MRGO ECOSYSTEM RESTORATION PLAN FEASIBILITY STUDY

COMMUNICATION

FROM

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

TRANSMITTING

MRGO ECOSYSTEM RESTORATION PLAN FEASIBILITY STUDY

PART 3 OF 7



DECEMBER 19, 2013.—Referred to the Committee on Transportation and Infrastructure and ordered to be printed

---

U.S. GOVERNMENT PRINTING OFFICE

87–145 WASHINGTON : 2013

AUTHENTICATED
U.S. GOVERNMENT
INFORMATION
GPO

Table 1. EFH Species and Their Life Stages for the MRGO Ecosystem Restoration Project Area.

Species	Life stage	System	EFH
Brown shrimp	larvae	Marine	<82 m; planktonic, sand/shell/soft bottom, SAV, emergent marsh, oyster reef
	juvenile	Estuarine	<18 m; SAV, sand/shell/soft bottom, SAV, emergent marsh, oyster reef
	adult	Marine	<14-110 m; sand/shell/soft substrate
White shrimp	juvenile	Estuarine	<30 m; SAV, soft bottom, emergent marsh
Pink shrimp	juvenile	Estuarine	<65 m; sand/shell substrate
Gulf stone crab	eggs	Estuarine/Marine	<18 m; sand/shell/soft bottom
	larvae/post larvae	Estuarine/Marine	<18 m; planktonic/oyster reefs, soft bottom
	juvenile	Estuarine	<18 m; sand/shell/soft bottom, oyster reef
Red drum	larvae/post larvae	Estuarine	all estuaries planktonic, SAV, sand/shell/soft bottom, emergent marsh
	juvenile	Estuarine/Marine	GOM <5 m W from Mobile Bay; all estuaries SAV, sand/shell/soft/hard bottom, emergent marsh
	adult	Estuarine/Marine	GOM 1-46 m W from Mobile Bay: all estuaries SAV, pelagic, sand/shell/soft/hard bottom, emergent marsh
Lane Snapper	larvae	Estuarine/Marine	4-132 m; reefs, SAV
	juvenile	Estuarine/Marine	<20 m; SAV, mangrove, reefs, sand/shell/soft btm.
Dog Snapper	juvenile	Estuarine/Marine	SAV, mangrove, emergent marsh
Dwarf Sand perch	juvenile	Marine	hard bottom
King mackerel	larvae	Marine	9-180 m; planktonic
	juvenile	Marine	<9 m; pelagic
	adults	Marine	35-180 m; pelagic
Spanish mackerel	eggs	Marine	<50 m; planktonic
	larvae	Marine	9-84 m; planktonic
	juvenile	Estuarine/Marine	<50 m; pelagic
	adults	Estuarine/Marine	<75 m; pelagic
Cobia	eggs	Marine	planktonic
	larvae	Marine	11-53 m, planktonic
	juvenile	Marine	5-183 m; pelagic
Bonnethead shark	juvenile	Marine	inlets, estuaries, coastal waters <25 m, FL Keys to Cedar Key; LA and TX
Atlantic sharpnose shark	adults	Marine	<50 m MS Sound & Galveston to Laguna Madre

Wildlife Resources

There are three federal and one state protected areas located within the project area. The federal areas include the Bayou Sauvage National Wildlife Refuge (NWR), Breton NWR, and the Gulf Island National Seashore (Mississippi Unit; western end of Cat Island); while the state area is the Biloxi Wildlife Management Area.

Prior to construction of the MRGO, the interior fresh to intermediate wetlands had high value for furbearing animals and wintering waterfowl including lesser snow geese, mallard, green-winged teal, and lesser scaup. Between 1969 and 1978, wildlife surveys recorded less than 20,000 annual wintering waterfowl in an area that had previously supported 250,000 individuals. Furbearers, supported in large numbers in this area, included muskrat, mink, nutria, river otter, and raccoons were once staples of the Louisiana fur industry. After construction of the MRGO, wildlife surveys showed a noticeable decline in the productivity of these wetlands.

The project area provides important habitat for several species of wildlife, including waterfowl, wading birds, shorebirds, mammals, reptiles and amphibians. The project area provides wintering habitat for migratory puddle ducks including gadwall, blue-winged teal, green-winged teal, American widgeon, and northern shoveler. Diving duck species which utilize the project area include lesser scaup and ring-necked ducks. The red-breasted merganser is also a common wintering waterfowl species in the Breton/Lake Borgne system. The resident mottled duck, which nests in fresh to brackish marshes, is found throughout the year.

Common wading bird species which utilize the project area include the great blue heron, green heron, tricolored heron, great egret, snowy egret, yellow-crowned night-heron, black-crowned night-heron, and white ibis. Mudflats and shallow-water areas provide habitat for numerous species of shorebirds and seabirds. The barrier island is habitat used by wintering piping plover, brown pelicans, and nesting terns Shorebirds include the American avocet, willet, black-necked stilt, dowitchers, common snipe, and various species of sandpipers. Seabirds include the white pelican, black skimmer, herring gull, laughing gull, and several species of terns.

Non-game birds, such as the boat-tailed grackle, red-winged blackbird, seaside sparrow, northern harrier, belted kingfisher, and marsh wrens, also utilize the project area. Important gamebirds found in the area include the clapper rail, sora rail, Virginia rail, American coot, common moorhen, and common snipe in addition to resident and migratory waterfowl.

Mammals found in the project area include swamp rabbit, raccoon, fox/gray squirrels, opossum, nine-banded armadillo, muskrat, mink, nutria, river otter, and raccoons, and bats. Reptiles and amphibians are fairly common in the low-salinity brackish marshes found within the project area. Reptiles present include the American alligator, water snakes, western cottonmouth speckled kingsnake, rat snake, and eastern mud turtle. Amphibians expected to occur include the bullfrog, southern leopard frog, and Gulf coast frog.

The barrier islands of the Chandeleur Island chain have provided numerous benefits to wildlife. Prior to the storms of the late 1990's and early 2000's and the resulting habitat loss, the use by nesting colonial seabirds and wintering migratory birds was tremendous. This is enhanced by

their proximity to the productive bays, marshes, seagrass beds, and shallow marine waters of Mississippi and Louisiana.

The islands supported the largest brown pelican nesting colonies of the entire Gulf coast from Florida to Texas, and production of young was higher than that of other colonies due to the high productivity of the surrounding waters. From a high of almost 13,000 nests in the late 1990's, the islands had fewer than 3,000 nesting pairs of brown pelicans in 2009. The same is true for other nesting colonial seabirds. With over 100,000 nesting pair of sandwich and royal terns (the largest colonies in North America) the islands now support less than ¼ of that number.

The Chandeleurs supported the largest group of wintering redhead ducks between Florida and Texas with over 20,000 making their winter home in the seagrass beds of Chandeleur Sound. That number has dropped precipitously following the loss of seagrass habitats. Likewise wintering piping plover and other shorebird numbers have also dropped due to loss of suitable wintering habitat. All of these reductions in bird numbers can be directly attributed to the loss of suitable habitat caused by island fragmentation and deterioration. The problem is that these habitats are not being replaced in other areas.

The barrier island, swamps, adjacent marshes, and the Bayou La Loutre ridge habitat serve as vital resting and foraging habitat for trans-Gulf neotropical migrant birds. Available habitat along the coast is very important to trans-Gulf migrants, they utilize wooded (swamp, bottomland hardwood, ridge and scrub/shrub) wetland habitats and adjacent spoil or bayou banks more than open marshes. This habitat is especially critical when severe weather in spring causes migrating birds to reach land exhausted, or during the fall, when bad weather forces the birds to abort their southward migration at the last moment, before leaving land. Many of these forested wetlands have been lost in the vicinity of the project area, and as the barrier island and few remaining ridges continue to subside below elevations that can support scrub/shrub habitat and maritime forest, very large numbers of neotropical migratory birds will be negatively affected.

Under the No Action Alternative, the project area would continue to provide habitat for a multitude of species including migratory waterfowl, wading birds, shorebirds, mammals, reptiles, and amphibians. However, the continued loss of emergent wetlands with the lack of sustainable freshwater sediment and nutrient input would negatively impact those species which utilize the project area. The intertidal marsh and shallow, isolated ponds and associated SAV, forested wetlands, and the barrier island habitats are utilized by those species for foraging, resting, or nesting habitat. Conversion of that habitat type to large, unvegetated open-water areas would diminish habitat value for all wildlife species.

Threatened and Endangered Species and Species of Concern

Threatened and Endangered Species

Federally listed threatened (T) and endangered (E) species and/or their designated critical habitat occurring in the project area include the Gulf sturgeon (T), pallid sturgeon (E), piping plover (T), and West Indian manatee (E). Several species of threatened/endangered sea turtles are also known to forage in the coastal waters of the study area. Those species include the loggerhead sea turtle (T), Kemp's ridley sea turtle (E), green sea turtle (T), leatherback sea turtle (E), and

hawksbill sea turtle (E). Additionally species of concern in the project area include the bald eagle, brown pelican, and other colonial wading birds protected under the Migratory Bird Treaty Act (40 Stat. 755, as amended; 16 U.S.C. 703 et seq.) and/or the Bald and Golden Eagle Act (54 Stat. 250, as amended, 16 U.S.C. 668a-d).

Gulf sturgeon

The Gulf sturgeon is an anadromous fish that occurs in many rivers, streams, and estuarine waters along the northern Gulf coast between the Mississippi River and the Suwannee River, Florida. In Louisiana, Gulf sturgeon have been reported at Rigolets Pass, rivers and lakes of the Lake Pontchartrain basin, and adjacent estuarine areas. Spawning occurs in coastal rivers between late winter and early spring (i.e., March to May). Adults and sub-adults may be found in those rivers and streams until November, and in estuarine or marine waters during the remainder of the year. Sturgeon less than two years old appear to remain in riverine habitats and estuarine areas throughout the year, rather than migrate to marine waters.

On March 19, 2003, the Fish and Wildlife Service and NMFS published a final rule in the Federal Register (Volume 68, No. 53) designating critical habitat for the Gulf sturgeon in Louisiana, Mississippi, Alabama, and Florida. Designated critical habitat in the project area includes Pontchartrain east of the Lake Pontchartrain Causeway, The Rigolets, Lake St. Catherine, Mississippi Sound, and Lake Borgne. Habitat alterations such as those caused by water control structures that limit and prevent spawning, poor water quality, and over-fishing have negatively affected this species.

Pallid sturgeon

The pallid sturgeon is an endangered fish found in Louisiana, in both the Mississippi and Atchafalaya Rivers (with known concentrations in the vicinity of the Old River Control Structure Complex); it is possibly found in the Red River as well. The pallid sturgeon requires large, turbid, free-flowing riverine habitat with rocky or sand substrate. They are usually found on the bottoms of the rivers on sand flats or gravel bars, and apparently prefer areas with strong currents in or near the main channel. It is one of the largest and rarest fish in the Mississippi and Missouri River basins. Pallid sturgeon are opportunistic feeders that eat insects, crustaceans, mollusks, annelids, fish and eggs of other fish. Scant information exists on the range and habitat preferences of pallid sturgeon for this part of the Mississippi River, but it is believed to spawn in Louisiana. Most data are from populations in upper Missouri and other Midwest rivers, and also the Atchafalaya River in Louisiana, however, it is possible that limited numbers of the species also exists in the Red River. Surveys are currently being conducted to determine the presence/absence of this species in the lower reaches of the Mississippi River, including the reach adjacent to the proposed Violet Diversion that is a part of the MRGO Ecosystem Restoration Plan.

Piping plover

Federally listed as a threatened species, the piping plover, as well as its designated critical habitat, occur along the Louisiana coast. Piping plovers winter in Louisiana, and may be present for 8 to 10 months annually. They arrive from the breeding grounds as early as late July and remain until late March or April. Piping plovers feed extensively on intertidal beaches, mudflats, sand flats, algal flats, and wash-over passes with no or very sparse emergent vegetation; they

also require unvegetated or sparsely vegetated areas for roosting. Roosting areas may have debris, detritus, or micro-topographic relief offering refuge to plovers from high winds and cold weather. In most areas, wintering piping plovers are dependent on a mosaic of sites distributed throughout the landscape, because the suitability of a particular site for foraging or roosting is dependant on local weather and tidal conditions. Plovers move among sites as environmental conditions change, and studies have indicated that they generally remain within a 2-mile area. Major threats to this species include the loss and degradation of habitat due to development, disturbance by humans and pets, and predation.

On July 10, 2001, the Service designated critical habitat for wintering piping plovers (Federal Register Volume 66, No. 132). Their designated critical habitat identifies specific areas that are essential to the conservation of the species. The primary constituent elements for piping plover wintering habitat are those habitat components that support foraging, roosting, and sheltering and the physical features necessary for maintaining the natural processes that support those habitat components. Constituent elements are found in geologically dynamic coastal areas that contain intertidal beaches and flats (between annual low tide and annual high tide), and associated dune systems and flats above annual high tide. Important components (or primary constituent elements) of intertidal flats include sand and/or mud flats with no or very sparse emergent vegetation. Adjacent unvegetated or sparsely vegetated sand, mud, or algal flats above high tide are also important, especially for roosting plovers.

West Indian Manatee

Federally listed as an endangered species, West Indian manatees occasionally enter Lakes Pontchartrain and Maurepas, and associated coastal waters and streams during the summer months (i.e., June through September). Manatee occurrences appear to be increasing, and they have been sighted in the Amite, Blind, Tchefuncte, and Tickfaw Rivers, the MRGO, the Inner Harbor Navigation Canal (IHNC) Lock and in canals within the adjacent coastal marshes of Louisiana. Manatees are known to travel long distances up coastal waterways from the Gulf of Mexico. The manatee population has declined in numbers due to collisions with boats and barges, entrapment in flood control structures, poaching, habitat loss, and pollution. Cold weather and outbreaks of red tide may also adversely affect these animals.

Sea turtles

Endangered and threatened sea turtles forage in the nearshore waters, bays and sounds of Louisiana. The National Marine Fisheries Service (NMFS) is responsible for aquatic marine threatened or endangered species. Please contact Eric Hawk (727/824-5312) at the NMFS Regional Office in St. Petersburg, Florida, for information concerning those species in the aquatic environment. When sea turtles leave the aquatic environment and come onshore to nest, however, the Service is responsible for consultation. Accordingly, we recommend that you contact this office if your activities would occur on beach areas during the sea turtle nesting season.

Species of Concern

The Chandeleur Island chain supported the largest brown pelican nesting colonies of the entire Gulf coast from Florida to Texas, and production of young was higher than that of other colonies

due to the high productivity of the surrounding waters. From a high of almost 13,000 nests in the late 1990's, the islands had fewer than 3,000 nesting pairs of brown pelicans in 2009. The same is true for other nesting colonial seabirds. With over 100,000 nesting pair of sandwich and royal terns (the largest colonies in North America) the islands now support less than ¼ of that number.

Colonial nesting birds

The proposed project would be located in an area where colonial nesting waterbirds may be present. Colonies may be present that are not currently listed in the database maintained by the Louisiana Department of Wildlife and Fisheries. That database is updated primarily by monitoring the colony sites that were previously surveyed during the 1980s. Until a new, comprehensive coast-wide survey is conducted to determine the location of newly-established nesting colonies, we recommend that a qualified biologist inspect the proposed work site for the presence of undocumented nesting colonies during the nesting season. To minimize disturbance to colonial containing nesting wading birds (i.e., herons, egrets, night-herons, ibis, and roseate spoonbills), anhingas, and/or cormorants, all activity occurring within 1,000 feet of a rookery should be restricted to the non-nesting period (i.e., September 1 through February 15, exact dates may vary within this window depending on species present). For colonies containing nesting gulls, terns, and/or black skimmers, all activity occurring within 650 feet of a rookery should be restricted to the non-nesting period (i.e., September 16 through April 1, exact dates may vary within this window depending on species present). In addition, we recommend that on-site contract personnel be informed of the need to identify colonial nesting birds and their nests, and should avoid affecting them during the breeding season.

Brown pelican

Brown pelicans were delisted (due to recovery) on December 17, 2009, and are no longer protected under the ESA, but they are still protected by the Migratory Bird Treaty Act (MBTA). Brown pelicans are known to nest on barrier islands and other coastal islands in St. Bernard, Plaquemines, and Jefferson parishes. Brown pelicans may occasionally feed in the shallow estuarine waters found within the project area.

Bald eagle

The project-area forested wetlands may provide nesting habitat for the bald eagle, which has officially been removed from the List of Endangered and Threatened Species as of August 8, 2007. Bald eagles nest in Louisiana from October through mid-May. Eagles typically nest in mature trees (e.g., bald cypress, sycamore, willow, etc.) near fresh to intermediate marshes or open water in the southeastern Parishes. Major threats to this species include habitat alteration, human disturbance, and environmental contaminants (i.e., organochlorine pesticides and lead).

The Service developed the National Bald Eagle Management (NBEM) Guidelines to provide information and recommendations to minimize potential project impacts to bald eagles, particularly where such impacts may constitute "disturbance," which is prohibited by the Bald and Golden Eagle Protection Act. A copy of the NBEM Guidelines is available at: http://www.fws.gov/southeast/es/baldeagle/NationalBaldEagleManagementGuidelines.pdf. Those guidelines recommend: (1) maintaining a specified distance between the activity and the nest (buffer area); (2) maintaining natural areas (preferably forested) between the activity and nest trees (landscape buffers); and (3) avoiding certain activities during the breeding season. On-

site personnel should be informed of the possible presence of nesting bald eagles within the project boundary, and should identify, avoid, and immediately report any such nests to this office. If a bald eagle nest is discovered within or adjacent to the proposed project area, then an evaluation must be performed to determine whether the project is likely to disturb nesting bald eagles. That evaluation may be conducted on-line at: http://www.fws.gov/southeast/es/baldeagle. Following completion of the evaluation, that website will provide a determination of whether additional consultation is necessary. The Division of Migratory Birds for the Southeast Region of the Service (phone: 404/679-7051, e-mail: SEmigratorybirds@fws.gov) has the lead role in conducting such consultations.

EVALUATION METHODOLOGY

Evaluation of project-related impacts on fish and wildlife resources for MRGO Ecosystem Restoration Plan Feasibility Study was conducted using the Wetland Value Assessment (WVA), the ERDC-Boustany model, a water quality model, and the Comprehensive Aquatic Systems Model (CASM) model.

The WVA is used to evaluate proposed Coastal Wetlands Planning, Protection, and Restoration Act (CWPPRA) projects, and is similar to the Service's HEP, in that habitat quality and quantity (acreage) are measured for baseline conditions, and predicted for future without-project and future with-project conditions. As with HEP, the WVA provides a quantitative estimate of project-related impacts to fish and wildlife resources. Results are annualized over the project life to determine the Average Annual Habitat Units (AAHUs) available for each habitat type. Separate models were used for fresh/intermediate marsh, brackish marsh, saline marsh, ridge habitat, swamp habitat, and barrier islands. The WVA models assess the suitability of each habitat type for providing resting, foraging, breeding, and nursery habitat to a diverse assemblage of fish and wildlife species. Using the WVA methodology, impact assessments were conducted by the Habitat Evaluation Team (HET), which included representatives of the Corps, Office of Coastal Protection and Restoration (OCPR), NMFS, National Resource Conservation Service (NRCS), and the Service.

To determine wetland benefits (net acres) of the Violet diversion for each alternative, an empirical model (ERDC-Boustany model) developed by the Engineering Research and Development Center (ERDC) and Mr. Ron Boustany of the Natural Resources Conservation Service (NRCS) was utilized by the HET. The ERDC-Boustany model estimates the benefits resulting from the introduction of sediments and nutrients into the study area. Model predictions are based on diversion flows into the project area and nutrient and sediment concentrations of the diversion water. The model derives an estimate of the wetland acreage sustained and/or created as a function of nutrients and sediments introduced into the system.

The CASM has been adapted to assess direct and indirect ecological effects of proposed freshwater diversions into Lake Borgne and associated coastal and marine areas that define the MRGO ecosystem. The CASM is a bioenergetics-based ecosystem model that simulates the daily production dynamics (gC/m2) of modeled populations of aquatic plants and animals. The

principal modeling objective was to assess the potential effects of alterations in salinity and other water quality parameters that will result from the proposed freshwater diversions on selected populations of valued ecological resources in the MRGO ecosystem.

The final array under a low relative sea level rise scenario and the TSP under a high, medium, and low relative sea level rise scenario were evaluated by the HET using the WVA. The ERDC-Boustany model was run for each final alternative and TSP and results (wetland acres) utilized in the WVA. Details of the ERDC-Boustany model, WVAs and assumptions for the TSP are available in Appendix B. WVA and assumption information on the final array of alternatives are available for review at the Service's Lafayette, Louisiana, field office.

DESCRIPTION OF TENATIVELY SELECTED PLAN

Description of Feature Types

Marsh Restoration

A hydraulic dredge would be used to discharge slurry (i.e., dredged material) into shallow open water areas and degraded marsh areas. Material would be obtained from study area borrow sites for each feature. Slurry would be discharged to an elevation conducive to the development of wetlands habitat following dewatering and compaction. It is anticipated that the final result of this dredged material placement would be a combination of wetlands, mud flat, and shallow water habitat within the placement site. Following compaction and dewatering, the area would be planted with marsh vegetation appropriate for the site. Material would be allowed to overflow over existing emergent marsh vegetation within the proposed restoration area.

Marsh Nourishment

Marsh nourishment is proposed for areas of degraded marsh, and consists of the placement of a thin layer of dredged material slurry material that would be allowed to overflow over existing emergent marsh vegetation within the proposed disposal area, but would not be allowed to exceed a height of about 1 – 1.5-feet above the existing marsh elevation to facilitate the recruitment and consolidation of marsh vegetation after dewatering. Unlike marsh restoration features, no plantings are associated with marsh nourishment features.

Swamp Restoration

Swamp restoration is proposed in areas that were historically cypress-tupelo swamps and are currently shallow open water. Swamp restoration consists of pumping dredged material from study area borrow areas to a maximum elevation of +4.5 feet (ft) within containment dikes. Swamp restoration areas would be planted with cypress. Swamp restoration features would have a dewatered and settled target elevation approximately +2ft to support cypress habitat.

Swamp Nourishment

Swamp nourishment is proposed for areas that are currently at marsh elevation, and consists of placing a thin layer of dredged material to nourish the area, raise elevation to approximately +2ft, and encourage the recruitment of cypress-tupelo community species. The depth of the layer of dredged material will be determined on a site-by-site basis to adjust for varying topography.

The PDT and HET have identified several critical factors that would need to be considered in the design phase for swamp restoration and nourishment features. These include: the level and timing of inundation, salinity levels in soil and area water bodies, elevation, invasive species and herbivory control, and water quality.

For marsh and swamp creation and nourishment
Retention dikes, deflection dikes, and/or closures may be used to contain material for each feature. Interior low-level earthen weirs also may be constructed within the disposal area to facilitate the deposition of sediments in a manner that would enhance wetlands development. Borrow material for dike/closure/weir construction would be taken from within the disposal area. Earthen dikes/closures would be allowed to degrade naturally. If earthen dikes/closures do not sufficiently degrade to provide fisheries and tidal ingress/egress following appropriate settlement of dredged material placed within the disposal area, earthen dikes/closures would be mechanically breached and/or degraded as necessary.

Access corridors for construction equipment and dredge pipeline are depicted in the plan view for each feature in the Engineering Appendix of the Feasibility Study. Access corridors would be a maximum of approximately 350 feet in width and would cross over wetlands and shallow water as necessary. Access corridors for some features may occur across existing levees and different methods will be utilized to best prevent compromise of the levee while allowing access. The level of protection provided by these levees would be maintained throughout construction, and any damage to levee vegetation would be repaired upon removal of the construction equipment. The construction, or designation, of staging areas may be necessary for construction equipment. Staging areas will be determined on a site-by-site basis to minimize impacts to existing wetlands.

Flotation access channels would be excavated, as needed, in shallow water areas to allow construction equipment to access the project features. If necessary, flotation access channels would be excavated by a mechanical dredge (as depicted on the plan view in the Engineering Appendix of the Feasibility Study). It is estimated that access channels will average approximately -2 feet. Flotation access channel material would be used in dike/closure construction or refurbishment, to backfill flotation access channels, or would be placed adjacent to and behind the dikes and closures in shallow water to a maximum initial elevation conducive to wetlands development following consolidation of the material. Flotation access channel material used to backfill the flotation access channels following completion of disposal work would be temporarily stockpiled on water bottom adjacent to the flotation access channel.

If existing canals are used for access, they may be dredged to facilitate flotation of pipeline and other necessary equipment from the dredging reach as designated in the plan feature to pipeline discharge sites within the designated staging areas. Dredged material removed from existing canals would be placed on adjacent existing levees and/or into shallow water on either side of canals. Canal dredged material placed in shallow water areas would be placed to a height conducive for wetlands development.

Shoreline Protection

These features consist of either foreshore (shoreline between high water and low water) rock dikes or rock dikes placed near the existing shoreline to dissipate wave energy before it reached the shoreline (shown in the plan views in the Engineering Appendix of the Feasibility Study). Foreshore rock dikes would be constructed by placing rock in a linear mound at the -1.5 to -2.0-foot depth contour, to a height above the water's surface. Height will be determined based on existing site conditions. Nearshore (beginning at foreshore and extending to the beginning of the offshore zone) rock dikes would be constructed in places where the bathymetry prohibits a foreshore dike (water deepens too quickly from the shore). Rock used for dike construction would be graded large enough to resist movement during high energy events, such as frontal passages. Shoreline protection features include site-specific, periodic gaps for organism access, navigation, and water exchange, as noted in the plan view for each feature.

Ridge Restoration

A ridge restoration feature is proposed on the south side of Bayou La Loutre. Restoration would consist of the placement of dredged silty sand material to be obtained from the Mississippi River. The initial elevation of the ridge would be approximately +8 feet, with a crown width of 25 feet and 1:8 side slopes. The base width of the ridge would vary, with an average width of approximately 120 feet. A 50-foot access corridor on the south side (marsh side) would be designated for construction equipment. Access along Bayou La Loutre may require excavation to the channel's authorized depth. If excavation is required material excavated for floatation will be placed in the footprint of the proposed ridge restoration work. The ridge would be planted to develop forested habitat as described in the planting plan for this study (see Appendix B, Attachment 8).

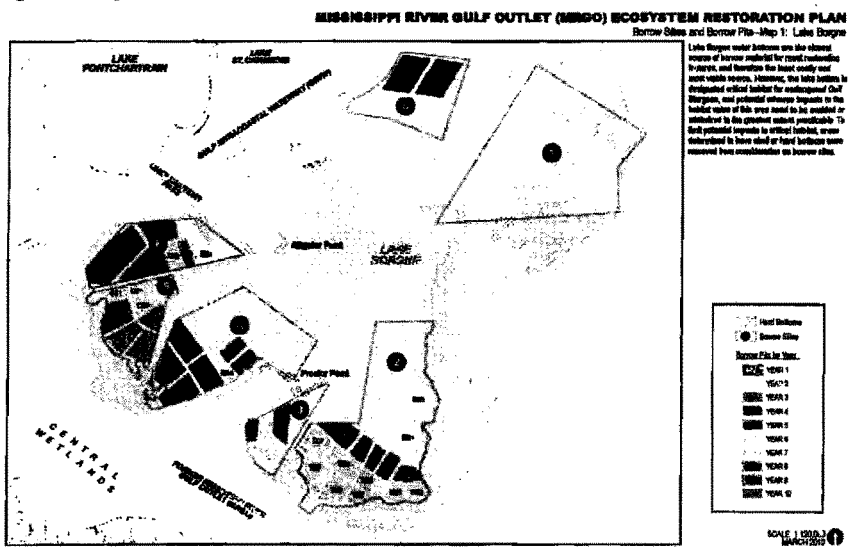
Violet Freshwater Diversion

The Central Wetland feature includes a freshwater diversion at Violet. The diversion will be built to have a maximum discharge of 7,000 cubic feet per second (cfs) depending on Mississippi River water level. In low water periods, the diversion is expected to discharge a minimum of 870 cfs for a total of 1000 cfs being discharged into the Central Wetlands once the Sewer and Water Board discharge is included. The Violet Freshwater Diversion is proposed to extend from the Mississippi River and Tributaries Levee to the 40 Arpent Levee via a controlled conveyance channel. The proposed river diversion channel would flow through the adjacent wetlands to an outfall structure in the Chalmette Loop Levee and discharge into the MRGO. Openings to adjacent channels in the Central Wetlands would provide the freshwater and nutrients required to maintain the restored cypress swamp. The diversion design includes a closure structure at Dupre Cut that is open to shallow draft navigation to better conduct the freshwater via the MRGO. A sediment trap is also proposed as a diversion component to reduce required maintenance and provide Mississippi River sediments for use in restoration projects in the vicinity.

Borrow

A significant amount of sediment will be required for the proposed features. Figure 2 illustrates the proposed borrow site for each proposed feature.

Figure 2. Proposed Borrow Sites for the MRGO Ecosystem Restoration Plan.

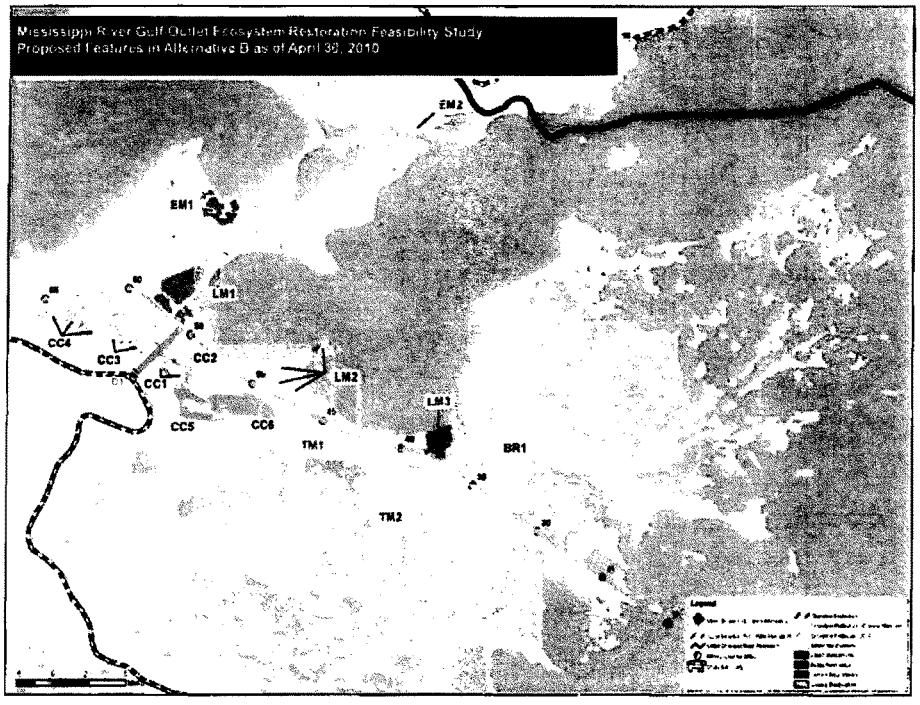


Final Array of Alternatives Considered

Three Best Buy plans (i.e., cost effective) were selected for the final array. Best Buy plans B, C, and D were chosen based on cost effective increments, i.e. where large amount of outputs (i.e., benefits) could be gained for minimal additional cost. All alternative plans in the final array include a freshwater diversion at Violet. These plans represent a wide range of costs and outputs. The alternatives retained for further evaluation build on each successive plan i.e., Plan C includes all of the features in Plan B, and Plan D incorporates all of the features in Plan C. Plan B includes the restoration of all targeted habitat types, but does not fully accomplish the planning objectives. Plan C meets all of the objectives and forms a complete, effective, efficient, and acceptable plan, and therefore has been selected as the Tentatively Selected Plan (TSP). Plan D meets or exceeds all of the restoration objectives and provides a more comprehensive restoration plan for the areas affected by the MRGO and the Lake Borgne ecosystem.

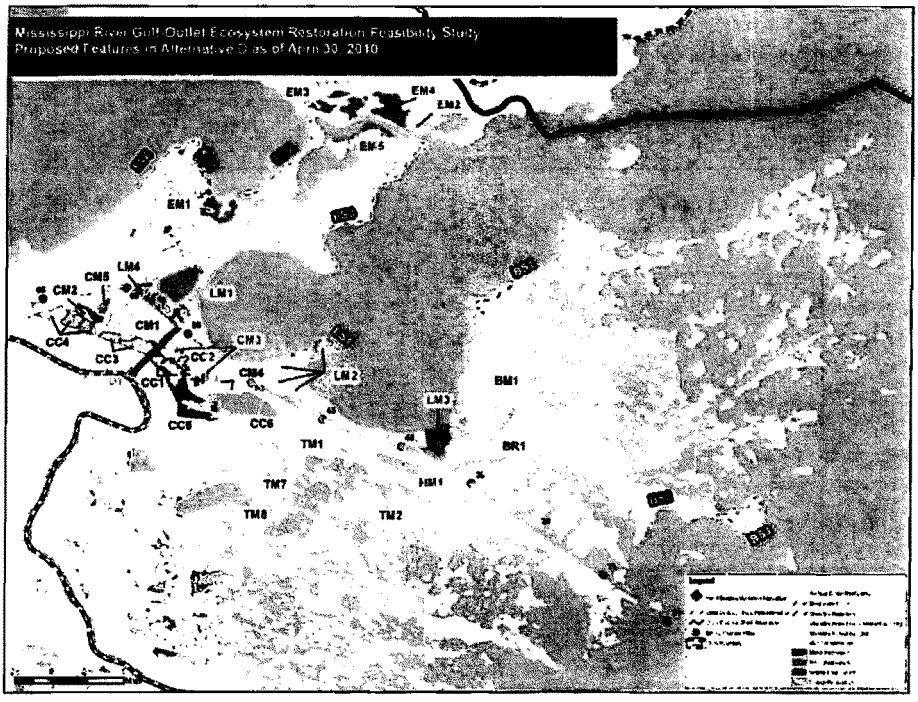
Alternative Plan B would restore approximately 10,431 acres of cypress swamp, 10,473 acres of fresh and intermediate marsh, 10,496 acres of brackish marsh, 0 acres of saline marsh, and 48 acres of ridge habitat (Figure 2). Features in the East Orleans Landbridge, South Lake Borgne, and Terre Aux Boeuf subunits include marsh creation and nourishment. The Central Wetland features include a freshwater diversion at Violet and cypress swamp restoration and nourishment. Features in the Biloxi Marshes consist of restoring part of the existing subsided ridge on the south bank of Bayou La Loutre.

Figure 3. MRGO Ecosystem Restoration, Alternative Plan B Features.



Alternative Plan D would restore approximately 10,431 acres of cypress swamp, 15,028 acres of fresh and intermediate marsh, 3,979 acres of brackish marsh, 699 acres of saline marsh, and 48 acres of ridge habitat (Figure 3). In addition to all of the features described for Plans B and C, Plan D includes additional restoration components in the East Orleans Landbridge, the Biloxi Marsh, and Terre aux Bouefs. Plan D also includes restoration features in the Hopedale area, and the most cost-effective features in the MRGO.

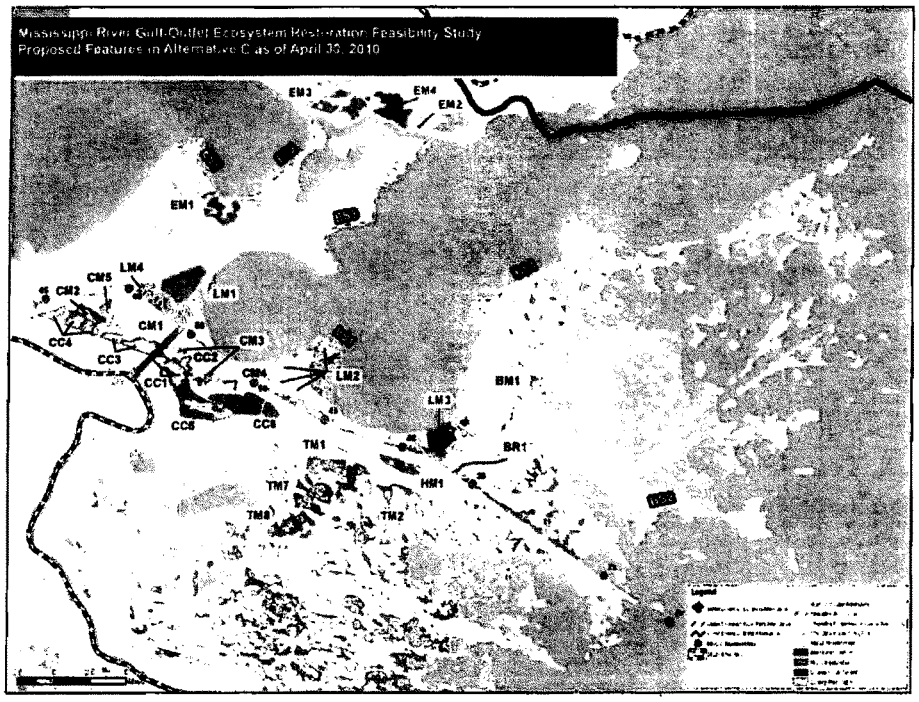
Figure 4. MRGO Ecosystem Restoration, Alternative Plan D Features.



Tentatively Selected Plan (TSP): Plan C

The Tentatively Selected Plan (TSP) would restore approximately 10,431 acres of cypress swamp, 13,890 acres of fresh and intermediate marsh, 33,696 acres of brackish marsh, 466 acres of saline marsh, and 48 acres of ridge habitat. Features in the East Orleans Landbridge and South Lake Borgne subunits include marsh creation and nourishment and shoreline protection. The Terre Aux Boeuf subunits include marsh creation and nourishment. The Central Wetland features include a freshwater diversion at Violet, cypress swamp and marsh restoration and nourishment. Features in the Biloxi Marshes consist of restoring part of the existing subsided ridge on the south bank of Bayou La Loutre, marsh creation and nourishment, and shoreline protection.

Figure 5. MRGO Ecosystem Restoration, Alternative Plan C – Tentatively Selected Plan Features.



Barrier Island Feature

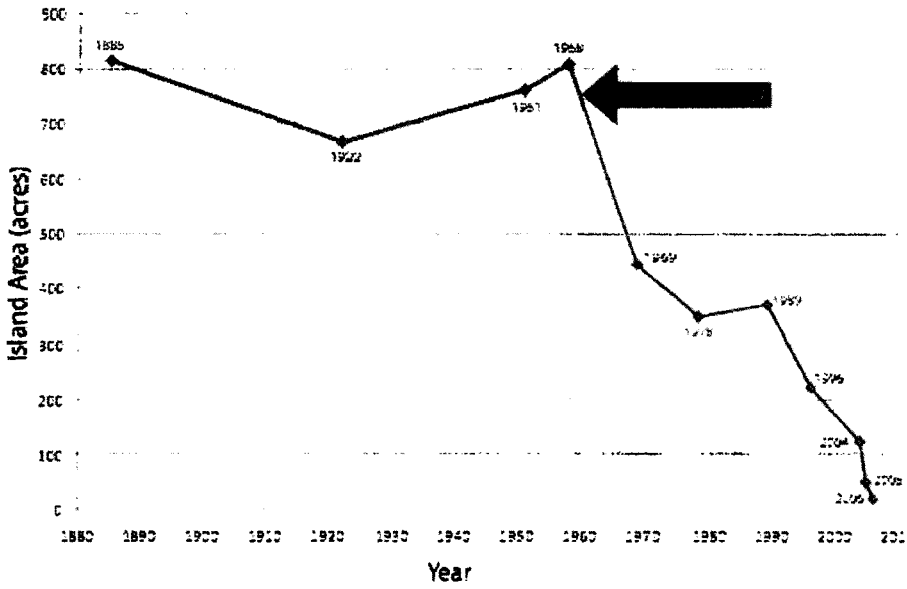
Six barrier island features were evaluated as part of the MRGO Ecosystem Restoration Plan. They included one Chandeleur alternative which faired extremely well in regard to benefits produced as well as cost per benefits. The remaining five alternatives were various designs on Breton Island. Breton Island alternatives one and three performed the best. Breton Island Alternative 1 is the most robust of the two alternatives including a 4-mile long, crescent shaped beach and dune with a 3,700 ft wide back barrier marsh. Breton Island Alternative 3 was developed as the least expensive approach to achieving as many benefits as possible by discharging at a single point to create a 1,000 ft wide, 10 ft high platform at the northern end of the island and allow the island to naturally rework itself. Even though alternatives for the islands were developed and conceptually ready for selection, the Corps choose not to include a barrier island component in the TSP. The reasons given included the need for more engineering investigations to complete feasibility level design prior to finalizing the document and more importantly the Corps position that impacts to Breton Island from the MRGO are difficult to quantify.

