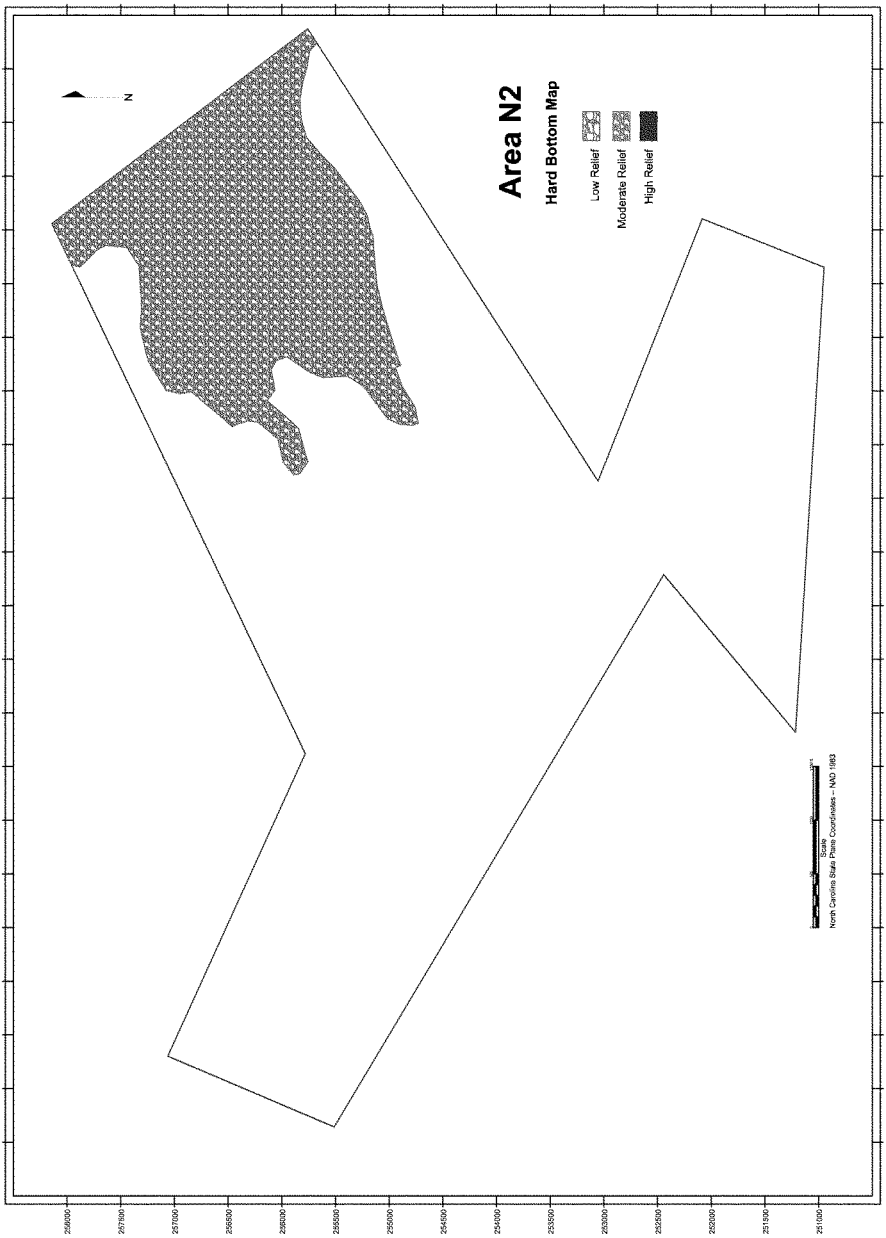


Figure 31. Area N2 Hard Bottom Map.