Though the Chandeleur alternative had the most benefits, the Service agrees the Chandeleur Islands were most likely not directly or indirectly affected by the MRGO. Conversely, the

Service believes that although barrier islands have many factors contributing to their reduction in area, that there were impacts to Breton Island from the MRGO.

Breton Island does not follow the same trends in island area change exhibited by Curlew and Grand Gosier Islands to the north. The difference is attributed to the construction of the MRGO outer bar channel for navigation purposes (Lavoie, D, ed., 2009). The MRGO intersects the Chandeleur Islands just north of Breton Island and was cut through the existing tidal inlet of Breton Island Pass. Deepened ship channels facilitated sand loss from littoral drift to offshore seafloor areas (Morton, R. A. 2008). Prior to construction of the MRGO, sand that was transported alongshore could bypass this inlet via the ebb tide delta, nourishing the flanking barrier islands (Thomson et al., 2009 and Thomson et al., 2010). The MRGO required frequent maintenance dredging to remove sand, which was placed in the Ocean Dredged Material Disposal Site (ODMDS), before being deauthorized in 2008. However, in 1992 and beyond, dredged material was occasionally used beneficially to enhance Breton Island. Strong tidal currents flow through MRGO because it is a major conduit for tidal exchange for much of the Lake Pontchartrain Basin. The increased tidal prism and strong ebb tide currents result in the seaward transport of sand to now distant ebb tide shoals that prevent sand from nourishing Breton Island (Thomson et al., 2009). As a result, Breton Island has undergone accelerated land loss due to the MRGO channel interrupting the natural sediment bypassing pathway, by removal of sediment through flushing action of the increased tidal prism, and by maintenance dredging of the MRGO channel, all of which remove sediments from the littoral system (Lavoie, D, ed., 2009; Thomson et al., 2009). These processes prohibit Breton Island from recovering from storms in a similar manner to the islands north of the MRGO and have resulted in a long-term reduction in the Breton Island area (Lavoie, D, ed., 2009). Further indirect evidence of these detrimental processes is provided by the restoration efforts that used dredged material from the MRGO. Some of the material removed from the MRGO was placed in a feeder berm that was most likely in closer proximity to the pre-MRGO ebb tide delta location that the more distal ODMDS. Material placed in the feeder berms eventually accreted to the island (Penland and Westphal 1996). Figure 6 shows the historic acreage of the islands from 1885 through 2006. This figure highlights that significant decreases in island acreage occurred immediately after the construction of the MRGO (Thomson et al., 2009).

Figure 6. Breton Island area change through time showing the impact of MRGO construction and maintenance dredging (Thomson et al., 2009).



Similar responses to navigation channels bisecting island chains are seen in other parts of coastal Louisiana and along the east coast. On the eastern side of Louisiana and western Mississippi, it is reported that deepened ship channels facilitate sand loss from littoral drift to offshore seafloor areas (Otvos & Carter, 2008). Specific to Louisiana, the evaluation of the deepening of the Houma Navigation Channel at Cat Island Pass, Rosati (2007) reported that a deeper channel will intercept sand presently bypassing the channel and will increase shoaling resulting in an approximately 15% increase in maintenance dredging. As a result, the study recommended sediment dredged from Cat Island Past should be placed on East Island, downdrift of the channel to renourish the island that would otherwise loose sediment as a result of the deeper channel. In addressing possible impacts of navigation channels to deltas Engineering Manual (1110-2-1100) states that "Sediment accumulation should increase with increasing channel depth until it becomes so deep that the channel traps all sediment crossing the inlet."

Breton Island is a National Wildlife Refuge, managed by the Service and is of national importance. Until recently (Lavoie, D, ed., 2009; Thomson et al., 2009) the Service was unaware of the long-term impacts to this important refuge as a result of the MRGO channel. However, the Service believes the connection between the areal loss of Breton Island and the MRGO channel has been proved and should be appropriately addressed in the TSP of the MRGO Ecosystem Restoration Plan. The importance of Breton Island is clear not only as America's second oldest Refuge (established in 1904) but also as the island provides tremendous benefits to nesting colonial seabirds, including the largest sandwich and royal terns colonies in North America, wintering migratory birds, wintering piping plover critical habitat, and other shorebird

habitat. Restoration of this island habitat will have benefits on a scale that cannot be realized anywhere else on the coast. Without restoration of the island, a great loss of habitat would occur with the islands disappearance.

PROJECT IMPACTS

The same features were evaluated looking at three different relative sea level rise scenarios (see Appendix B for more details) as reported in Table 2. For the purposes of discussion, the medium rate will be reported.

The TSP would initially restore and/or protect approximately 10,431 acres of cypress swamp, 13,890 acres of fresh and intermediate marsh, 33,696 acres of brackish marsh, 466 acres of saline marsh, and 48 acres of ridge habitat. The implementation of the TSP is anticipated to restore unique habitats, significant ecosystem functions, structure, and dynamic processes through a comprehensive systems-based approach. Construction of a 7,000 cfs (maximum flow) diversion at Violet, marsh creation and nourishment, swamp creation and nourishment, shoreline protection, and ridge restoration features would have 15,628 AAHUs and 20,767 net acres at the end of 50 years based on a medium relative sea level rise scenario (Table 2).

Table 2. Potential Estimated Impacts (AAHU and Net Acres at 50 years) for the Tentatively Selected Plan for the MRGO Ecosystem Restoration Project for Low, Medium, and High Relative Sea level Rise Scenarios.

	LOW RSLR		MEDIUM RSLR		HIGH RSLR	
Feature	AAHU	Net Acres	AAHU	Net Acres	AAHU	Net Acres
Inner Biloxi marsh	2,412	2,809	2,324	2,220	1,739	0
Bayou La Loutre outer SP	29	49	23	48	4	0
Bayou La Loutre ridge	10	14	15	25	27	48
Central Wetlands marsh	2,340	6,478	1,693	4,785	733	0
Central Wetlands swamp	5,201	3,793	5,511	4,914	4,686	7,340
Diversion footprint impacts	-220	-325	-192	-224	-88	0
MRGO	10	95	5	75	3	0
East Orleans Landbridge	1,428	819	1,030	642	955	0
Lower Pearl River	851	1,056	764	905	364	0
Lower Lake Borgne marsh	2,882	6,326	2,467	5,031	546	0
Hopedale	186	244	154	181	75	0
Inner Terre Aux Boufs	2,168	2,937	1,834	2,165	674	0
TOTAL	17,298	24,295	15,628	20,767	9,717	7,388

Construction of several features would have an initial negative impact on existing wetland vegetation, primarily through the excavation of the diversion outfall channel, placement of excavated material on existing marsh to create ridge and swamp, and freshwater inputs from the diversion that would convert existing brackish marsh to intermediate marsh. According to the WVA, the TSP would result in the direct and indirect loss of 12,430 acres (13,460 AAHUs) at the end of 50 years, of brackish marsh habitats due to the channel excavation, swamp creation, and conversion to fresher habitat and saline marsh due to ridge restoration (Table 3). However, the placement of excavated material for swamp and ridge restoration and the conversion to fresher wetlands will provide a base for the regeneration of approximately 27,036 acres (22,959 AAHUs) of bottomland hardwood and wetland vegetation (Table 4) and a net increase of 20,767 acres (15,628 AAHUs, Table 2).

Table 3. Negative Impacts to wetlands due to Habitat Switching.

	LOW RSLR		MEDIUM RSLR		HIGH RSLR	
Feature	AAHU	Net Acres	AAHU	Net Acres	AAHU	Net Acres
Diversion footprint Impacts	-220	-325	-192	-224	-88	0
Brackish to Swamp	-2,373	-3,547	-2,064	-2,426	-1,124	0
Saline to Ridge	-27	-34	-22	-23	-9	0
Brackish to Intermediate	-13,877	-19,970	-11,183	-9,757	-6,360	0
TOTAL	**-16,497**	**-23,876**	**-13,460**	**-12,430**	**-7,582**	**0**

Table 4. Positive Impacts to wetlands due to Habitat Switching.

	LOW RSLR		MEDIUM RSLR		HIGH RSLR	
Feature	AAHU	Net Acres	AAHU	Net Acres	AAHU	Net Acres
Brackish to Swamp	7,575	7,340	7,575	7,340	5,810	7,340
Saline to Ridge	37	48	37	48	36	48
Brackish to Intermediate	19,109	32,869	15,347	19,648	7,642	0
TOTAL	**26,721**	**40,257**	**22,959**	**27,036**	**13,488**	**7,388**

A freshwater diversion is necessary to achieve habitat objectives adopted for this study and enhance surrounding wetlands. The forecast future without project salinity conditions suggest that salinities in the study area will be reduced by the closures on the MRGO and other authorized projects. However, additional freshwater, sediment (fines), and nutrient inputs will enhance many of the nearby wetland habitats.

The diversion was originally conceived to meet habitat objectives for the Lake Borgne ecosystem, including cypress swamp in the Central Wetlands, intermediate marsh in the lower Lake Borgne marshes, and enhancing other surrounding marshes, as well as achieving desirable habitat conditions of the Mississippi Sound and the upper Biloxi marshes. Habitat salinity targets that would be favorable to oysters were used as an indication of the health of the Mississippi Sound and the upper Biloxi marshes. The HET agreed that the established salinity targets based on the Chatry line originally proposed for the Bonnet Carre Freshwater Diversion

and then for the Violet Diversion (in WRDA 2006) was an appropriate indicator of the health of that ecosystem. However, based on hydrologic modeling results that incorporated the MRGO closure the target salinities are met, or exceeded, for all but one month (May) of the year and in that month there was only a 1part per thousand (ppt) difference. The HET agreed that meeting the Chatry salinity line in May was not crucial to the health of that ecosystem. In addition, there is a concern that the required high pulse (i.e., increased) flow in April and/or May to meet the Chatry target might have an over freshening effect on the estuarine fisheries in the Lake Borgne ecosystem and possibly the Mississippi Sound and the upper Biloxi marshes. It was agreed by the HET that a diversion capable of flowing up to 7,000 cfs provides the flexibility necessary to achieve the habitat objectives throughout the Lake Borgne ecosystem, however, the goal is no longer to achieve all the monthly (i.e., May) Chatry salinity targets in the upper Biloxi marshes. Under this scenario, a range of high flows can help control/eliminate salinity spikes as needed while not requiring the diversion to have a high pulse flow in April and/or May each year, unless needed. It is expected that through the associated Adaptive Management and Monitoring Plan, the diversion operation plan will be refined to achieve optimal habitat benefits of the Central Wetlands and the Lake Borgne ecosystem and surrounding marsh.

Though the actual operation may be somewhat different, the diversion was modeled at the original maximum proposed flows which show the full capability of the diversion. Specifically, the diversion was modeled to operate at a constant flow of 870 cfs, with a pulsing of 7,000 cfs during April and/or May. A combined 1,000 cfs was modeled to flow through the Central Wetlands and during the pulse while the remaining 6000 cfs will flow directly out of the Central Wetlands into the Lake Borgne/Biloxi Marsh ecosystem. It should be noted that wetland benefits analysis incorporated this operation scheme and will have to be adjusted once further refinement of the operation is developed. The Violet Diversion is designed so that management of the estimated base flow of 1,000 cfs can provide conditions favorable to bald cypress germination, growth, and reproduction by controlling depth and duration of inundation and salinity levels. In addition, an estimated 7,000 cfs diversion rate to achieve the earlier proposed salinity levels in May in the Biloxi marsh target area was modeled. The management of the diversion control structures will allow maintenance of favorable conditions for forested wetlands of the Central Wetlands as well as enhancing the habitat of the lower Lake Borgne marshes and parts of the East Orleans Landbridge and Biloxi marshes (see Appendix B – WVA Assumptions for more detail on the diversion operation).

Operation of the maximum 7,000 cfs diversion alternative would provide an inflow of fresh water, sediments, and nutrients to the project area and support the re-establishment and nourishment of wetland vegetation in the project area. It is anticipated that the Central Wetlands currently classified as brackish marsh would be converted to swamp and fresh marsh and the brackish marsh of lower Lake Borgne would convert to intermediate marsh following the start of the diversion operation. A gain in wetlands of the Central Wetlands area is expected while other area wetlands influenced by the diversion (East Orleans Landbridge, Lake Borgne marshes, and the inner Biloxi marshes) will become more sustainable.

Additionally, the ERDC-Boustany model land loss calculations conducted in support of the WVA for the 7,000 cfs diversion, including all features constructed with in the diversion influence area, projected that the TSP would produce an overall gain, in fresh/intermediate,

brackish, and saline marsh, swamp, and ridge habitat of approximately 17,592 acres and 13,025 AAHUs 50 years after project implementation (Table 2).

Wildlife Resources

Construction of the project features may disrupt or displace wildlife in the immediate vicinity. However, the long-term impact of construction is expected to be beneficial to overall habitat quality. By the proposed diversion having a potential pulse as needed, the salinity gradient of the Lake Borgne and Biloxi marsh estuary is maintained while sustaining and enhancing existing marsh in the study area. Because ridge and swamp habitat are considered to be a limiting factor for migrating birds, the creation of these habitats are considered an essential restoration need of the project area. The TSP will have a positive effect on wildlife resources by increasing unique critical habitat that will be utilized by wildlife species.

Currently the TSP does not include a barrier island component. If a barrier island feature was included it would increase the sustainability of the barrier island; help restore the geomorphic function of the barrier island thus restoring the hydrologic benefits of the islands to the basin; and create and restore shoreline and island habitat. By restoring the barrier island, the vital seagrass bed habitat would be enhanced and maintained for sea turtles, manatee, and wintering migratory waterfowl in the northern Gulf of Mexico. The restored island would greatly benefit nesting colonial seabirds, especially brown pelican and sandwich and royal terns nesting colonies, piping plover and other shorebirds. Restoration of these island habitats will have benefits on a scale that cannot be realized anywhere else on the coast. Without a barrier island component many of these benefits to wildlife may be lost.

Overall, the TSP would result in improved habitat conditions for several species of wildlife including migratory and resident waterfowl, shorebirds, wading birds, and furbearers. Migratory waterfowl utilizing the project area would benefit from a greater food supply resulting from the increased abundance and diversity of emergent, submerged, and floating-leaved species. Enhanced marsh and marsh edge would provide increased foraging opportunities for shorebirds and wading birds. Small fishes and crustaceans are often found in greater densities along vegetated marsh edge (Castellanos and Rozas 2001, Rozas and Minello 2001), and many of those species are important prey items for wading birds such as the great blue heron, little blue heron, great egret, black-crowned night-heron, and snowy egret. Furbearers (such as muskrat) which feed on vegetation would benefit from the increased marsh acreage in the project area. Representative furbearers such as the mink, river otter, and raccoon have a diverse diet and feed on many different species of fishes and crustaceans. Those species often feed along vegetated shorelines which provide cover for many of their prey species.

Fisheries Resources

There would be negative impacts to fisheries resulting from swamp and ridge construction as the existing marsh (2,449 acres) is lost to those new habitats (Table 3). There would be positive impacts to fisheries habitat from marsh creation as marsh edge is restored, nourished, and protected. The shoreline protection features of the TSP will provide additional fisheries habitats for estuarine fish. If a barrier island feature was part of the TSP, it would have a positive effect

on fish resources by reestablish a barrier between a deteriorating estuarine ecosystem and the Gulf of Mexico thereby increasing unique and essential habitat that will be utilized by various fisheries species. The seagrass beds associated with the barrier island feature would enhance that rapidly declining vital habitat for juvenile aquatic species. Without the barrier island component these benefits may be lost.

The potential impact of the TSP proposed borrow sites on water quality, specifically in regards to low dissolved oxygen and anaerobic or anoxic conditions is a significant concern to the Service. To help reduce the potential for anoxic conditions to occur the borrow sites are proposed to be dredged to approximately 10 ft with 5 ft of allowable over depth and sloping edges up to the adjacent water bottoms. Because borrow material is primarily designated to be excavated from Lake Borgne (see Figure 2), a large portion of the lake will be affected in both the alteration in water bottom substrate habitat as well as, the increased potential of change in the flushing ability that otherwise would prevent anerobic conditions from occurring.

Anerobic conditions in dredge holes can severely limit species diversity and often eliminate all benthic organisms except certain bacteria that can tolerate those conditions (Taylor and Saloman 1968, in: USFWS undated; Sullivan and Hancock 1973, in: USFWS 1977). While some species of fish are attracted to the holes during certain times of the year when water quality improves, they must evacuate those areas when severe oxygen stress forces them to either leave or die (USFWS undated). Evacuation of study areas may occur in the late spring or summer when low oxygen levels are most likely to occur (Kinne 1963, in: USFWS undated).

Because a very large quantity of dredged material will be needed to create approximately 10,430 acres of cypress swamp, 13,898 acres of fresh and intermediate marsh, 26,067 acres of brackish marsh, 10,588 acres of saline marsh, and 50 acres of ridge habitat, careful consideration should be given to the borrow site design. Though borrow sites are proposed to be dredged to shallow depths to avoid creating anoxic sumps, the need for excavating material over more surface area is necessary to collect the needed quantity of material. By dredging over a larger surface area, potential complications may include: 1) alteration in water bottom substrate habitat: 2) more benthos may be directly removed, which may (at least temporarily) reduce food availability for fishery organisms; 3) other sessile resources, such as oysters could be affected; and 4) by continually moving the dredge, the resuspended sediments will take longer to settle and could prolong the periods of high turbidity associated with dredging operations.

Recovery (both in terms of organisms and re-filling with sediment) of these borrow sites appears to be a function of the original depth and other local factors. Several scientific studies indicate that recovery may take from 6 to 10 years in relatively shallow holes (e.g. 6 feet below natural bottom) or, as is more frequently reported, much longer in the deeper holes (USFWS undated).

Implementation of the TSP following the operational plan evaluated in the hydraulic modeling, CASM, and WVA (i.e., 7,000 cfs flow in April and May; 870 cfs rest of year) is expected to freshen much of project area including the Central Wetlands, lower Lake Borgne marshes, part of the inner Biloxi marshes, and some of the East Orleans Landbridge while the diversion is at full flow and for several weeks after the return to maintenance flow. The overall effect of the diversion is that it is expected to decrease salinities spikes throughout the project area and

convert the brackish marsh of the Central Wetlands to fresh marsh and swamp and the brackish marsh of the lower Lake Borgne marshes to intermediate marsh. Water levels, velocities, and turbidity in outfall areas are all expected to increase during full flow conditions. Entrainment of eggs, larvae or fry of Mississippi River fish species in the immediate vicinity of the diversion inflow may occur during operation of the structure.

High nutrient levels could result in blooms of algae and phytoplankton, and subsequent decomposition of these organisms could decrease dissolved oxygen levels of water bodies within the project area. These changes could result in localized adverse impacts to estuarine fishery productivity, particularly when the diversion is at full flow.

Freshwater fishery species especially in the Central Wetlands, such as crawfish, crappie, bluegill, redear sunfish, warmouth, channel catfish, and blue catfish, largemouth bass, yellow bullhead, freshwater drum, bowfin, carp, buffaloes, and gars should benefit from implementation of the diversion. Some fishery species would be impacted by anticipated decreases in salinity and water temperature, and increased turbidity during maximum flow periods. Less freshwater tolerant species, such as brown shrimp and spotted seatrout, may be displaced from the Central Wetlands portion of the project area. In fact, modeling results show that running the Violet Diversion at maximum flow of 7,000 cfs in the Central Wetlands may negate tidal input to the area limiting aquatic organism access to the marshes.

CASM modeling results are preliminary due to some incorrect assumptions incorporated into the model but those are being corrected in consultation with NMFS and LDWF. Once completed, information will be provided in this section to discuss the impacts of the freshwater diversion on representative fishery species.

By implementing an operational plan to enhance surrounding wetlands, estuarine-dependent fisheries may be enhanced by reducing high salinity spikes (without over-freshening), increasing organic production, increasing biological productivity and improving fisheries habitat. The introduction of freshwater to the project area would ensure that the project area continues to provide important nursery functions beyond the 50-year project life. However some species, such as oysters in Lake Borgne, may be displaced. Oysters may benefit from the diversion during normal base flow years depending on environmental conditions but over freshening would occur during high pulse years.

Historically, salinity appears to be the chief controlling factor in the number of plankton species present, while temperature, competition, and predation control the numbers of individuals present (Day et al., 1989). Therefore, introduction of large amounts of river water (pulsing) into estuarine systems may have dramatic short-term impacts on plankton populations in adjacent coastal waters (Hawes and Perry 1978). Freshwater inflow is an important component of circulation and flushing processes in estuaries that assist in the transportation of planktonic organisms, nutrients, and detritus to the Gulf of Mexico. Over the long term, operation of the diversion is expected to help support the aquatic food web of marine fishery species.

Essential Fish Habitat

Direct impacts of swamp and ridge construction would disturb and displace managed species in the construction footprint. Marsh creation would result in the loss of mud bottom and estuarine water column as emergent marsh would replace those habitat types. If the TSP had a barrier island component, it would have a positive effect on EFH resources by increasing the essential habitats of the barrier island and associated seagrass beds. The diversion may reduce fishery use of the Central Wetlands as tidal exchange is diminished by diversion flows. Although adverse impacts would occur to some types of EFH, overall more productive types of EFH (i.e., estuarine emergent wetlands) would be created and enhanced with the diversion and marsh creation features. The input of freshwater, sediments, and nutrients are expected to benefit estuarine EFH within the project area. The TSP is projected to increase SAV in the project area and decrease emergent marsh loss across all marsh zones (fresh/intermediate, brackish, and saline). These changes in the project area would not only increase the aerial extent of EFH, but would also improve the quality of EFH for several managed species.

As discussed in greater detail in the above Fisheries Resources section, the large quantity of borrow material proposed to be taken from Lake Borgne for the TSP may have an adverse effect to species designated under EFH by presenting the potential for low dissolved oxygen or anaerobic conditions to occur, altering water bottom substrate, and by directly affecting more benthos, which may (at least temporarily) reduce food availability for EFH.

Threatened and Endangered Species and Species of Concern

Habitat alterations and poor water quality are two of the known impacts to have negatively affected the Gulf sturgeon. One of the primary constituent elements for Gulf sturgeon critical habitat is water quality, including temperature, salinity, pH, hardness, turbidity, oxygen content, and other chemical characteristics, necessary for normal behavior, growth, and viability of all life stages. The large quantity of proposed borrow excavation in Lake Borgne and high diversion flows through Gulf sturgeon critical habitat may be a concern for this species by altering a potential habitat alteration, by increasing the potential of poor water quality as a result of numerous borrow holes, and by decreased water temperatures as a result of high flows from the cooler Mississippi River through the proposed diversion. In riverine waters, the Service is responsible for all consultations regarding Gulf sturgeon and critical habitat, while in marine waters the NMFS is responsible for consultation. Therefore, please contact Dr. Stephania Bolden (727/824-5312) in St. Petersburg, Florida, for information concerning that species and its critical habitat. Should the proposed project directly or indirectly affect the Gulf sturgeon or its critical habitat in Louisiana, further consultation with that office will be necessary.

Entrainment issues of the pallid sturgeon through diversion structures off the Mississippi River is a potential effect that should be addressed in future planning studies and/or in analyzing current project effects. Should the proposed project directly or indirectly affect the pallid sturgeon or its habitat, further consultation with this office will be necessary. Possible entrainment of pallid sturgeon in the Mississippi River in the immediate vicinity of the diversion inflow may occur during operation of the structure.

The study area encompasses piping plover Critical Habitat Unit LA–7 which includes, at the time of designation, 3,116 ha (7,700 ac) of the Breton, Grand Gosier, and Curlew Islands and the

Chandeleur Island chain in Plaquemines and St. Bernard parishes. Those islands are part of the Breton National Wildlife Refuge or are state owned. The entire islands where primary constituent elements occur to mean low low water (MLLW) are included in this unit. Should the proposed project directly or indirectly affect the piping plover or its critical habitat, further consultation with this office will be necessary.

Colonies nesting birds maybe present in the outer Biloxi marshes, on Bayou Savage NWR, on the barrier islands and new nesting colonies may have been established in the project area since the 1980 surveys. Brown pelicans are known to nest on barrier islands and other coastal islands in St. Bernard Parish. Bald eagle are known to occur within the study area north of Violet, north of the Rigolets, and near the Central Wetlands area. Other unknown nest sites may potentially exist in the project area as well.

The Corps is responsible for determining whether the proposed plan is likely (or not likely) to adversely affect any listed species and/or critical habitat, and for requesting the Service's concurrence with that determination. If the Corps determines, and the Service concurs, that the selected alternative is likely to adversely affect listed species and/or critical habitat, a request for formal consultation in accordance with Section 7 of the ESA should be submitted to the Service. That request should also include the Corps' rationale supporting their determination. If project construction has not been initiated within 1 year of the Corps determination and the Service's concurrence, follow-up consultation should be accomplished prior to making expenditures for construction. If the scope or location of the proposed work is changed, consultation should be reinitiated as soon as such changes are made.

FISH AND WILDLIFE CONSERVATION MEASURES

Coastal wetlands are considered by the Service to be aquatic resources of national importance due to their increasing scarcity and high habitat value for fish and wildlife within Federal trusteeship (i.e., migratory waterfowl, wading birds, other migratory birds, threatened and endangered species, and inter-jurisdictional fisheries). Because of the Services' close coordination with the Corps on this project, and because the project is expected to have an overall benefit to the wetlands of the MRGO Ecosystem Restoration Project Area, the Service has no conservation measures to offer at this time.

SERVICE POSITIONS AND RECOMMENDATIONS

The TSP will benefit the fish and wildlife resources of the MRGO Ecosystem Restoration area by providing freshwater, nutrients, and sediments, and restoring ridge, swamp and marsh habitats in the study area thus facilitating increasing organic production, increasing biological productivity, increasing habitat diversity, and reducing wetland loss. Approximately 15,628 AAHUS and 20,767 net acres of fresh/intermediate, brackish, and saline marsh, swamp and ridge habitats would benefit by the proposed project at the end of the project life given a medium sea level rise scenario. The Service supports implementation of the TSP provided the following fish and wildlife recommendations are implemented concurrently with project implementation:

1. The Service recommends the selection of a barrier island component of the MRGO Ecosystem Restoration Plan be a part of the TSP. The Service feels the design and evaluation of the barrier island alternatives was sufficient to warrant selection, though further engineering would be required prior to construction. Breton Island is a National Wildlife Refuge (NWR), managed by the Service and is of National importance. Until recently (Lavoie, D, ed., 2009; Thomson et al., 2009) the Service was unaware of the long-term impacts to this important refuge as a result of the MRGO channel. However, the Service believes restoration of the areal loss of Breton Island due to the construction and maintenance of the MRGO channel should be appropriately addressed in the TSP .

2. The Corps should contact the Service regarding a compatibility determination, Wilderness Act provisions and special use permits that may be necessary to conduct activities on Breton Island NWR. The Corps should establish and continue coordination with the Service until construction of any project feature is complete and prior to any subsequent maintenance. Points of contacts for the Service are: Kenneth Litzenberger, Project Leader for the Service's Southeast National Wildlife Refuges and Jack Bohannan (985) 822-2000, Refuge Manager for the Breton Island NWR.

3. The Service recommends the operational plans for the Violet Diversion be evaluated to include more flexibility of flow (flows between 1000cfs and 7000cfs) to achieve optimal habitat conditions favorable to nearby intermediate marsh and to bald cypress germination, growth, and reproduction by controlling depth and duration of inundation and salinity levels. As the operational plan for the Violet Diversion is further developed, future hydrological and fisheries (i.e., CASM) modeling, and updated habitat assessements (i.e., Wetland Value Assessements) should be conducted.

4. The Service recommends the diversion operational plan be developed in a way to avoid or minimize adverse impacts to marine fisheries and Essential Fish Habitat (EFH) while maximizing freshwater and nutrient input to the extent practicable to meet habitat objectives.

5. The Service recommends the diversion be adaptively managed to enhance surrounding wetlands, that habitat switching (as a result of re-introduced river water) is allowed to occur in a manner that is not detrimental or destructive to the ecological processes, and that the diversion allows for draw down periods sufficient for cypress regeneration and cypress growth.

6. The Service recommends a comprehensive examination of the river and all existing and proposed diversions to coordinate their operation and ensure that their operation will maximize their restoration capabilities. The ongoing Mississippi River Hydrodynamic and Delta Management Study should be utilized to address this issue. The Service and other natural resource agencies should be involved in this study.

7. The Service recommends establishment of a committee similar to the Caernarvon

Interagency Advisory Committee or Davis Pond Advisory Committee to review the operation and the monitoring and adaptive management results of the Violet diversion and when necessary, provide recommendations regarding any future operational and maintenance changes. The Service and other natural resource agencies should be on this committee.

8. The Service recommends that all shoreline protection features include one fish dip every 1,000 feet (ft) constructed to a 25 ft bottom width to the pre-project elevation. On a case by case basis the 1,000 ft distance can be adjusted, in consultation with National Marie Fisheries Service (NMFS), to incorporate existing exchange points.

9. The Monitoring and Adaptive Management Plan, once developed, should be provided to the Service, NMFS, and Louisiana Department of Wildlife and Fisheries (LDWF) for review, comment, and input.

10. If a proposed project feature is changed significantly or is not implemented within one year of the Endangered Species Act consultation letter, we recommend that the Corps reinitiate coordination with the Service and NMFS to ensure that the proposed project would not adversely affect any Federally listed threatened or endangered species or their habitat.

11. Avoid adverse impacts to nesting bald eagles, gulls, terns, and/or black skimmers, wading birds, and brown pelicans through the careful design of project features and timing of construction. A qualified biologist should inspect the proposed work area for the presence of undocumented nesting colonies and bald eagles during the nesting season (i.e., September 15 through March 31 for brown pelican, September 1 through February 15 for wading bird nesting colonies, September 16 through April 1 for colonies containing nesting gulls, terns, and/or black skimmers, and October through mid-May for bald eagles).
    - To minimize disturbance to colonies containing nesting wading birds (i.e., herons, egrets, night-herons, ibis, and roseate spoonbills), anhingas, and/or cormorants, all activity occurring within 1,000 feet of a rookery should be restricted to the non-nesting period (i.e., September 1 through February 15, exact dates may vary within this window depending on species present).
    - For colonies containing nesting brown pelicans, all activity occurring within 2,000 feet of a rookery should be restricted to the non-nesting period (i.e., September 15 through March 31). Nesting periods vary considerably among Louisiana's brown pelican colonies, however, so it is possible that this activity window could be altered based upon the dynamics of the individual colony.
    - For colonies containing nesting gulls, terns, and/or black skimmers, all activity occurring within 650 feet of a rookery should be restricted to the non-nesting period (i.e., September 16 through April 1, exact dates may vary within this window depending on species present).
    - If a bald eagle nest is discovered within or adjacent to the proposed project area, then an evaluation must be performed to determine whether the project is likely to disturb nesting bald eagles. That evaluation may be conducted on-line at:

http://www.fws.gov/southeast/es/baldeagle. Following completion of the evaluation, that website will provide a determination of whether additional consultation is necessary and those results should be forwarded to this office.

12. Land clearing associated with project features should be conducted during the fall or winter to minimize impacts to nesting migratory birds, when practicable.

13. Further detailed planning of project features (e.g., Design Documentation Report, Engineering Documentation Report, Plans and Specifications, or other similar documents) should be coordinated with the Service and other State and Federal natural resource agencies, and shall be provided an opportunity to review and submit recommendations on all work addressed in those reports.

14. A report documenting the status of implementation, maintenance, and adaptive management measures should be prepared every three years by the managing agency and provided to the Corps, the Service, NMFS, U.S. Environmental Protection Agency (EPA), Louisiana Department of Natural Resources (LDNR), Office of Coastal Protection and Restoration (OCPR), and LDWF. That report should also describe future management activities, and identify any proposed changes to the existing management plan.

15. The Service recommends minimizing impacts to marsh from marsh buggy activities. One way is to limit repetitive use of the same marsh buggy route to prevent ruts and lasting damage while at the same time reducing the amount of marsh buggy tracts as much as possible. Another option is to build temporary boardwalks over marsh where feasible and then backfilling the boardwalk area if needed. In areas with large marsh creation features that have minimal access routes, such as the inner Terre Aux Bouef marsh features, the Service recommends that work begin at the farthest location and proceed to the outer edges of the site to minimize the amount of damage.

16. The large quantity of borrow material proposed to be taken from Lake Borgne for the TSP may have an adverse effect to fisheries, EFH, and the threatened Gulf sturgeon by: 1) alteration in water bottom substrate habitat: 2) direct removal of benthos from a large area which may (at least temporarily) reduces food availability for fishery organisms; 3) other sessile resources, such as oysters could be affected; and 4) by continually moving the dredge, the resuspended sediments will take longer to settle and could prolong the periods of high turbidity associated with dredging operations. The Service recommends careful consideration be given to the affects of taking all borrow from Lake Borgne and consideration should be give to obtaining borrow from other "outside" sources, such as the Mississippi River, and adjacent bays, and offshore areas.

LITERATURE CITED

Bethel, M. and Martinez, L., 2008, Assessment of Seagrass Critical Habitat in Response to Dramatic Shoreline Change Resulting from the 2005 Hurricane Season for the Chandeleur Islands (abs.): Geological Society of America, 2008 Annual Meeting, Abstracts and Programs, v. 40, no. 6, p. 486.

Browder, J.A., H.A. Barley, and K.S. Davis. 1985. A probabilistic model of the relationship between marshland-water interface and marsh disintegration. Ecological Modeline 29:245-260.

Browder, J.A., L.N. May, A. Rosental, J.G. Gosselink, and R.H. Baumann. 1989. Modeling future trends in wetland loss and brown shrimp production in Louisiana using thematic mapper imagery. Remote Sensing of the Environment 28:45-59.

Byron, D. and Heck, K.L., Jr., 2006, Hurricane Effects on Seagrass Along Alabama's Gulf Coast: Estuaries and Coasts, v. 29, no. 6a, p. 939-942.

Chabreck, R.H., and G. Linscombe. 1982. Changes in vegetative types in Louisiana coastal marshes over a ten-year period. Louisiana Academy of Sciences 45:98-102.

Chesney, E.J., D.M. Balz, and R.G. Thomas. 2000. Louisiana estuarine and coastal fisheries and habitats: Perspectives from a fish's eye view. Ecological Applications 10:350-366.

Day, Jr., J.W., C.A.S. Hall, W.M. Kemp, and A. Yanex-Arancibia 1989. Estuarine Ecology. John Wiley & Sons, Inc.

Federal Register, Tuesday, July 10, 2001, Part II, Department of the Interior, Fish and Wildlife Service, 50 CFR Part 17, Endangered and Threatened Wildlife and Plants; Final Determinations of Critical Habitat for Wintering Piping Plovers; Final Rule, 36074 Federal Register / Vol. 66, No. 132 / Tuesday, July 10, 2001 / Rules and Regulation

Hawes, S. R., and H. M. Perry. 1978. Effects of 1973 floodwaters on plankton populations in Louisiana and Mississippi. Gulf Research Reports 6(2):109-124.

Herke, W.H. 1995. Natural fisheries, marsh management, and mariculture: complexity and conflict in Louisiana. Estuaries 18:10-17.

Lavoie, D., ed., 2009, Sand resources, regional geology, and coastal processes of the Chandeleur Islands coastal system—an evaluation f the Breton National Wildlife Refuge: U.S. Geological Survey Scientific Investigations Report 2009—5252, 180 p.

Louisiana Coastal Wetlands Conservation and Restoration Task Force and the Wetlands Conservation and Restoration Authority. 1999. Coast 2050: Toward a sustainable coastal Louisiana, The appendices. Appendix C—Region 1 Supplemental Information.

Louisiana Department of Natural Resources. 128 pp.

McKee, K.L., and I.A. Mendelssohn. 1989. Response of a freshwater marsh plant community to increased salinity and increased water level. Aquatic Botany 34:301-316.

Michot, T.C., Woodin, M.C., and Nault, A.J., 2008, Food Habits of Redheads (Athya Americana) Wintering in Seagrass Beds of Coastal Louisiana and Texas, USA: Acta Zoological Academiae Scientarum Hungaricaie, v. 54, sup. 1, p. 239-250.

Minello, T. J. and L. P. Rozas. 2002. Nekton in Gulf coast wetlands: fine-scale distributions, landscape patterns, and restoration implications. Ecological Applications, 12(2), pp. 441-455.

Mitsch, W. J. and J. G. Gosselink. 1993. Wetlands. 2nd Edition. Van Nostrand Reinhold, New York, USA. 722pp.

Morton, R., J. Bernier, J. Barras, and N. Fernia. 2005. Rapid subsidence and historical wetland loss in the Mississippi Delta Plain, likely causes and future implications: U.S. Geological Survey Open-File Report 2005-1216, 124 pp. http://pubs.usgs.gov/of/2005/1216/, accessed August 9, 2006.

MsCIP, 2008. USACE Mississippi Improvements Program (MsCIP) Hancock, Harrison, and Jackson Counties, Mississippi: Draft Comprehensive Plan and Integrated Programmatic Environmental Impact Statement.

Otvos, E. G., & Carter, G. A. (2008). Hurricane Degradation-Barrier Development Cycles, Northeastern Gulf of Mexico: Landform Evolution and Island Chain History. Journal of Coastal Research: Vol 24 , 463-478.

National Marine Fisheries Service (NMFS). 2006. Commercial Landings of Fish and Shellfish by U.S. Fishing Craft, 2006. Accessed 16 May, 2008 from http://www.st.nmfs.noaa.gov/st1/fus/fus06/02_commercial 2006. pdf.

Penland, S. and Westphal, K.A. 1996. Beneficial Use of Dredged Material Monitoring Program Report 1995 Annual Report. U.S. Army Corps of Engineers, New Orleans District and Louisiana State University, Coastal Studies Institute, Baton Rouge, LA. 14 p.

Poirrier, M.A. and Handley, L.R., 2006, Chandeleur Islands, in: Handley, L., Altsman, D., and Demay, R. (eds.), Seagrass Status and Trends in the Northern Gulf of Mexico: 1940-2002: USGS Scientific Investigation Report 2006-5278, p. 62-71.

Rosati, J. D. (2007). Scoping Study to Evaluate Deepening of Houma Navigation Channel at Cat Island Pass, Louisiana. U.S. Army Engineer Research and Development Center, Coastal and Hydraulics Laboratory. Vicksburg: ERDC/LAB TR-08-X.

Ritchie, W., K. A. Westphal, R. A. McBride, S. Penland. 1992. "Coastal Geology Technical Report No. 7, The Coastal Sand Dunes of Louisiana An Inventory – The Chandeleur Islands Barrier System." Louisiana Geological Survey and University of Aberdeen. Baton Rouge, La.

Saucier, M.H. and DM. Baltz. 1993. Spawning site selection by spotted seatrout, Cynoscion nebulosus, and black drum, Pogonias cromis, in Louisiana. Environmental Biology of Fishes 36:257-272.

Schmid, K., 2001a, Cat Island evolution, morphology, and hurricane response - 1995 to 2000: MDEQ, Office of Geology, Open File Report 132, 32 p.

Thomson, G., Miner, M., Wycklendt, A., and Rees, M., 2009. MRGO Ecosystem Restoration Feasibility Study – Chandeleur and Breton Islands. Boca Raton, Florida: Coastal Planning & Engineering, Inc. 100p. (Report prepared for USACE under contract to URS)

Thomson, G., Miner, M., Wycklendt, A., and Rees, M., Swigler, D., 2010. MRGO Ecosystem Restoration Feasibility Study – Chandeleur and Breton Islands. Boca Raton, Florida: Coastal Planning & Engineering, Inc. 96p. (Report prepared for USACE under contract to URS)

USACE, 2009. USACE Louisiana Coastal Protection and Restoration (LACPR): Technical Report.

USACE, 2002. Hydrodynamics of Tidal Inlets. EM 1110-2-1100 (PartII).

U.S. Fish and Wildlife Service. Undated. Biological implications of dredge holes. U.S. Fish and Wildlife Service, DRBS. Annapolis, Maryland.

U.S. Fish and Wildlife Service. 1977. Ecological effects of dredging and dredge spoil disposal: a literature review. Technical Paper 94. U.S. Fish and Wildlife Service. 33pp.

Walme, P.R. 1972. The importance of estuaries to commercial fisheries. Pages 107-118 in R.S.K. Barnes and J. Green (eds.). The Estuarine Environment. Applied Science Publications, London.

Whittaker, R.H., and G. E. Likens. 1973. Primary production: the biosphere and man. Human Ecology. 1:357-369.

Williams, P.R. 1998. Nekton assemblages associated with the barrier island aquatic habitats of East Timbalier Island, Louisiana. M.S. thesis, Louisiana State University. 121 pp.

Zimmerman, R.J., T.J. Minello, and L.P. Rozas. 2000. Salt marsh linkages to productivity of penaeid shrimps and blue crabs in the ecology. Kluwer Academic Publishers, Dordrecht.

The TSP will benefit the fish and wildlife resources of the MRGO Ecosystem Restoration area by providing freshwater, nutrients, and sediments, and restoring ridge, swamp and marsh habitats in the study area thus facilitating increasing organic production, increasing biological productivity, increasing habitat diversity, and reducing wetland loss. Approximately 37,980 Average Annual Habitat Units (AAHUs) and 31,930 net acres of fresh/intermediate, brackish, and saline marsh, swamp and ridge habitats would benefit by the proposed project at the end of the project life given an intermediate sea level rise scenario. The Service supports implementation of the TSP and respectfully request the following fish and wildlife recommendations be implemented concurrently with project construction:

1. Regarding the barrier island component of the MRGO Ecosystem Restoration; the Service recommends, with support from NMFS and LDWF, the selection of a barrier island component be a part of the TSP. The Service feels the design and evaluation of the barrier island alternatives was sufficient to warrant selection, though further engineering would be required prior to construction. Breton Island is a National Wildlife Refuge, managed by the Service and is of National importance. Recent scientific investigations (Lavoie, D, ed., 2009; Thomson et al., 2009) demonstrate the long-term impacts to this important refuge as a result of the MRGO channel. Therefore, the Service recommends amelioration of the areal loss of Breton Island due to the construction and maintenance of the MRGO channel should be appropriately addressed in the TSP. The Corps should contact the Service regarding a compatibility determination, Wilderness Act provisions and special use permits that may be necessary to conduct activities on Breton NWR. The Corps is encouraged to establish and continue coordination with the Service until construction of any project feature is complete and prior to any subsequent maintenance. Points of contacts for the Service are: Kenneth Litzenberger, Project Leader for the Service's Southeast National Wildlife Refuges and Neil Lalonde (985) 882-2000, Refuge Manager for the Breton Island NWR.

USACE Response. The USACE recognizes the importance of the barrier island chain and the need for restoration; however, we believe that additional study is warranted before a sustainable restoration plan can be recommended for construction. Given the uncertainties of conditions at this time due to the oil spill and recovery efforts, USACE would seek additional authority for further study before recommending a viable restoration plan. The Corps will continue to coordinate with the Service throughout the study process.

2. The Corps should contact the Service regarding a compatibility determination, and special use permits that may be necessary to conduct activities on Bayou Sauvage NWR. The Corps should establish and continue coordination with the Service until construction of any project feature is complete and prior to any subsequent maintenance. Points of contacts for the Service are: Kenneth Litzenberger, Project Leader for the Service's Southeast National Wildlife Refuges and Neil Lalonde (985) 882-2000, Refuge Manager for the Breton Island NWR.

USACE Response. The Corps will continue to coordinate with the Service throughout the study process.

3. The final recommendations for the MRGO Ecosystem Restoration Plan include additional analysis, design and implementation of the Violet Freshwater Diversion as authorized by WRDA 2007 Section 3083. This means the Violet Diversion will be funded and constructed under a different authorization than the authorization for the MRGO Ecosystem Restoration Plan. The Service recommends any additional study, design, and implementation include the Service and other resource agency involvement. In addition if the diversion location or other aspects of the diversion change significantly from what was analyzed in the MRGO Ecosystem Restoration Plan, the Service recommends the Sediment and Nutrient Diversion model (SAND2) and Wetland Value Assessment benefits analysis be revised to reflect the changes.

USACE Response. Concur. The Service and other resource agencies would be included in any additional study, design and implementation of the Violet Diversion.

4. The Service recommends the operational plans for the Violet Diversion be evaluated to include more flexibility of flow (flows between 1000cfs and 7000cfs) to achieve optimal habitat conditions favorable to nearby intermediate marsh and to bald cypress germination, growth, and reproduction by controlling depth and duration of inundation and salinity levels. As the operational plan for the Violet Diversion is further developed, future hydrological and fisheries (i.e., CASM) modeling, and updated habitat assessments (i.e., Wetland Value Assessments) should be conducted.

USACE Response. The USACE plans to adaptively manage the freshwater flows from the diversion to promote a sustainable swamp habitat and fresh/intermediate marsh in the Central Wetlands. Additional hydrologic modeling and aquatic modeling would be conducted during additional studies of the diversion. The diversion would be operated in coordination with other diversions planned in the watershed to achieve the goals and objectives of the study.

5. The Service recommends, with support from NMFS and LDWF, the diversion operational plan be developed in a way to avoid or minimize adverse impacts to marine fisheries and Essential Fish Habitat (EFH) while maximizing freshwater and nutrient input to the extent practicable to meet habitat objectives.

USACE Response. Concur.

6. The Service and LDWF recommend salinity meters be placed in appropriate locations to assist in determining when target salinities are met.

USACE Response. Seven hourly recorders will be deployed to measure salinity, temperature, water level and turbidity at three sites located along the MRGO / Lake Borgne Landbridge, three sites in the Biloxi Marsh, and one site located in the western Mississippi Sound.

7. The Service recommends the diversion be adaptively managed to enhance surrounding wetlands, that habitat switching (as a result of re-introduced river water) is allowed to occur in a manner that is not detrimental or destructive to the ecological processes, and

that the diversion allows for draw down periods sufficient for cypress regeneration and cypress growth.

USACE Response. The diversion would be adaptively managed to achieve the study goals and objectives and minimize adverse effects to the extent practicable.

8. The Service recommends, with support from LDWF, a comprehensive examination of the river and all existing and proposed diversions to coordinate their operation and ensure that their operation will maximize their restoration capabilities. The ongoing Mississippi River Hydrodynamic and Delta Management Study could be utilized to address this issue.

USACE Response. USACE supports the need for a comprehensive plan to coordinate the water needs of the basin. The Mississippi River Hydrodynamic and Delta Management Study is anticipated to address those needs with full participation by natural resource agencies.

9. The Service recommends, with support from NMFS and LDWF, establishment of a committee similar to review the operation and monitoring and adaptive management results of the Violet diversion and when necessary, provide recommendations regarding any future operational and maintenance changes. The Service and other natural resource agencies are amenable to participate on this committee.

USACE Response. Concur. An adaptive management planning team, including members from other natural resource agencies would be established for recommending project and program adaptive management actions.

10. The large quantity of borrow material proposed to be taken from Lake Borgne, which is designated Gulf sturgeon critical habitat, for the TSP may have an adverse effect to fisheries, EFH, and the threatened Gulf sturgeon by: 1) alteration in water bottom substrate habitat: 2) direct removal of benthos from a large area which may (at least temporarily) reduce food availability for fishery organisms; 3) other sessile resources, such as oysters could be affected; and 4) by continually moving the dredge, the resuspended sediments will take longer to settle and could prolong the periods of high turbidity associated with dredging operations. The Service recommends, with support from NMFS and LDWF, careful consideration be given to the affects of taking all borrow, including monitoring for benthos and water quality, from Lake Borgne and consideration should be give to obtaining borrow from other "outside" sources, such as the Mississippi River, and adjacent bays, and offshore areas. Over the project life, search for borrow from outside sources should continue as alternative sources may become economically feasible or as new advances in technology become available.

USACE Response. Concur. Additional analyses on borrow areas has been conducted and the borrow plan modified, in coordination with NMFS, to minimize adverse impacts to fisheries, EFH, and the threatened Gulf sturgeon including additional borrow sources. The corps will continue to consider sources outside of Lake Borgne throughout the study process.

11. The NMFS is responsible for consultations regarding impacts to the Gulf sturgeon and its critical habitat for the MRGO Ecosystem Restoration project. Therefore, please contact Dr. Stephania Bolden (727/824-5312) in St. Petersburg, Florida, for information concerning that species and its critical habitat. Should the proposed project directly or indirectly affect the Gulf sturgeon or its critical habitat in Louisiana, further consultation with that office will be necessary.

USACE Response. the NMFS has been a member of the habitat evaluation team throughout the planning process. The Corps will continue to coordinate with both NMFS offices.

12. The Service, with support from NMFS and LDWF, recommends the Lake Borgne borrow plan should initially specify monitoring three different depths of borrow sites for a minimum of two-years post dredging and prior to continued excavation. The Service recommends monitoring of water quality parameters are included in the MAMP in order to assess if anoxic or hypoxic conditions occur. If anoxia is a problem at 10 feet below the existing sediment surface with a +/- 5 foot tolerance, then the borrow sites will have to be dug shallower and other borrow source options explored to minimize impacts to estuarine water bottoms and EFH. The Service, NMFS, and LDWF recommend a summary of the Monitoring and Adaptive Management Plan for borrow be included in the Feasibility Study or Environmental Impact Statement. The Service, NMFS, and LDWF also recommend that all borrow sites be at least 1,000 feet from the shoreline to help avoid increasing shoreline erosion via increased wave height.

USACE Response. All borrow sites would be excavated at a minimum of 3,000 feet from the Lake Borgne shoreline. Three test sites would be dredged and monitored to determine the maximum depth of future borrow pits. If anoxia is a problem at 15 feet below water surface, then the borrow sites would be dug shallower and other borrow source options would be explored. This is part of the adaptive management plan. A brief summary of this test pit monitoring plan is included in the borrow section of the EIS.

13. The proposed borrow areas in Lake Borgne do include private leases as well as public oyster seed grounds. LDWF manages the public seed grounds and should be consulted before final borrow locations are determined.

USACE Response. Concur. Borrow sites would be excavated at a minimum of 3,000 feet from the Lake Borgne shoreline. LDWF is an active member of the habitat evaluation team.

14. The Service recommends that all shoreline protection features include one fish dip every 1,000 feet (ft) constructed to a 25 ft bottom width to the pre-project elevation. On a case by case basis the 1,000 ft distance can be adjusted, in consultation with NMFS, to incorporate existing water exchange points.

USACE Response. Concur. During the detail design phase for each feature, USACE would closely coordinate with USFWS and NMFS before implementation of these measures.

15. The Service and NMFS recommends the retention dikes constructed for swamp and marsh creation and nourishment areas be gapped and degraded within three years of use if they have not naturally degraded on their own. Please coordinate gapping and degrading efforts with the Service and NMFS.

USACE Response. Concur. The dike features would be mechanically breached or degraded within three years of construction, if natural degradation has not sufficiently removed the earthen material.

16. The Service and LDWF recommend a buffer of at least 500 feet be placed around existing hard bottom and oyster leases to minimize impacts to those resources.

USACE Response. Non-concur. Designated borrow areas are estimated larger than needed for each feature to ensure that adequate material is available in the event that environmental or cultural resources are discovered during construction that require avoidance. Hard bottom areas would be avoided because they are considered preferred habitat for the Gulf sturgeon. Borrow sites would be located a minimum of 3,000 feet from the Lake Borgne shoreline to avoid existing oyster leases to the maximum extent practicable. However, in the southern lobe proposed borrow sites do overlap existing oyster leases and these oyster leases would be impacted by dredging acitivity.

17. The Monitoring and Adaptive Management Plan, as it is further developed, should be provided to the Service, NMFS, and LDWF for continued review, comment, and input.

USACE Response. Concur.

18. If a proposed project feature is changed significantly or is not implemented within one year of the Endangered Species Act consultation letter, we recommend that the Corps reinitiate coordination with the Service and NMFS to ensure that the proposed project would not adversely affect any Federally listed threatened or endangered species or their critical habitat.

USACE Response. Concur.

19. The proposed Violet Freshwater Diversion structure off the Mississippi River has the potential to entrain pallid sturgeon, that effect should be addressed in the diversions future planning studies. Should the proposed project directly or indirectly affect the pallid sturgeon or its habitat, further consultation with this office will be necessary.

USACE Response. Concur. The Corps would coordinate with the Service during the future planning studies of the diversion.

20. Avoid adverse impacts to nesting bald eagles, gulls, terns, and/or black skimmers, wading birds, and brown pelicans through the careful design of project features and timing of construction. A qualified biologist should inspect the proposed work area for the presence of undocumented nesting colonies and bald eagles during the nesting season

(i.e., September 15 through March 31 for brown pelican, September 1 through February 15 for wading bird nesting colonies, September 16 through April 1 for colonies containing nesting gulls, terns, and/or black skimmers, and October through mid-May for bald eagles).

- To minimize disturbance to colonies containing nesting wading birds (i.e., herons, egrets, night-herons, ibis, and roseate spoonbills), anhingas, and/or cormorants, all activity occurring within 1,000 feet of a rookery should be restricted to the non-nesting period (i.e., September 1 through February 15, exact dates may vary within this window depending on species present).
- For colonies containing nesting brown pelicans, all activity occurring within 2,000 feet of a rookery should be restricted to the non-nesting period (i.e., September 15 through March 31). Nesting periods vary considerably among Louisiana's brown pelican colonies so it is possible that this activity window could be altered based upon the dynamics of the individual colony.
- For colonies containing nesting gulls, terns, and/or black skimmers, all activity occurring within 650 feet of a rookery should be restricted to the non-nesting period (i.e., September 16 through April 1, exact dates may vary within this window depending on species present).
- If a bald eagle nest is discovered within or adjacent to the proposed project area, then an evaluation must be performed to determine whether the project is likely to disturb nesting bald eagles. That evaluation may be conducted on-line at: http://www.fws.gov/southeast/es/baldeagle. Following completion of the evaluation, that website will provide a determination of whether additional consultation is necessary and those results should be forwarded to this office.

USACE Response. Concur.

21. Land clearing associated with project features should be conducted during the fall or winter to minimize impacts to nesting migratory birds, when practicable.

USACE Response. The USACE will to the extent practicable implement land clearing activities during the fall and winter. When this is not feasible, the USACE would coordinate with the USFWS and conducted surveys for nesting colonies and bald eagles prior to initiating work activities.

22. Further detailed planning of project features (e.g., Design Documentation Report, Engineering Documentation Report, Plans and Specifications, or other similar documents) should be coordinated with the Service and other State and Federal natural resource agencies, and shall be provided an opportunity to review and submit recommendations on all work addressed in those reports.

USACE Response. Concur

23. A report documenting the status of implementation, maintenance, and adaptive management measures should be prepared every three years by the managing agency and provided to the Corps, the Service, NMFS, U.S. Environmental Protection Agency

(EPA), Louisiana Department of Natural Resources (LDNR), Office of Coastal Protection and Restoration (OCPR), and LDWF. That report should also describe future management activities, and identify any proposed changes to the existing management plan.

USACE Response. Concur. The adaptive management team would be the responsible party for preparation of this report.

24. The Service recommends minimizing impacts to marsh from marsh buggy activities. Options to achieve that minimization include limiting the repetitive use of a route or to build temporary boardwalks over marsh where feasible and then backfilling the boardwalk area if needed. In areas with large marsh creation features that have minimal access routes, such as the inner Terre Aux Bouef marsh features, the Service recommends that work begin at the farthest location and proceed to the outer edges of the site to minimize the amount of damage.

    USACE Response. Concur. USACE plans to utilize boardwalks over existing marsh to reduce marsh impacts and backfill impacted marsh when the boardwalks are removed. USACE would restore the farthest location of Bayou Terre aux Boeufs and work to the outer edges to minimize adverse impacts to existing and newly restored marsh. Marsh buggies would be required to avoid repetitive use of the same tracts to reduce marsh impacts. Any impacts to existing marsh would be backfilled to the extent practicable.

25. The Service recommends the CASM model should be updated to incorporate conditions from the oil spill in the adaptive management plan. This model should also use the corrected assumptions.

USACE Response. Funding and time constraints limit the ability to re-run any models at this stage. An update of the CASM model could potentially take place during PED phase.

26. Due to the significant acreage of marsh that will be accessed for swamp and marsh creation/nourishment, the Service request the Corps quantify the estimated acreage of flotation and construction access canal impacts to shallow open water habitat.

    USACE Response. Concur. Additional analyses on flotation access and construction access will be conducted during the detailed planning, engineering and design phase following approval of the recommended plan.

APPENDIX C

Basis for Analysis

Following the identification of the tentatively selected plan (TSP), a construction sequence was developed. Assumptions factoring into the construction sequence include production rates for building rock projects, dredge equipment availability, land loss rates, and the limitation of alternating dredging cycles in the lobes of Lake Borgne. The Agency coordination for the MRGO plan was based on this construction sequence and without the incorporation of Operation and maintenance (O&M). However, due to uncertainties associated with the timing and availability of funding for the plan, only those features that are sustainable without the implementation of any other feature (such as a diversion) are recommended for construction at this time. A tiered implementation approach has been developed for the TSP (Table 2-28 of EIS) based on these uncertainties. In addition, O&M has been included in the TSP. The benefits have been recalculated by tier utilizing the previously developed construction sequence and without O&M. Due to the uncertainty of when each feature will be implemented, analysis may require updating in later phases of the project. The USACE will continue to coordinate with the agencies throughout the project study and implementation.

Draft Implementation Plan (used to calculate benefits without O&M)	
Measure	**Description**
Construction Year 1	
LS1	47,000 linear feet (8.9 miles) of shoreline protection beginning at the terminus of the Bayou Dupre supplemental shoreline project, extending around Proctor Point to the West of Shell Beach supplemental funding shoreline protection.
MRGO1	3,850 feet of new foreshore protection between MRGO miles 56.6 and 57.4. This stone protection feature is embedded within the limits of MRGO7.
MRGO6	8,132 linear feet of new, non-continuous foreshore protection between MRGO miles 36.0 and 34.2, immediately east of the existing stone closure of the MRGO. MRGO6 ties into an existing foreshore dike immediately downstream.
LM1	3,240 acres of marsh restoration from open water and nourishment of 777 adjacent acres in the Golden Triangle, south of the IHNC Surge Barrier. Approximately 12.8 million cubic yards of borrow to be obtained from Lake Borgne Borrow Area 6.
LM4	289 acres of marsh restoration and nourishment of 95 adjacent acres of marsh in the portion of the Golden Triangle bordered by the GIWW, the IHNC Surge Barrier, and the MRGO. Approximately 1.4 million cubic yards of borrow material would be obtained from Lake Borgne Area 6.
LM2	422 acres of marsh restoration and 2,523 acres of marsh nourishment in the area between Proctor Point and the MRGO. Approximately 4.9 million cubic yards of borrow material to be obtained from Lake Borgne Borrow Area 3.

Draft Implementation Plan (used to calculate benefits without O&M)	
Measure	**Description**
Construction Year 2	
BS1	Approximately 51,000 linear feet (9.7 miles) of shoreline protection along the southeast shore of Lake Borgne. This feature begins at the northern terminus of the Biloxi Marsh Shoreline Protection Project (PO-72) south of Point aux Marchettes and extends north to Malheureax Point.
BS2	Approximately 39,600 linear feet (7.5 miles) of artificial oyster reef development on the Chandeleur Sound side of the Biloxi Marsh between Eloi Point and the mouth of Bayou La Loutre.
CC4-A	420 acres of cypress restoration in the Bienvenue Triangle. Approximately 2.9 million cubic yards of material to be obtained from the Mississippi River.
BR1	Approximately 48 acres of ridge restoration on the south bank of Bayou La Loutre. 425,000 cubic yards of silty sand material to be obtained from the Mississippi River.
CM2	795 acres of marsh restoration and 190 acres of marsh nourishment north of Paris Road. 3.3 million cubic yards of material are required, 2.6 million cubic yards of which can be obtained from the adjacent reach of the GIWW. The remaining material would be obtained from the Michoud Canal.
Construction Year 3	
ES1	24,000 linear feet (4.6 miles) of shoreline protection from the south shore of Lake Pontchartrain to the terminus of the existing Bayou Chevee shoreline protection feature.
ES2	30,750 linear feet of shoreline protection in Lake Pontchartrain between Chef Menteur Pass and The Rigolets.
ES3	70,000 feet of foreshore protection along Lake Borgne between Alligator Point and The Rigolets.
Construction Year 4	
HM1	757 acres of marsh restoration and the nourishment of 973 acres of adjacent marsh, located in the Hopedale area bordered by MRGO to the northeast. 4.1 million cubic yards of dredged material would be obtained from Lake Borgne Borrow Area 2.
TM1	760 acres of marsh restoration and 223 acres of marsh nourishment, requiring approximately 3.2 million cubic yards of material to be obtained from Lake Borgne Borrow Site 2.
TM2	770 acres of marsh restoration and 3,400 acres of marsh nourishment in the vicinity of Lake Ameda. Approximately 7.4 million cubic yards of borrow material would be obtained from Lake Borgne Borrow Area 2.
MRGO5	188 acres of marsh would be restored behind 14,485 linear feet of vinyl sheet pile wall to establish the shoreline. 2.7 million cubic yards of material would be obtained from Lake Borgne.

Draft Implementation Plan (used to calculate benefits without O&M)	
Measure	**Description**
MRGO8	200 acres of marsh restoration adjacent to approximately 20,640 linear feet of bank reclamation constructed using vinyl sheet pile wall. 3.2 million cubic yards of material would be obtained from Lake Borgne. Approximately 13,572 linear feet of new foreshore protection would also be included between approximate channel miles 51.0 and 48.3
Construction Year 5	
MRGO7	91 acres of marsh restoration adjacent to approximately 9,700 linear feet of bankline reclamation, consisting of 9,700 linear feet of vinyl sheet pile wall. 1.3 million cubic yards of material would be obtained from Lake Borgne.
EM1	1,175 acres of marsh restoration and nourishment of 2,830 acres of surrounding marsh in the area bounded by the Lake Pontchartrain shoreline, Chef Menteur Pass, and the levee. Approximately 8.1 million cubic yards of material would be obtained from Lake Borgne Borrow Area 6.
Construction Year 6	
LM3	911 acres of marsh creation and 950 acres of marsh nourishment in South Lake Borgne north of Lena Lagoon in the area bounded by the lake, Bayou St. Malo, MRGO, and Doulets Canal. Approximately 4.6 million cubic yards of borrow to be obtained from Lake Borgne Borrow Area 2.
BM1	8,295 acres of marsh nourishment along the south shore of Lake Borgne. 10.8 million cubic yards of material would be obtained from Lake Borgne Borrow Area 2.
Construction Year 7	
CM1	1,240 acres of marsh nourishment south of Paris Road between cypress restoration feature CC3 and the Chalmette Loop Levee. Approximately 3.0 million cubic yards of material would be dredged from Lake Borgne Borrow Area 5 for this feature.
CM3	300 acres of marsh restoration and 215 acres of marsh nourishment in the area north of Bayou Dupre and south of MRGO. 1.9 million cubic yards of borrow material would be obtained from Lake Borgne Borrow Area 5.
CM4	98 acres of marsh restoration and 129 acres of marsh nourishment south of Bayou Dupre. 900,000 cubic yards of dredged material would be obtained from Lake Borgne Borrow Area 4.
CM5	245 acres of marsh restoration and 70 acres of marsh nourishment in the area north of Bayou Bienvenue and Paris Road. 1.2 million cubic yards of material would be obtained from Lake Borgne Borrow Area 4.
Construction Year 8	
TM7	2,255 acres of marsh restoration and up to 3,338 acres of adjacent marsh nourishment on the east side of Bayou Terre aux Boeufs. 11.5 million cubic yards of material would be obtained from Lake Lery if available, but it is currently assumed that material will be obtained from Lake Borgne Borrow Area 2.

Draft Implementation Plan (used to calculate benefits without O&M)	
Measure	**Description**
TM8	1,511 acres of marsh restoration on the east side of Bayou Terre aux Boeufs in the vicinity of Delacroix. 5.5 million cubic yards of material would be dredged from Lake Lery if possible, but it is currently assumed that material will be obtained from Lake Borgne Borrow Area 2.
EM2	1,095 acres of marsh nourishment on Hog Island, located between the west and east mouth of the West Pearl River. Approximately 2.2 million cubic yards of dredged material would be obtained from Lake Borgne Borrow Area 8.
EM3	861 acres of marsh restoration and 180 acres of adjacent marsh nourishment in the area bounded by Highway 433, Little Lagoon, Salt Bayou and Highway 90. Approximately 3.5 million cubic yards of dredged material would be obtained from Lake Borgne Borrow Area 8.
EM4	2,625 acres of marsh restoration and 1,455 acres of adjacent marsh nourishment in the area bounded by Salt Bayou to the north, the West Pearl River to the east, the Rigolets to the south and Highway 80 to the north. Approximately 10.6 million cubic yards of material would be obtained from Lake Borgne Borrow Area 8.
Construction Year 9	
CC1	1,020 acres of cypress swamp restoration and 953 acres of cypress swamp nourishment in the area north of the existing Violet Canal along the Forty Arpent levee. 8.5 million cubic yards of borrow material to be obtained from Lake Borgne Borrow Area 5.
CC2	250 acres of cypress swamp restoration and 250 acres of swamp nourishment to the northeast of CC1. 2.4 million cubic yards of borrow material to be obtained from Lake Borgne Borrow Area 5.
CC3	370 acres of cypress swamp restoration and 790 acres of swamp nourishment along the Forty Arpent Levee south of Paris Road. Approximately 5.3 million cubic yards of material to be obtained from Lake Borgne Borrow Area 5.
CC4	1,465 acres of cypress swamp restoration in the open water areas adjacent to the Forty Arpent Levee north of Paris Road, including the Bienvenue Triangle area in Orleans Parish. 11.3 million cubic yards of borrow material to be obtained from Lake Borgne Borrow Area 6.
Construction Year 10	
CC5	1,120 acres of swamp restoration and 1,645 acres of swamp nourishment south of the Violet Canal along the Forty Arpent Levee and the Chalmette Loop Levee. 9.6 million cubic yards of borrow material to be obtained from Lake Borgne Borrow Area 4.
CC6	1,028 acres of swamp restoration and 1,540 acres of swamp nourishment in the southwest corner of the Central Wetlands. 11.2 million cubic yards of borrow material would be obtained Lake Borgne Borrow Area 4.
Maintenance As Needed	

Draft Implementation Plan (used to calculate benefits without O&M)	
Measure	**Description**
MRGO2	Repair and maintenance of approximately 15,070 linear feet (2.85 miles) of foreshore protection between Mile 44.4 and 39.9 of the MRGO.
MRGO3	Repair and maintenance of existing approximately 10,420 linear feet (1.97 miles) of foreshore protection between approximately Mile 56 to 51 of the MRGO.
MRGO4	Repair and maintenance of approximately 6,690 linear feet (1.27 miles) of existing retention dike MRGO Miles 36.6 to 37.1 and MRGO Miles 33.9 to 32.9.

DEPARTMENT OF THE ARMY
NEW ORLEANS DISTRICT, CORPS OF ENGINEERS
P. O. BOX 60267
NEW ORLEANS, LOUISIANA 70160-0267

REPLY TO
ATTENTION OF

November 23, 2011

Regional Planning and
Environmental Division South
New Orleans Environmental Branch

David Bernhart
NMFS – Protected Species Division
263 13th Avenue South
St. Petersburg, FL 33701

Dear Mr. Bernhart:

The US Army Corps of Engineers, New Orleans District (CEMVN) is requesting initiation of consultation for potential impacts to the Gulf sturgeon under Section 7 of the Endangered Species Act for the MRGO Ecosystem Restoration Project. The endangered species that may be present in the project area are the pallid sturgeon, Gulf sturgeon, piping plover, West Indian manatee, green sea turtle, Kemp's Ridley sea turtle, loggerhead sea turtle, hawksbill sea turtle, and leatherback sea turtle species. The purpose of this study is for CEMVN to develop a comprehensive ecosystem restoration plan to restore the areas affected by the former MRGO navigation channel as required by Section 7013 of WRDA 2007. The period of analysis is from implementation and extends 50 years into the future from the estimated first year of construction, 2015 – 2065.

The CEMVN has prepared a biological assessment (enclosure 1) which analyzes impacts to listed species from the construction of the proposed MRGO Ecosystem Restoration Project. Our impact analysis incorporated the best scientific, commercial, and internal data available to determine impacts to protected species. The CEMVN has determined that the proposed action *"may affect"* the Gulf sturgeon species and would *"not destroy or adversely modify"* its critical habitat. The CEMVN has determined that the proposed action is *"not likely to adversely affect"* the pallid sturgeon, shovelnose sturgeon, West Indian manatee, piping plover, green sea turtle, Kemp's Ridley sea turtle, loggerhead sea turtle, hawksbill sea turtle, and leatherback sea turtle species.

The CEMVN requests the initiation of formal consultation with the NMFS for impacts to the Gulf sturgeon and its Critical Habitat, and concurrence with our *"not likely to adversely affect"* determination for the green sea turtle, Kemp's Ridley sea turtle, loggerhead sea turtle, hawksbill sea turtle, and leatherback sea turtle species. The NMFS will be notified immediately if any of the actions considered in this document are modified and require further consultation.

Please review the enclosed biological assessment which addresses impacts to endangered, threatened, and sensitive species within the project area, and provide us with your biological

opinion for the species under your purview. If any questions or issues arise, please contact Mr. Thomas Parker of my staff at (504) 862-2526 or by email at Thomas.w.parker@usace.army.mil.

Sincerely,

for Joan M. Exnicios
Chief, New Orleans Environmental Branch

Enclosure

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/

FEB 1 1 2011

Colonel Edward Fleming
District Engineer
New Orleans District, U.S. Army Corps of Engineers
Post Office Box 60267
New Orleans, Louisiana 70160-0267

Dear Col. Fleming:

NOAA's National Marine Fisheries Service (NMFS) has reviewed the Draft Environmental Impact Statement (DEIS) for the Mississippi River-Gulf Outlet Ecosystem Restoration Study dated December 9, 2010. NMFS conducted its review in accordance with a "findings" with the Army Corps of Engineers, New Orleans District (NOD) pursuant to the regulations (50 CFR 600.920(f)(3)) that implement the essential fish habitat (EFH) provisions of the Magnuson-Stevens Fishery Conservation and Management Act (Magnuson-Stevens Act). In accordance with these "findings," the consultation requirements pertaining to impacts of civil works projects on EFH are met through NMFS' review and comments on National Environmental Policy Act documents. As such, the transmittal of this DEIS constitutes initiation of the EFH consultation. Based on our review, NMFS finds the EFH sections of the DEIS satisfy the requirements of an EFH Assessment as defined at 50 CFR 600.920(e). In addition, NMFS is providing comments on this project under the authority of the Fish and Wildlife Coordination Act (16 U.S.C. 661 et seq.).

The tentatively selected plan, Alternative C, includes the creation of 48 acres of ridge habitat in the Biloxi Marsh area, preservation of 10,431 acres of cypress swamp in the Central Wetlands, and protection of 45,471 acres of various marsh types in the Lower Pontchartrain sub-basin. The tentatively selected plan also includes a diversion of fresh water and nutrients from the Mississippi River through the Central Wetlands into Lake Borgne. That diversion would pulse 7,000 cubic feet per second in April and May, and 1,000 cubic feet per second the remainder of the year. The project also includes approximately 70 miles of shoreline protection, primarily in the Mississippi River-Gulf Outlet and Lake Borgne, using rock or artificial oyster reefs.

Much of the material for wetland restoration would be obtained by dredging more than 19,500 acres of Lake Borgne water bottoms to generate sufficient fill for the marsh creation effort. The existing water bottoms of Lake Borgne, which are six to eight feet in depth, may be dredged to as deep as 18 to 20 feet. In addition, the construction of the diversion canal would result in the

destruction of 245 acres of intermediate marsh, and the construction of the ridge would result in the conversion of 48 acres from marsh to upland habitat. The shoreline protection features would result in the additional excavation of more than 2,000 acres of flotation and access channels. Dredging activities would persist for at least ten years in the Lake Borgne ecosystem. Hydrologic changes caused by the Violet Diversion component would block tidal inflow into the Central Wetlands and reduce salinities to zero parts per thousand. In addition, the proposed swamp restoration would require the construction of 1,149 acres of retention dike, but there are no plans to degrade the dike upon project completion.

The enclosed comments (Enclosure 1) provide additional clarification or information needs concerning impacts to EFH and other resources. NMFS concurs with the Corps of Engineers' determination that project-related benefits should more than offset adverse impacts to EFH. However, to attain this net benefit, measures identified in the DEIS intended to avoid, minimize, and offset adverse effects must be implemented. These measures include, but are not limited to, use of best management practices during project construction and operation, and implementation of proposed monitoring and adaptive management actions as needed to measure project-related impacts and to provide a framework for decision-making.

Based on our review of the DEIS, NMFS provides the following

EFH Conservation Recommendations

1. To avoid and minimize impacts to EFH and associated marine fisheries resources, specific details and documents for each restoration feature of the Tentatively Selected Plan (TSP) shall be provided to NMFS for evaluation, discussion, review and comment during the preliminary engineering and design (PED) stage.

2. The borrow pits in Lake Borgne initially shall be limited to no deeper than 15 feet below the water surface (i.e., total water depth) unless monitoring and adaptive management, or modeling of the hydrology of the borrow pits, clearly indicate deeper pits would have little impact on water quality.

3. The Monitoring and Adaptive Management Plan (MAMP) shall be revised to include monitoring of benthic communities and dissolved oxygen (DO) levels within borrow areas in Lake Borgne. Water quality monitoring shall be conducted at least during April through October for a minimum of three years post-dredging to verify the relative success of the borrow pit design in avoiding impacts to water quality. Specific conductance, temperature, DO, and pH shall be sampled from the bottom to the surface in five-foot profiles. Samples shall be collected at least one time during April, September, and October. Samples shall be collected twice, about two weeks apart, during May, June, July, and August. Benthos should be sampled annually pre- and post-construction to evaluate changes in community structure. This information shall be used to adaptively manage borrow site design to minimize adverse impacts, if any.

4. The retention dikes constructed for marsh creation and nourishment areas shall be gapped and degraded within three years of use in a manner acceptable to NMFS.

5. Shoreline protection features in the TSP shall include 25-foot wide gaps down to pre-project depth elevations for fisheries ingress and egress every 1,000 linear feet, unless otherwise refined in coordination with NMFS during PED. Scour aprons may be incorporated so as not to decrease the pre-project water depth, or offset sections of rock in front of or behind foreshore rock dikes may be included to minimize erosion in the vicinity of gaps.

Consistent with Section 305(b)(4)(B) of the Magnuson-Stevens Act and the implementing regulation at 50 CFR 600.920(k), the NOD is required to provide a written response to these EFH conservation recommendations within 30 days of receipt. The NOD must include a description of measures to be required to avoid, mitigate or offset the adverse impacts of the proposed activity. If the NOD's response is inconsistent with these EFH conservation recommendations, the NOD must provide a substantive discussion justifying the reasons for not implementing those recommendations. If it is not possible to provide a substantive response within 30 days, the NOD should provide an interim response to NMFS, to be followed by the detailed response. The detailed response should be provided in a manner to ensure that it is received by NMFS at least ten days prior to the signing of the Record of Decision for the action.

Thank you for considering these comments. If you wish to discuss the project further, please contact Kimberly Clements at (225) 389-0508, extension 204.

Sincerely,

Miles M. Croom

Miles M. Croom
Assistant Regional Administrator
Habitat Conservation Division

Enclosures

cc (with Enclosure):
FWS, Lafayette, Walther
EPA, Dallas, Ettinger
LA DNR, Consistency, Ducote
LDWF, Finley
F/SER4, Dale
F/SER46, Swafford
F/SER, Keyes
NOAA PPI, Reid
Files

Enclosure 1

NOAA's National Marine Fisheries Service (NMFS) provides these comments on the Draft Environmental Impact Statement (DEIS) for the Mississippi River-Gulf Outlet (MRGO) Ecosystem Restoration Study in elaboration of the comments contained in the body of our letter.

General comments

NMFS supports ecosystem restoration including efforts to restore impacts that resulted from the construction of the MRGO Navigation Channel. NMFS recognizes that the formulation of alternatives was developed with the intent to maximize ecosystem benefits while minimizing environmental impacts. However, specific details for many project components are not included in the DEIS. NMFS stresses the need for the NOD to consult with NMFS on specific plans regarding the construction of all restoration features in the tentatively selected plan (TSP) that may impact estuarine and marine fisheries and associated EFH. Specific details and documents for each restoration feature footprint, including ridge, diversion canal, shoreline protection, dredging and disposal area location, initial and final target dredged material elevations, containment plans, and flotation and access channel routing should be provided during the preliminary engineering and design (PED) phase of construction to allow for NMFS review and comment. Adequate review periods should be allowed prior to issuance of solicitations for bids to accommodate any changes recommended by NMFS to avoid and minimize impacts to EFH and associated marine fishery resources.

NMFS recognizes that the proposed marsh creation and nourishment features in the TSP intend to restore 45,471 acres of marsh and protect 333,329 linear feet of shoreline in the study area. Restoration of that magnitude would also result in the construction of at least 6,515 acres of retention dikes across marsh and shallow water bottoms that are temporary structures which may eventually degrade to wetland elevations. However, the Wetland Value Assessment for the marsh model evaluated the passage of aquatic organisms to have access to these restored marshes within three years of project construction. NMFS recommends that all retention dikes be degraded or gapped, as described in our EFH Conservation Recommendations, within three years of construction to allow for tidal connectivity of the restored areas to the adjacent system. NMFS suggests this recommendation should be included in all sections that pertain to retention dike construction in the Final Environmental Impact Statement (FEIS). NMFS has provided reference in the specific comments below.

With the implementation of the TSP, active dredging in the Lake Borgne ecosystem would persist for at least ten years. NMFS is concerned that the prolonged disturbance in the lake has the potential to impact to EFH and associated marine fisheries resources within this portion of the project area, potentially to a greater extent than the ten years specified in the DEIS. Although the DEIS states there is a potential for direct impacts associated with the dredging activity over this period of time for some resources, NMFS recommends the NOD include a more thorough analysis of direct and indirect impacts in the "aquatic and fishery resources", "commercial fisheries", "water bottoms and benthic resources", "oyster resources", "EFH", and "recreational resources" sections of the FEIS.

Freshwater diversions are an important technique for habitat restoration, especially at the ecosystem level. The proposed location for the freshwater diversion would include the construction of a sediment trap, the use of the existing MRGO channel, and the delivery of sediment and water into the Lake Borgne ecosystem. All of the sources identified above would be potential sinks for the sediment introduced from the diversion. Further, the extent of shoreline protection in Lake Borgne, including the Biloxi marsh, would limit the introduction of fresh water, nutrients, and sediment into the targeted marsh areas. Therefore, it is reasonably foreseeable that these physical features would limit the benefits to marsh from a diversion, despite the intent to maximize those benefits and/or attempts to modify the salinity regime to promote fisheries production in the study area. Given the sediment trap in the outfall channel and impediments to sediment and freshwater introduction to project area marshes, NMFS is concerned that project-level benefits to creating or sustaining wetland habitats are likely overestimated. This concern should be addressed in the FEIS.

The MRGO Ecosystem Restoration Study area and alternatives analyzed are of a scale and scope that would result in ecosystem level impacts. As such, it is paramount that the rigor or level of the analysis and data used to inform the plan selection should be commensurate with the magnitude of the impacts. As such, NMFS appreciates the investment in both the statistical analysis of fisheries-independent data and the Comprehensive Aquatics Systems Model (CASM MRGO), both of which enabled more informed decision-making. In consideration of this and other information, NMFS is concerned with the local displacement of marine fisheries species, including benthic species, and the EFH associated with the Lake Borgne ecosystem. Although the CASM MRGO model has indicated that there will be no significant impacts to net productivity in the project area as a whole, results of the model have indicated localized displacement of white shrimp, brown shrimp, red drum, oysters and spotted sea trout. This displacement has potential commercial and recreational resource economic implications. While it is difficult to quantify the socioeconomic impacts associated with these potential displacements, NMFS stresses the need to identify, to the maximum extent practicable, these localized impacts on aquatic and fishery resources, commercial fisheries, EFH, and recreational resources in the FEIS.

Additionally, the description of environmental risks from low dissolved oxygen (DO) in the DEIS is inadequate, and the potential impact should be further analyzed and discussed in the FEIS. Development and pervasiveness of hypoxia associated with open water borrow pits is case- and estuary-specific. Lacking project specific analyses, literature is available to make broad inferences to assist in further characterizing the potential effects on water quality and develop measures to avoid or minimize those impacts. Our preliminary evaluation of literature indicates that of seven studies reviewed by NMFS, three indicated an occurrence of hypoxia in depths greater than 13 to 16 feet and an additional study indicating it occurred at or below 20 feet deep (Shurtz and St Pé 1984; Palm Beach County Department of Environmental Resources Management 1994; Cooper and Morse 1996; Flocks and Franze 2001). The reported hypoxia typically occurred during the warmest months of the year, specifically the late summer and early fall months. NMFS HCD staff in Baton Rouge is available to discuss these findings in detail, if needed.