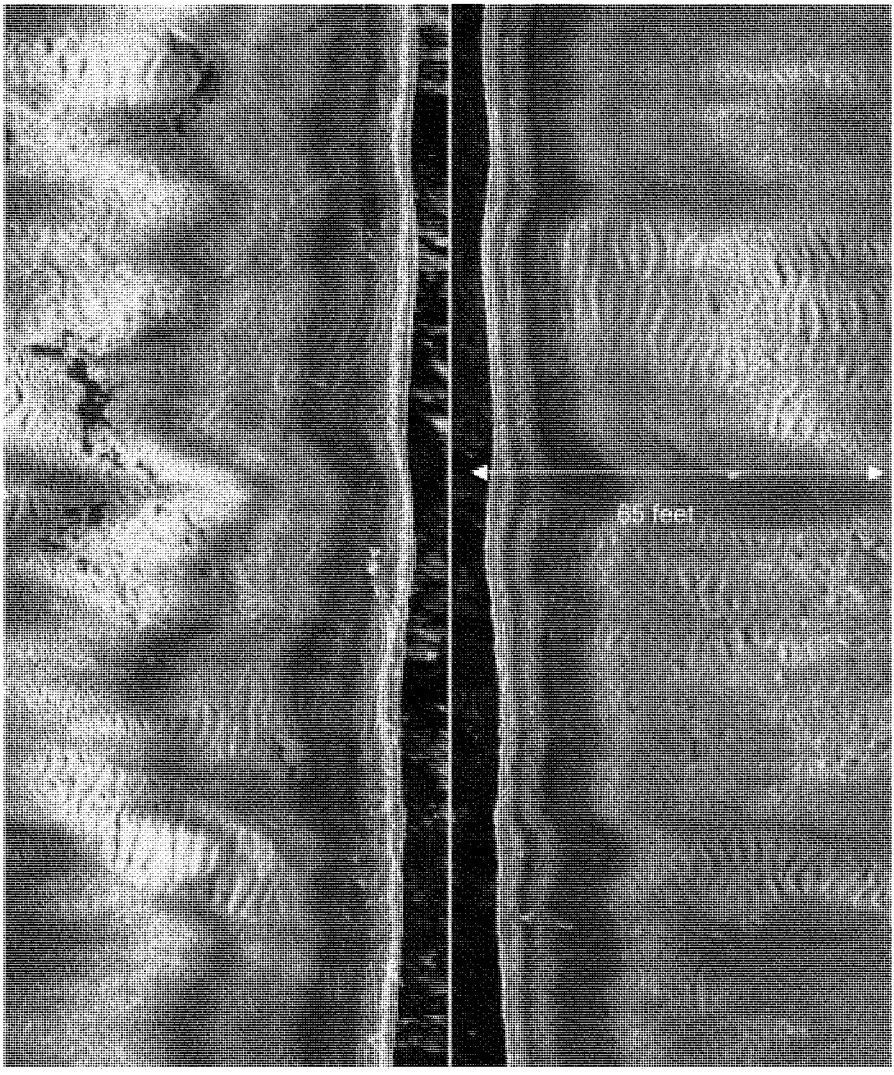


Figure 32. Example Sonar Image of Low to Moderate Relief in Area N3.

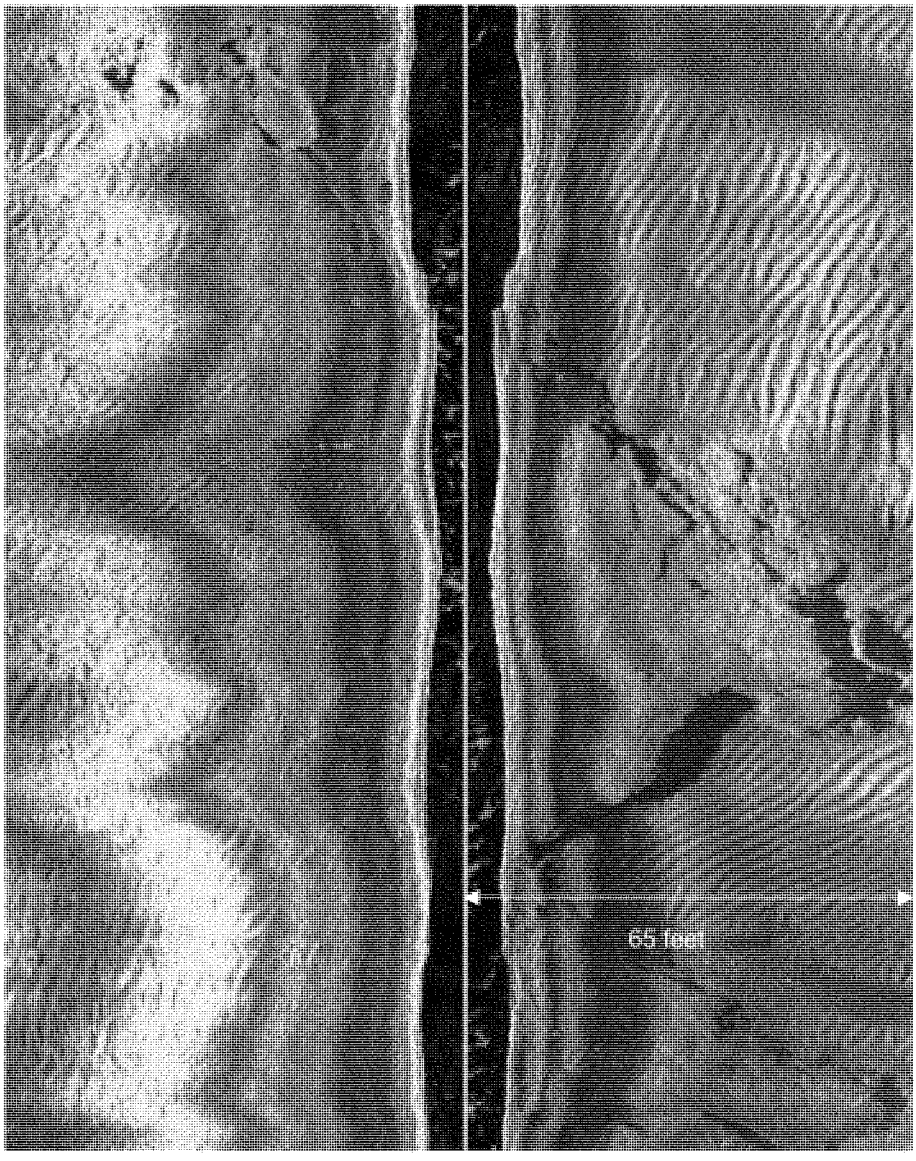


Figure 33. Example Sonar Image of Moderate to High Relief in Area N3.