The TSP proposes to borrow 157.2 million cubic yards of material that would require the

excavation of 19,537 acres of waters bottoms, mostly from Lake Borgne. If borrow pit design remains at 10 to 12 feet below existing bottom elevations, there is a potential for portions of Lake Borgne to reach anoxic and hypoxic conditions. Hypoxic conditions could be exacerbated by the creation of a fresh water layer on top of Lake Borgne from the Violet diversion component.

Furthermore, it should be noted that the University of New Orleans box model and therefore the CASM MRGO model did not include the potential impacts to EFH and associated marine fisheries resources as a result of the proposed borrow areas in its evaluation. Therefore, the DEIS did not discuss these potential long term impacts to water quality or the various fisheries that inhabit Lake Borgne. Due to the spatial extent of borrow needed for the TSP, this could be a significant impact. NMFS stresses the need to identify, to the maximum extent practicable, these potential impacts in the environmental consequences section of the FEIS for the following resources: "aquatic and fishery resources", "commercial fisheries", "oyster resources", "water bottoms and benthic resources", "EFH", and "recreational resources". The document should fully discuss the potential for hypoxia in the borrow pits and evaluate alternatives to mitigate such conditions, if their occurrence appears likely. NMFS recommends the maximum borrow pit depth be restricted to 15 feet below the water surface and be adaptively managed over the ten years worth of dredging required to implement the marsh creation in the TSP. Site-specific monitoring within the Lake Borgne ecosystem should be included in the final Monitoring and Adaptive Management Plan (MAMP), and that information should be used to revise borrow pit designs and depths, if warranted.

NMFS is concerned that the localized impacts associated with the restoration of the Central Wetlands Ecosystem have not been adequately discussed in the DEIS. The DEIS states there are no impediments to fishery access to the Central Wetlands. However, it also states in the environmental consequences discussion of the recreational resources section (Page 4-123) that node 75 (Central Wetlands) will observe reverse tidal flow impeding passage of blue crab into the area. Both maintenance and pulse flows may result in continuous or long term outgoing water movement through the existing water control structures at Bayou Bienvenue and Bayou Dupre. Such water flows would impede immigration of most young marine fishery species, not just blue crab, into the Central Wetlands. Smith (2008) reports swimming speeds of small teleost fishes may have burst speeds of 1.6 to 4.9 feet per second (fps) over very short periods, their normal maximum swimming speed would be much less. The maximum sustained swimming speed for blue crab megalopae is 0.4 fps with the burst speed of 0.7 fps (Luckenbach and Orth 1992). The maximum swimming speed for oyster larvae is approximately 0.01 fps (North et al. 2008). Because the migration of postlarval and juvenile forms of most estuarine-dependent marine fisheries species would not be possible due to flow velocities, the Central Wetlands frequently would be eliminated as nursery habitat for many species. Impacts to the access of most estuarine-dependent marine fisheries species into the Central Wetlands should be discussed and analyzed in the appropriate sections of the FEIS.

Furthermore, according to the DEIS, the 1,149 acres of retention dikes constructed for swamp restoration will not be degraded post construction and the salinity model predicts a complete freshening of the Central Wetlands unit. These hydrologic and water quality changes have the potential to convert EFH to an area no longer supportive of marine fisheries6 species. This

impact should be discussed and analyzed in the "aquatic and fishery resources", "commercial fisheries", "EFH", and "recreational resources" sections of the FEIS. NMFS recommends the TSP include plans to breach containment dikes, following sediment compaction and tree planting, to assist in tree survival and the health of the swamp vegetative community.

NMFS recognizes that the NOD quantifies environmental impacts and benefits with the implementation of all alternatives in multiple chapters of the DEIS. However, the acreages associated with both impacts and benefits are not consistent with the description of the TSP. NMFS recommends correct acreages for the impacted and benefited habitats be consistent in the FEIS. The habitats acreages should include impacts during construction of the freshwater diversion canal, ridge restoration, shoreline protection flotation and access channels, as well as for retention dikes for marsh creation and nourishment. Specific references identifying these inconsistencies are located in the specific comments below.

NMFS supports the recommendations specified in the U.S. Fish and Wildlife Service's Coordination Act Report for the MRGO Ecosystem Restoration Feasibility Study. NMFS recognizes the NOD response concurs with all the recommendations in the report. However, NMFS believes there are additional potential marine fisheries and EFH impacts with the proposed freshwater diversion and potential marine fisheries and EFH impacts with the spatial and temporal extent of borrow sites in Lake Borgne. In this regard, NMFS stresses the importance of compliance with recommendations number 3, 4, 6, 7, 16, and 17 in the Fish and Wildlife Coordination Act Report to the NOD. Those recommendations are provided in section 6.8 of the DEIS as well as in Enclosure 2 of this letter.

Specific comments pertaining to multiple sections of the DEIS

Potential Water Quality Impacts to Fisheries

Chapter 4.14-18, 24 AQUATIC AND FISHERY RESOURCES, COMMERICAL FISHERIES, OYSTER RESOURCES, WATER BOTTOMS AND BENTHIC RESOURCES, ESSENTIAL FISH HABITAT, and RECREATIONAL RESOURCES
Pages 4-64 through 4-91 and Pages 4-122 through 4-126
Sections titled "Direct Impacts" and "Indirect Impacts"

NMFS recommends the FEIS include the following information under the direct impacts and indirect impacts analyses for each of the resource sections identified above for all action alternatives:

Low DO levels could be a potential impact during construction activities in Lake Borgne and continue to persist after construction. In addition, there is a concern that the diversion could exacerbate low DO conditions in Lake Borgne due to the high level of nutrients causing algal blooms. The potential for this impact should be monitored to a greater extent than is indicated in the DEIS or Supporting Documentation and addressed with adaptive management, if needed. These impacts should be identified in the FEIS as direct and/or indirect impacts to these resources.

The diversion should be operated to avoid and minimize adverse impacts to aquatic and fishery resources in the project area to the maximum extent practicable. Revisions to the CASM MRGO report that were not included in the DEIS should be updated in each of these sections for inclusion of the FEIS. Localized impacts should be identified by node in the direct impacts of each of these resources, even if there is a regional gain in net productivity for the project area as a whole.

Potential Hydrologic Impacts to Fisheries

Chapter 4.14-15, 24 AQUATIC AND FISHERY RESOURCES, COMMERICAL FISHERIES, and RECREATIONAL RESOURCES,
Pages 4-64 through 4-71, and pages 4-122 through 4-126
Sections titled "Direct Impacts"

NMFS recommends the FEIS include the following information under the direct impacts for each of the resource sections identified above for Alternatives B, C, and D:

The restoration of the Central Wetlands area involves an alteration of the existing hydrologic conditions that may result in: a) reverse tidal flow at the water control structures at Bayou Bienvenue and Bayou Dupre; and b) the construction of 1,149 acres of retention dikes for swamp creation and nourishment. These impacts likely would result in the loss or reduction in marine fishery productivity in the Central Wetlands area, and the potential conversion of EFH to an area no longer supportive of federally managed marine fishery species.

Gapping and Degrading Retention Dikes

Chapter 2.9 IDENTIFICATION OF THE TENTATIVELY SELECTED PLAN
2.9.1 1 Marsh Restoration
Page 2-98

Chapter 4.12 COASTAL RESTORATION RESOURCES
4.12.2 Alternative B – MRGO Restoration Plan 2
Page 4-54

Chapter 4.12 COASTAL RESTORATION RESOURCES
4.12.3 Alternative C-MRGO Restoration Plan 7
Page 4-56

The DEIS indicates that earthen dikes and closures would be breached or degraded if necessary; however, no time frame for such actions is provided. The above sections of the FEIS should indicate that these features would be breached or degraded within three years of construction, if necessary.

Inconsistency among Environmental Impacts with TSP

Chapter 4.3 HYDROLOGY AND HYDRAULICS

4.3.2 Alternative B – MRGO Restoration Plan 2
Page 4-13
Section titled "Indirect Impacts"

Chapter 4.5 NAVIGABLE WATERWAYS
4.5.2 Alternative B – MRGO Restoration Plan 2
Page 4-30
Section titled "Direct Impacts"

The extent of impact of the retention dike to be constructed under the TSP is not consistent among all sections in the document (ranging from 6,515, 8,871, and 10,020 acres). NMFS recommends the NOD verify the correct acreages are provided in the appropriate sections of the FEIS.

Specific Comments Pertaining to Individual Sections of the DEIS

EXECUTIVE SUMMARY

Table S-1: Evaluation of Potential Impacts to Significant Resource by Alternatives

Page ES-8 WATER QUALITY

This section of the table suggests that project implementation has the potential to increase DO levels in the area. Considering concerns regarding DO levels in the borrow areas described above, NMFS recommends this section be revised to indicate that DO levels in borrow areas could be reduced, especially during warmer months, and that adaptive management efforts would be undertaken to limit the geographic extent of such impacts.

Page ES-9 COASTAL VEGETATION RESOURCES

NMFS recognizes that Alternatives B, C and D would reduce the rate of loss of coastal vegetation in the project area. However, given the extent of the project area (3.86 million acres), the system as a whole will continue to encounter coastal vegetative losses that should be quantified in the description of the action alternatives in this table. Lacking such information, readers may believe that project implementation would result in a net gain over the wetland acreage present today, and that additional restoration efforts may not be warranted.

Page ES-10 AQUATIC AND FISHERY RESOURCES, COMMERCIAL FISHERIES

While NMFS agrees that project implementation may not result in adverse impacts to marine fishery resources over the entire 3.86 million acre project area, CASM MRGO model results suggest there would be localized impacts to some species in some areas. This table should be revised to indicate the potential for localized reductions in marine fishery species in areas closest to the Violet diversion, as well as the potential for increased production in areas further from the diversion.

Page ES-11 ESSENTIAL FISH HABITAT

While NMFS agrees that project implementation would create and protect vegetated habitats that are very productive categories of EFH, it should be recognized in this section that it is likely that the creation of the cypress swamp in the Central Wetlands, combined with reverse tidal flows through the Bayou Dupree and Bayou Bienvenue floodgates, could convert EFH in the Central Wetlands to an area that is no longer supportive of federally managed marine fishery species.

Chapter 1 INTRODUCTION
1.3 STUDY AREA
Pages 1-6

NMFS recommends the FEIS include a map, with each node clearly labeled, to illustrate the revised study area as described in this section, including the spatial limits of analysis and results. The map should include the designated numbers labeled for each node to observe more closely as they are referenced during future sections of the FEIS.

2.9 IDENTIFICATION OF THE TENTATIVELY SELECTED PLAN
2.9.1.3 *Swamp Restoration*
Page 2-99, paragraph 5

This section of the DEIS indicates that dikes would be constructed to an elevation of +6.5 ft. Dikes at this elevation would impede drainage from the swamp area, potentially leading to wetland degradation. NMFS recommends the TSP include plans to breach containment dikes, following sediment compaction and tree planting, to assist in tree survival and the health of the swamp vegetative community.

2.9.1.5 *Shoreline Protection*

Page 2-101, paragraph 1.

NMFS recommends the following be included in this paragraph: "The shoreline protection will include 25-foot wide fish ingress and egress gaps, which will be open to pre-project construction bottom elevations, every 1,000 linear feet." The fish gap designs can be further refined through coordination with NMFS during the PED phase of the project.

2.11 ENVIRONMENTAL COMMITMENTS
Page 2-119

The third paragraph in this section quantifies environmental impacts and benefits with the implementation of the TSP. However the acreages associated with both impacts and benefits are not consistent with the description of the TSP throughout the entire DEIS. For example, the DIES in this sections states that there will be 277 acres of intermediate marsh, 363 acres of shallow open water and five acres of bottomland hardwoods impacted with the construction of the diversion canal. In previous sections of the document, it states 245 acres of impact to wetlands. It also states that there will be 32 acres of ridge restoration, where in previous

sections it states 48 of acres ridge restoration. In addition, not all impacts and benefits associated with implementation of the TSP were identified in this section. As previously recommended in the general comments of our letter, NMFS recommends the NOD verify correct acreages are provided and identify all adverse and beneficial impacts to habitats for consistency in the FEIS.

Chapter 4 ENVIRONMENTAL CONSEQUENCES
4.2 ENVIRONMENTAL CONSEQUENCES SUMMARY TABLE

Table 4-1, pages 4-3 through 4-9.

This is the same table as presented in the executive summary (Table S-1). NMFS recommends the same revisions to Table 4-1 as recommended above for Table S-1.

4.4 WATER QUALITY
4.4.2 Alternative B – MRGO Restoration Plan 2

Direct Impacts
Borrow Sites

Page 4-19, paragraph 1.

This paragraph should be revised to indicate that DO impacts could occur throughout the ten years of dredging activity and could continue long term post construction. As previously referenced in Sections 3.7.2.2 and 3.7.2.5, there are low DO areas in the southeastern portion of Lake Pontchartrain due to water depths of borrow pits being greater than 15 feet below the water surface (i.e., total water depth) and salinity stratification.

If borrow pit design remains at 10 to 12 feet below existing bottom elevations, the potential for Lake Borgne to reach anoxic and hypoxic conditions could result. Due to the spatial and temporal extent of borrow needed for the TSP, this could potentially be a significant adverse impact that should be monitored or scientifically researched to a greater extent than is indicated in the DEIS or Supporting Documentation. To avoid the potential for this impact, the depth of cut could be revised with adaptive management to a depth where hypoxia does not occur. This is of particular concern with the anticipation of a freshwater layer from the Violet Diversion in the shallow water depths of Lake Borgne that may cause salinity stratification. This section of the FEIS should commit to allowing borrow pits to be no deeper than 15 feet below the water surface. The dredging program should be adaptively managed to minimize adverse impacts on DO levels and water quality in the borrow pits should be monitored during the ten year construction period to allow for design changes if needed.

Violet Freshwater Diversion Channel

Page 4-21

The high level of nutrients in water diverted from the Mississippi River could lead to algal blooms in Lake Borgne which could contribute to low DO conditions. In addition, the fresh

water from the diversion could help stratify water levels in Lake Borgne, also contributing to low DO conditions. The FEIS should discuss this potential impact.

Placement and Construction Sites

Page 4-24, paragraph 4

The duration of construction impacts due to dredging in Lake Borgne will persist over a period of ten years. NMFS recommends that the last sentence of this paragraph in this section be revised to indicate the ten year duration of construction.

Appendix T: Monitoring and Adaptive Management Plan (MAMP)

Page 9

The MAMP identifies four questions that, when answered appropriately, suggest proposed actions being taken which could benefit from adaptive management. As it pertains to the questions shown on Page 9: 1) the dredging of borrow pits is not well understood in their long term impacts on benthos and water quality; 2) the most effective design of the pits is not easily identifiable; and 3) the measures of how those options would perform are not well understood. Since management actions can be revised by changing the depth of the borrow pits or the configuration, and because the dredging of borrow pits is expected to proceed in a piecemeal fashion over a period of approximately ten years, NMFS believes that borrow pit dredging qualifies for adaptive management. As such, NMFS recommends the MAMP be revised to include a plan for monitoring benthic community structure and water quality until a depth and design that limits adverse impacts can be identified and used for future borrow pit dredging efforts.

Objective 1

Page 12, Monitoring Design

This section indicates that a nutrient sampling plan would be developed, if needed, in coordination with the Louisiana Department of Environmental Quality. Given the potential for high freshwater flow rates to cause eutrophication in Lake Borgne, NMFS believes a nutrient sampling plan is necessary. Because high nutrient levels could result in phytoplankton blooms, which could eventually impair DO, NMFS believes Objective 1 of the MAMP should be revised to include monitoring of nutrient levels, phytoplankton populations and DO in Lake Borgne. Such monitoring should be undertaken at least during the spring, summer, and fall months for a sufficiently long period of time to determine the potential for adverse impacts and identify measures to limit such impacts.

Objective 2.

Page 13. Monitoring Design

Given sediment loads in the Mississippi River, it is not clear whether diverting river water through the Central Wetlands and into Lake Borgne would provide sufficient sediment to create and maintain swamp and marsh elevations in those areas. NMFS recommends the monitoring design be revised to include the establishment of sediment erosion tables or some other measure of accretion, at a number of sites in the Central Wetlands and marsh habitats on the southwestern perimeter of Lake Borgne. Those accretion stations should be established for several years prior to construction and sampled at least annually until pre-construction and post-construction patterns of accretion have been established.

In addition, there is some concern over the impacts of high nutrient levels in Mississippi River waters impacting shear strength of marsh soils, potentially leaving them more vulnerable to storm generated erosion. NMFS recommends this objective be revised to include pre- and post-construction monitoring of marsh soil shear strength at a number of sites in the Central Wetlands.

Section 1502.9(c)(1.)(ii) of the Regulations for Implementing Provisions of the National Environmental Policy Act specifies that agencies shall prepare supplements to either draft or final environmental impact statements if there are significant new circumstances or information relevant to environmental concerns and bearing on the proposed action or its impacts. In the paragraph 3 of "Direct Impacts" on page 4-74 in the DEIS, the NOD states that: "access channels, shoreline protection, borrow sites and wetland creation/nourishment sites would be designed to avoid oyster leases and nearby Louisiana Oyster Seed Grounds." NMFS recommends that should any of these design features change resulting in impacts to identified oyster resources, the NOD should prepare a supplemental National Environmental Policy Act document. The commitment to perform environmental monitoring and undertake adaptive management as needed to protect and restore EFH and federally managed fishery resources is essential to the determination that adverse impacts to EFH will be sufficiently averted and offset. As such, any future action that would curtail environmental monitoring and adaptive management of the project would also necessitate preparation of supplemental National Environmental Policy Act documentation.

Literature Cited

Cooper, D.C. and J.W. Morse. 1996. The chemistry of Offatts Bayou, Texas: a seasonally highly sulfidic basin. Estuaries 19(3):595-611.

Flocks, J. and C. Franze. 2001. Dredge pit characterization, *in* S. Penland, A. Beall and J Waters, (eds.), Environmental Atlas of the Lake Pontchartrain Basin. Lake Pontchartrain Basin Foundation, New Orleans, LA, p. 153.

Luckenbach, M.W. and R.J. Orth. 1992. Swimming velocities and behavior of blue crab (Callinectes sapidus Rathbun) megalopae in still and flowing water. Estuaries 15(2):186-192.

M.H. Shurtz and K.M. St. Pé. 1984. Report on interim findings: water quality investigation of environmental conditions in Lake Pontchartrain. Louisiana Department of Environmental Quality Water Pollution Control Division. 85 pp.

North, E.W., Z. Schlag, R.R. Hood, M. Li, L. Zhong, T. Gross, V.S. Kennedy. 2008. Vertical swimming behavior influences in a coupled particle-tracking and hydrodynamic model of Chesapeake Bay. Marine Ecology Progress Series 359:99-115.

Palm Beach County Department of Environmental Resources Management. 1994. The dredged site survey, benthic macro invertebrate samples. pp 246-260.

Smith, D.L. 2008. Reconnaissance study of fish passage impacts resulting from structures in the MRGO, IHNC and GIWW – Letter report. ERDC/EL TR-08-X, May 2008. 25 pp.

Enclosure 2

U.S. Fish and Wildlife Service's Fish and Wildlife Conservation Recommendations for the Mississippi River-Gulf Outlet Ecosystem Restoration project.

1. The Service recommends, with support from NMFS and LDWF, the selection of a barrier island component of the MRGO Ecosystem Restoration Plan be a part of the TSP. The Service feels the design and evaluation of the barrier island alternatives was sufficient to warrant selection, though further engineering would be required prior to construction. Breton Island is a National Wildlife Refuge (NWR), managed by the Service and is of National importance. Until recently (Lavoie, D, ed., 2009; Thomson et al., 2009) the Service was unaware of the long-term impacts to this important refuge as a result of the MRGO channel. However, the Service believes restoration of the areal loss of Breton Island due to the construction and maintenance of the MRGO channel should be appropriately addressed in the TSP .

2. The Corps should contact the Service regarding a compatibility determination, Wilderness Act provisions and special use permits that may be necessary to conduct activities on Breton Island NWR. The Corps should establish and continue coordination with the Service until construction of any project feature is complete and prior to any subsequent maintenance. Points of contacts for the Service are: Kenneth Litzenberger, Project Leader for the Service's Southeast National Wildlife Refuges and Jack Bohannan (985) 822-2000, Refuge Manager for the Breton Island NWR.

3. The Service recommends the operational plans for the Violet Diversion be evaluated to include more flexibility of flow (flows between 1000cfs and 7000cfs) to achieve optimal habitat conditions favorable to nearby intermediate marsh and to bald cypress germination, growth, and reproduction by controlling depth and duration of inundation and salinity levels. As the operational plan for the Violet Diversion is further developed, future hydrological and fisheries (i.e., CASM) modeling, and updated habitat assessments (i.e., Wetland Value Assessments) should be conducted.

4. The Service recommends, with support from LDWF, the diversion operational plan be developed in a way to avoid or minimize adverse impacts to marine fisheries and Essential Fish Habitat (EFH) while maximizing freshwater and nutrient input to the extent practicable to meet habitat objectives.

5. The Service recommends the diversion be adaptively managed to enhance surrounding wetlands, that habitat switching (as a result of re-introduced river water) is allowed to occur in a manner that is not detrimental or destructive to the ecological processes, and that the diversion allows for draw down periods sufficient for cypress regeneration and cypress growth.

6. The Service recommends, with support from LDWF, a comprehensive examination of the river and all existing and proposed diversions to coordinate their operation and ensure that their operation will maximize their restoration capabilities. The ongoing Mississippi

River Hydrodynamic and Delta Management Study should be utilized to address this issue. The Service and other natural resource agencies should be involved in this study.

7. The Service recommends, with support from LDWF, establishment of a committee similar to the Caernarvon Interagency Advisory Committee or Davis Pond Advisory Committee to review the operation and the monitoring and adaptive management results of the Violet diversion and when necessary, provide recommendations regarding any future operational and maintenance changes. The Service and other natural resource agencies should be on this committee.

8. The Service recommends that all shoreline protection features include one fish dip every 1,000 feet (ft) constructed to a 25 ft bottom width to the pre-project elevation. On a case by case basis the 1,000 ft distance can be adjusted, in consultation with National Marie Fisheries Service (NMFS), to incorporate existing exchange points.

9. The Monitoring and Adaptive Management Plan, as it is further developed, should be provided to the Service, NMFS, and Louisiana Department of Wildlife and Fisheries (LDWF) for continued review, comment, and input.

10. If a proposed project feature is changed significantly or is not implemented within one year of the Endangered Species Act consultation letter, we recommend that the Corps reinitiate coordination with the Service and NMFS to ensure that the proposed project would not adversely affect any Federally listed threatened or endangered species or their habitat.

11. Avoid adverse impacts to nesting bald eagles, gulls, terns, and/or black skimmers, wading birds, and brown pelicans through the careful design of project features and timing of construction. A qualified biologist should inspect the proposed work area for the presence of undocumented nesting colonies and bald eagles during the nesting season (i.e., September 15 through March 31 for brown pelican, September 1 through February 15 for wading bird nesting colonies, September 16 through April 1 for colonies containing nesting gulls, terns, and/or black skimmers, and October through mid-May for bald eagles).
    - To minimize disturbance to colonies containing nesting wading birds (i.e., herons, egrets, night-herons, ibis, and roseate spoonbills), anhingas, and/or cormorants, all activity occurring within 1,000 feet of a rookery should be restricted to the non-nesting period (i.e., September 1 through February 15, exact dates may vary within this window depending on species present).
    - For colonies containing nesting brown pelicans, all activity occurring within 2,000 feet of a rookery should be restricted to the non-nesting period (i.e., September 15 through March 31). Nesting periods vary considerably among Louisiana's brown pelican colonies, however, so it is possible that this activity window could be altered based upon the dynamics of the individual colony.
    - For colonies containing nesting gulls, terns, and/or black skimmers, all activity occurring within 650 feet of a rookery should be restricted to the non-nesting period (i.e., September 16 through April 1, exact dates may vary within this

window depending on species present).

- If a bald eagle nest is discovered within or adjacent to the proposed project area, then an evaluation must be performed to determine whether the project is likely to disturb nesting bald eagles. That evaluation may be conducted on-line at: http://www.fws.gov/southeast/es/baldeagle. Following completion of the evaluation, that website will provide a determination of whether additional consultation is necessary and those results should be forwarded to this office.

12. Land clearing associated with project features should be conducted during the fall or winter to minimize impacts to nesting migratory birds, when practicable.

13. Further detailed planning of project features (e.g., Design Documentation Report, Engineering Documentation Report, Plans and Specifications, or other similar documents) should be coordinated with the Service and other State and Federal natural resource agencies, and shall be provided an opportunity to review and submit recommendations on all work addressed in those reports.

14. A report documenting the status of implementation, maintenance, and adaptive management measures should be prepared every three years by the managing agency and provided to the Corps, the Service, NMFS, U.S. Environmental Protection Agency (EPA), Louisiana Department of Natural Resources (LDNR), Office of Coastal Protection and Restoration (OCPR), and LDWF. That report should also describe future management activities, and identify any proposed changes to the existing management plan.

15. The Service recommends minimizing impacts to marsh from marsh buggy activities. One way is to limit repetitive use of the same marsh buggy route to prevent ruts and lasting damage while at the same time reducing the amount of marsh buggy tracts as much as possible. Another option is to build temporary boardwalks over marsh where feasible and then backfilling the boardwalk area if needed. In areas with large marsh creation features that have minimal access routes, such as the inner Terre Aux Boeufs marsh features, the Service recommends that work begin at the farthest location and proceed to the outer edges of the site to minimize the amount of damage.

16. The large quantity of borrow material proposed to be taken from Lake Borgne for the TSP may have an adverse effect to fisheries, EFH, and the threatened Gulf sturgeon by: 1) alteration in water bottom substrate habitat: 2) direct removal of benthos from a large area which may (at least temporarily) reduces food availability for fishery organisms; 3) other sessile resources, such as oysters could be affected; and 4) by continually moving the dredge, the resuspended sediments will take longer to settle and could prolong the periods of high turbidity associated with dredging operations. The Service recommends, with support from LDWF, careful consideration be given to the affects of taking all borrow from Lake Borgne and consideration should be give to obtaining borrow from other "outside" sources, such as the Mississippi River, and adjacent bays, and offshore areas.

17. The proposed borrow areas in Lake Borgne do include private leases as well as public oyster seed grounds. LDWF manages the public seed grounds and should be consulted before final borrow locations are determined. LDWF also recommends that all borrow sites be less than 10 feet below the existing sediment surface and 1000 feet from the shoreline.

18. The aquatic modeling, Comprehensive Aquatic Systems Model (CASM) used to help evaluate the impacts of the freshwater diversion on representative fish species as well as the potential impacts from low dissolved oxygen levels on fisheries resources in Lake Borgne was developed and had produced initial results. The Service, LDWF, and NMFS support the CASM modeling effort and agree the trends may provide reasonable results. However, because the model results represent the first draft and have since been provided corrected assumptions and interactions to better represent Louisiana waters, a final model run is necessary to obtain more accurate results relative to Louisiana. The assumptions were corrected in consultation with NMFS and LDWF. Because of funding constraints the CASM modeling efforts were halted. The Service recommends completion of the CASM model to achieve more accurate results that will be used to fully address impacts to aquatic resources.

19. In addition the Service recommends the CASM model should be updated to incorporate conditions from the oil spill in the adaptive management plan. This model should also use the corrected assumptions.

20. Due to the significant acreage of marsh that will be accessed for swamp and marsh creation/nourishment, the Service request the Corps quantify the estimated flotation access and construction access impacts to shallow open water habitat.

DEPARTMENT OF THE ARMY
NEW ORLEANS DISTRICT, CORPS OF ENGINEERS
P.O. BOX 60267
NEW ORLEANS, LOUISIANA 70160-0267

DECEMBER 12, 2011

REPLY TO
ATTENTION OF

Regional Planning and
Environmental Division, South
Environmental Planning Branch

Miles M. Croom
National Oceanic and Atmospheric Administration
National Marine Fisheries Service
Southeast Regional Office
263 13th Avenue, South
St. Petersburg, FL 33701-5505

Dear Mr. Croom:

Please reference your letter dated February 11, 2011 providing comments on the Mississippi River Gulf Outlet Ecosystem Restoration Draft Environmental Impact Statement (DEIS) and Feasibility Study.

The U.S. Army Corps of Engineers Regional Division South New Orleans District appreciates your input and is actively working to address your comments. The volume of comments received was extremely high (over 25,000+ comments/form letters) and as a result it is taking more time than normally required to review and efficiently develop responses. Our office will send a letter with responses to all your comments prior to finalizing the EIS and releasing for the final thirty day review.

If you have any questions or require additional information please contact Ms. Tammy Gilmore at U.S. Army Corps of Engineers; Regional Planning and Environmental Division South; Environmental Planning Branch; CEMVN-PDN-CEP; P.O. Box 60267; New Orleans, Louisiana 70160-0267. Ms. Gilmore can also be reached at (504) 862-1002 or by email at tammy.h.gilmore@usace.army.mil.

Sincerely,

Joan M. Exnicios
Chief, Environmental Planning Branch

DEPARTMENT OF THE ARMY
NEW ORLEANS DISTRICT, CORPS OF ENGINEERS
P.O. BOX 60267
NEW ORLEANS, LOUISIANA 70160-0267

MARCH 27, 2012

REPLY TO
ATTENTION OF

Regional Planning and
Environmental Division, South
Environmental Planning Branch

Miles M. Croom
National Oceanic and Atmospheric Administration
National Marine Fisheries Service
Southeast Regional Office
263 13th Avenue, South
St. Petersburg, FL 33701-5505

Dear Mr. Croom:

Please reference your letter dated February 11, 2011 providing comments on the Mississippi River Gulf Outlet Ecosystem Restoration Draft Environmental Impact Statement (DEIS) and Feasibility Study and the U.S. Army Corps of Engineers Regional Division South New Orleans District (CEMVN) preliminary response letter dated December 12, 2011.

The CEMVN appreciates your input and has concurred with and addressed all comments. Please find attached responses that address your general and specific comments on the DEIS.

If you have any questions or require additional information please contact Ms. Tammy Gilmore at U.S. Army Corps of Engineers; Regional Planning and Environmental Division South; Environmental Planning Branch; CEMVN-PDN-CEP; P.O. Box 60267; New Orleans, Louisiana 70160-0267. Ms. Gilmore can also be reached at (504) 862-1002 or by email at tammy.h.gilmore@usace.army.mil.

Sincerely,

Joan M Exnicios

Joan M. Exnicios
Chief, Environmental Planning Branch

Enclosures

Copies Furnished
USFWS
NMFS Baton Rouge Ofc.

DEPARTMENT OF THE ARMY
NEW ORLEANS DISTRICT, CORPS OF ENGINEERS
P.O. BOX 60267
NEW ORLEANS, LOUISIANA 70160-0267

MARCH 20, 2012

REPLY TO
ATTENTION OF

Regional Planning and
Environmental Division, South
Environmental Planning Branch

Miles M. Croom
National Oceanic and Atmospheric Administration
National Marine Fisheries Service
Southeast Regional Office
263 13th Avenue, South
St. Petersburg, FL 33701-5505

Dear Mr. Croom:

Please reference your letter dated February 11, 2011 providing Essential Fish Habitat (EFH) conservation recommendations on the Mississippi River Gulf Outlet Ecosystem Restoration Draft Environmental Impact Statement (DEIS) and Feasibility Study and the U.S. Army Corps of Engineers Regional Division South New Orleans District (CEMVN) preliminary response letter dated December 12, 2011.

The CEMVN appreciates your input and is actively working to address all of your comments. The EFH conservation recommendations have been reviewed and addressed. Please find enclosed responses to NOAA's EFH recommendations.

If you have any questions or require additional information please contact Ms. Tammy Gilmore at U.S. Army Corps of Engineers; Regional Planning and Environmental Division South; Environmental Planning Branch; CEMVN-PDN-CEP; P.O. Box 60267; New Orleans, Louisiana 70160-0267. Ms. Gilmore can also be reached at (504) 862-1002 or by email at tammy.h.gilmore@usace.army.mil.

Sincerely,

Joan M Exnicios

Joan M. Exnicios
Chief, Environmental Planning Branch

Enclosures

Copies Furnished
NMFS Baton Rouge office
USFWS

NOAA EFH Conservation Recommendations

And

CEMVN Responses

1. To avoid and minimize impacts to EFH and associated marine fisheries resources, specific details and documents for each restoration feature of the Tentatively Selected Plan (TSP) shall be provided to NMFS for evaluation, discussion, review and comment during the preliminary engineering and design (PED) stage.

   CEMVN Response. Concur. Detailed documents will be provided to NMFS during the PED stage.

2. The borrow pits in Lake Borgne initially shall be limited to no deeper than 15 feet below the water surface (i.e., total water depth) unless monitoring and adaptive management, or modeling of the hydrology of the borrow pits, clearly indicate deeper pits would have little impact on water quality.

   CEMVN Response. Concur. CEMVN in coordination with NMFS has developed a borrow plan and Monitoring and Adaptive Management Plan (MAMP) to minimize impacts to water quality. This includes three test pits to determine the depth at which water quality might be affected.

3. The MAMP shall be revised to include monitoring of benthic communities and dissolved oxygen (DO) levels within borrow areas in Lake Borgne. Water quality monitoring shall be conducted at least during April through October for a minimum of three years post-dredging to verify the relative success of the borrow pit design in avoiding impacts to water quality. Specific conductance, temperature, DO, and pH shall be sampled from the bottom to the surface in five-foot profiles. Samples shall be collected at least one time during April, September, and October. Samples shall be collected twice, about two weeks apart, during May, June, July and August. Benthos should be sampled annually pre- and post-construction to evaluate changes in community structure. This information shall be used to adaptively manage borrow site design to minimize adverse impacts, if any.

   CEMVN Response. Both pre- and post-construction monitoring will be utilized to determine Project success. Nutrient sampling will be designed in coordination with Louisiana Department of Environmental Quality, if needed as to not contribute to low dissolved oxygen (DO) conditions. Hourly salinity, temperature, water level and turbidity monitoring will be initiated in PED and maintained throughout construction and 10 years post-construction at seven locations within the project area. Gulf sturgeon have been found to feed primarily on species associated with sandy, polyhaline habitats which

are absent from Lake Borgne. Nearby boring data indicates that the sediment stratification within Lake Borgne is fairly uniform. Fat clay interspersed with small bands of lean clay, silty sand and pear are the predominant sediments occurring in the project area, based on this data. Once borings are completed for the borrow pits, if sediment composition does not conform to the before mentioned assumption of uniformity, then consultation with the resource agencies would be re-initiated to document impacts to sediment composition and the benthic assemblage.

4. The retention dikes constructed for marsh creation and nourishment areas shall be gapped and degraded within three years of used in a manner acceptable to NMFS.

   CEMVN Response. Concur. The dike features would be mechanically breached or degraded within three years of construction, if natural degradation has not sufficiently removed the earthen material.

5. Shoreline protection features in the TSP shall include 25-foot wide gaps down to pre-project depth elevations for fisheries ingress and egress every 1,000 linear feet, unless otherwise refined in coordination with NMFS during PED. Scour aprons may be incorporated so as not to decrease the pre-project water depth, or offset sections of rock in front of or behind foreshore rock dikes may be included to minimize erosion in the vicinity of gaps.

   CEMVN Response. Concur. During the detail design phase for each feature, CEMVN would closely coordinate with USFWS and NMFS before implementation of these measures.

APPENDIX D

PROGRAMMATIC AGREEMENT
AMONG
The US ARMY CORPS OF ENGINEERS
NEW ORLEANS DISTRICT
The LOUISIANA STATE HISTORIC PRESERVATION OFFICER
The CHITMACHA TRIBE OF LOUISIANA,
And
The JENA BAND OF CHOCTAW INDIANS
The ADVISORY COUNCIL ON HISTORIC PRESERVATION
Regarding The
MISSISSIPPI RIVER GULF OUTLET
ECOSYSTEM RESTORATION PROJECT

WHEREAS, the United States Army Corps of Engineers, New Orleans District (USACE) is planning to restore the ecosystem damaged by the effects of the construction and use of the Mississippi River Gulf Outlet (MRGO); and

WHEREAS, the authorization for the development of a comprehensive ecosystem restoration plan to restore the areas affected by the former MRGO navigation channel is contained in Section 7013 of the Water Resource Development Act, 2007; and

WHEREAS, project elements will be constructed over a fifteen (15) year period and project elements may be added and subtracted over the life of the project; and

WHEREAS, USACE has determined that the construction of restoration elements are an undertaking as defined in the regulations of the Advisory Council on Historic Preservation (ACHP) 36 CFR § 800.16(y) implementing Section 106 of the National historic Preservation Act (16 USC § 470f) that may have an adverse effect on properties included in or eligible for inclusion in the National Register of Historic Places (NRHP); and

WHEREAS, USACE has elected to fulfill its obligations under Section 106 of the National Historic Preservation Act of 1966, as amended, through the execution and implementation of this Programmatic Agreement (AGREEMENT) as provided in 36 CFR § 800.14(b)(1)(ii); and

WHEREAS, The ACHP has been invited to participate and has agreed to participate in this AGREEMENT process to seek ways to avoid, reduce or mitigate adverse effects to historic properties; and

A. USACE has invited the Alabama Coushatta Tribe of Texas, the Caddo Nation of Oklahoma, the Chitimacha Tribe of Louisiana, the Choctaw Nation of Oklahoma, the Coushatta Tribe of Louisiana, the Jena Band of Choctaw Indians, the Mississippi Band of Choctaw Indians, the Quapaw tribe of Oklahoma, the Seminole Nation of Oklahoma, the Seminole Tribe of Florida and the Tunica Biloxi Tribe of Louisiana to consult in the development of this AGREEMENT. The Jena Band of Choctaw Indians and the Chitimacha Tribe of Louisiana (TRIBES) agreed to participate in the development of the AGREEMENT and have been invited to sign the AGREEMENT as Invited Signatories.

II. Public Involvement

A. USACE shall use its existing public outreach procedures to provide the interested public with information on this undertaking and its effect on historic properties. USACE will provide the public appropriate documentation regarding its effects findings and will provide an opportunity for public input and comment on the resolution of any potential adverse effects of the undertaking. Public meetings will be advertised by placing notices in local newspapers and notices to local governments.

B. USACE, in coordination with the SHPO, will continue efforts during the duration of this AGREEMENT to identify other parties with demonstrated interests in preservation issues and invite them to participate in this AGREEMENT as consulting parties.

III. Identification of Historic Properties

A. USACE shall, in consultation with the SHPO, TRIBES and other consulting parties identify the Area of Potential Effect (APE). The APE will include all areas impacted either directly or indirectly such as viewshed impacts, by the activities identified in Appendix 1. Should the location of some project elements change or if project elements are subtracted or added, all parties to this agreement will be notified by standard mail by no later than fifteen (15) days after the alteration has been determined. USACE shall ensure that all elements within the APE will be surveyed to identify historic properties. USACE, in consultation with SHPO and TRIBES, may develop project-specific survey strategies. If project-specific survey strategies are not implemented then surveys will adhere to the standards of the Louisiana Division of Archaeology. USACE will provide a project update to SHPO and TRIBES at the end of each year. This update will be in the form of a Management Summary, following the format set out by the Louisiana Division of Archaeology. The Management Summary will be due one year after the signing of this AGREEMENT and on that date each year thereafter until termination of this agreement. The Management Summary will be used to determine National Register eligibility and effect on all sites identified during that year. If determinations of eligibility and/or effect are needed prior to the end of the

with the Louisiana Division of Archaeology. Human remains and associated funerary objects will be curated in accordance with Stipulation III.B.

V. Resolution of Adverse Effects

A. USACE will consult with SHPO and Tribes to seek ways to avoid, minimize or mitigate any adverse effects of the project.

B. USACE, in consultation with SHPO and TRIBES, will develop and implement treatment measures to resolve the adverse effects of the project on all National Register eligible historic properties within project elements. Treatment measures will include, but are not limited to:

1. Public Interpretation;

2. Documentation consistent with the Level II Standards of the Historic American Building Survey/Historic American Engineering Record (HABS/HAER).

3. Historic, Architectural or Archaeological Monographs;

4. Rehabilitation of historic buildings in accordance with the Secretary of Interior's *Standards for the Treatment of Historic Properties* (36 CFR 68);

5. Off-site mitigation, including acquisition of property or preservation easements on property, as appropriate, containing threatened resources of comparable significance in circumstances where there is an imminent need to proceed with construction activity and it is in the public interest;

6. Ethnographic Studies

7. Studies of traditional cultural properties

8. Relocation of historic properties to sites approved by SHPO as possessing similar overall character; and

9. Data recovery for archaeological properties.

C. Once the signatory parties agree to a treatment plan for the resolution of adverse effect on historic properties, that plan shall be implemented by USACE.