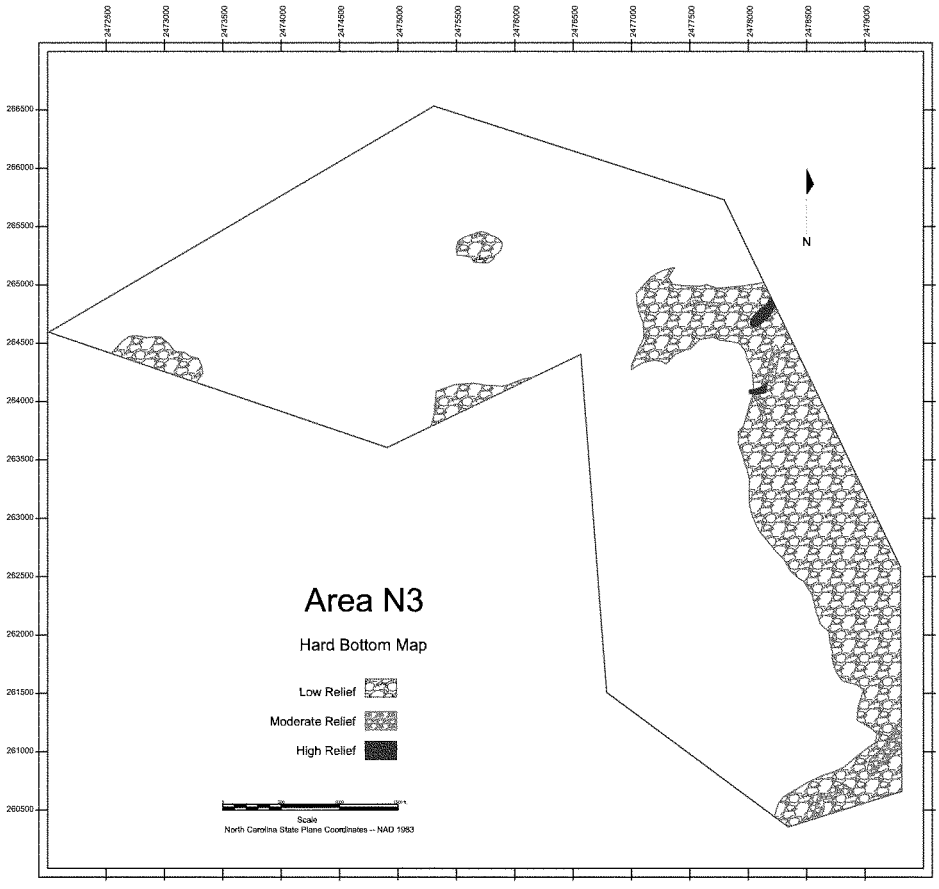


Figure 34. Area N3 Hard Bottom Map.

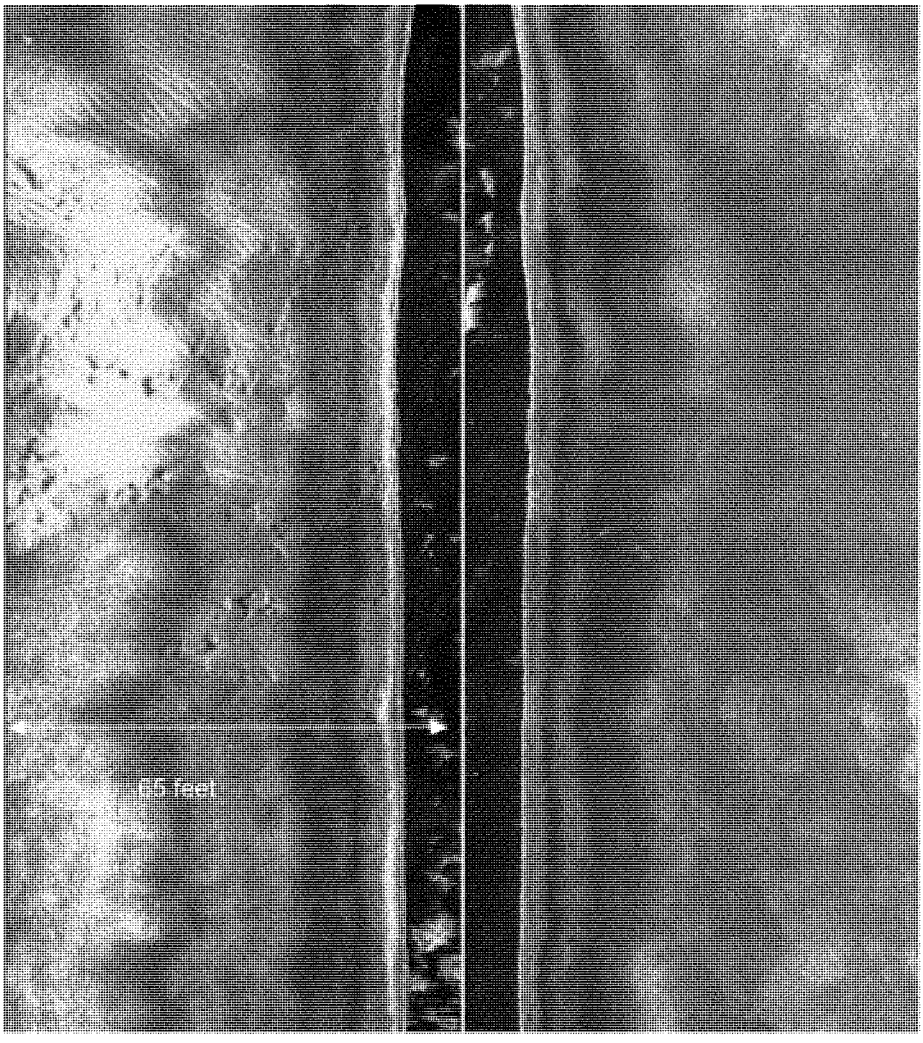
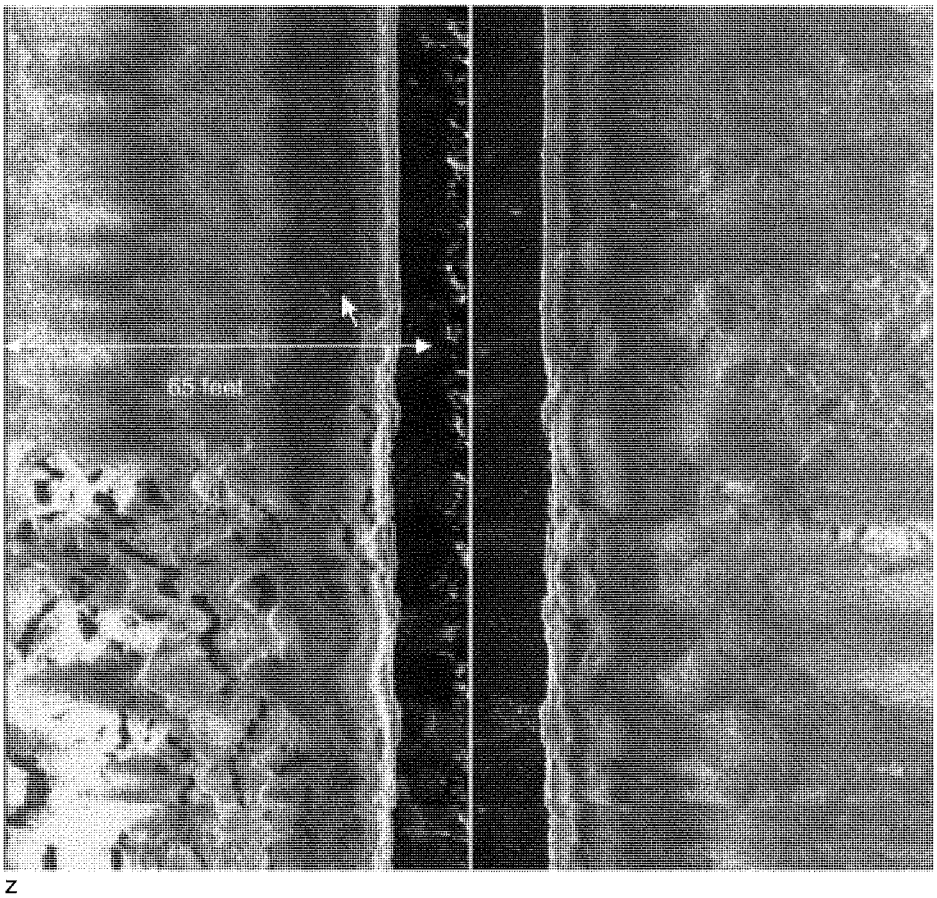


Figure 35. Example of Sonar Image of Low Relief in Area P.



z

Figure 36. Example Sonar Image of Moderate Relief in Area P.