D. Should USACE, SHPO and/or TRIBES disagree on the proposed mitigation measures, USACE shall seek to resolve such objection through consultation in accordance with Stipulation VII of this AGREEMENT.

VI. Unanticipated Discoveries

C. The Signatory parties to this AGREEMENT shall meet annually, or as needed, to evaluate the effectiveness of this AGREEMENT.

D. If Implementation of the project has not begun within three (3) yers of the effective date of this agreement, the signatory parties will consult to determine whether this agreement should be modified or terminated.

E. USACE shall provide a copy of the executed agreement to each signatory party within fifteen (15) days of execution by the final signatory.

IX. Amendment and Termination

A. Notwithstanding any provision of this AGREEMENT, the Signatories and Invited Signatories may request that the AGREEMENT be amended whereupon the Signatories and Invited Signatories will consult to consider such amendment. USACE shall facilitate such consultation within thirty (30) days of the request from one of the Signatory parties. Any amendment will be in writing and will be signed by USACE, SHPO and TRIBES and shall be effective on the date of signing by the final Signatory.

B. If any Signatory determines that the terms of this AGREEMENT cannot be or are not being carried out, the Signatories will consult to determine whether an amendment to the AGREEMENT would cure the deficiency.

C. If amendment would not cure the deficiency or if the Signatories cannot agree to an amendment this AGREEMENT may be terminated at the request of any of the Signatory parties.

Programmatic Agreement
among
The United States Army Corps of Engineers,
The Louisiana State Historic Preservation Officer,
The Chitimacha Tribe of Louisiana,
The Jena Band of Choctaw Indians
and
The Advisory Council on Historic Preservation
Regarding the
Mississippi River Gulf Outlet Ecosystem Restoration Project

Execution of this Programmatic Agreement and implementation of its terms evidences that the USACE has taken into account the effects of the Mississippi River Gulf Outlet Ecosystem Restoration Project upon historic properties and has afforded the ACHP an opportunity to comment.

Signatory:

United States Army Corps of Engineers

By: _____ Date: 7 June 2012

Colonel Edward R. Fleming
District Commander
U.S. Army Corps of Engineers, New Orleans District

Programmatic Agreement
Among
The United States Army Corps of Engineers,
The Louisiana State Historic Preservation Officer
The Chitimacha Tribe of Louisiana
The Jena Band of Choctaw Indians
And
The Advisory Council on Historic Preservation
Regarding the
Mississippi River Gulf Outlet Ecosystem Restoration Project

Execution of this Programmatic Agreement and implementation of its terms evidences that the USACE has taken into account the effects of the Mississippi River Gulf Outlet Ecosystem Restoration Project upon historic properties and has afforded the Jena Band of Choctaw Indians an opportunity to comment.

Signatory:

LOUISIANA STATE HISTORIC PRESERVATION OFFICER

By: Pam Breaux **Date:** May 21, 2012

Ms. Pam Breaux
Louisiana State Historic Preservation Officer

Programmatic Agreement
Among
The United States Army Corps of Engineers,
The Louisiana State Historic Preservation Officer
The Chitimacha Tribe of Louisiana
The Jena Band of Choctaw Indians
And
The Advisory Council on Historic Preservation
Regarding the
Mississippi River Gulf Outlet Ecosystem Restoration Project

Execution of this Programmatic Agreement and implementation of its terms evidences that the USACE has taken into account the effects of the Mississippi River Gulf Outlet Ecosystem Restoration Project upon historic properties and has afforded the Chitimacha Tribe of Louisiana an opportunity to comment.

Signatory:

The Chitimacha Tribe of Louisiana

By: John Paul Darden **Date:** 5/16/12
John Paul Darden, Chairman

Programmatic Agreement
Among
The United States Army Corps of Engineers,
The Louisiana State Historic Preservation Officer
The Chitimacha Tribe of Louisiana
The Jena Band of Choctaw Indians
And
The Advisory Council on Historic Preservation
Regarding the
Mississippi River Gulf Outlet Ecosystem Restoration Project

Execution of this Programmatic Agreement and implementation of its terms evidences that the USACE has taken into account the effects of the Mississippi River Gulf Outlet Ecosystem Restoration Project upon historic properties and has afforded the Jena Band of Choctaw Indians an opportunity to comment.

Signatory:

Jena Band of Choctaw Indians

By: B. Cheryl Smith **Date:** 5-18-12
Principal Chief, B. Cheryl Smith

Programmatic Agreement
Among
The United States Army Corps of Engineers,
The Louisiana State Historic Preservation Officer
The Chitimacha Tribe of Louisiana
The Jena Band of Choctaw Indians
And
The Advisory Council on Historic Preservation
Regarding the
Mississippi River Gulf Outlet Ecosystem Restoration Project

Execution of this Programmatic Agreement and implementation of its terms evidences that the USACE has taken into account the effects of the Mississippi River Gulf Outlet Ecosystem Restoration Project upon historic properties and has afforded the Jena Band of Choctaw Indians an opportunity to comment.

Signatory:

Advisory Council on Historic Preservation

By: John M. Fowler Date: 6/11/12
John M. Fowler
Executive Director
Advisory Council on Historic Preservation

DEPARTMENT OF THE ARMY
NEW ORLEANS DISTRICT, CORPS OF ENGINEERS
P.O. BOX 60267
NEW ORLEANS, LOUISIANA 70160-0267
FEBRUARY 5, 2010

Regional Planning and
Environmental Division, South
New Orleans Environmental Branch

Mr. Scott Hutcheson
State Historic Preservation Officer
Office of Cultural Development
Department of Culture, Recreation and Tourism
P.O. Box 4427
Baton Rouge, Louisiana 70804

Dear Mr. Hutcheson:

RE: Initiation of Section 106 Consultation for the Mississippi River Gulf Outlet Ecosystem Restoration Project, Orleans and St. Bernard Parishes, Louisiana

The US Army Corps of Engineers, New Orleans District (CEMVN) in accordance with 36CFR Part 800.4(a)(1) is enclosing a map showing the area of potential effect (APE) for the above project. Those areas to be affected are those identified in the legend found in the right hand corner of the map. As per 36CFR Part 800.3(a) we believe that this undertaking as defined in Part 800.16(y), has the potential to have an effect on historic properties. Therefore as per Part 800.3 we are formally initiating the Section 106 process.

Elements of the project consist in marsh creation, marsh nourishment, ridge restoration, swamp nourishment, swamp restoration and shoreline protection. All of these actions except ridge restoration will involve the offshore excavation of floatation channels and offshore borrow areas. As discussed with your office, CEMVN plans to visit all existing sites to record the current condition and survey all high probability areas. All offshore activity will be surveyed using side-scan sonar, magnetometer and in the case of flotation channels, sub-bottom profiler.

Thank you for your help with this project. If you have any questions or require additional information, please contact Mr. DeMarcay at (504)862-2039.

Sincerely,

Joan M. Exnicios
Chief, New Orleans Environmental Branch

w/attachments

DEPARTMENT OF THE ARMY
NEW ORLEANS DISTRICT, CORPS OF ENGINEERS
P.O. BOX 60267
NEW ORLEANS, LOUISIANA 70160-0267
FEBRUARY 5, 2010

Regional Planning and
Environmental Division, South
New Orleans Environmental Branch

Chief Kevin Sickey
Coushatta Tribe of Louisiana
P.O. Box 818
Elton, LA 70532

Dear Chief Sickey:

RE: Initiation of Section 106 Consultation for the Mississippi River Gulf Outlet Ecosystem Restoration Project in Orleans and St. Bernard Parishes, Louisiana.

US Army Corps of Engineers, New Orleans District (CEMVN) in accordance with 36 CFR Part 800.4(a)(1) is enclosing a map showing the Area of Potential Effect (APE) for the above project. Those areas to be affected are those identified in the legend found in the upper right hand corner of the map. As per 36 CFR Part 800.3(a) we believe that this undertaking as defined in Part 800.16(y) has the potential to have an effect on historic properties. Therefore as per Part 800.3 we are formally initiating the Section 106 process.

Elements of the project consist in marsh creation, marsh nourishment, ridge restoration, swamp nourishment, swamp restoration and shoreline protection. All of these actions, except possibly the ridge restoration will involve the excavation of floatation channels and offshore borrow areas. CEMVN plans to visit all existing sites to record the current condition and make preliminary determinations of eligibility and survey all high probability areas. All offshore activity will be surveyed using side-scan sonar, magenetometer and in the case of flotation channels, sub-bottom profiler. The use of the sub-bottom profiler will be to attempt to identify offshore archaeological sites.

A Copy of this letter and the attachments are being sent to the Coushatta Tribe of Louisiana Cultural Contacts Bertney and Linda Langley. If you wish to see the attachments, please contact Mr. or Ms. Langley, or, if you wish you may contact Mr. Gary DeMarcay of my staff at (504) 862-2039.

In accordance with 36CFR Part 800.4(a)(4) we request that you review the attached maps and identify any cultural properties that may be of interest to the Coushatta Tribe of Louisiana. If so, please contact the Louisiana State Historic Preservation Officer at (225) 342-8170 or Mr. DeMarcay at the number above.

Thank you for your help with this project. If you have any questions or require additional information, please contact Mr. DeMarcay.

Sincerely,

Joan M. Exnicios
Chief, New Orleans Environmental Branch

cc: Bertney and Linda Langley, Cultural Contacts
w/attachments

DEPARTMENT OF THE ARMY
NEW ORLEANS DISTRICT, CORPS OF ENGINEERS
P.O. BOX 60267
NEW ORLEANS, LOUISIANA 70160-0267
FEBRUARY 5, 2010

Regional Planning and
Environmental Division, South
New Orleans Environmental Branch

John Berrey, Chairman and
Tribal Historic Preservation Officer
Quapaw Tribe of Oklahoma
P.O. Box 765
Quapaw, OK 74363

Dear Chairman Berrey:

RE: Initiation of Section 106 Consultation for the Mississippi River Gulf Outlet Ecosystem Restoration Project in Orleans and St. Bernard Parishes, Louisiana.

US Army Corps of Engineers, New Orleans District (CEMVN) in accordance with 36 CFR Part 800.4(a)(1) is enclosing a map showing the Area of Potential Effect (APE) for the above project. Those areas to be affected are those identified in the legend found in the upper right hand corner of the map. As per 36 CFR Part 800.3(a) we believe that this undertaking as defined in Part 800.16(y) has the potential to have an effect on historic properties. Therefore as per Part 800.3 we are formally initiating the Section 106 process.

Elements of the project consist in marsh creation, marsh nourishment, ridge restoration, swamp nourishment, swamp restoration and shoreline protection. All of these actions, except possibly the ridge restoration will involve the excavation of floatation channels and offshore borrow areas. CEMVN plans to visit all existing sites to record the current condition and make preliminary determinations of eligibility and survey all high probability areas. All offshore activity will be surveyed using side-scan sonar, magenetometer and in the case of flotation channels, sub-bottom profiler. The use of the sub-bottom profiler will be to attempt to identify offshore archaeological sites.

In accordance with 36CFR Part 800.4(a)(4) we request that you review the attached maps and identify any cultural properties that may be of interest to the Quapaw Tribe of Oklahoma. If so, please contact the Louisiana State Historic Preservation Officer at (225) 342-8170 or Mr. DeMarcay at (504) 862-2039.

Thank you for your help with this project. If you have any questions or require additional information, please contact Gary DeMarcay at the number above.

Sincerely,

Joan M. Exnicios
Chief, New Orleans Environmental Branch

w/ attachments

DEPARTMENT OF THE ARMY
NEW ORLEANS DISTRICT, CORPS OF ENGINEERS
P.O. BOX 60267
NEW ORLEANS, LOUISIANA 70160-0267
FEBRUARY 5, 2010

Regional Planning and
Environmental Division, South
New Orleans Environmental Branch

Chairman Mitchell Cypress
Seminole Tribe of Florida
6300 Sterling Rd.
Hollywood, FL 33024

Dear Chairman Cypress:

RE: Initiation of Section 106 Consultation for the Mississippi River Gulf Outlet Ecosystem Restoration Project in Orleans and St. Bernard Parishes, Louisiana.

US Army Corps of Engineers, New Orleans District (CEMVN) in accordance with 36 CFR Part 800.4(a)(1) is enclosing a map showing the Area of Potential Effect (APE) for the above project. Those areas to be affected are those identified in the legend found in the upper right hand corner of the map. As per 36 CFR Part 800.3(a) we believe that this undertaking as defined in Part 800.16(y) has the potential to have an effect on historic properties. Therefore as per Part 800.3 we are formally initiating the Section 106 process.

Elements of the project consist in marsh creation, marsh nourishment, ridge restoration, swamp nourishment, swamp restoration and shoreline protection. All of these actions, except possibly the ridge restoration will involve the excavation of floatation channels and offshore borrow areas. CEMVN plans to visit all existing sites to record the current condition and make preliminary determinations of eligibility and survey all high probability areas. All offshore activity will be surveyed using side-scan sonar, magenetometer and in the case of flotation channels, sub-bottom profiler. The use of the sub-bottom profiler will be to attempt to identify offshore archaeological sites.

A Copy of this letter and the attachments are being sent to the Seminole Tribe of Florida Historic Preservation Officer, Mr. Willard Steele. If you wish to see the attachments, please contact Mr. Steele, or, if you wish you may contact Mr. Gary DeMarcay of my staff at (504) 862-2039.

In accordance with 36CFR Part 800.4(a)(4) we request that you review the attached maps and identify any cultural properties that may be of interest to the Seminole Tribe of Florida. If so, please contact the Louisiana State Historic Preservation Officer at (225) 342-8170 or Mr. DeMarcay at the number above.

Thank you for your help with this project. If you have any questions or require additional information, please contact Gary DeMarcay.

Sincerely,

Joan M. Exnicios
Chief, New Orleans Environmental Branch

cc: Willard S. Steele, Tribal Historic Preservation Officer
w/attachments

DEPARTMENT OF THE ARMY
NEW ORLEANS DISTRICT, CORPS OF ENGINEERS
P.O. BOX 60267
NEW ORLEANS, LOUISIANA 70160-0267
FEBRUARY 5, 2010

Regional Planning and
Environmental Division, South
New Orleans Environmental Branch

Principal Chief Oscola Clayton M. Sylestine
Alabama Coushatta Tribe of Texas
571 State Park Rd. 56
Livingston, TX 77351

Dear Principal Chief Sylestine:

RE: Initiation of Section 106 Consultation for the Mississippi River Gulf Outlet Ecosystem Restoration Project in Orleans and St. Bernard Parishes, Louisiana.

US Army Corps of Engineers, New Orleans District (CEMVN) in accordance with 36 CFR Part 800.4(a)(1) is enclosing a map showing the Area of Potential Effect (APE) for the above project. Those areas to be affected are those identified in the legend found in the upper right hand corner of the map. As per 36 CFR Part 800.3(a) we believe that this undertaking as defined in Part 800.16(y) has the potential to have an effect on historic properties. Therefore as per Part 800.3 we are formally initiating the Section 106 process.

Elements of the project consist in marsh creation, marsh nourishment, ridge restoration, swamp nourishment, swamp restoration and shoreline protection. All of these actions, except possibly the ridge restoration will involve the excavation of floatation channels and offshore borrow areas. CEMVN plans to visit all existing sites to record the current condition and make preliminary determinations of eligibility and survey all high probability areas. All offshore activity will be surveyed using side-scan sonar, magenetometer and in the case of flotation channels, sub-bottom profiler. The use of the sub-bottom profiler will be to attempt to identify offshore archaeological sites.

A copy of this letter and the attachments are being sent to the Alabama Coushatta Tribe of Texas Historic Preservation Officer Bryant Celestine. If you wish to see the attachments, please contact Mr. Celestine, or, if you wish you may contact Mr. Gary DeMarcay of my staff at (504) 862-2039.

In accordance with 36CFR Part 800.4(a)(4) we request that you review the attached maps and identify any cultural properties that may be of interest to the Alabama Coushatta Tribe of Texas. If so, please contact the Louisiana State Historic Preservation Officer at (225) 342-8170 or Mr. DeMarcay at the number above.

Thank you for your help with this project. If you have any questions or require additional information, please contact Mr. DeMarcay.

Sincerely,

Joan Exnicios
Chief, New Orleans Environmental Branch

cc: Bryant J. Celestine
Historic Preservation Officer
w/attachments

DEPARTMENT OF THE ARMY
NEW ORLEANS DISTRICT, CORPS OF ENGINEERS
P.O. BOX 60267
NEW ORLEANS, LOUISIANA 70160-0267
FEBRUARY 5, 2010

Regional Planning and
Environmental Division, South
New Orleans Environmental Branch

Chairperson LaRue Parker
Caddo Nation of Oklahoma
P.O. Box 487
Binger, OK 73009

Dear Chairperson Parker:

RE: Initiation of Section 106 Consultation for the Mississippi River Gulf Outlet Ecosystem Restoration Project in Orleans and St. Bernard Parishes, Louisiana.

US Army Corps of Engineers, New Orleans District (CEMVN) in accordance with 36 CFR Part 800.4(a)(1) is enclosing a map showing the Area of Potential Effect (APE) for the above project. Those areas to be affected are those identified in the legend found in the upper right hand corner of the map. As per 36 CFR Part 800.3(a) we believe that this undertaking as defined in Part 800.16(y) has the potential to have an effect on historic properties. Therefore as per Part 800.3 we are formally initiating the Section 106 process.

Elements of the project consist in marsh creation, marsh nourishment, ridge restoration, swamp nourishment, swamp restoration and shoreline protection. All of these actions, except possibly the ridge restoration will involve the excavation of floatation channels and offshore borrow areas. CEMVN plans to visit all existing sites to record the current condition and make preliminary determinations of eligibility and survey all high probability areas. All offshore activity will be surveyed using side-scan sonar, magenetometer and in the case of flotation channels, sub-bottom profiler. The use of the sub-bottom profiler will be to attempt to identify offshore archaeological sites.

A copy of this letter and the attachments are being sent to the Caddo Nation of Oklahoma Tribal Historic Preservation Officer Mr. Robert Cast. If you wish to see the attachments, please contact Mr. Cast, or, if you wish you may contact Mr. Gary DeMarcay of my staff at (504) 862-2039.

In accordance with 36CFR Part 800.4(a)(4) we request that you review the attached maps and identify any cultural properties that may be of interest to the Caddo Nation of Oklahoma. If so, please contact the Louisiana State Historic Preservation Officer at (225) 342-8170 or Mr. DeMarcay at the number above.

Thank you for your help with this project. If you have any questions or require additional information, please contact Gary DeMarcay.

Sincerely,

Joan M Exnicios

Joan M. Exnicios
Chief, New Orleans Environmental Branch

cc: Robert Cast, Historic Preservation Officer
w/attachments

DEPARTMENT OF THE ARMY
NEW ORLEANS DISTRICT, CORPS OF ENGINEERS
P.O. BOX 60267
NEW ORLEANS, LOUISIANA 70160-0267
FEBRUARY 5, 2010

Regional Planning and
Environmental Division, South
New Orleans Environmental Branch

Principal Chief Enoch Kelley Haney
Seminole Nation of Oklahoma
P.O. Box 1498
Wewoka, OK 74884

Dear Chief Haney:

RE: Initiation of Section 106 Consultation for the Mississippi River Gulf Outlet Ecosystem Restoration Project in Orleans and St. Bernard Parishes, Louisiana.

US Army Corps of Engineers, New Orleans District (CEMVN) in accordance with 36 CFR Part 800.4(a)(1) is enclosing a map showing the Area of Potential Effect (APE) for the above project. Those areas to be affected are those identified in the legend found in the upper right hand corner of the map. As per 36 CFR Part 800.3(a) we believe that this undertaking as defined in Part 800.16(y) has the potential to have an effect on historic properties. Therefore as per Part 800.3 we are formally initiating the Section 106 process.

Elements of the project consist in marsh creation, marsh nourishment, ridge restoration, swamp nourishment, swamp restoration and shoreline protection. All of these actions, except possibly the ridge restoration will involve the excavation of floatation channels and offshore borrow areas. CEMVN plans to visit all existing sites to record the current condition and make preliminary determinations of eligibility and survey all high probability areas. All offshore activity will be surveyed using side-scan sonar, magenetometer and in the case of flotation channels, sub-bottom profiler. The use of the sub-bottom profiler will be to attempt to identify offshore archaeological sites.

A Copy of this letter and the attachments are being sent to the Seminole Nation of Oklahoma Tribal Historic Preservation Officer, Ms. Natalie Deere. If you wish to see the attachments, please contact Ms. Deere, or, if you wish you may contact Mr. Gary DeMarcay of my staff at (504) 862-2039.

In accordance with 36CFR Part 800.4(a)(4) we request that you review the attached maps and identify any cultural properties that may be of interest to the Seminole Nation of Oklahoma. If so, please contact the Louisiana State Historic Preservation Officer at (225) 342-8170 or Mr. DeMarcay at the number above.

Thank you for your help with this project. If you have any questions or require additional information, please contact Gary DeMarcay.

Sincerely,

Joan M. Exnicios
Chief, New Orleans Environmental Branch

cc: Natalie Deere
Tribal Historic Preservation Officer
Enclosure

DEPARTMENT OF THE ARMY
NEW ORLEANS DISTRICT, CORPS OF ENGINEERS
P.O. BOX 60267
NEW ORLEANS, LOUISIANA 70160-0267
FEBRUARY 5, 2010

Regional Planning and
Environmental Division, South
New Orleans Environmental Branch

Chief Beasley Denson
Mississippi Band of Choctaw Indians
P.O. Box 6257
Choctaw, MS 39350

Dear Chief Denson:

RE: Initiation of Section 106 Consultation for the Mississippi River Gulf Outlet Ecosystem Restoration Project in Orleans and St. Bernard Parishes, Louisiana.

US Army Corps of Engineers, New Orleans District (CEMVN) in accordance with 36 CFR Part 800.4(a)(1) is enclosing a map showing the Area of Potential Effect (APE) for the above project. Those areas to be affected are those identified in the legend found in the upper right hand corner of the map. As per 36 CFR Part 800.3(a) we believe that this undertaking as defined in Part 800.16(y) has the potential to have an effect on historic properties. Therefore as per Part 800.3 we are formally initiating the Section 106 process.

Elements of the project consist in marsh creation, marsh nourishment, ridge restoration, swamp nourishment, swamp restoration and shoreline protection. All of these actions, except possibly the ridge restoration will involve the excavation of floatation channels and offshore borrow areas. CEMVN plans to visit all existing sites to record the current condition and make preliminary determinations of eligibility and survey all high probability areas. All offshore activity will be surveyed using side-scan sonar, magenetometer and in the case of flotation channels, sub-bottom profiler. The use of the sub-bottom profiler will be to attempt to identify offshore archaeological sites.

A Copy of this letter and the attachments are being sent to the Mississippi Band of Choctaw Indians tribal Historic Preservation Officer, Mr. Kenneth Carleton. If you wish to see the attachments, please contact Mr. Carleton, or, if you wish you may contact Mr. Gary DeMarcay of my staff at (504) 862-2039.

In accordance with 36CFR Part 800.4(a)(4) we request that you review the attached maps and identify any cultural properties that may be of interest to the Mississippi Band of Choctaw Indians. If so, please contact the Louisiana State Historic Preservation Officer at (225) 342-8170 or Mr. DeMarcay at the number above.

Thank you for your help with this project. If you have any questions or require additional information, please contact Gary DeMarcay.

Sincerely,

Joan M. Exnicios
Chief, New Orleans Environmental Branch

cc: Kenneth H. Carleton, Historic Preservation Officer
w/attachments

DEPARTMENT OF THE ARMY
NEW ORLEANS DISTRICT, CORPS OF ENGINEERS
P.O. BOX 60267
NEW ORLEANS, LOUISIANA 70160-0267
FEBRUARY 5, 2010

Regional Planning and
Environmental Division, South
New Orleans Environmental Branch

Chairman John Paul Darden
Chitimacha Tribe of Louisiana
P.O. Box 661
Charenton, LA 70523

Dear Chairman Darden:

RE: Initiation of Section 106 Consultation for the Mississippi River Gulf Outlet Ecosystem Restoration Project in Orleans and St. Bernard Parishes, Louisiana.

US Army Corps of Engineers, New Orleans District (CEMVN) in accordance with 36 CFR Part 800.4(a)(1) is enclosing a map showing the Area of Potential Effect (APE) for the above project. Those areas to be affected are those identified in the legend found in the upper right hand corner of the map. As per 36 CFR Part 800.3(a) we believe that this undertaking as defined in Part 800.16(y) has the potential to have an effect on historic properties. Therefore as per Part 800.3 we are formally initiating the Section 106 process.

Elements of the project consist in marsh creation, marsh nourishment, ridge restoration, swamp nourishment, swamp restoration and shoreline protection. All of these actions, except possibly the ridge restoration will involve the excavation of floatation channels and offshore borrow areas. CEMVN plans to visit all existing sites to record the current condition and make preliminary determinations of eligibility and survey all high probability areas. All offshore activity will be surveyed using side-scan sonar, magenetometer and in the case of flotation channels, sub-bottom profiler. The use of the sub-bottom profiler will be to attempt to identify offshore archaeological sites.

A Copy of this letter and the attachments are being sent to the Chitimacha Tribe of Louisiana Cultural Director Ms. Kimberly Walden. If you wish to see the attachments, please contact Ms. Walden, or, if you wish, you may contact Mr. Gary DeMarcay of my staff at (504) 862-2039.

In accordance with 36CFR Part 800.4(a)(4) we request that you review the attached maps and identify any cultural properties that may be of interest to the Chitimacha Tribe of Louisiana. If so, please contact the Louisiana State Historic Preservation Officer at (225) 342-8170 or Mr. DeMarcay at the number above.

Thank you for your help with this project. If you have any questions or require additional information, please contact Mr. DeMarcay.

Sincerely,

Joan M. Exnicios

Joan M. Exnicios
Chief, New Orleans Environmental Branch

cc: Kimberly S. Walden, Cultural Director w/atttachments

DEPARTMENT OF THE ARMY
NEW ORLEANS DISTRICT, CORPS OF ENGINEERS
P.O. BOX 60267
NEW ORLEANS, LOUISIANA 70160-0267
FEBRUARY 5, 2010

Regional Planning and
Environmental Division, South
New Orleans Environmental Branch

Chief Gregory E. Pyle
Choctaw Nation of Oklahoma
P.O. Box Drawer 1210
Durant, OK 74701

Dear Chief Pyle:

RE: Initiation of Section 106 Consultation for the Mississippi River Gulf Outlet Ecosystem Restoration Project in Orleans and St. Bernard Parishes, Louisiana.

US Army Corps of Engineers, New Orleans District (CEMVN) in accordance with 36 CFR Part 800.4(a)(1) is enclosing a map showing the Area of Potential Effect (APE) for the above project. Those areas to be affected are those identified in the legend found in the upper right hand corner of the map. As per 36 CFR Part 800.3(a) we believe that this undertaking as defined in Part 800.16(y) has the potential to have an effect on historic properties. Therefore as per Part 800.3 we are formally initiating the Section 106 process.

Elements of the project consist in marsh creation, marsh nourishment, ridge restoration, swamp nourishment, swamp restoration and shoreline protection. All of these actions, except possibly the ridge restoration will involve the excavation of floatation channels and offshore borrow areas. CEMVN plans to visit all existing sites to record the current condition and make preliminary determinations of eligibility and survey all high probability areas. All offshore activity will be surveyed using side-scan sonar, magenetometer and in the case of flotation channels, sub-bottom profiler. The use of the sub-bottom profiler will be to attempt to identify offshore archaeological sites.

A Copy of this letter and the attachments are being sent to the Choctaw Nation of Oklahoma Tribal Historic Preservation Officer Mr. Terry Cole. If you wish to see the attachments, please contact Mr. Cole, or, if you wish you may contact Mr. Gary DeMarcay of my staff at (504) 862-2039.

In accordance with 36CFR Part 800.4(a)(4) we request that you review the attached maps and identify any cultural properties that may be of interest to the Choctaw Nation of Oklahoma. If so, please contact the Louisiana State Historic Preservation Officer at (225) 342-8170 or Mr. DeMarcay at the number above.

Thank you for your help with this project. If you have any questions or require additional information, please contact Mr. DeMarcay.

Sincerely,

Joan M. Exnicios
Chief, New Orleans Environmental Branch

cc: Terry D. Cole, Director/THPO
w/attachments

DEPARTMENT OF THE ARMY
NEW ORLEANS DISTRICT, CORPS OF ENGINEERS
P.O. BOX 60267
NEW ORLEANS, LOUISIANA 70160-0267
FEBRUARY 5, 2010

Regional Planning and
Environmental Division, South
New Orleans Environmental Branch

Principal Chief Christine Norris
Jena Band of the Choctaw Indians
P.O. Box 14
Jena, LA 71342

Dear Chief Norris:

RE: Initiation of Section 106 Consultation for the Mississippi River Gulf Outlet Ecosystem Restoration Project in Orleans and St. Bernard Parishes, Louisiana.

US Army Corps of Engineers, New Orleans District (CEMVN) in accordance with 36 CFR Part 800.4(a)(1) is enclosing a map showing the Area of Potential Effect (APE) for the above project. Those areas to be affected are those identified in the legend found in the upper right hand corner of the map. As per 36 CFR Part 800.3(a) we believe that this undertaking as defined in Part 800.16(y) has the potential to have an effect on historic properties. Therefore as per Part 800.3 we are formally initiating the Section 106 process.

Elements of the project consist in marsh creation, marsh nourishment, ridge restoration, swamp nourishment, swamp restoration and shoreline protection. All of these actions, except possibly the ridge restoration will involve the excavation of floatation channels and offshore borrow areas. CEMVN plans to visit all existing sites to record the current condition and make preliminary determinations of eligibility and survey all high probability areas. All offshore activity will be surveyed using side-scan sonar, magenetometer and in the case of flotation channels, sub-bottom profiler. The use of the sub-bottom profiler will be to attempt to identify offshore archaeological sites.

A Copy of this letter and the attachments are being sent to the Jena Band of Choctaw Indians Tribal Historic Preservation Officer, Mr. Michael Tarpley and Ms. Lillie McCormick, Environmental Director. If you wish to see the attachments, please contact Mr. Tarpley or Ms. McCormick or, if you wish you may contact Mr. Gary DeMarcay of my staff at (504) 862-2039.

In accordance with 36CFR Part 800.4(a)(4) we request that you review the attached maps and identify any cultural properties that may be of interest to the Alabama Coushatta Tribe of Texas. If so, please contact the Louisiana State Historic Preservation Officer at (225) 342-8170 or Mr. DeMarcay at the number above.

Thank you for your help with this project. If you have any questions or require additional information, please contact Gary DeMarcay at the number above.

Sincerely,

Joan M. Exnicios
Chief, New Orleans Environmental Branch

Cc: Michael Tarpley, Tribal Historic Preservation Officer
Lillie McCormick, Environmental Director
w/attachments

DEPARTMENT OF THE ARMY
NEW ORLEANS DISTRICT, CORPS OF ENGINEERS
P.O. BOX 60267
NEW ORLEANS, LOUISIANA 70160-0267
FEBRUARY 5, 1010

Regional Planning and
Environmental Division, South
New Orleans Environmental Branch

Chairman Earl J. Barbry, Sr.
Tunica-Biloxi Tribe of Louisiana
P.O. Box 1589
Marksville, LA 71351

Dear Chairman Barbry:

RE: Initiation of Section 106 Consultation for the Mississippi River Gulf Outlet Ecosystem Restoration Project in Orleans and St. Bernard Parishes, Louisiana.

US Army Corps of Engineers, New Orleans District (CEMVN) in accordance with 36 CFR Part 800.4(a)(1) is enclosing a map showing the Area of Potential Effect (APE) for the above project. Those areas to be affected are those identified in the legend found in the upper right hand corner of the map. As per 36 CFR Part 800.3(a) we believe that this undertaking as defined in Part 800.16(y) has the potential to have an effect on historic properties. Therefore as per Part 800.3 we are formally initiating the Section 106 process.

Elements of the project consist in marsh creation, marsh nourishment, ridge restoration, swamp nourishment, swamp restoration and shoreline protection. All of these actions, except possibly the ridge restoration will involve the excavation of floatation channels and offshore borrow areas. CEMVN plans to visit all existing sites to record the current condition and make preliminary determinations of eligibility and survey all high probability areas. All offshore activity will be surveyed using side-scan sonar, magenetometer and in the case of flotation channels, sub-bottom profiler. The use of the sub-bottom profiler will be to attempt to identify offshore archaeological sites.

A Copy of this letter and the attachments are being sent to the Tunica-Biloxi Tribe of Louisiana Cultural Director Mr. Earl Barbry, Jr. If you wish to see the attachments, please contact Mr. Barbry, or, if you wish you may contact Mr. Gary DeMarcay of my staff at (504) 862-2039.

In accordance with 36CFR Part 800.4(a)(4) we request that you review the attached maps and identify any cultural properties that may be of interest to the Tunica-Biloxi Tribe of Louisiana. If so, please contact the Louisiana State Historic Preservation Officer at (225) 342-8170 or Mr. DeMarcay at the number above.

Thank you for your help with this project. If you have any questions or require additional information, please contact Gary DeMarcay.

Sincerely,

Joan M. Exnicios
Chief, New Orleans Environmental Branch

cc: Earl Barbry, Jr. Cultural Director
w/ Enclosure

Appendix E

SECTION 404(b)(1) EVALUATION REPORT

MRGO Ecosystem Restoration Project

Basis for Analysis

Following the identification of the tentatively selected plan (TSP), a construction sequence was developed. Assumptions factoring into the construction sequence include production rates for building rock projects, dredge equipment availability, land loss rates, and the limitation of alternating dredging cycles in the lobes of Lake Borgne. The Agency coordination for the MRGO plan was based on this construction sequence and without the incorporation of Operation and maintenance (O&M). However, due to uncertainties associated with the timing and availability of funding for the plan, only those features that are sustainable without the implementation of any other feature (such as a diversion) are recommended for construction at this time. A tiered implementation approach has been developed for the TSP (Table 2-28 of EIS) based on these uncertainties. In addition, O&M has been included in the TSP. The benefits have been recalculated by tier utilizing the previously developed construction sequence and without O&M. Due to the uncertainty of when each feature will be implemented, analysis may require updating in later phases of the project. The USACE will continue to coordinate with the agencies throughout the project study and implementation.

Draft Implementation Plan (used to calculate benefits without O&M)	
Measure	**Description**
Construction Year 1	
LS1	47,000 linear feet (8.9 miles) of shoreline protection beginning at the terminus of the Bayou Dupre supplemental shoreline project, extending around Proctor Point to the West of Shell Beach supplemental funding shoreline protection.
MRGO1	3,850 feet of new foreshore protection between MRGO miles 56.6 and 57.4. This stone protection feature is embedded within the limits of MRGO7.
MRGO6	8,132 linear feet of new, non-continuous foreshore protection between MRGO miles 36.0 and 34.2, immediately east of the existing stone closure of the MRGO. MRGO6 ties into an existing foreshore dike immediately downstream.
LM1	3,240 acres of marsh restoration from open water and nourishment of 777 adjacent acres in the Golden Triangle, south of the IHNC Surge Barrier. Approximately 12.8 million cubic yards of borrow to be obtained from Lake Borgne Borrow Area 6.
LM4	289 acres of marsh restoration and nourishment of 95 adjacent acres of marsh in the portion of the Golden Triangle bordered by the GIWW, the IHNC Surge Barrier, and the MRGO. Approximately 1.4 million cubic yards of borrow material would be obtained from Lake Borgne Area 6.
LM2	422 acres of marsh restoration and 2,523 acres of marsh nourishment in the area between Proctor Point and the MRGO. Approximately 4.9 million cubic yards of borrow material to be obtained from Lake Borgne Borrow Area 3.

Draft Implementation Plan (used to calculate benefits without O&M)	
Measure	**Description**
Construction Year 2	
BS1	Approximately 51,000 linear feet (9.7 miles) of shoreline protection along the southeast shore of Lake Borgne. This feature begins at the northern terminus of the Biloxi Marsh Shoreline Protection Project (PO-72) south of Point aux Marchettes and extends north to Malheureax Point.
BS2	Approximately 39,600 linear feet (7.5 miles) of artificial oyster reef development on the Chandeleur Sound side of the Biloxi Marsh between Eloi Point and the mouth of Bayou La Loutre.
CC4-A	420 acres of cypress restoration in the Bienvenue Triangle. Approximately 2.9 million cubic yards of material to be obtained from the Mississippi River.
BR1	Approximately 48 acres of ridge restoration on the south bank of Bayou La Loutre. 425,000 cubic yards of silty sand material to be obtained from the Mississippi River.
CM2	795 acres of marsh restoration and 190 acres of marsh nourishment north of Paris Road. 3.3 million cubic yards of material are required, 2.6 million cubic yards of which can be obtained from the adjacent reach of the GIWW. The remaining material would be obtained from the Michoud Canal.
Construction Year 3	
ES1	24,000 linear feet (4.6 miles) of shoreline protection from the south shore of Lake Pontchartrain to the terminus of the existing Bayou Chevee shoreline protection feature.
ES2	30,750 linear feet of shoreline protection in Lake Pontchartrain between Chef Menteur Pass and The Rigolets.
ES3	70,000 feet of foreshore protection along Lake Borgne between Alligator Point and The Rigolets.
Construction Year 4	
HM1	757 acres of marsh restoration and the nourishment of 973 acres of adjacent marsh, located in the Hopedale area bordered by MRGO to the northeast. 4.1 million cubic yards of dredged material would be obtained from Lake Borgne Borrow Area 2.
TM1	760 acres of marsh restoration and 223 acres of marsh nourishment, requiring approximately 3.2 million cubic yards of material to be obtained from Lake Borgne Borrow Site 2.
TM2	770 acres of marsh restoration and 3,400 acres of marsh nourishment in the vicinity of Lake Ameda. Approximately 7.4 million cubic yards of borrow material would be obtained from Lake Borgne Borrow Area 2.
MRGO5	188 acres of marsh would be restored behind 14,485 linear feet of vinyl sheet pile wall to establish the shoreline. 2.7 million cubic yards of material would be obtained from Lake Borgne.

Draft Implementation Plan (used to calculate benefits without O&M)	
Measure	**Description**
MRGO8	200 acres of marsh restoration adjacent to approximately 20,640 linear feet of bank reclamation constructed using vinyl sheet pile wall. 3.2 million cubic yards of material would be obtained from Lake Borgne. Approximately 13,572 linear feet of new foreshore protection would also be included between approximate channel miles 51.0 and 48.3
Construction Year 5	
MRGO7	91 acres of marsh restoration adjacent to approximately 9,700 linear feet of bankline reclamation, consisting of 9,700 linear feet of vinyl sheet pile wall. 1.3 million cubic yards of material would be obtained from Lake Borgne.
EM1	1,175 acres of marsh restoration and nourishment of 2,830 acres of surrounding marsh in the area bounded by the Lake Pontchartrain shoreline, Chef Menteur Pass, and the levee. Approximately 8.1 million cubic yards of material would be obtained from Lake Borgne Borrow Area 6.
Construction Year 6	
LM3	911 acres of marsh creation and 950 acres of marsh nourishment in South Lake Borgne north of Lena Lagoon in the area bounded by the lake, Bayou St. Malo, MRGO, and Doulets Canal. Approximately 4.6 million cubic yards of borrow to be obtained from Lake Borgne Borrow Area 2.
BM1	8,295 acres of marsh nourishment along the south shore of Lake Borgne. 10.8 million cubic yards of material would be obtained from Lake Borgne Borrow Area 2.
Construction Year 7	
CM1	1,240 acres of marsh nourishment south of Paris Road between cypress restoration feature CC3 and the Chalmette Loop Levee. Approximately 3.0 million cubic yards of material would be dredged from Lake Borgne Borrow Area 5 for this feature.
CM3	300 acres of marsh restoration and 215 acres of marsh nourishment in the area north of Bayou Dupre and south of MRGO. 1.9 million cubic yards of borrow material would be obtained from Lake Borgne Borrow Area 5.
CM4	98 acres of marsh restoration and 129 acres of marsh nourishment south of Bayou Dupre. 900,000 cubic yards of dredged material would be obtained from Lake Borgne Borrow Area 4.
CM5	245 acres of marsh restoration and 70 acres of marsh nourishment in the area north of Bayou Bienvenue and Paris Road. 1.2 million cubic yards of material would be obtained from Lake Borgne Borrow Area 4.
Construction Year 8	
TM7	2,255 acres of marsh restoration and up to 3,338 acres of adjacent marsh nourishment on the east side of Bayou Terre aux Boeufs. 11.5 million cubic yards of material would be obtained from Lake Lery if available, but it is currently assumed that material will be obtained from Lake Borgne Borrow Area 2.

Draft Implementation Plan (used to calculate benefits without O&M)	
Measure	**Description**
TM8	1,511 acres of marsh restoration on the east side of Bayou Terre aux Boeufs in the vicinity of Delacroix. 5.5 million cubic yards of material would be dredged from Lake Lery if possible, but it is currently assumed that material will be obtained from Lake Borgne Borrow Area 2.
EM2	1,095 acres of marsh nourishment on Hog Island, located between the west and east mouth of the West Pearl River. Approximately 2.2 million cubic yards of dredged material would be obtained from Lake Borgne Borrow Area 8.
EM3	861 acres of marsh restoration and 180 acres of adjacent marsh nourishment in the area bounded by Highway 433, Little Lagoon, Salt Bayou and Highway 90. Approximately 3.5 million cubic yards of dredged material would be obtained from Lake Borgne Borrow Area 8.
EM4	2,625 acres of marsh restoration and 1,455 acres of adjacent marsh nourishment in the area bounded by Salt Bayou to the north, the West Pearl River to the east, the Rigolets to the south and Highway 80 to the north. Approximately 10.6 million cubic yards of material would be obtained from Lake Borgne Borrow Area 8.
Construction Year 9	
CC1	1,020 acres of cypress swamp restoration and 953 acres of cypress swamp nourishment in the area north of the existing Violet Canal along the Forty Arpent levee. 8.5 million cubic yards of borrow material to be obtained from Lake Borgne Borrow Area 5.
CC2	250 acres of cypress swamp restoration and 250 acres of swamp nourishment to the northeast of CC1. 2.4 million cubic yards of borrow material to be obtained from Lake Borgne Borrow Area 5.
CC3	370 acres of cypress swamp restoration and 790 acres of swamp nourishment along the Forty Arpent Levee south of Paris Road. Approximately 5.3 million cubic yards of material to be obtained from Lake Borgne Borrow Area 5.
CC4	1,465 acres of cypress swamp restoration in the open water areas adjacent to the Forty Arpent Levee north of Paris Road, including the Bienvenue Triangle area in Orleans Parish. 11.3 million cubic yards of borrow material to be obtained from Lake Borgne Borrow Area 6.
Construction Year 10	
CC5	1,120 acres of swamp restoration and 1,645 acres of swamp nourishment south of the Violet Canal along the Forty Arpent Levee and the Chalmette Loop Levee. 9.6 million cubic yards of borrow material to be obtained from Lake Borgne Borrow Area 4.
CC6	1,028 acres of swamp restoration and 1,540 acres of swamp nourishment in the southwest corner of the Central Wetlands. 11.2 million cubic yards of borrow material would be obtained Lake Borgne Borrow Area 4.
Maintenance As Needed	

Draft Implementation Plan (used to calculate benefits without O&M)	
Measure	**Description**
MRGO2	Repair and maintenance of approximately 15,070 linear feet (2.85 miles) of foreshore protection between Mile 44.4 and 39.9 of the MRGO.
MRGO3	Repair and maintenance of existing approximately 10,420 linear feet (1.97 miles) of foreshore protection between approximately Mile 56 to 51 of the MRGO.
MRGO4	Repair and maintenance of approximately 6,690 linear feet (1.27 miles) of existing retention dike MRGO Miles 36.6 to 37.1 and MRGO Miles 33.9 to 32.9.

TABLE OF CONTENTS

1.0 PROJECT DESCRIPTION 1
1.1 LOCATION 1
1.2 PURPOSE 1
1.3 RECOMMENDED PLAN 3
1.4 AUTHORITY 14
1.5 GENERAL DESCRIPTION OF DREDGED AND FILL MATERIAL 16
1.5.1 General Characteristics 16
1.5.2 Quantity of Material 16
1.6 DESCRIPTION OF PROPOSED DISCHARGE SITES 16
1.6.1 Location and Size 16
1.6.2 Type of Site/Habitat of Discharge Sites 16
1.6.3 Timing and Duration of Discharge 17
1.7 DESCRIPTION OF DISCHARGE METHODS 17
2.0 FACTUAL DETERMINATIONS 18
2.1 PHYSICAL SUBSTRATE DETERMINATIONS 18
2.1.1 Substrate Elevation and Slope 18
2.1.2 Sediment Type 25
2.1.3 Dredged and Fill Material Movement 32
2.1.4 Physical Effects on Substrate 35
2.1.5 Duration and Extent of Change 39
2.1.6 Actions Taken to Minimize Adverse Impacts 39
2.2 WATER COLUMN DETERMINATIONS 43
2.2.1 Salinity 43
2.2.2 Water Chemistry 50
2.2.2.1 pH 50
2.2.2.2 Water Column Impacts 56
2.2.3 Clarity/Turbidity 70
2.2.5 Odor 84
2.2.6 Taste 87
2.2.7 Dissolved Oxygen Levels 87
2.2.8 Nutrients and Eutrophication 95
2.2.9 Actions Taken to Minimize Adverse Impacts 100
2.3.1 Actions Taken to Minimize Impacts 111
2.4 CONTAMINANT DETERMINATIONS 114
2.5 AQUATIC ECOSYSTEM ORGANISM DETERMINATION 124
2.5.1 Effects on Plankton 124
2.5.2 Effects on Benthos 126
2.5.2.1 Physical Effect on Benthos 129
2.5.2.2 Toxic Effect and Bioaccumulation on Benthos 131
2.5.3 Effects on Nekton 134
2.5.4 Effects on Aquatic Food Web 136
2.5.5 Special Aquatic Sites Effects 139
2.5.5.1 Sanctuaries and Refuges 139
2.5.5.2 Wetlands 141
2.5.5.3 Mud Flats 144
2.5.5.4 Vegetated Shallows 146

2.5.5.5 Coral Reefs. *148*
2.5.5.6 Riffle Pool Complexes. *150*
2.5.6 Effects on Threatened and Endangered Species 152
2.5.7 Other Wildlife 156
2.6 PROPOSED DISCHARGE SITE DETERMINATIONS 159
2.7 DETERMINATION OF CUMULATIVE EFFECTS ON THE AQUATIC ECOSYSTEM 159
2.7.1 Potential Effects on Aquatic Ecosystems 159
2.7.2 Potential Effects on Human Use Characteristics 162
2.7.2.1 Municipal and Private Water Supply *162*
2.7.2.2 Water Related Restoration *162*
2.8 DETERMINATION OF SECONDARY EFFECTS ON THE AQUATIC ECOSYSTEM 162
3.0 FINDINGS OF COMPLIANCE OR NON-COMPLIANCE WITH THE RESTRICTIONS ON DISCHARGE 165
3.1 ADAPTION OF THE SECTION 404(B)(1) GUIDELINES TO THIS EVALUATION 165
3.2 EVALUATION OF AVAILABILITY OF PRACTICABLE ALTERNATIVES TO THE PROPOSED DISCHARGE THAT WOULD HAVE LESS ADVERSE IMPACT ON THE AQUATIC ECOSYSTEM 165
3.3 DETERMINATION OF COMPLIANCE WITH APPLICABLE WATER QUALITY STANDARDS 165
3.4 COMPLIANCE WITH APPLICABLE TOXIC EFFLUENT STANDARD OF PROHIBITION UNDER SECTION 307 OF THE CLEAN WATER ACT 165
3.5 COMPLIANCE WITH THE ENDANGERED SPECIES ACT OF 1973 166
3.6 COMPLIANCE WITH THE SPECIFIED PROTECTION MEASURES FOR MARINE SANCTUARIES DESIGNATED BY THE MARINE PROTECTION, RESEARCH, AND SANCTUARIES ACT OF 1972 166
3.7 EVALUATION OF EXTENT OF DEGRADATION OF THE WATERS OF THE UNITES STATES 166
3.8 APPROPRIATE AND PRACTICABLE STEPS TAKEN TO MINIMIZE POTENTIAL ADVERSE IMPACTS OF THE DISCHARGE ON THE AQUATIC ECOSYSTEM 166
4.0 EVALUATION RESPONSIBILITY 172
5.0 REFERENCES 174

LIST OF FIGURES

1-1 Recommended Plan Restoration Measures..... 1

1-2 Borrow Sites for Recommended Plan..... 13

LIST OF TABLES

1-1 Restoration Features of the Recommended Plan..... 3

1-2 Acreages/Linear Footage of Alternative C..... 13

2-1 Borrow Area Physical Properties, Including Average Percent Sand and Average Percent Silt and Clay For All Samples Associated With Each Borrow Area..... 25

ANNEX 1: DATA TABLES

See Annex 1 for list of data tables

1.0 PROJECT DESCRIPTION

1.1 Location

The proposed work would be performed within portions of the Mississippi River Deltaic Plain within coastal southeast Louisiana and parts of southwest Mississippi (**figure 1-1**). **Figure 1-1** also shows the locations of all the restoration features being considered under the recommended plan. The project is bounded roughly to the north by Interstate Highway 10, to the south by the Gulf of Mexico, to the east by the Chandeleur Island Chain, and to the west by the Mississippi River. Work is planned to impact the Lake Borgne ecosystem, the Breton and Grand Gossier Islands (segments of the lower Chandeleur Island chain), Bayou Terre aux Boeufs ridge, Western Mississippi Sound, and the Pontchartrain Basin.

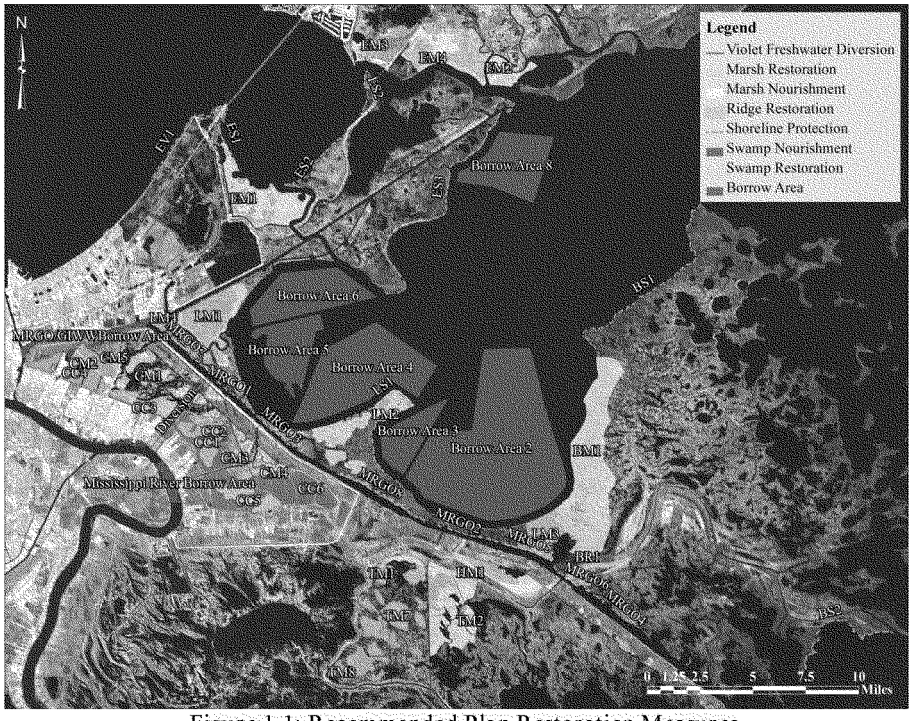


Figure 1-1: Recommended Plan Restoration Measures

1.2 Purpose

The Pontchartrain Basin as a whole has been cut-off from the natural flooding of the Mississippi River by the extensive Mississippi River levee system. The loss of freshwater inflow has led to poor productivity of the wetlands partly due to the lack of vital nutrients and sediments. Poor

productivity combined with subsidence has left the wetlands vulnerable to saltwater intrusion and sea level rise. Subsidence is attributed to both natural and human induced causes such as oil and gas, and groundwater withdrawals. Accretion (soil build-up) is not keeping pace with subsidence as a result of reduced biological productivity and lack of inorganic sediment. The natural flow and drainage patterns have been impacted by a complex of levee systems throughout the area, drainage channels, pipelines and other utilities, roadways and most importantly navigation channels. Navigation channels and other channels serve as a conduit for tidal flows and saltwater intrusion subjecting the sensitive marsh to the erosive forces of wind and wave action.

Congress authorized the Mississippi River Gulf Outlet (MRGO) in 1956 as a Federal navigation channel to provide a short route between the Port of New Orleans and the Gulf of Mexico. It was authorized as a 36-foot-deep, 500-foot bottom width waterway (38-foot-deep, 600-foot wide at the Gulf of Mexico entrance) extending from the Inner Harbor Navigation Canal (IHNC) to the 38-foot depth contour in the Gulf of Mexico. Construction of the channel began in 1958 and was completed in 1968. Following the aftermath of Hurricane Katrina, the depth of the channel was reduced to 22 feet impeding deep-draft navigation. As a result of the degraded condition of the channel Congress requested a plan for de-authorization of the MRGO (see Public Law 109-234) in June 2006. On June 5, 2008, the MRGO navigation channel was officially de-authorized from the GIWW to the Gulf of Mexico as a federal navigation channel. As a result of the de-authorization and to prevent deep draft navigation, a rock closure structure was constructed across the MRGO near the Bayou La Loutre Ridge in St. Bernard Parish, Louisiana. The barrier structure was completed in late August 2009.

Construction and maintenance of the MRGO caused widespread wetland loss and damages to estuarine habitats from the outer marshes in Breton Sound to the swamps and tidal fresh marsh in the western reaches of the Lake Borgne basin. Land loss, bank/shoreline erosion, habitat change and loss, modification of natural hydrology, retreating and eroding barrier islands, ridge habitat degradation and destruction, invasive species introduction and spread, marsh herbivory, and increased susceptibility to storm surge are some of the direct and indirect effects the MRGO channel has caused. Construction of the MRGO channel resulted in the conversion of 19,400 acres of wetlands and 4,750 acres of shallow open water to deep open water or spoil. Estimated habitat shifts caused by saline waters brought in by the MRGO are believed to have caused 3,350 acres of fresh/intermediate marsh and 8,000 acres of swamp to convert to brackish marsh and 19,170 acres of brackish marsh and swamp to convert to saline marsh in areas adjacent to MRGO (USACE, 1999).

Ecosystem restoration is one of the primary missions of the Corps of Engineers Civil Works program. Corps of Engineers Regulation (ER) 1105-2-100 Chapter 3-5 (b) (1) states:

The objective of ecosystem restoration is to restore degraded ecosystem structure, function, and dynamic processes to a less degraded, more natural condition. Restored ecosystems should mimic, as closely as possible, conditions which would occur in the area in the absence of human changes to the landscape and hydrology. Indicators of success would include the presence of a large variety of native plants and animals, the ability of the area to sustain larger numbers of certain indicator species or more biologically desirable species, and the ability of the restored

area to continue to function and produce the desired outputs with a minimum of continuing human intervention. Those restoration opportunities that are associated with wetlands, riparian and other floodplain and aquatic systems are most appropriate for Corps involvement.

Additionally, ER 1165-2-501 describes the US Army Corps of Engineers Water Resources Policies and Authorities, Civil Works Ecosystem Restoration Policy.

The overarching goals of the MRGO Ecosystem Restoration Plan are to restore the Lake Borgne ecosystem and the areas affected by the MRGO navigation channel, restore natural features of the ecosystem that would reduce or prevent damage from storm surge, and achieve ecosystem sustainability to the greatest degree possible. The goals would be met primarily through habitat restoration and increased freshwater input to the project area.

1.3 Recommended Plan

The recommended plan would restore approximately 55,026 acres of habitat in the study area, including 13,140 acres of fresh and intermediate marsh; 31,048 acres of brackish marsh; 10,318 acres of swamp; 466 acres of saline marsh; and 54 acres of ridge habitat. The recommended plan includes approximately 71 miles of shoreline protection. **Table 1-1** details each of the restoration features including area to be restored, the amount of borrow required, and the year the featured would be constructed.

Table 1-1: Recommended Plan Restoration Features

Measure	Description
Construction Year 1	
LS1	45,000 linear feet (8.5 miles) of shoreline protection beginning at the terminus of the Bayou Dupre supplemental shoreline project, extending around Proctor Point to the West of Shell Beach supplemental funding shoreline protection.
MRGO1	3,850 feet (0.75 miles) of new foreshore protection between MRGO miles 56.6 and 57.4. This stone protection feature is embedded within the limits of MRGO7.
MRGO6	8,132 linear feet (1.5 miles) of new, non-continuous foreshore protection between MRGO miles 36.0 and 34.4, immediately east of the existing stone closure of the MRGO. MRGO6 ties into an existing foreshore dike immediately downstream.
LM1	3,253 acres of marsh restoration from open water and nourishment of 1,064 adjacent acres in the Golden Triangle, south of the IHNC Surge Barrier. Approximately 14.3 million cubic yards of borrow to be obtained from North Lake Borgne Borrow Cycle 1.
LM4	225.5 acres of marsh restoration and nourishment of 54.8 adjacent acres of marsh in the portion of the Golden Triangle bordered by the GIWW, the IHNC Surge Barrier, and the MRGO. Approximately 1.16 million cubic yards of borrow material would be obtained from North Lake Borgne Borrow Cycle 1.
LM2	225 acres of marsh restoration and 2,628 acres of marsh nourishment in the area between Proctor Point and the MRGO. Approximately 4.45 million cubic yards of borrow material to be obtained from North Lake Borgne Borrow Cycle 1.

Table 1-1: Recommended Plan Restoration Features

Measure	Description
Construction Year 2	
BS1	Approximately 50,637 linear feet (9.5 miles) of shoreline protection along the southeast shore of Lake Borgne. This feature begins at the northern terminus of the Biloxi Marsh Shoreline Protection Project (PO-72) south of Point aux Marchettes and extends north to Malheureax Point.
BS2	Approximately 30,750 linear feet (5.8 miles) of artificial oyster reef development on the Chandeleur Sound side of the Biloxi Marsh between Eloi Point and the mouth of Bayou La Loutre.
CC4-A	400 acres of cypress restoration in the Bienvenue Triangle. Approximately 2.6 million cubic yards of silty sand material to be obtained from the Mississippi River between river miles 84.45R and 83R.
BR1	Approximately 54.1 acres of ridge restoration on the south bank of Bayou La Loutre. 400,000 cubic yards of silty sand material to be obtained from the Mississippi River between river miles 83R and 85R.
CM2	795 acres of marsh restoration and 190 acres of marsh nourishment north of Paris Road. Approximately 4.72 million cubic yards of material would be obtained from North Lake Borgne Borrow Cycle 2.
Construction Year 3	
ES1	20,530 linear feet (3.8 miles) of shoreline protection from the south shore of Lake Pontchartrain to the terminus of the existing Bayou Chevee shoreline protection feature.
ES2	30,750 (5.8 miles) linear feet of shoreline protection in Lake Pontchartrain between Chef Menteur Pass and The Rigolets.
ES3	69,900 linear feet (13.2 miles) of foreshore protection along Lake Borgne between Alligator Point and The Rigolets.
Construction Year 4	
HM1	757 acres of marsh restoration and the nourishment of 973 acres of adjacent marsh, located in the Hopedale area bordered by MRGO to the northeast. 4.5 million cubic yards of dredged material would be obtained from South Lake Borgne Borrow Cycle 4.
TM1	798 acres of marsh restoration and 223 acres of marsh nourishment, requiring approximately 3.8 million cubic yards of material to be obtained from South Lake Borgne Borrow Cycle 4.
TM2	770 acres of marsh restoration and 3,396 acres of marsh nourishment in the vicinity of Lake Ameda. Approximately 8.8 million cubic yards of borrow material would be obtained from South Lake Borgne Borrow Cycle 4.
MRGO5	202 acres of marsh would be restored behind 13,685 linear feet (2.5 miles) of vinyl sheet pile wall to establish the shoreline. 3 million cubic yards of material would be obtained from South Lake Borgne Borrow Cycle 4.
MRGO8	236 acres of marsh restoration adjacent to approximately 17,785 linear feet (3.3 miles) of bank reclamation constructed using vinyl sheet pile wall. 3.5 million cubic yards of material would be obtained from South Lake Borgne Cycle 4.. Approximately 14,225 linear feet (2.6 miles) of new foreshore protection would also be included between approximate channel miles 51.0 and 48.3.
Construction Year 5	
MRGO7	110 acres of marsh restoration adjacent to approximately 9,170 linear feet of bankline reclamation, consisting of 9,700 linear feet (1.8 miles) of vinyl sheet pile wall. 1.65 million cubic yards of material would be obtained from North Lake Borgne borrow cycle 5.
EM1	1,175 acres of marsh restoration and nourishment of 2,830 acres of surrounding marsh in the area bounded by the Lake Pontchartrain shoreline, Chef Menteur Pass, and the levee. Approximately 8.1 million cubic yards of material would be obtained from North Lake Borgne Borrow Cycle 5.
Construction Year 6	
LM3	911 acres of marsh creation and 950 acres of marsh nourishment in South Lake Borgne north of Lena Lagoon in the area bounded by the lake, Bayou St. Malo, MRGO, and Doulluts Canal. Approximately 6.4 million cubic yards of borrow to be obtained from South Lake Borgne Borrow Cycle 6.

Table 1-1: Recommended Plan Restoration Features

Measure	Description
BM1	8,000 acres of marsh nourishment along the south shore of Lake Borgne. 11 million cubic yards of material would be obtained from South Lake Borgne Borrow Cycle 6.
Construction Year 7	
CM1	1,240 acres of marsh nourishment south of Paris Road between cypress restoration feature CC3 and the Chalmette Loop Levee. Approximately 1.5 million cubic yards of material would be obtained from GIWW/MRGO Reach 1 starting at mile 66, as well as the turning basin at mile 65.5 and the Michoud Canal project that ties into MRGO/GIWW at mile 60.
CM3	300 acres of marsh restoration and 215 acres of marsh nourishment in the area north of Bayou Dupre and south of MRGO. 1.6 million cubic yards of borrow material would be obtained from North Lake Borgne Borrow Cycle 7.
CM4	97.5 acres of marsh restoration and 128.5 acres of marsh nourishment south of Bayou Dupre. 600,000 cubic yards of dredged material would be obtained from North Lake Borgne Borrow Cycle 7.
CM5	245 acres of marsh restoration and 70 acres of marsh nourishment in the area north of Bayou Bienvenue and Paris Road. 1million cubic yards of material would be obtained from GIWW/MRGO Reach 1 starting at mile 66, as well as the turning basin at mile 65.5 and the Michoud Canal project that ties into MRGO/GIWW at mile 60.
Construction Year 8	
TM7	2,255 acres of marsh restoration and up to 2,144 acres of adjacent marsh nourishment on the east side of Bayou Terre aux Boeufs. 12.4 million cubic yards of material would be obtained from South Lake Borgne Borrow Cycle 8.
TM8	1,511 acres of marsh restoration on the east side of Bayou Terre aux Boeufs in the vicinity of Delacroix. 9.7 million cubic yards of material will be obtained from South Lake Borgne Borrow Cycle 8.
EM2	1,095 acres of marsh nourishment on Hog Island, located between the west and east mouth of the West Pearl River. Approximately 1.3 million cubic yards of dredged material would be obtained from Northeast Lake Borgne Borrow Cycle 8.
EM3	861 acres of marsh restoration and 180 acres of adjacent marsh nourishment in the area bounded by Highway 433, Little Lagoon, Salt Bayou and Highway 90. Approximately 4.1 million cubic yards of dredged material would be obtained from Northeast Lake Borgne Borrow Cycle 8.
EM4	2,625 acres of marsh restoration and 1,455 acres of adjacent marsh nourishment in the area bounded by Salt Bayou to the north, the West Pearl River to the east, the Rigolets to the south and Highway 80 to the north. Approximately 9.2 million cubic yards of material would be obtained from North east Lake Borgne Borrow Cycle 8.
Construction Year 9	
CC1	1,020 acres of cypress swamp restoration and 935 acres of cypress swamp nourishment in the area north of the existing Violet Canal along the Forty Arpent Levee. 6 million cubic yards of borrow material to be obtained from North Lake Borgne Borrow Cycle 9.
CC2	250 acres of cypress swamp restoration and 250 acres of swamp nourishment to the northeast of CC1. 1.7 million cubic yards of borrow material to be obtained from North Lake Borgne Borrow Cycle 9.
CC3	370 acres of cypress swamp restoration and 790 acres of swamp nourishment along the Forty Arpent Levee south of Paris Road. Approximately 3.7 million cubic yards of material to be obtained from North Lake Borgne Borrow Cycle 9.
CC4 (Sites 2,3,4)	1,065 acres of cypress swamp restoration in the open water areas adjacent to the Forty Arpent Levee north of Paris Road. 7.8 million cubic yards of borrow material to be obtained from North Lake Borgne Borrow Cycle 9.

Table 1-1: Recommended Plan Restoration Features

Measure	Description
Construction Year 10	
CC5	1,120 acres of swamp restoration and 1,550 acres of swamp nourishment south of the Violet Canal along the Forty Arpent Levee and the Chalmette Loop Levee. 7.8 million cubic yards of borrow material to be obtained from North Lake Borgne Borrow Cycle 10.
CC6	2,568 acres of swamp nourishment in the southwest corner of the Central Wetlands. 5.2 million cubic yards of borrow material would be obtained from North Lake Borgne Borrow Cycle 10.
Maintenance As Needed	
MRGO2	Repair and maintenance of approximately 21,630 linear feet (4.1 miles) of foreshore protection between Mile 44.5 and 40 of the MRGO.
MRGO3	Repair and maintenance of existing approximately 26,650 linear feet (5 miles) of foreshore protection between approximately Mile 56 to 51 of the MRGO.
MRGO4	Repair and maintenance of approximately 11,770 linear feet (2.2 miles) of existing retention dike MRGO Miles 36.6 to 37.1 and MRGO Miles 33.9 to 32.9.

Below is a summary of the construction techniques that would be used for each restoration component.

Marsh Restoration (MRGO5, MRGO7, MRGO8, CM2-5, EM1, EM3, EM4, LM1-4, TM1, TM2, TM7, TM8, and HM1)

Marsh restoration would be performed in the following areas: MRGO Channel (MRGO), Central Wetlands, East Orleans, South Lake Borgne, Terre aux Boeufs, and Hopedale.

A hydraulic dredge would be used to discharge slurry into shallow water areas and degraded marsh areas. Material would be obtained from study area borrow sites as noted for each feature. Slurry would be discharged to an elevation conducive to the development of wetlands habitat following dewatering and compaction. It is anticipated that the final result of this dredged material placement would be a combination of wetlands, mud flat, and shallow water habitat within the placement site. Following compaction and dewatering, the area would be planted with marsh vegetation appropriate for the site. Material would be allowed to overflow over existing emergent marsh vegetation within the proposed restoration area.

In general for marsh restoration it was assumed that existing elevations within the marsh restoration site average -0.5 foot and that adjacent marsh is approximately +1.5. Maximum slurry elevation would be +4.0. Retention dikes and interior weirs were included where needed. Dikes would be constructed from adjacent borrow and would be at +6.0 feet with a 5-foot crown width and 1 vertical on 3 horizontal side slopes and a 40-foot interior berm. Interior weirs would be built from adjacent borrow to an elevation of +3.0 feet with a 5-foot crown width and 1 vertical on 3 horizontal side slopes. In some cases, closures comprised of either adjacent earthen borrow material, sheet pile or stone may be required in order to retain the dredged slurry.

Earthen dikes/closures would be allowed to degrade naturally. If earthen dikes/closures do not sufficiently degrade to provide fisheries and tidal ingress/egress following appropriate settlement

of dredged material placed within the disposal area, earthen dikes/closures would be mechanically breached and/or degraded as necessary.

Canal Closures
An earthen plug would be constructed in the canal utilizing sediments from the canal. The earthen plug would serve to prevent the flow of sediment laden water from the dredging activity to flow outside of the designated area of impact. The method for plugging canals would be the same for marsh nourishment as well as swamp restoration and nourishment features.

Weirs
Interior low-level earthen weirs may be constructed within the disposal area to facilitate the deposition of sediments in a manner that would enhance wetlands development. Borrow material for weir construction would be taken from within the disposal area. Earthen dikes/closures would be allowed to degrade naturally. If earthen dikes/closures do not sufficiently degrade to provide fisheries and tidal ingress/egress following appropriate settlement of dredged material placed within the disposal area, earthen dikes/closures would be mechanically breached and/or degraded as necessary.

Planting Plan

Below is a summary of the planting plan for the Marsh Restoration features. Refer to the *MRGO Ecosystem Restoration Study Environmental Impact Statement*, **appendix M** for the complete planting plan.

Fresh and Intermediate Marsh
The location of fresh and intermediate marsh species within the marsh depends on their ability to tolerate flooding. The Coastal Wetlands Planning Protection and Restoration Act (CWPPRA) estimate for proper density of vegetative planting is 625 plants/acre planted on 8-foot center on rows 8 feet apart. Some of the fresh and intermediate marsh species are available commercially and can be propagated.

Some of the dominant marsh plants in freshwater and intermediate wetlands are: maidencane (*Panicum hemitomon*), bull tongue (*Sagittaria lancifolia*), giant cutgrass (*Zizaniopsis miliacea*) California bulrush (*Schoenoplectus californicus*), coast cockspur (*Echinochloa walteri*), saltmeadow cordgrass (*Spartina patens*), and common reed (*Phragmites australis*). Although common reed is considered a dominant marsh plant, because it is an invasive species it would not be included in the planting plan.

Brackish Marsh
The CWPPRA estimate for proper density of vegetative planting of brackish marshes is 875 plants/acre planted on 7-foot centers on rows 7 feet apart. Some brackish marsh species are available commercially and can be propagated. Species usually dominant in a brackish marsh are: saltmeadow cordgrass (*Spartina patens*), saltgrass (*Distichlis spicata*), American bulrush (*Schoenoplectus americanus*), black needle rush (*Juncus roemerianus*), seashore paspalum *(Paspalum vaginatum*), and switchgrass (*Panicum virgatum*). The low marsh is typically dominated by smooth cordgrass (*Spartina alterniflora*).

Marsh Nourishment (BM1, CM1-5, EM1-4, LM1-4, TM1, TM2, TM7, HM1)

Marsh nourishment would be performed in the following areas: Biloxi Marsh, Central Wetlands, East Orleans, South Lake Borgne, Terre aux Boeufs, and Hopedale.

For marsh nourishment it was assumed that existing marsh is between +0.5 foot and 1.0 feet and fill would be to +2 feet. Retention dikes and interior weirs were included where needed. Dikes would be constructed from adjacent borrow and would be at +6.0 feet with a 5-foot crown width and 1 vertical on 3 horizontal side slopes and a 40-foot interior berm. Interior weirs will be built from adjacent borrow to an elevation of +3.0 feet with a 5-foot crown width and 1 vertical on 3 horizontal side slopes. In some cases, closures comprised of either adjacent earthen borrow material, sheet pile or stone may be required in order to retain the dredged slurry.

Dredged material would be obtained from study area borrow sites as noted for each feature. The elevation of marsh nourishment areas varies from +1 foot to 1.5 feet. Material would be allowed to overflow over existing emergent marsh vegetation and into waterbodies within the project boundaries; some shallowing of these features would be anticipated.

Unlike marsh restoration features, no plantings are associated with marsh nourishment features. Dikes/closures would be allowed to degrade naturally and would be breached and/or degraded within 3 years following construction to provide fisheries access if they do not sufficiently degrade following settlement of dredged material.

Swamp Restoration (CC1-CC5)

Swamp restoration would be performed in the Central Wetlands area.

Swamp restoration is proposed in areas that were historically cypress-tupelo swamps and are currently shallow water. Swamp restoration areas would be planted with species typical of a cypress-tupelo swamp habitat.

The construction of swamp restoration features is similar to marsh restoration features as described above.

In general, for swamp restoration an existing average elevation of -1.0 to -3.0 feet was assumed based on the bathymetry available with an adjacent marsh elevation of +1.5 feet. The maximum slurry elevation would be +4.5 feet and effluent would be discharged on adjacent swamp/marsh lands for nourishment. Retention dikes would be constructed where needed. Dikes would be constructed from adjacent borrow to an elevation of +6.5 feet with a 5-foot crown width and 1 vertical on 3 horizontal side slopes and a 40-foot interior berm. In some cases, closures comprised of either adjacent earthen borrow material, sheet pile or stone may be required in order to retain the dredged slurry.

Swamp Nourishment (CC1-3, CC5, CC6)

Swamp nourishment would be performed in the Central Wetlands area.

Swamp nourishment is proposed for areas that are currently at marsh elevation, and consists of placing a layer of dredged material to nourish the area, raise elevation to approximately +2 feet, and encourage the recruitment of cypress-tupelo community species. The depth of the later of dredged material will be determined on a site-by-site basis to adjust for varying topography.

Shoreline Protection (BS1, BS2, MRGO1-8, ES1-ES3, LS1)

These features consist of either foreshore (shore between high water and low water) rock dikes or rock dikes placed near the existing shoreline to dissipate wave energy before it reaches the shoreline. Foreshore rock dikes would be constructed by placing rock in a linear mound at the -1.5 to -2.0-foot depth contour, to a height above the water's surface.

Shoreline protection designs were based on designs for existing features constructed in similar locations. The work consists of protection on the north and south banks of the MRGO, the shore of Lake Borgne, the Biloxi Marsh, the East New Orleans Landbridge, and other areas.

Work along the banks of the MRGO consists mainly of repairs to existing foreshore dikes. Existing dikes would be brought up to elevations ranging from +3 to +6 feet depending on the location. Crown widths range from 4 to 5 feet. For areas with no existing dike, a concrete panel wall to elevation +4 feet was assumed.

Protection along the Biloxi Marsh consists of a stone dike constructed of 5,000 pound stone with a crown width of 8 to 10 feet and a top elevation of from +4 to +8 feet. Gulf-side slope would be 1 vertical to 3 horizontal and land side slope would be 1 vertical to 2 horizontal. To minimize subsidence, the dike section would be underlain with a 2-foot crushed stone blanket.

Protection along Lake Borgne consists of a rock dike to elevation +4.0 with a crown width of 4 feet and 1 vertical on 2 horizontal side slopes. The dike would be constructed on geotechnical filter fabric to minimize settlement.

Protection along the New Orleans East Landbridge would consist of a rock foreshore dike constructed to a crown elevation of +3.5 feet with a 5-foot crown and 1 vertical on 2 horizontal side slopes. The dike would be constructed on a layer of Geotextile fabric to minimize settlement.

Ridge Restoration (BR1)

A ridge restoration feature is proposed on the south side of Bayou La Loutre. Restoration would consist of the placement of dredged silty sand material to be obtained from the Mississippi River. The initial elevation of the ridge would be approximately +8 feet, with a crown width of 25 feet and 1 vertical to 8 horizontal side slopes. The base width of the ridge would vary, with an average width of approximately 120 feet. A 50 foot access corridor on the south side would be

designated for construction equipment. Access along Bayou La Loutre may require excavation to the channel's authorized depth. If excavation is required, material excavated for floatation would be placed in the footprint of the proposed ridge restoration work. The ridge would be planted to develop forested habitat as described in the planting plan for this study.

Planting Plan

Based on the ongoing studies and evaluation of current projects the following guidelines have been developed. A layered, phased approach may be the most suitable to help stabilize the ridge, promote growth of the different tree stories, and create habitat for neotropical migrant birds.

Side slopes of the ridge affected by tides would be seeded for critical area cover and/or planted with herbaceous species in much the same manner as above based on salinity and depth of flooding. Plantings on the bayou-side of the ridge should mimic the pattern outlined for shorelines with no protection while behind the ridge would be planted using a method similar to applicable marsh.

Side slopes of the ridge not affected by the tides as well as the ridge top are suitable for midstory/shrub-scrub species such as wax myrtle (*Myrica cerifera*), groundsel bush (*Baccharis halimifolia*), marsh elder (*Iva frutescens*), and yaupon (*Ilex vomitoria*). These would aid in stabilization and provide needed habitat for neo-tropical migrants. It is suggested to plant bare-root seedlings with typically 200-300 plant/acre density. Other woody species such as red mulberry (*Morus rubra*), hackberry/sugarberry (*Celtis laevigata*), California desert-thorn (*Lycium carolinianum*), and green ash (*Fraxinus pennsylvanica*) could also be used on the high side slopes.

Hardwoods should be planted on upper sides of the ridge slopes and the ridge top. Several species typically grow on ridge tops based on studies of cheniers, dredge material banks, and a few natural ridges left in the deltaic plain. Species such as live oak (*Quercus virginiana*), sugarberry (*Celtis laevigata*), dwarf palmetto (*Sabal minor*), and white cedar (*Thuja occidentalis*) would likely be suitable for high ridge planting. Seedlings should be planted on 8-foot centers on rows 8 feet apart, totaling about 680 trees/acre. Chinese Tallow (*Triadica sebifera*) control would be included in operations and management.

Access Corridors

Access corridors would be a maximum of approximately 350 feet in width and would cross over wetlands and shallow water as necessary. Access corridors for some features may occur across existing levees and different methods would be utilized to best prevent compromise of the levee while allowing access. The level of protection provided by these levees would be maintained throughout construction, and any damage to levee vegetation would be repaired upon removal of the construction equipment. The construction, or designation, of staging areas would be necessary for construction equipment; however, they have not been identified at this time. At the point when staging areas are identified, if they do not fall within the area assessed for project impacts, supplemental agency coordination would be initiated.

Where access corridors cross existing wetlands, board roads would be utilized for equipment and pulling pipe. Upon completion of construction, the wetlands impacted by the board roads would

be restored by dredge material. It is anticipated that a thin layer of dredged slurry would overflow and nourish adjacent marsh.

Flotation Access Corridors

Flotation access channels would be excavated, as needed, in shallow water areas to allow construction equipment to access the project features. If necessary, flotation access channels would be excavated by a mechanical dredge. It is estimated that access channels would average approximately -2 feet. Flotation access channel material would be used in dike/closure construction or refurbishment, to backfill flotation access channels, or would be placed adjacent to and behind the dikes and closures in shallow water to a maximum initial elevation conducive to wetlands development following consolidation of the material. Flotation access channel material used to backfill the flotation access channels following completion of disposal work would be temporarily stockpiled on the water bottom adjacent to the flotation access channel.

If existing canals are used for access, they may be dredged to facilitate flotation of pipeline and other necessary equipment from the dredging reach to pipeline discharge sites within the designated staging areas. Dredge material removed from existing canals would be placed on adjacent existing levees and/or into shallow water on either side of canals. Canal dredge material placed in shallow water areas would be placed to a height conducive for wetlands development.

Freshwater Diversion (D05)

Currently, the design for the diversion is not developed to a feasibility level. Footprints detailing the constructible features for the diversion structure are not complete and therefore an analysis of the potential impacts resulting from construction of this feature cannot be conducted at a level to recommend this feature for construction without completing a supplemental environmental assessment prior to construction.

The Violet Freshwater Diversion is proposed to extend from the Mississippi River and Tributaries Levee to the Forty Arpent Levee via a controlled conveyance channel. The proposed river diversion channel would flow through the adjacent wetlands of the Central Wetlands Area to an outfall structure in the Chalmette Loop Levee and discharge into the MRGO. The grade of the diversion channel is designed such that the water would overflow the banks of the diversion channel into adjacent wetlands to provide the freshwater and nutrients required to maintain the restored swamp. The diversion design includes a closure structure at Dupre Cut that is open to shallow draft navigation to better conduct the freshwater via the MRGO. A sediment trap is proposed as a diversion component to reduce required maintenance and provide Mississippi River sediments for use in restoration projects in the vicinity. The conceptual operating scheme consists of a 1,000 cubic feet per second (cfs) maintenance flow from June to March with a controlled pulse of 7,000 cfs in April and May. Additional details regarding the freshwater diversion proposed as part of the MRGO Ecosystem Restoration Plan are available in the Engineering Appendix and the Adaptive Management Plan.

The channel design is a 12-foot-deep channel with 1 vertical on 3 horizontal side slopes; a 250-foot bottom width; and an almost imperceptible gradient of one foot over the 20,560-foot length of the channel.

The five culverts at the Mississippi River are sized as 14-foot by 14-foot gated concrete box culverts. The culverts at the east end of the channel (Chalmette levee) would be seven 12-foot by 12-foot gated culverts. The head loss through the MRGO culvert would be 1.58 feet.

This configuration would satisfy the need to route the proposed amount of water through the Central Wetlands. The channel dredging for this proposed configuration would involve the removal of an estimated 2.7 million cubic yards of material that would be used for constructing the guide levees necessary for the diversion channel.

The design configuration given above uses a relatively small channel width so that the velocity for the 7,000 cfs would be slightly greater than 2 feet per second, thus reducing the potential for sedimentation.