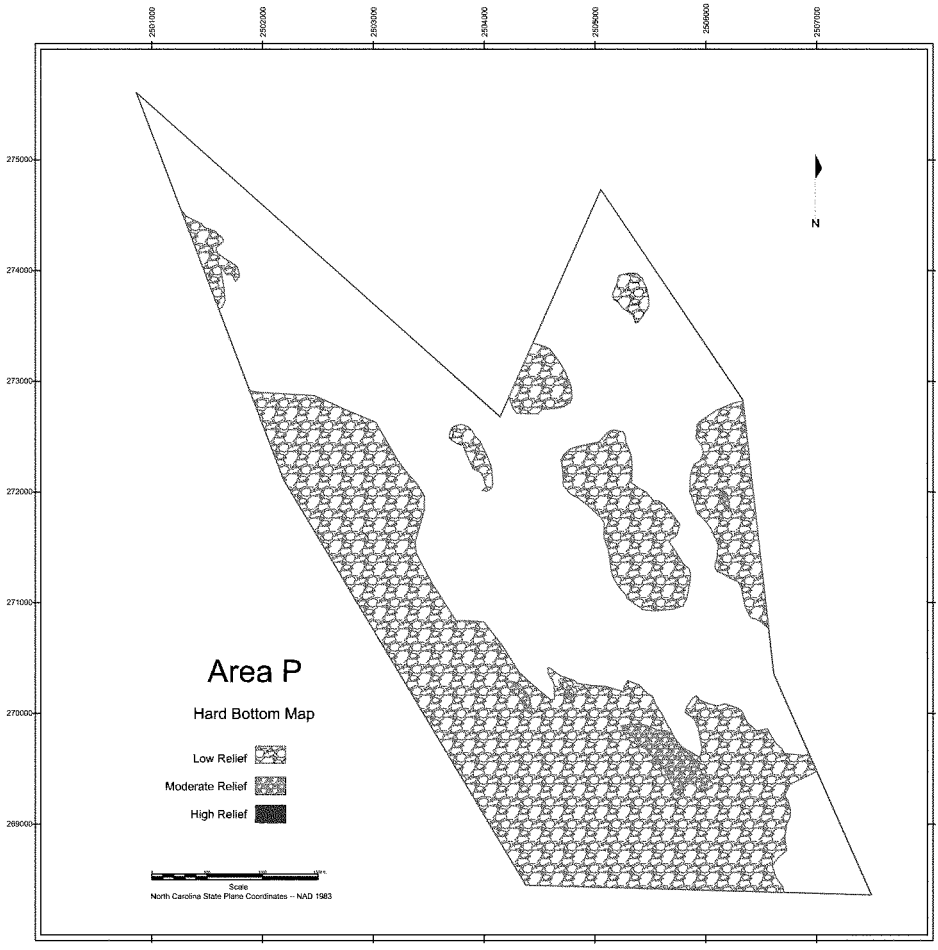


Figure 37. Area P Hard Bottom Map.

CONCLUSIONS AND RECOMMENDATIONS

The remote sensing survey identified no single-source magnetic anomalies or the acoustic targets within any of the seven proposed sand borrow areas. No additional archaeological investigations or actions are recommended.

Hard bottom ranging from low to high relief was found in each proposed borrow area. Appropriate action to avoid or mitigate sand mining impacts to these areas should be exercised.

REFERENCES

Angley, Wilson
1984 *An Historical Overview of New Topsail Inlet*. North Carolina Division of Archives and History, Raleigh, NC.

Stick, David
1952 *Graveyard of the Atlantic: Shipwrecks of the North Carolina Coast*. The University of North Carolina Press, Chapel Hill, NC.

Kimmel, Richard
1988 *Report of Magnetic Survey, New Topsail Inlet Borrow Area (New River Inlet, West Onslow Beach)*.

Tubby, Raymond
2000 *Historical and Archaeological Investigation of the 1750 Spanish Plate Fleet Vessel El Salvador*. Unpublished Masters thesis, East Carolina University.

Watts, Gordon P. Jr. et al.
1975 *Report of the Activities of the 1975 Field School in Underwater Archaeology*. Unpublished report by Underwater Archaeology Unit, prepared for the North Carolina Department of Cultural Resources and the University of North Carolina at Wilmington.