The diversion control structure would be a sluice gated type structure with U-frames at the inlet and outlet of the structures and box culverts in-between. Weirs, gates, small control structures to feed the inner marsh are proposed to be a sluice gated type structure with U-frames at the inlet and outlet of the structures and box culverts in-between. The diversion design includes a closure structure at Dupre Cut that is open to shallow draft navigation to better conduct the freshwater via the MRGO. A sediment trap is proposed as a diversion component to reduce required maintenance and provide Mississippi River sediments for use in restoration projects in the vicinity.

Two highways, a railroad, and a few levees would require relocation during construction.

Borrow Sites

The implementation of the recommended plan would require a significant amount of sediment. **Figure 1-2** illustrates the proposed borrow site for each feature included in the recommended plan.

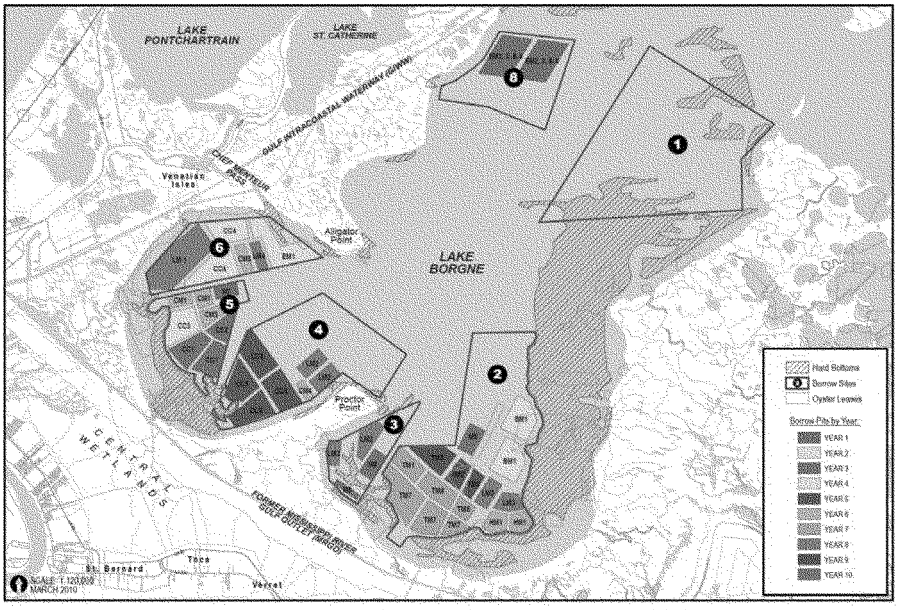


Figure 1-2: Borrow Sites for Recommended Plan

Table 1-2 summarizes the borrow area sources for each restoration feature.

Table 1-2: Restoration Feature Borrow Area

Borrow Area	Feature							
Borrow Area 2	BMI	TM1	TM2	TM7	TM8	HMI	LM3	MRGO5
Borrow Area 3		MRGO8						
Borrow Area 4	CC5	CC6		LM2				
Borrow Area 5	CC1	CC2	CC3		CM3	MRGO7	LM4	CM4
Borrow Area 6	CC4 (Sites 2, 3, and 4)		EM1	LM1		CM2		
Borrow Area 8	EM2	EM3	EM4					
MRGO/GIWW Borrow Area	CM1	CM5						
Mississippi River Borrow Area	BR1	CC4 (Site 1)						

Data Tables

Data tables referenced within this 404(b)(1) Evaluation are contained within Annex 1 at the end of this appendix following **section 5**. **Data table 1.3-1** depicts the water quality monitoring stations associated with each restoration feature. **Data table 1.3-2** depicts the sediment quality monitoring stations associated with each restoration feature. **Data table 1.3-3** depicts the sediment physical property samples associated with each restoration feature. A series of maps depicting the locations of the water quality monitoring stations and sediment monitoring stations is included within Annex 1 preceding the data tables.

1.4 Authority

In 2005, U.S. Congress provided $75,000,000 for operation and maintenance of the MRGO channel (as authorized at that time) in the Department of Defense Emergency Supplemental Appropriations to Address Hurricanes in the Gulf of Mexico and Pandemic Influenza Act, 2005 (Public Law 109-148).

In 2006, the U.S. Congress directed the Secretary of the Army, acting through the Chief of Engineers, to develop a plan for de-authorization of deep-draft navigation on the MRGO in the Emergency Supplemental Appropriations Act for Defense, the Global War on Terror, and Hurricane Recovery, 2006 (Public Law 109-234). Public Law 109-234 also modified Public Law 109-148, to clarify that the $75,000,000 provided in Public Law 109-148 was to be used for "the repair, construction or provision of measures or structures necessary to protect, restore or increase wetlands, to prevent saltwater intrusion or storm surge."

The requirements for the de-authorization plan in Public Law 109-234 were addressed in the MRGO Deep-Draft De-Authorization Study that was submitted to the U.S. Congress on June 5, 2008 by providing a comprehensive plan, at full Federal expense, to deauthorize deep draft navigation on the MRGO from the Gulf of Mexico to the Gulf Intracoastal Waterway (GIWW). At the time that report was undergoing State and Agency review, the Water Resources Development Act (WRDA) 2007 became law, expanding the scope of the MRGO Deep Draft De-authorization Study to include ecosystem restoration. The MRGO Deep Draft De-authorization Study preliminarily addresses the requirements of WRDA 2007; however, in order to continue processing the MRGO Deep Draft De-authorization Study, U.S. Army Corps of Engineers (USACE) leadership decided to develop a supplemental report to completely address the requirements of WRDA 2007.

WRDA 2007 Section 7013, the authority for this study, is provided below:

> SEC. 7013. MISSISSIPPI RIVER-GULF OUTLET.
> (a) DEAUTHORIZATION.-
> (3) CLOSURE AND RESTORATION PLAN.-
> (A) IN GENERAL.-Not later than 180 days after the date of enactment of this Act, the Secretary shall submit to the Committee on Environment and Public Works of the Senate and the Committee on Transportation and Infrastructure of the House of Representatives a final report on the deauthorization of the Mississippi River-Gulf outlet, as described under the heading "INVESTIGATIONS" under chapter 3 of title II of the Emergency Supplemental Appropriations Act for Defense, the Global War on Terror, and Hurricane Recovery, 2006 (120 Stat. 453).
> (B) INCLUSIONS.-At a minimum, the report under subparagraph (A) shall include-
> (i) a plan to physically modify the Mississippi River-Gulf Outlet and restore the areas affected by the navigation channel;
> (ii) a plan to restore natural features of the ecosystem that will reduce or prevent damage from storm surge;
> (iii) a plan to prevent the intrusion of saltwater into the waterway;

(iv) efforts to integrate the recommendations of the report with the program authorized under section 7003 and the analysis and design authorized by title I of the Energy and Water Development Appropriations Act, 2006 (119 Stat. 2247); and
(v) consideration of-
(I) use of native vegetation; and
(II) diversions of fresh water to restore the Lake Borgne ecosystem.
(4) CONSTRUCTION.-The Secretary shall carry out a plan to close the Mississippi River-Gulf Outlet and restore and protect the ecosystem substantially in accordance with the plan required under paragraph (3), if the Secretary determines that the project is cost-effective, environmentally acceptable, and technically feasible.

Section 7003 of WRDA 2007, which is referenced in Section 7013(a)(3)(B)(iv) above, refers to the Louisiana Coastal Area (LCA) Program. Title I of the Energy and Water Development Appropriations Act, 2006 (119 Stat. 2247) refers to the Louisiana Coastal Protection and Restoration (LACPR) Final Technical Report. Both are described further in **section 1.5**.

WRDA 2007 Section 7012 (b) states that the activities described in Section 7013 will be carried out consistent with the cost-share requirements in PL 109-234. Therefore, the MRGO Ecosystem Restoration Plan Feasibility Study is being conducted at full federal expense. Study funds were appropriated through Public Law 109-234 (4th Supplemental Appropriations).

The feasibility report recommending the MRGO Ecosystem Restoration Plan will be accompanied by a letter of transmission from the District (New Orleans) to the Division Commander (MVD). The Division Commander will transmit the report to Headquarters (HQ). HQ will produce a Report of the Chief of Engineers (Chief's Report) to be signed by the Chief of Engineers. This report will go to the Office of the Assistant Secretary of the Army (Civil Works), abbreviated ASA(CW). The ASA(CW) will review the report and provide it to the Office of Management and Budget (OMB) for Administration fiscal review. Following the OMB review, the ASA(CW) will determine whether the plan recommendations are cost-effective, environmentally acceptable, and technically feasible. If the ASA(CW) makes such determination, the recommendations are authorized and may be carried out and ASA(CW) will transmit the report package to the appropriate U.S. Congressional committees to seek implementation funding and appropriations.

When implementation funds are appropriated, a non-Federal sponsor would need to be identified. The States of Louisiana and Mississippi have been identified as potential non-Federal sponsors for the plan. Cost-sharing for the Plan is subject to the rules for ecosystem restoration projects established in Section 210 of WRDA 1996, with the exception of the Violet Freshwater Diversion, which would be divided between the States of Louisiana and Mississippi as stipulated in WRDA 2007, Section 3083. Accordingly, the non-Federal share will be 35 percent of the implementation costs. Non-Federal sponsors are responsible for 100 percent of lands, easements, rights-of-way, utility or public facility relocations, and dredged or excavated material disposal areas (LERRD), and operation, maintenance, repair, rehabilitation, and replacement (OMRR&R). The value of LERRD is credited to the 35 percent share.

1.5 General Description of Dredged and Fill Material

1.5.1 General Characteristics

Borrow sites for habitat restoration are proposed primarily within Lake Borgne, although the Mississippi River, MRGO/GIWW confluence, and Michoud Canal/Slip would also be used. Sediments in proposed borrow areas are poorly sorted sandy mud with a mean grain size in the range of very coarse silts. Total silts and clays accounted for more than 64 percent of the sediment with the remainder dominated by very fine sand. Sediments in proposed access channel sites differ somewhat with innermost (shoreward) stations dominated by peat and outermost stations resembling those of borrow areas. Shoreline protection features would use crushed stone. Restored ridges would be constructed of silty-sand. See **section 2.1.2** for details regarding the physical properties of borrow areas.

1.5.2 Quantity of Material

Approximately 151,980,000 cubic yards (cy) of material would be used to execute the recommended plan. **Table 1-1** provides estimated quantities of borrow material predicted for each restoration feature of the Recommended Plan.

1.6 Description of Proposed Discharge Sites

1.6.1 Location and Size

Figure 1-1 shows the location of the restoration projects and **table 1-1** provides a brief description of each restoration feature included in the recommended plan, as well as the year of construction.

1.6.2 Type of Site/Habitat of Discharge Sites

Marsh restoration and nourishment would occur in shallow water areas and degraded marsh areas. Swamp restoration is proposed in areas that were historically cypress-tupelo swamps and are currently shallow water. Swamp nourishment is proposed for areas that are currently at marsh elevation to encourage the recruitment of cypress-tupelo community species. Shoreline protection features would be placed near the existing shoreline to dissipate wave energy before it reaches the shoreline. A ridge restoration feature is proposed on the south side of Bayou La Loutre within forested habitat. Access corridors would cross over wetlands and shallow water as necessary. Flotation access channels would be excavated, as needed, in shallow water areas to allow construction equipment to access the project features. It is estimated that access channels would average approximately -2 feet. The Violet Freshwater Diversion is proposed to extend from the Mississippi River and Tributaries Levee to the Forty Arpent Levee via a controlled conveyance channel. The proposed river diversion channel would flow through the adjacent wetlands to an outfall structure in the Chalmette Loop Levee and discharge into the MRGO.

Shallow open-water and emergent marsh within the disposal area provide estuarine habitat that supports marine life of the Gulf of Mexico. These estuarine habitats function as critical nursery areas for various species of finfish and shellfish, including shrimp, crab, oyster, and fish species.

Interior marsh adjacent to the project area is necessary for the successful completion of the life cycles of several of these species, and provides detritus that forms the basis of the food chain for organisms in the system.

1.6.3 Timing and Duration of Discharge

The proposed implementation schedule for the recommended plan/Alternative C is based on the assumption that two dedicated dredges working full time can produce approximately 15 and 20 million cubic yards of material in a year. Marsh restoration prioritization is based on land loss rates. Areas with the lowest land loss rates would be constructed first. This sequencing produces the largest possible net acreage for the fifty year project life. **Table 1-1** details what features would be constructed in each of the 10 years of the projects duration.

1.7 Description of Discharge Methods

For marsh restoration, a hydraulic dredge would be used to discharge slurry into shallow water areas and degraded marsh areas. Slurry would be discharged to an elevation conducive to the development of wetlands habitat following dewatering and compaction. Material would be allowed to overflow over existing emergent marsh vegetation within the proposed restoration area. Marsh nourishment will consist of the placement of a thin layer of dredged material slurry that would be allowed to overflow over existing emergent marsh vegetation within the proposed disposal area, but would not be allowed to exceed a height of about 1 - 1.5 feet above the existing marsh elevation. The elevation of marsh restoration areas varies from +1 to 1.5 feet.

Swamp restoration consists of pumping dredged material to a maximum elevation of +4.5 feet within containment dikes and is similar to marsh restoration features as described above. Swamp restoration features would have a dewatered and settled target elevation of approximately 2 feet to support cypress habitat. Swamp nourishment will consist of placing a layer of dredged material to nourish the area, raise elevation to approximately +2 feet. The depth of the later of dredged material will be determined on a site-by-site basis to adjust for varying topography.

Retention dikes, deflection dikes, earthen weirs, and/or closures may be used to contain material for marsh and swamp restoration and nourishment. Dikes consist of a minimum 5 foot crown width and slopes no steeper than 1 vertical to 3 horizontal and a minimum 40-foot-wide interior berm. Interior low-level earthen weirs also may be constructed within the disposal area to facilitate the deposition of sediments in a manner that would enhance wetlands development. Dikes/closures would be allowed to degrade naturally and would be breached and/or degraded within 3 years following construction to provide fisheries access if they do not sufficiently degrade following settlement of dredged material.

Shoreline protection features are categorized into two types, foreshore and nearshore. Foreshore rock dikes would be constructed by placing rock in a linear mound at the -1.5 to -2.0 foot depth contour, to a height above the water's surface. Height will be determined based on existing site conditions. Nearshore (beginning at foreshore and extending to the beginning of the offshore zone) rock dikes would be constructed in places where the bathymetry prohibits a foreshore dike (water deepens quickly from the shore). Rock used for dike construction would be graded large enough to resist movement during high energy events, such as frontal passages.

Ridge restoration features proposed on the south side of Bayou La Loutre would consist of the placement of dredged silty sand material to an elevation of approximately +8 feet, with a crown width of 25 feet and 1:8 side slopes. The base width of the ridge would vary, with an average width of approximately 120 feet.

2.0 FACTUAL DETERMINATIONS

2.1 Physical Substrate Determinations

2.1.1 Substrate Elevation and Slope

Biloxi Marsh (BM, BS, BR)

BM1 (Marsh Nourishment)
Estimated existing marsh elevations within the footprint of this feature range from +1 foot to +1.5 feet. For this feature, approximately 8,000 acres of marsh and open water habitat would be raised approximately 1 foot above existing elevations. An earthen weir, approximately 94,800 feet in length and with a footprint of 544 acres, would be constructed, with a maximum crest elevation of +2.0 feet NAVD88 feet, a maximum crown width of 5 feet, side slopes of approximately 1V on 3H, and a minimum interior berm to be maintained between the inside toe of the earthen dikes and the top of cut of the adjacent borrow pits of 40 feet.

BR1 (Ridge Restoration)
The estimated existing ground elevation along the reach of this feature is +2 feet. For feature BR1, a 17,500 feet reach of the Bayou La Loutre Ridge would be raised to +8 feet. The constructed addition to the existing ridge would have a crown width of 25 feet and side slopes of 1V on 8H. While the base width of the ridge would vary with the topography, the average base width would be approximately 140 feet.

If Bayou La Loutre is not of sufficient depth to allow for flotation access over the reach of the feature, a flotation access channel within Bayou La Loutre with a bottom elevation of -8 feet and bottom width of 60 feet would be constructed. Any material excavated for flotation access channel construction would be placed within the footprint of feature BR1 (the flotation access channel would not be backfilled).

BS1 (Shoreline Protection)
Estimated existing water bottom elevations along the reach of this feature range from -2 to -3 feet. For feature BS1, 50,637 linear feet of rock foreshore dike would be constructed landward of the -2 to -3 feet bank line contour, requiring a footprint of 351 acres of existing shallow water habitat, and would be constructed to an elevation of +4 feet, with a crown width of 4 feet and side slopes of 1V on 2H. Flotation dredging is anticipated for access to the site for construction equipment and material barges. Flotation excavation along the dike alignment will be limited to an 80 feet wide channel bottom not to exceed elevation -8 feet. Flotation access channel material would be stockpiled on the channel side of rock foreshore dike during construction, and would be used to backfill flotation access channels after construction of these features is completed.

BS2 (Oyster Reef)
The existing footprint of this feature consists of shallow (approximately 10 feet deep or less) water bottoms. Feature BS2 would be constructed with different materials, divided by reaches: Reach 1) 11,200 feet of triangular steel structures made of a welded frame measuring 5 feet on each side and 3 feet high; Reach 2) 11,400 feet of 5 feet diameter concrete rings; and Reach 3) 13,200 feet of crushed stone and oyster shells, constructed to a height of 3 feet and a base width of 15 feet. The reaches would occupy a footprint of 273 acres of water bottom.

MRGO Channel

MRGO1 and MRGO6 (Shoreline Protection)
The footprints of features MRGO1 and MRGO6 consist of shallow (approximately 10 feet deep or less) water bottoms near the left descending bankline of the MRGO channel. For MRGO1 and MRGO6, 11,980 cumulative linear feet of rock foreshore dike would be constructed to an elevation of +3 and +4 feet, respectively, with a crown width of 4 feet and side slopes of 1V on 2H on the marsh side, and 1V on 3H on the channel side.

The requirement for flotation excavation to access the site with rock and equipment barges is anticipated. Allowances for flotation dredging will be limited to an access channel located 50 feet off the centerline of the proposed structure, not to exceed 80 feet in width or elevation -8.0 feet. Minimum dredging is anticipated due to adjacent deeper water for feature MRGO1, and for MRGO6, approximately 3 feet of flotation excavation may be required. Material excavated for flotation will be stockpiled channelward of the rock structure and backfilled upon completion of the construction effort.

MRGO2, MRGO3, and MRGO4 (Shoreline Protection Repairs/Maintenance)
The footprints of features MRGO2, MRGO3, and MRGO4 consist of subsiding existing rock foreshore protection and shallow (approximately 10 feet deep or less) water bottoms near the left descending bankline of the MRGO channel. For these features, 60,050 cumulative linear feet of existing rock foreshore dike would be re-graded. Rock foreshore dike would be constructed to an elevation of +3 feet, with a crown width of 4 feet and side slopes of 1V on 2H.

MRGO5, MRGO7, and MRGO8 (Shoreline Protection & Marsh Restoration)
Existing water bottoms along the shoreline protection reaches of features MRGO5, MRGO7, and MRGO8 consist of shallow (approximately 10 feet deep) water bottoms, while the elevation of existing marsh adjacent to the footprint of these features is approximately +1.5 feet. For these features: 40,635 cumulative linear feet of vinyl sheet pile wall occupying a footprint of approximately 230 acres; 53,400 linear feet of earthen retention dikes (on land) and earthen closure dikes (across water); and 17,865 linear feet of stone tie-in dikes and foreshore dikes, with a footprint of approximately 308 acres, would be constructed. Shoreline protection and marsh restoration in these areas would restore approximately 548 cumulative acres of marsh. Features would be constructed to retain dredged material slurry during hydraulic dredged material placement activities for marsh platform construction. The vinyl sheet pile wall would be constructed along the -6 feet MRGO bank line contour to an elevation of +4 feet. Earthen retention dikes and weirs would be constructed to an elevation of +4 feet with a crown width of 5 feet and side slopes varying from 1V on 2H on the land side and 1V on 4H between existing

marsh. Approximately 1,500 linear feet of stone tie-ins would be constructed to +4 feet with a 4 foot crown width. And 14,225 linear feet of stone dike, used to tie into the vinyl sheet pile wall, would be constructed to +3 feet with a 4 feet crown width, with side slopes of 1V on 2H land side and 1V on 3H channel side. Additionally, 2,140 linear feet of stone foreshore dike would be constructed between the two sheet pile walls at elevations between + 3 to + 4 feet.

Minimal excavation for construction of a flotation access channel along the western half of feature MRGO5 reach may be required to assure adequate access to the feature during construction. If constructed, the flotation access channel would have a maximum bottom elevation of -8 feet and a maximum bottom width of 80 feet. Material excavated for flotation access channel construction would be placed within the footprint of feature MRGO5 for marsh restoration.

Central Wetlands (CC, CM)

CC1, CC2, CC3, CC5, and CC6 (Swamp Restoration and Nourishment)
Estimated existing water bottom elevations within the footprint of features CC1, CC2, CC3, CC5, and CC6 range from -3 feet to -.5 feet, while the elevation of existing marsh adjacent to the footprint of these features is approximately +1.5 feet. These features would cumulatively restore 3,788 acres and nourish 6,093 acres of swamp habitat, and would raise existing elevations in feature areas to support swamp vegetation. A cumulative amount of 132,100 feet of earthen retention dikes occupying a footprint of 859 acres would be constructed for these features. For feature CC2, in order to assist in the development of the swamp restoration site, approximately 7,300 feet of interior earthen weirs occupying a footprint of 42 acres would be constructed to an elevation of +2.5 feet. For feature CC3, approximately 53,400 feet of earthen closures would be constructed. Earthen retention dikes and closures would have a maximum crest elevation of +5 feet. All earthen retention dikes, interior earthen weirs, and closures would have a crown width of 5 feet, side slopes no steeper than 1V on 3H, and a minimum interior berm to be maintained between the inside toe of the earthen dikes and the top of cut of the adjacent borrow pits of 40 feet.

For feature CC1, in addition to the earthen retention dikes, it is estimated that four (4) closures, totaling approximately 1,545 feet in length, would be required along the west bank of Bayou Dupre in order to retain the dredge slurry. One of the closures would consist of vinyl sheet pile, 25 foot long sheets, with timber piles spaced 6 feet on center to an elevation of +5 feet; and three of the closures would be earthen, totaling 1,345 linear feet constructed to an elevation of +5 feet with a 5 foot crown width and side slopes of 1V on 4H.

CC4 Sites 2, 3, 4 (Swamp Restoration):
Estimated existing water bottom elevations within the footprint of this feature range from -1 to -3 feet, while the elevation of existing marsh adjacent to the footprint of this feature is approximately +1.5 feet. These features would cumulatively restore 1,465 acres of swamp habitat, and would raise existing elevations in the feature area to support swamp vegetation. Approximately 32,200 feet of earthen retention dikes occupying a footprint of 284 acres would be constructed for these features. Earthen retention dikes would have a crest elevation of +5 to +6.5 feet, a crown width of 5 feet, side slopes no steeper than 1V on 3H, and a minimum interior

berm to be maintained between the inside toe of the earthen dikes and the top of cut of the adjacent borrow pits of 40 feet. The earthen dikes, constructed from adjacent borrow, would be breached upon completion of the project.

CM1 (Marsh Nourishment)
The estimated existing marsh elevations within the footprint of this feature range from +0.5 feet to +1 foot. This feature would nourish 870 acres of existing marsh and 370 acres of adjacent open water habitat. Dredged material placed for marsh nourishment would be placed unconfined so as not to exceed 1.5 feet above existing marsh and to a maximum elevation ranging from +2.5 feet to +3 feet. Approximately 27,800 feet of earthen retention dikes occupying a footprint of 208 acres, which includes approximately seven (7) earthen closures totaling approximately 3,500 feet in length, and three (3) vinyl sheet pile closures approximately 4,870 feet in length would be constructed for feature CM1. Upon feature completion, the closures would be removed. The earthen dikes and closures would have a crest elevation of +4.5 feet, crown width of 5 feet, side slopes no steeper than 1V on 3H, and a minimum interior berm to be maintained between the inside toe of the earthen dikes and the top of cut of the adjacent borrow pits of 40 feet.

CM2, CM3, CM4, and CM5 (Marsh Restoration and Nourishment)
Estimated existing water bottom elevations within the footprints of features CM2, CM3, CM4, and CM5 range from -1.5 feet to -0.5 feet, while the elevations of existing marsh adjacent to the footprints of these features range from approximately +1 foot to +1.5 feet. These features would cumulatively restore 1,438 acres and nourish 604 acres of marsh habitat, and would raise existing elevations in feature areas by 1.5 feet. Approximately 79,150 feet of earthen retention dikes occupying a footprint of 543 acres would be constructed for these features. Feature CM3 includes eight (8) earthen closures totaling approximately 4,230 linear feet, three (3) vinyl sheet pile closures totaling approximately 2,915 feet, and approximately 9,400 feet of interior earthen weirs occupying a footprint of 54 acres to assist in the development of marsh creation and nourishment sites. Feature CM4 includes five (5) earthen closures totaling approximately 2,390 feet. Earthen retention dikes and earthen closures would be constructed to a maximum elevation of +4.5 feet; earthen closures would have side slopes of 1V on 4H. Interior earthen weirs would be constructed to an elevation of +2 feet. Earthen dikes, interior weirs, and closures would have a crown width of 5 feet, side slopes no steeper than 1V on 3H, and a minimum interior berm to be maintained between the inside toe of the earthen dikes and the top of cut of the adjacent borrow pits of 40 feet. Feature CC4 also requires retention dikes along the northern end of its swamp restoration sites that would be constructed prior to Feature CM2, therefore, it was assumed that those same dikes would be able to serve as a retention barrier for the southern boundary of Feature CM2. Upon completion of features CM3 and CM4, all closures would be removed.

East Orleans (EM, ES)

EM1, EM3, and EM4 (Marsh Restoration and Nourishment)
The estimated existing water bottom elevation within the footprints of features EM1, EM3, and EM4 is -0.5 feet, while the elevation of existing marsh adjacent to the footprints of these features is +1.5 feet. These features would cumulatively restore 4,661 acres and nourish 4,465 acres of marsh habitat, and would raise existing elevations in feature areas. A total of 138,300 feet of

earthen retention dikes occupying a footprint of 794 acres would be constructed for these features. In addition, a total of approximately 220,100 feet of interior earthen weirs occupying a footprint of 1,030 acres would be constructed in order to assist in maximizing development of marsh creation sites. Earthen retention dikes and interior weirs would have a crown width of 5 feet, side slopes no steeper than 1V on 3H, and a minimum interior berm to be maintained between the inside toe of the earthen dikes and the top of cut of the adjacent borrow pits of 40 feet. Earthen retention dikes would be constructed to a maximum elevation ranging from +0.5 to +4.5 feet, while interior earthen weirs would be constructed to an elevation ranging from +0.5 feet to +2 feet.

For feature EM1, in addition to the earthen dikes and weirs, it is estimated that three (3) closures, totaling approximately 3,820 feet in length, would be required in order to retain dredge slurry. The closures would consist of vinyl sheet pile sheets averaging approximately 30 feet in length, along with timber piles spaced approximately 6 feet on center. These closures would be removed after project completion. In addition, a flotation access channel approximately 1 mile long may be required for feature EM1. If this flotation access channel is constructed, it would be backfilled following the completion of this feature.

EM2 (Marsh Nourishment)
The estimated existing marsh habitat elevations within the footprint of this feature range from +1 to +1.5 feet. Construction of this feature would nourish 1,095 acres of existing marsh and 295 acres of adjacent open water habitat. Dredged material placed for marsh nourishment would be placed unconfined so as not to exceed 1 foot above existing elevations. Approximately 37,150 feet of earthen retention dikes occupying a footprint of 213 acres would be constructed for feature EM2. Earthen retention dikes would have a maximum crest elevation ranging from+0.5 to +4.5 feet, a crown width of 5 feet, side slopes no steeper than 1V on 3H, and a minimum interior berm to be maintained between the inside toe of the earthen dikes and the top of cut of the adjacent borrow pits of 40 feet.

ES1, ES2, and ES3 (Shoreline Protection)
Estimated existing water bottom elevations along the reaches of features ES1, ES2, and ES3 range from –2 to -3 feet. For these features, 121,180 cumulative linear feet of rock foreshore dike would be constructed landward of the -2 to -3 feet bank line contour. Rock foreshore dike would be constructed to an elevation of +4 feet, with a crown width of 4 feet to 5 feet and side slopes of 1V on 2H. If the depth of adjacent waters is not sufficient for allowing flotation access in the areas of the proposed features, flotation access channels having a maximum bottom elevation of –8 feet and maximum bottom width of 80 feet would be constructed. Flotation access channel material would be stockpiled on the channel side of rock foreshore dike during construction, and would be used to backfill flotation access channels after the construction of these features is completed.

South Lake Borgne (LM, LS)

LM1, LM2, LM3, and LM4 (Marsh Restoration and Nourishment)
The estimated existing water bottom elevations within the footprints of features LM1, LM2, LM3, and LM4 range from -0.5 feet to +1.5 feet, and the elevation of existing marsh adjacent to

the footprints of these features is +1.5 feet. These features would cumulatively restore 4,615 acres and nourish 4,697 acres of marsh habitat, and would raise existing elevations in feature areas. For features LM1, LM3, and LM4, approximately 176,700 feet of earthen retention dikes occupying a footprint of 1,014 acres would be constructed. For features LM1, LM2, LM3, and LM4, a total of approximately 148,700 feet of interior earthen weirs occupying a footprint of 853 acres would be constructed in order to assist in maximizing development of marsh creation sites. Earthen retention dikes and weirs would have a crown width of 5 feet, side slopes no steeper than 1V on 3H, and a minimum interior berm to be maintained between the inside toe of the earthen dikes and the top of cut of the adjacent borrow pits of 40 feet. Earthen retention dikes would be constructed to elevations ranging between +.5 to +4.5 feet, while interior earthen weirs would be constructed to elevations ranging between +.5 to +2 feet.

For feature LM1, in addition to earthen retention dikes and internal weirs, nine (9) vinyl sheet pile closures, totaling approximately 10,050 feet in length, would be required in order to prevent effluent sedimentation from entering the GIWW and Bayou Bienvenue during pumping operations. Vinyl sheet pile would be 40 feet lengths, with timber piles spaced 6 feet on center. Upon completion of the project, the closures would be removed.

For feature LM2, in addition to internal earthen retention dikes and weirs, three (3) vinyl sheet pile closures would be placed at canals, in 40 feet lengths with timber piles placed at 6 feet centers, required to prevent effluent sedimentation from entering Lake Borgne via a natural bayou during pumping operations. The closures would be approximately 100 feet in width and extend 50 feet beyond canal banks. Upon completion of the project, the closures would be removed.

For feature LM4, in addition to 27,200 linear feet of earthen retention dikes and internal weirs, a vinyl sheet pile closure in 40 feet lengths, totaling approximately 800 linear feet, placed along timber piles spaced 6 feet on center, would be required in order to prevent effluent sedimentation from entering the GIWW and Bayou Bienvenue during placement of dredged sediments.

LS1 (Shoreline Protection)

Estimated existing water bottom elevations along the reach of this feature range from –1 to -3 feet. For this feature, 45,000 cumulative linear feet of rock foreshore dike would be constructed landward of the -1 foot bank line contour. Rock foreshore dike would be constructed to an elevation of +4 feet, with a crown width of 4 feet and side slopes of 1V on 2H. If the depth of adjacent waters is not sufficient for allowing flotation access in the areas of the proposed features, flotation access channels having a maximum bottom elevation of –8 feet and maximum bottom width of 80 feet would be constructed. Flotation access channel material would be stockpiled on the channel side of the proposed rock foreshore dike during construction, and would be used to backfill flotation access channels after the construction of these features is completed.

Terre aux Boeufs (TM)

TM1, TM2, and TM7 (Marsh Restoration and Nourishment)
For features TM1 and TM2 the estimated existing water bottom elevation within the footprint of these features is -0.5 feet, while the elevation of adjacent existing marsh is +1.5 feet. These features would cumulatively restore 3,823 acres and nourish 5,763 acres of marsh habitat, and would raise existing elevations in feature areas. Approximately 286,200 cumulative feet of earthen retention dikes occupying a footprint of 1,643 acres would be constructed for these features. In addition, for features TM1 and TM2, a total of approximately 64,150 feet of interior earthen weirs occupying a footprint of 368 acres would be constructed in order to assist in maximizing development of marsh creation sites. Earthen retention dikes and weirs would have a crown width of 5 feet, slopes no steeper than 1V on 3H, and a minimum interior berm to be maintained between the inside toe of the earthen dikes and the top of cut of the adjacent borrow pits of 40 feet. Earthen retention dikes would be constructed to a maximum elevation of +4.5 feet, while interior earthen weirs would be constructed to an elevation between +1.5 and +2 feet.

For feature TM1, in addition to the earthen perimeter retention dikes and weirs, two 2 closures, totaling approximately 2,930 feet in length, will be constructed. The closures would consist of vinyl sheet pile, 35 feet and 40 feet sheet lengths, with timber piles spaced 6 feet on center. Upon completion of the project, the closures would be removed.

For feature TM7, estimated existing water bottom elevation within the footprint of this feature is -0.5 feet, while the elevation of existing marsh adjacent to the footprint of this feature is +1.5 feet. This feature would restore 2,255 acres and nourish 2,144 acres of marsh habitat; marsh nourishment would raise existing marsh elevations in feature areas by up to 1 foot. Approximately 105,000 feet of earthen retention dikes, weirs, and closures would be constructed for this feature. Earthen retention dikes, weirs, and closures would have a crown width of 5 feet, slopes no steeper than 1V on 3H, and a minimum interior berm to be maintained between the inside toe of the earthen dikes and the top of cut of the adjacent borrow pits of 40 feet. Earthen retention dikes would be constructed to an approximate elevation of +4.5 feet, vinyl sheet pile closures would be constructed to an approximate elevation of +3.5 feet, and interior earthen weirs would be constructed to an elevation of between +1.5 and +2 feet.

For feature TM7, in addition to the earthen perimeter retention dikes, weirs and closures, five (5) closures, consisting of 10,275 linear feet of vinyl sheet pile, 35 feet in length, with timber piles spaced 6 feet on center, would be constructed. Upon completion of the project, the closures would be removed.

TM8 (Marsh Restoration)
Within the footprint of feature TM8, the estimated existing water bottom elevation is -0.5 feet, while the elevation of existing marsh adjacent to the footprint of this feature is +1.5 feet. This feature would restore 1,511 acres of marsh habitat and would raise elevations within the feature area. Approximately 63,900 linear feet of earthen retention dikes occupying a footprint of 367 acres would be constructed for this feature. Retention dikes would be constructed to an approximate elevation of +4.5 feet with 1V on 3H slopes, with a minimum interior berm to be maintained between the inside toe of the earthen dikes and the top of cut of the adjacent borrow

pits of 40 feet. Retention dikes and weirs would both have a crown width of 5 feet. Approximately 14,700 linear feet of interior earthen wiers would occupy a footprint of 84 acres, and would be constructed to assist in maximizing development of marsh creation sites. Wiers would be constructed to an approximate elevation of +2 feet, and with side slopes of 1V to 3H. Five (5) closures would be constructed, approximately 6,970 linear feet in length, to an approximate elevation of +4.5 feet, with a 5 feet wide crown and 1V on 4H slopes. Upon completion of the project, 500 linear feet of each closures would be removed to allow for surface interchange.

Hopedale (HM)

HM1 (Marsh Restoration and Nourishment)

The estimated existing water bottom elevation within the footprint of this feature is -0.5 feet, while the elevation of existing marsh adjacent to the footprint of this feature is +1.5 feet. Construction of feature HM1 would restore 757 acres and nourish 973 acres of marsh habitat, and would raise existing elevations within the feature footprint. Approximately 54,500 linear feet of earthen retention dikes occupying a footprint of 313 acres and 17,300 linear feet of interior earthen weir occupying a footprint of 99 acres would be constructed for this feature. Earthen retention dikes and interior weirs would have a crown width of 5 feet, slopes no steeper than 1V to 3H, and a minimum interior berm to be maintained between the inside toe of the earthen dikes and the top of cut of the adjacent borrow pits of 40 feet. Earthen retention dikes would be constructed to an approximate elevation of +4.5 feet, while interior earthen weirs would be constructed to an elevation of +2 feet.

2.1.2 Sediment Type

Physical Properties of Borrow Areas

Table 2-1 depicts borrow area sediment physical properties. Sediment physical properties for Lake Borgne borrow areas (Borrow Area 2, 3, 4, 5, 6, and 8) display consistent average sand and silt and clay contents, with sand content ranging from 50-75 percent, and silt and clay content ranging from 4-23 percent. Material from the MRGO/GIWW borrow area is anticipated to have a relatively high (approximately 90 percent) silt and clay content based on available boring data, while material from the Mississippi River is expected to have a relatively high (approximately 50 percent) sand content based on available boring data.

Table 2-1: Borrow Area Physical Properties, Including Average Percent Sand and Average Percent Silt and Clay For All Samples Associated With Each Borrow Area

		Borrow Area							
Parameter	Units	Borrow Area 2	Borrow Area 3	Borrow Area 4	Borrow Area 5	Borrow Area 6	Borrow Area 8	Mississippi River Borrow Area	MRGO/GIWW Borrow Area
Percent Sand	%	22.8	5.80	4.40	4.40	4.40	22.2	51.4	9.06
Percent Silt and Clay	%	59.3	72.9	68.8	74.4	74.4	50.6	48.6 *	90.5 *

*Percent Silt and Clay = 100 - (Percent Sand + Percent Gravel [if available])

Soil Descriptions

The following soil types are used to describe substrate within the footprint of restoration features, and are described in further detail in NCSS (1989a, 1989b, and 1990):

- Aquents: level, poorly drained soils that are stratified and clayey to mucky throughout; located on spoil banks
- Aquents-Allemands-Harahan: level to gently sloping, poorly drained soils; some vary in texture throughout, some have a mucky surface layer and subsoil.
- Barbary: level, very poorly drained soils that are clayey throughout; located in freshwater swamps
- Clovelly-Lafitte-Gentilly: level, very poorly drained soils that have a moderately thick, thick, or thin mucky surface layer and clayey underlying material.
- Fausse: level, very poorly drained soils that are clayey throughout; located in saline swamps
- Harahan-Westwego: level, poorly drained soils that have a clayey surface layer and a clayey subsoil
- Lafitte-Clovelly: level, poorly drained soils that have a thick or moderately thick mucky surface layer and clayey underlying material; located in brackish marshes
- Scatlake: level, very poorly drained soils that are clayey throughout; in saline marshes
- Sharkey-Commerce: level, poorly drained or somewhat poorly drained soils that have a clayey or loamy surface layer and a clayey subsoil, or that is loamy throughout; located on natural levees that are protected from flooding
- Timbalier-Bellpass: level, poorly drained soils that have a thick or moderately thick mucky surface layer and clayey underlying material; located in saline marshes

Biloxi Marsh (BM, BS, BR)

BM1 (Marsh Nourishment)
Substrate within the footprint of feature BM1 consists of Lafitte-Clovelly, Timbalier-Bellpass soils, whose surface layers are defined as being mucky. The borrow area associated with feature BM1 is Borrow Area 2, which is comprised of a relatively high (23 percent) average sand content. The placement of material from Borrow Area 2 for construction of feature BM1 is therefore expected to result in a thin layer of relatively high sand content soils overlying existing mucky soils within the footprint of this feature.

BR1 (Ridge Restoration)
Substrate within the footprint of feature BR1 consists of Fausse soils which consist of a clayey surface layer. The borrow area associated with feature BR1 is the Mississippi River borrow area, which contains substrate with a high (approximately 50 percent) average sand content. The placement of material from the Mississippi River at feature BR1 is therefore expected to result in an existing clayey surface layer overlain by relatively sandy material.

Material excavated for flotation access channel construction will be placed within the footprint of feature BR1. Due to the proximity between the area where material will be excavated and

feature BR1, it is expected that excavated material will have similar physical properties to existing soils within the footprint of feature BR1.

BS1 (Shoreline Protection)
Although Lake Borgne Shoreline soils are not defined in soil surveys, the soil types of marsh areas adjacent to feature BS1 (Timbalier-Belpass and Scatlake) are generally defined as having a mucky and clayey surface layer. The placement of rock for shoreline protection repairs/maintenance for feature BS1 would therefore result in a layer of rock overlying what are expected to be mucky and clayey soils.

Material excavated for flotation access channel construction will be used to backfill the flotation access channel. Access channel depths are not expected to be great enough to excavate anything more than surface sediment layers, which should be relatively homogenous. Therefore, no net changes in sediment physical properties are expected to result from the excavation and backfilling of the proposed flotation access channel.

BS2 (Oyster Reef)
Substrate within the footprint of feature BS2 consists of Scatlake soils, whose surface layers are defined as being mucky and clayey. The placement of materials for oyster reef construction at feature BS2 would convert the footprint of this feature from having a muckey and clayey bottom to having a water bottom comprised of hard materials.

MRGO Channel (MRGO)

MRGO1 and MRGO6 (Shoreline Protection)
Although MRGO Channel soils are not defined in soil surveys, adjacent soil types (Lafitte-Clovelly, Aquents, and Timbalier-Belpass) are generally defined as having mucky and clayey surface layers. The placement of rock for shoreline protection repairs/maintenance for features MRGO1 and MRGO6 would therefore result in a layer of rock overlying what are expected to be mucky and clayey surface layer soils.

Material excavated for flotation access channel construction will be used to backfill the flotation access channel. Access channel depths are not expected to be great enough to excavate anything more than surface sediment layers, which should be relatively homogenous. Therefore, no net changes in sediment physical properties are expected to result from the excavation and backfilling of the proposed flotation access channels for these features.

MRGO2, MRGO3, and MRGO4 (Shoreline Protection Repairs/Maintenance)
Although MRGO channel soils are not defined in soil surveys, adjacent soil types (Lafitte-Clovelly, Aquents, and Timbalier-Belpass) are generally defined as having mucky and clayey surface layers. The placement of rock for shoreline protection repairs/maintenance for features MRGO2, MRGO3, and MRGO4 would therefore result in an additional layer of rock overlying what are expected to be mucky and clayey surface layer soils.

MRGO5, MRGO7, and MRGO8 (Shoreline Protection & Marsh Restoration)
Although MRGO channel soils are not defined in soil surveys, adjacent soil types (Lafitte-Clovelly, Aquents, and Timbalier-Belpass) are generally defined as having mucky and clayey surface layers. The placement of rock for shoreline protection for features MRGO5, MRGO7, and MRGO8 would therefore result in a layer of rock overlying what are expected to be mucky and clayey surface layer soils.

The borrow area associated with feature MRGO5 is Borrow Area 2, while the borrow area associated with feature MRGO8 is Borrow Area 3, and the borrow area associated with feature MRGO7 is Borrow Area 5. Borrow Area 2 sediments contain a relatively high sand content (23 percent). Therefore, the placement of material from this borrow area for the construction of feature MRGO5 will result in a relatively sand-rich sediment layer overlaying mucky/clayey sediments. Borrow areas 3 and 5 contain a relatively high (between 73 and 74 percent) average silt and clay content. Therefore, the placement of sediments from these borrow areas for marsh restoration for features MRGO7 and MRGO8 is not anticipated to result in significant alterations to sediment type for surface layers within the footprint of these features.

Material excavated for flotation access channel construction for feature MRGO5 will be placed within the footprint of this feature. Due to the proximity between the area where material will be excavated and feature MRGO5, it is expected that excavated material will have similar physical properties to existing soils within the footprint of feature MRGO5.

Central Wetlands (CC, CM)

CC1, CC2, CC3, and CC5 (Swamp Restoration/Nourishment)
Substrate within the footprint of features CC1, CC2, CC3, and CC5, consist of Lafitte-Clovelly and Barbary soils. The surface layer of Lafitte-Clovelly soils are mucky, while the surface layer of Barbary soils are clayey. The borrow areas associated with features CC1, CC2,CC3,and CC5 are Borrow Areas 4 and 5, which contain substrate having average silt and clay contents of 69 percent and 74 percent, respectively. Because both borrow area sediments and restoration feature substrate are expected to contain a high silt and clay content, the placement of sediments from Borrow Areas 4 and 5 for marsh restoration for features CC1, CC2, CC3, and CC5 is not anticipated to result in significant alterations to sediment type within the footprint of these features.

CC4 (Swamp Restoration)
Substrate within the footprint of feature CC4 consists of Lafitte-Clovelly soils, whose surface layers are defined as being mucky. The borrow areas associated with feature CC4 are Borrow Area 6 and the Mississippi River Borrow Area. While Borrow Area 6 contains a relatively high average silt and clay content (74 percent), the Mississippi River Borrow Area does not (48.6 percent), and also has a very high (51 percent) sand content. Therefore, the placement of sediments from Borrow Area 6 for construction of feature CC4 is not anticipated to result in significant alterations to sediment type for surface layers within the footprint of this feature; however, placement of sediments from the Mississippi River Borrow Area is anticipated to result in some changes to substrate type, as high sand content sediment from this borrow area will be placed upon soils described as mucky.

CC6 (Swamp Nourishment)
Substrate within the footprint of feature CC6 consists of Lafitte-Clovelly and Barbary soils. The surface layer of Lafitte-Clovelly soils are mucky, while the surface layer of Barbary soils are clayey. The borrow area associated with feature CC6 is Borrow Area 6, which is comprised of a relatively high (74 percent) average silt and clay content. Therefore, the placement of sediments from Borrow Area 6 for construction of feature CC6 is not anticipated to result in significant alterations to sediment type for surface layers within the footprint of this feature.

CM1 (Marsh Nourishment)
Substrate within the footprint of feature CM1 consists of Lafitte-Clovelly soils, whose surface layers are defined as being mucky. The borrow area associated with feature CM1 is the MRGO/GIWW Borrow Area, which is comprised of a relatively high (90 percent) average silt and clay content. Therefore, the placement of sediments from the MRGO/GIWW Borrow Area for construction of feature CM1 is not anticipated to result in significant alterations to sediment type for surface layers within the footprint of this feature.

CM2, CM3, CM4, and CM5 (Marsh Restoration/Nourishment)
Substrate within the footprint of these features consists of Lafitte-Clovelly soils, whose surface layers are defined as being mucky. The borrow area associated with feature CM2 is Borrow Area 6, which is comprised of a relatively high (74 percent) average silt and clay content; the borrow area associated with features CM3 and CM4 is Borrow Area 5, which is also comprised of a relatively high (74 percent) average silt and clay content; and the borrow area associated with feature CM5 is the MRGO/GIWW Borrow Area, which is comprised of a relatively high (90 percent) average silt and clay content. Therefore, the placement of sediments from these borrow areas for construction of features CM2, CM3, CM4, and CM5 is not anticipated to result in significant alterations to sediment type for surface layers within the footprint of these features.

East Orleans-St. Tammany (EM)

EM1, EM3 and EM4 (Marsh Restoration/Nourishment)
Substrate within the footprints of these features consist of Lafitte-Clovely and Clovely-Lafitte-Gentilly soils, whose surface layers are described as being mucky. The borrow area associated with feature EM1 is Borrow Area 6, which is comprised of a relatively high (74 percent) average silt and clay content; the borrow area associated with features EM3 and EM4 is Borrow Area 8, which is comprised of a relatively high (22 percent) average sand content. Therefore, the placement of sediments from Borrow Area 6 for construction of feature EM1 is not anticipated to result in significant alterations to sediment type for surface layers within the footprint of this feature, and the placement of material from Borrow Area 8 for construction of features EM3 and EM4 is expected to result in a thin layer of relatively high sand content soils overlying existing mucky soils within the footprints of these features.

For feature EM1, material excavated for flotation access channel construction will be used to backfill the flotation access channel. Access channel depths are not expected to be great enough to excavate anything more than surface sediment layers, which should be relatively homogenous. Therefore, no net changes in sediment physical properties are expected to result from the

excavation and backfilling of the proposed flotation access channel.

EM2 (Marsh Nourishment)
Substrate within the footprint of feature EM2 consists of Lafitte-Clovely soils, whose surface layers are described as being mucky. The borrow area associated with this feature is Borrow Area 8, which is comprised of a relatively high (22 percent) average sand content. The placement of material from Borrow Area 8 for construction of feature EM2 is expected to result in a thin layer of relatively high sand content soils overlying existing mucky soils within the footprint of this feature.

For feature EM2, material excavated for flotation access channel construction will be used to backfill the flotation access channel. Access channel depths are not expected to be great enough to excavate anything more than surface sediment layers, which should be relatively homogenous. Therefore, no net changes in sediment physical properties are expected to result from the excavation and backfilling of the proposed flotation access channel.

ES1, ES2, and ES3 (Shoreline Protection)
Although Lake Pontchartrain and Lake Borgne Shoreline soils are not defined in soil surveys, the soil type for land adjacent to features ES1, ES2, and ES3 (Lafitte-Clovely-Gentilly) are generally defined as having a mucky surface layer. The placement of rock for shoreline protection for these features would therefore result in a layer of rock overlying what are expected to be mucky surface soils.

Material excavated for flotation access channel construction will be used to backfill the flotation access channel. Access channel depths are not expected to be great enough to excavate anything more than surface sediment layers, which should be relatively homogenous. Therefore, no net changes in sediment physical properties are expected to result from the excavation and backfilling of the proposed flotation access channels for these features.

Lake Borgne Area (LM, LS)

LM1, LM2, LM3, and LM4 (Marsh Restoration/Nourishment)
Substrate within the footprints of these features consist of Lafitte-Clovely and Clovely-Lafitte-Gentilly soils, whose surface layers are described as being mucky. The borrow area associated with features LM1 is Borrow Area 6, which is comprised of a relatively high (74 percent) average silt and clay content; the borrow area associated with features LM2 is Borrow Area 4, which is comprised of a relatively high (69 percent) average silt and clay content; the borrow area associated with feature LM3 is Borrow Area 2, which consists of a relatively high (23 percent) sand content; and the borrow area associated with feature LM4 is Borrow Area 5, which is comprised of a relatively high (74 percent) average silt and clay content. Therefore, the placement of sediments from Borrow Areas 4, 5, and 6 for construction of features LM1, LM2, and LM4 is not anticipated to result in significant alterations to sediment type for surface layers within the footprint of these features, and the placement of material from Borrow Area 2 for construction of feature LM3 is expected to result in a thin layer of relatively high sand content soils overlying existing mucky soils within the footprint of this feature.

LS1 (Shoreline Protection)
Although Lake Pontchartrain Shoreline soils are not defined in soil surveys, the soil type for marsh area adjacent to features LS1 (Lafitte-Clovely) is generally defined as having a mucky surface layer. The placement of rock for shoreline protection for feature LS1 would therefore result in a layer of rock overlying what are expected to be mucky surface soils.

Material excavated for flotation access channel construction will be used to backfill the flotation access channel. Access channel depths are not expected to be great enough to excavate anything more than surface sediment layers, which should be relatively homogenous. Therefore, no net changes in sediment physical properties are expected to result from the excavation and backfilling of the proposed flotation access channel.

Terre aux Boeufs (TM)

TM1, TM2, and TM7 (Marsh Restoration/Nourishment)
Substrate within the footprint of these features consists of Lafitte-Clovely soils, whose surface layers are described as being mucky. The borrow area associated with these features is Borrow Area 2, which is comprised of a relatively high (23 percent) average sand content. The placement of material from Borrow Area 2 for construction of these features is expected to result in a thin layer of relatively high sand content soils overlying existing mucky soils within the footprint of these features.

TM8 (Marsh Restoration)
Substrate within the footprint of feature TM8 consists of Lafitte-Clovely soils, whose surface layers are described as being mucky. The borrow area associated with this features is Borrow Area 2, which is comprised of a relatively high (23 percent) average sand content. The placement of material from Borrow Area 2 for construction of this feature is expected to result in a thin layer of relatively high sand content soils overlying existing mucky soils within the footprint of this feature.

Hopedale (HM)

HM1 (Marsh Restoration/Nourishment)
Substrate within the footprint of feature HM1 consists of Lafitte-Clovely soils, whose surface layers are described as being mucky. The borrow area associated with this features is Borrow Area 2, which is comprised of a relatively high (23 percent) average sand content. The placement of material from Borrow Area 2 for construction of this feature is expected to result in a thin layer of relatively high sand content soils overlying existing mucky soils within the footprint of this feature.

2.1.3 Dredged and Fill Material Movement

Biloxi Marsh (BM, BS, BR)

BM1 (Marsh Nourishment)
Dredged material placed for marsh nourishment would be contained within confinement dikes and is not expected to shift or move. Confinement dikes would be allowed to degrade naturally following the settlement of dredged material. If confinement dikes do not sufficiently degrade to provide fisheries and tidal ingress/egress following settlement of dredged material, they would be mechanically breached and/or degraded.

BR1 (Ridge Restoration)
Mississippi River borrow sediments placed along the Bayou La Loutre Ridge for construction of this feature are not expected to move following construction, as these sediments would be dewatered prior to transport and would therefore undergo very little sloughing after placement.

Material excavated for flotation access channel construction would be temporarily stockpiled during construction activities, and would be used to backfill the flotation access channel following the completion of feature BR1. Therefore, no net movement of water bottom sediment is expected to result from flotation access channel excavation and backfilling.

BS1 (Shoreline Protection)
Rock placed for shoreline protection for feature BS1 is expected to gradually sink over time due to the overburden pressure that the rock would create on underlying unconsolidated substrate. However, rocks are not expected to shift laterally following placement.

Material excavated for flotation access channel construction would be temporarily stockpiled during construction activities, and would be used to backfill the flotation access channel following the completion of feature BS1. Therefore, no net movement of water bottom sediment is expected to result from flotation access channel excavation and backfilling.

BS2 (Oyster Reef)
Materials placed for oyster reef construction are not expected to move following the completion of construction for feature BS2.

MRGO Channel (MRGO)

MRGO 1 and MRGO6 (Shoreline Protection)
Rock placed for shoreline protection for feature BS1 is expected to gradually sink over time due to the overburden pressure that the rock would create on underlying unconsolidated substrate. However, rocks are not expected to shift laterally following placement.

Material excavated for flotation access channel construction for feature MRGO1 would be temporarily stockpiled during construction activities, and would be used to backfill the flotation access channel following the completion of this feature. Therefore, no net movement of water bottom sediment is expected to result from flotation access channel excavation and backfilling.

MRGO2, MRGO3, and MRGO4 (Shoreline Protection Repairs/Maintenance)
Rock placed for shoreline protection repairs and maintenance for these features is expected to gradually sink over time due to the overburden pressure that the rock would create on underlying unconsolidated substrate. However, rocks are not expected to shift laterally following placement.

MRGO5, MRGO7, and MRGO8 (Shoreline Protection & Marsh Restoration)
Rock placed for shoreline protection for these features is expected to gradually sink over time due to the overburden pressure that the rock would create on underlying unconsolidated substrate. However, rocks are not expected to shift laterally following placement.

Dredged material placed for marsh restoration would be contained within confinement dikes and is not expected to shift or move. Confinement dikes would be allowed to degrade naturally following the settlement of dredged material. If confinement dikes do not sufficiently degrade to provide fisheries and tidal ingress/egress following settlement of dredged material, they would be mechanically breached and/or degraded.

Any material excavated for flotation access channel construction for feature MRGO5 would be temporarily stockpiled during construction activities, and would be used to backfill the flotation access channel following the completion of this feature. Therefore, no net movement of water bottom sediment is expected to result from flotation access channel excavation and backfilling.

Central Wetlands (CC, CM)

CC1, CC2, CC3, and CC5 (Swamp Restoration/Nourishment)
Dredged material placed for swamp restoration and nourishment would be contained within confinement dikes and is not expected to shift or move. Confinement dikes would be allowed to degrade naturally following the settlement of dredged material. If confinement dikes do not sufficiently degrade to provide fisheries and tidal ingress/egress following settlement of dredged material, they would be mechanically breached and/or degraded.

CC4 (Swamp Restoration)
Dredged material placed for swamp restoration would be contained within confinement dikes and is not expected to shift or move. Confinement dikes would be allowed to degrade naturally following the settlement of dredged material. If confinement dikes do not sufficiently degrade to provide fisheries and tidal ingress/egress following settlement of dredged material, they would be mechanically breached and/or degraded.

CC6 (Swamp Nourishment)
Dredged material placed for swamp nourishment would be contained within confinement dikes and is not expected to shift or move. Confinement dikes would be allowed to degrade naturally following the settlement of dredged material. If confinement dikes do not sufficiently degrade to provide fisheries and tidal ingress/egress following settlement of dredged material, they would be mechanically breached and/or degraded.

CM1 (Marsh Nourishment)
Dredged material placed for marsh nourishment would be contained within confinement dikes and is not expected to shift or move. Confinement dikes would be allowed to degrade naturally following the settlement of dredged material. If confinement dikes do not sufficiently degrade to provide fisheries and tidal ingress/egress following settlement of dredged material, they would be mechanically breached and/or degraded.

East Orleans (EM, ES)

EM1, EM3 and EM4 (Marsh Restoration/Nourishment)
Dredged material placed for marsh restoration and nourishment would be contained within confinement dikes and is not expected to shift or move. Confinement dikes would be allowed to degrade naturally following the settlement of dredged material. If confinement dikes do not sufficiently degrade to provide fisheries and tidal ingress/egress following settlement of dredged material, they would be mechanically breached and/or degraded.

Any material excavated for flotation access channel construction for feature EM1 would be temporarily stockpiled during construction activities, and would be used to backfill the flotation access channel following the completion of this feature. Therefore, no net movement of water bottom sediment is expected to result from flotation access channel excavation and backfilling.

EM2 (Marsh Nourishment)
Dredged material placed for marsh nourishment would be contained within confinement dikes and is not expected to shift or move. Confinement dikes would be allowed to degrade naturally following the settlement of dredged material. If confinement dikes do not sufficiently degrade to provide fisheries and tidal ingress/egress following settlement of dredged material, they would be mechanically breached and/or degraded.

ES1, ES2, and ES3 (Shoreline Protection)
Rock placed for shoreline protection for these features is expected to gradually sink over time due to the overburden pressure that the rock would create on underlying substrate. However, rocks are not expected to shift laterally following placement.

Material excavated for flotation access channel construction for these features would be temporarily stockpiled during construction activities, and would be used to backfill the flotation access channel following the completion of this feature. Therefore, no net movement of water bottom sediment is expected to result from flotation access channel excavation and backfilling.

South Lake Borgne (LM, LS)

LM1, LM2, LM3, and LM4 (Marsh Restoration/Nourishment)
Dredged material placed for marsh restoration and nourishment would be contained within confinement dikes and is not expected to shift or move. Confinement dikes would be allowed to degrade naturally following the settlement of dredged material. If confinement dikes do not sufficiently degrade to provide fisheries and tidal ingress/egress following settlement of dredged material, they would be mechanically breached and/or degraded.

LS1 (Shoreline Protection)
Rock placed for shoreline protection for feature LS1 is expected to gradually sink over time due to the overburden pressure that the rock would create on underlying substrate. However, rocks are not expected to shift laterally following placement.

Terre aux Boeufs (TM)

TM1, TM2, and TM7 (Marsh Restoration/Nourishment)
Dredged material placed for marsh restoration and nourishment would be contained within confinement dikes and is not expected to shift or move. Confinement dikes would be allowed to degrade naturally following the settlement of dredged material. If confinement dikes do not sufficiently degrade to provide fisheries and tidal ingress/egress following settlement of dredged material, they would be mechanically breached and/or degraded.

TM8 (Marsh Restoration)
Dredged material placed for marsh restoration would be contained within confinement dikes and is not expected to shift or move. Confinement dikes would be allowed to degrade naturally following the settlement of dredged material. If confinement dikes do not sufficiently degrade to provide fisheries and tidal ingress/egress following settlement of dredged material, they would be mechanically breached and/or degraded.

Hopedale (HM)

HM1 (Marsh Restoration/Nourishment)
Dredged material placed for marsh restoration and nourishment would be contained within confinement dikes and is not expected to shift or move. Confinement dikes would be allowed to degrade naturally following the settlement of dredged material. If confinement dikes do not sufficiently degrade to provide fisheries and tidal ingress/egress following settlement of dredged material, they would be mechanically breached and/or degraded.

2.1.4 Physical Effects on Substrate

Biloxi Marsh (BM, BS, BR)

BM1 (Marsh Nourishment)
The placement of material from Borrow Area 2 for construction of feature BM1 is expected to result in a thin layer of relatively high sand content soils overlying existing mucky soils within the footprint of this feature.

BR1 (Ridge Restoration)
The placement of material from the Mississippi River at feature BR1 is expected to result in an existing clayey surface layer overlain by relatively sandy material.

Material excavated for flotation access channel construction will be placed within the footprint of feature BR1. Due to the proximity between the area where material will be excavated and

feature BR1, it is expected that excavated material will have similar physical properties to existing soils within the footprint of feature BR1.

BS1 (Shoreline Protection)
The placement of rock for shoreline protection repairs/maintenance for feature BS1 would result in a layer of rock overlying what are expected to be mucky and clayey soils.

No net changes in sediment physical properties are expected to result from the excavation and backfilling of the proposed flotation access channel.

BS2 (Oyster Reef)
The placement of materials for oyster reef construction at feature BS2 would convert the footprint of this feature from having a muckey and clayey bottom to having a water bottom comprised of hard materials.

MRGO Channel (MRGO)

MRGO1 and MRGO6 (Shoreline Protection)
The placement of rock for shoreline protection repairs/maintenance for features MRGO1 and MRGO6 would result in a layer of rock overlying what are expected to be mucky and clayey surface layer soils.

No net changes in sediment physical properties are expected to result from the excavation and backfilling of the proposed flotation access channels for these features.

MRGO2, MRGO3, and MRGO4 (Shoreline Protection Repairs/Maintenance)
The placement of rock for shoreline protection repairs/maintenance for features MRGO2, MRGO3, and MRGO4 would result in an additional layer of rock overlying what are expected to be mucky and clayey surface layer soils.

MRGO5, MRGO7, and MRGO8 (Shoreline Protection & Marsh Restoration)
The placement of rock for shoreline protection for features MRGO5, MRGO7, and MRGO8 would result in a layer of rock overlying what are expected to be mucky and clayey surface layer soils.

The placement of sediments from Borrow Areas 3 and 5 for marsh restoration for features MRGO7 and MRGO8 is not anticipated to result in significant alterations to sediment type for surface layers within the footprint of these features. For feature MRGO5, placement of sediments from Borrow Area 2 for marsh restoration is expected to result in a layer of material with a relatively high (23 percent) sand content overlying sediments described as mucky.

Material excavated for flotation access channel construction for feature MRGO5 will be placed within the footprint of this feature. Due to the proximity between the area where material will be excavated and feature MRGO5, it is expected that excavated material will have similar physical properties to existing soils within the footprint of feature MRGO5.

Central Wetlands (CC, CM)

CC1, CC2, CC3, and CC5 (Swamp Restoration/Nourishment)
The placement of sediments from Borrow Areas 4 and 5 for marsh restoration for features CC1, CC2, CC3, and CC5 is not anticipated to result in significant alterations to sediment type within the footprint of these features.

CC4 (Swamp Restoration)
The placement of sediments from Borrow Area 6 for construction of feature CC4 is not anticipated to result in significant alterations to sediment type for surface layers within the footprint of this feature.

CC6 (Swamp Nourishment)
The placement of sediments from the Borrow Area 6 for construction of feature CC6 is not anticipated to result in significant alterations to sediment type for surface layers within the footprint of this feature.

CM1 (Marsh Nourishment)
The placement of sediments from Borrow Area 5 for construction of feature CM1 is not anticipated to result in significant alterations to sediment type for surface layers within the footprint of this feature.

CM2, CM3, CM4, and CM5 (Marsh Restoration/Nourishment)
The placement of sediments from Borrow Areas 5 and 6, and the MRGO/GIWW Borrow Area for construction of features CM2, CM3, CM4, and CM5 is not anticipated to result in significant alterations to sediment type for surface layers within the footprint of these features.

East Orleans-St. Tammany (EM)

EM1, EM3 and EM4 (Marsh Restoration/Nourishment)
The placement of sediments from Borrow Area 6 for construction of feature EM1 is not anticipated to result in significant alterations to sediment type for surface layers within the footprint of this feature, and the placement of material from Borrow Area 8 for construction of features EM3 and EM4 is expected to result in a thin layer of relatively high sand content soils overlying existing mucky soils within the footprints of these features.

No net changes in sediment physical properties are expected to result from the excavation and backfilling of the proposed flotation access channel for feature EM1.

EM2 (Marsh Nourishment)
The placement of material from Borrow Area 8 for construction of feature EM2 is expected to result in a thin layer of relatively high sand content soils overlying existing mucky soils within the footprint of this feature.

No net changes in sediment physical properties are expected to result from the excavation and backfilling of the proposed flotation access channel.

ES1, ES2, and ES3 (Shoreline Protection)
The placement of rock for shoreline protection for these features would result in a layer of rock overlying what are expected to be mucky surface soils.

No net changes in sediment physical properties are expected to result from the excavation and backfilling of the proposed flotation access channels for these features.

Lake Borgne Area (LM, LS)

LM1, LM2, LM3, and LM4 (Marsh Restoration/Nourishment)
The placement of sediments from Borrow Areas 4, 5, and 6 for construction of features LM1, LM2, and LM4 is not anticipated to result in significant alterations to sediment type for surface layers within the footprint of these features, and the placement of material from Borrow Area 2 for construction of feature LM3 is expected to result in a thin layer of relatively high sand content soils overlying existing mucky soils within the footprint of this feature.

LS1 (Shoreline Protection)
The placement of rock for shoreline protection for feature LS1 would result in a layer of rock overlying what are expected to be mucky surface soils.

No net changes in sediment physical properties are expected to result from the excavation and backfilling of the proposed flotation access channel.

Terre aux Boeufs (TM)

TM1, TM2, and TM7 (Marsh Restoration/Nourishment)
The placement of material from Borrow Area 2 for construction of these features is expected to result in a thin layer of relatively high sand content soils overlying existing mucky soils within the footprint of these features.

TM8 (Marsh Restoration)
The placement of material from Borrow Area 2 for construction of this feature is expected to result in a thin layer of relatively high sand content soils overlying existing mucky soils within the footprint of this feature.

Hopedale (HM)

HM1 (Marsh Restoration/Nourishment)
The placement of material from Borrow Area 2 for construction of this feature is expected to result in a thin layer of relatively high sand content soils overlying existing mucky soils within the footprint of this feature.

2.1.5 Duration and Extent of Change

The restoration project would cause temporary ecosystem changes, due to construction and dredging, and permanent changes, as a result of full restoration plans. Coastal studies have suggested that systems characterized by estuarine muds recover in approximately 6-8 months, while sand and gravel communities may take 2-3 years after dredging. Once all phases of construction are completed, the system would move toward a natural equilibrium. Different habitat types within the project area would have different recovery times. A study conducted in similar marshes along the mid-Atlantic coast predicted full recovery time for most marsh ecosystem attributes within created marshes to achieve equivalence to natural marshes at 5 to 15 years after construction. Marsh recovery would be accelerated by replanting efforts. Overall, permanent changes would provide a net increase in valuable marsh, swamp, barrier island, and ridge habitat within the project area.

2.1.6 Actions Taken to Minimize Adverse Impacts

Borrow Areas

Borrow material for most wetlands restoration and/or nourishment features would come from Lake Borgne borrow areas. Borrow pit dimensions may influence the potential formation of dissolved oxygen (DO) deficits. The tendency for a borrow pit to accumulate organic material can be reduced by: 1) limiting the depth of the pit; 2) increasing the surface area of the pit; 3) decreasing side-slopes that transition from the pit to adjacent water bottoms; and 4) clustering borrow pits to create contiguous pit areas. A shallow and broad "pan-shaped" series of adjacent borrow pits would facilitate circulation with adjacent waters, thereby decreasing the likelihood that organic material would become entrained, as well as allow for periodic flushing of the pit during storm events. In contrast, narrow and deep pits would be less influenced by circulation in the overlying water column and would require greater energy for flushing of organic material. Shallower pits would require less energy to mix the water column and would facilitate mixing with adjacent waters.

Borrow pits in Lake Borgne that would be utilized as a sediment source for marsh restoration projects would have dimensions restrictive of DO deficit formation. Contiguous borrow pits would be pan-shaped with large surface area and relatively shallow depths (not to exceed 12 feet below existing depths in most cases) and would gradually transition from adjacent water bottoms to project depth (side slopes of 2:1). The borrow pits would be located some distance from sources of rock inputs for shoreline protection measures (1,000 feet minimum distance from shoreline or tidal passes), and sedimentation rates within the project area are relatively low without the presence of predominant organic layers. Moreover, circulation within Lake Borgne is not restricted by physical barriers, and storm fronts generating considerable wave energy commonly occur. Proposed borrow pit dimensions combined with observed characteristics of the project area would therefore not be expected to favor the formation of dissolved oxygen deficits.

Biloxi Marsh (BM, BS, BR)

BM1 (Marsh Nourishment)
Confinement dikes would be utilized to prevent dredged material from flowing from this feature.

BR1 (Ridge Restoration)
Material excavated for flotation access channel construction would be placed in the footprint of feature BR1 for ridge restoration. The flotation access channel will be limited to a 60 ft. bottom width channel not to exceed an elevation of -6 feet.

BS1 (Shoreline Protection)
Gaps would be left in shoreline protection feature BS1 to allow for fish passage and water circulation.

Material excavated for flotation access channel construction will be used to backfill the access channel. The flotation access channel will be limited to an 80 ft. bottom width channel not to exceed an elevation of -8 feet.

BS2 (Oyster Reef)
The material used to create the reef would be placed on geotextile fabric to minimize settlement. Where the oyster shells will be used for reef construction, shells would be placed in mesh bags to minimize material losses and structure migration.

MRGO Channel (MRGO)

MRGO1 and MRGO6 (Shoreline Protection)
For features MRGO1 and MRGO6, material excavated for flotation access channel construction will be used to backfill the access channels. The flotation access channels will be limited to an 80 feet bottom width channel not to exceed an elevation of -8 feet.

MRGO2, MRGO3, and MRGO4 (Shoreline Protection Repairs/Maintenance)
No actions taken.

MRGO5, MRGO7, and MRGO8 (Shoreline Protection & Marsh Restoration)
Confinement dikes would be utilized to prevent dredged material from flowing from these features.

Material excavated for flotation access channel construction would be placed within the footprint of feature MRGO5 for marsh restoration. The flotation access channel will be limited to an 80 feet bottom width channel not to exceed an elevation of -8 feet.

Central Wetlands (CC, CM)

CC1, CC2, CC3, and CC5 (Swamp Restoration/Nourishment)
Confinement dikes would be utilized to prevent dredged material from flowing from these features.

CC4 (Swamp Restoration)
Confinement dikes would be utilized to prevent dredged material from flowing from this feature.

CC6 (Swamp Nourishment)
Confinement dikes would be utilized to prevent dredged material from flowing from this feature.

CM1 (Marsh Nourishment)
Confinement dikes would be utilized to prevent dredged material from flowing from this feature.

Upon completion of construction activities for this feature, all closures would be removed.

CM2, CM3, CM4, and CM5 (Marsh Restoration/Nourishment)
Confinement dikes would be utilized to prevent dredged material from flowing from these features.

Upon completion of construction activities for features CM3 and CM4, all closures would be removed.

East Orleans (EM, ES)

EM1, EM3 and EM4 (Marsh Restoration/Nourishment)
Confinement dikes would be utilized to prevent dredged material from flowing from these features.

For feature EM1, material excavated for flotation access channel construction will be used to backfill the access channel.

EM2 (Marsh Nourishment)
Confinement dikes would be utilized to prevent dredged material from flowing from this feature.

For feature EM2, material excavated for flotation access channel construction will be used to backfill the access channel.

ES1, ES2, and ES3 (Shoreline Protection)
Gaps would be left in shoreline protection feature BS1 to allow for fish passage and water circulation. Gaps will also be left in the rock dike to allow boat access into the Irish Bayou Community, and at the I-10 and I-11 corridor.

For these features, material excavated for flotation access channel construction will be used to backfill access channels. Flotation access channels will be limited to an 80 feet bottom width channel not to exceed an elevation of -8 feet.

For Feature ES1, the northern half appears to front a fairly unbroken shoreline. As such the alignment will be placed immediately fronting this shoreline, with all required flotation material being cast lakeward. The southern half of the project alignment offers a more broken shoreline.

The required flotation excavation will be cast landward of the dike alignment in an effort to beneficially use this material to restore the shoreline embankment.

For Feature ES2, The project alignment offers a fairly broken shoreline. The required flotation excavation will be cast landward of the dike alignment in an effort to beneficially use this material to restore the shoreline embankment where possible.

South Lake Borgne (LM, LS)

LM1, LM2, LM3, and LM4 (Marsh Restoration/Nourishment)
Confinement dikes would be utilized to prevent dredged material from flowing from these features.

Upon completion of construction activities for features LM1, LM2, and LM4, all closures would be removed.

For Feature LM2, based upon preliminary lake bottom classification surveys, approximately 3 acres of hard bottom surface falls within the northern-most access corridor leading from the borrow sites in Lake Borgne Site No 4. As excavation for flotation access will not be performed, marsh buggy access will simply be required within this 3 acres area in order to access the marsh restoration sites.

LS1 (Shoreline Protection)
Gaps would be left in shoreline protection feature BS1 to allow for fish passage and water circulation.

For feature BS1, material excavated for flotation access channel construction will be used to backfill the access channel. The flotation access channel will be limited to an 80 feet bottom width channel not to exceed an elevation of -8 feet.

Terre aux Boeufs (TM)

TM1, TM2, and TM7 (Marsh Restoration/Nourishment)
Confinement dikes would be utilized to prevent dredged material from flowing from these features.

Upon completion of construction activities for features TM1 and TM7, all closures would be removed.

TM8 (Marsh Restoration)
Confinement dikes would be utilized to prevent dredged material from flowing from this feature.

Upon completion of construction activities for this feature, all closures would be removed.

Hopedale (HM)

HM1 (Marsh Restoration/Nourishment)
Confinement dikes would be utilized to prevent dredged material from flowing from this feature.

2.2 Water Column Determinations

2.2.1 Salinity

Data table 2.2.1-1 depicts pre- and post-MRGO closure salinities for each feature (including borrow areas). Overall, pre- and post-MRGO closure salinity regimes for restoration features range from brackish (2-10 parts per thousand [ppt]) to marine (10+ ppt), with the exception of the Mississippi River borrow area, which is freshwater (less than 2 ppt).

Biloxi Marsh (BM, BS, BR)

BM1 (Marsh Nourishment)
Pre-MRGO closure salinities for this feature range from 7.4 to 23.5 ppt, with an average salinity of 14.4 ppt, while post-MRGO closure salinities for this feature range from 8.4 to 24.8 ppt, with an average salinity of 16.6 ppt.

Because salinities in Lake Borgne are lower than salinities within the footprint of feature BM1, hydraulic dredging of sediments from Borrow Area 2 for marsh nourishment of feature BM1 is anticipated to result in a localized, short-term reduction in salinities, as substantial quantities and proportions of water from the borrow area would be required for hydraulic transport of dredged sediments from the lake and into the footprint of this feature. Because no confinement dikes would be constructed for this feature, dredged slurry (a mixture of water and sediment from Borrow Area 2 in Lake Borgne) would be allowed to flow freely from the footprint of the area, and any changes in salinity resulting from the hydraulically dredged material placement activity for feature BM1 would quickly become dispersed and thereby diluted.

BR1 (Ridge Restoration)
Pre-MRGO closure salinities for this feature range from 8.4 to 24.5 ppt, with an average salinity of 15.6 ppt, while post-MRGO closure salinities for this feature range from 2.7 to 24.8 ppt, with an average salinity of 9.3 ppt.

Construction of this feature is not expected to impact salinity gradients in the vicinity, as the existing Bayou La Loutre ridge, in combination with the MRGO closure, already serves as a barrier to high-salinity Gulf of Mexico waters.

If a flotation access channel is constructed for this feature, it would be constructed to an elevation no lower than -6 feet, and would not induce the formation of salinity gradients. Therefore, access channel construction is not expected to have a significant effect on salinity of adjacent waters.

BS1 (Shoreline Protection)
Pre-MRGO closure salinities for this feature range from 8.0 to 26.7 ppt, with an average salinity of 15.2 ppt. no post-MRGO closure salinity records could be located in the vicinity of feature BS1.

By providing a hydraulic barrier for the exchange of water between Lake Borgne and the Biloxi Marsh, feature BS1 may induce some localized changes to salinities for the area of the Biloxi Marsh immediately behind the shoreline protection feature, the polarity of which would be dependent upon salinity conditions in Lake Borgne.

Because the flotation access channel constructed for this feature would be backfilled following the completion of feature construction, no long-term impacts to salinity are anticipated to result from flotation access channel construction.

BS2 (Oyster Reef)
Pre-MRGO closure salinities for this feature range from 12 to 23.9 ppt, with an average salinity of 18.4 ppt, post-MRGO closure salinities for this feature are not available.

The construction of feature BS2 would not cause substantial changes in the flow of water in the area where it would be constructed. No substantial salinity impacts are anticipated.

MRGO Channel (MRGO)

MRGO 1 and MRGO6 (Shoreline Protection)
Pre-MRGO closure salinities for feature MRGO 1 (west of the closure) range from 6.8 to 19.9 PPT, with an average salinity of 12.4 PPT; pre-MRGO closure salinities for feature MRGO 6 (east of the closure) range from 10.3 to 29.5 PPT, with an average salinity of 16.6 PPT. Post-MRGO closure salinities for feature MRGO 1 range from 2.44 to 14.9 PPT, with an average salinity of 6.7 PPT; post-MRGO closure salinities for feature MRGO 6 range from 11.0 to 32.7 PPT, with an average salinity of 19.1 PPT.

These shoreline protection features would provide a hydraulic barrier for the exchange of water between the MRGO channel and the marsh platform behind each feature. This barrier may induce some localized changes to salinities for the areas immediately behind the shoreline protection feature, the polarity of which would be dependent upon the salinities in the MRGO channel.

Because the flotation access channel for these features would be backfilled following the completion of feature construction, no long-term impacts to salinity are anticipated to result from flotation access channel construction.

MRGO2, MRGO3, and MRGO4 (Shoreline Protection Repairs/Maintenance)
Pre-MRGO closure salinities for feature MRGO 2 (west of the closure) range from 7.4 to 20.2 PPT, with an average salinity of 13.8 PPT; pre-MRGO closure salinities for feature MRGO 3 (west of the closure) range from 6.7 to 17.3 PPT, with an average salinity of 9.8 PPT; pre-MRGO closure salinities for feature MRGO 4 (east of the closure) range from 10.3 to 29.5 PPT,

with an average salinity of 16.6 PPT. Post-MRGO closure salinities for feature MRGO 2 ranges from 2.0 to 19.2 PPT, with an average salinity of 7.3 PPT; post-MRGO closure salinities for feature MRGO 3 range from 2.3 to 13.0 PPT, with an average salinity of 6.2 PPT; post-MRGO closure salinities for feature MRGO 4 range from 11.0 to 32.7 PPT, with an average salinity of 19.1 PPT.

Features MRGO2, MRGO3, and MRGO4 would repair and maintain an existing shoreline protection system. These features are not expected to cause any significant changes in the exchange of water, and salinity levels are expected to remain similar to pre-project conditions.

MRGO5, MRGO7, and MRGO8 (Shoreline Protection & Marsh Restoration)
Pre-MRGO closure salinities for feature MRGO 5 (west of the closure) range from 8.4 to 24.4 PPT, with an average salinity of 15.6 PPT; pre-MRGO closure salinities for feature MRGO 7 (west of the closure) range from 6.8 to 19.9 PPT, with an average salinity of 12.4 PPT; pre-MRGO closure salinities for feature MRGO 8 (west of the closure) range from 6.7 to 17.3 PPT, with an average salinity of 9.8 PPT. Post-MRGO closure salinities for feature MRGO 5 range from 2.7 to 24.8 PPT, with an average salinity of 9.5 PPT; post-MRGO closure salinities for feature MRGO 7 range from 2.4 to 14.9 PPT, with an average salinity of 6.9 PPT; post-MRGO closure salinities for feature MRGO 8 range from 2.3 to 13.0 PPT, with an average salinity of 6.2 PPT.

For the marsh creation components of these features, minor, short-term salinity differences may occur within the areas enclosed by confinement dikes as compared to tidal waters outside of feature areas, until dikes are breached following consolidation of dredged sediments. Following the breaching of the confinement dikes and settling of dredged sediments, tidally influenced waters would return salinities to pre-project conditions.

The shoreline protection features would provide a hydraulic barrier for the exchange of water between the MRGO channel and the marsh platform behind the protection feature. This barrier may induce some localized changes to salinities for the areas immediately behind the shoreline protection feature, the polarity of which would be dependent upon salinities in the MRGO channel.

If a flotation access channels are constructed for these features, they would be constructed to an elevation no lower than -8 feet, and would not induce the formation of salinity gradients. Therefore, access channel construction is not expected to have a significant effect on salinity of adjacent waters.

Central Wetlands (CC, CM)

CC1, CC2, CC3, and CC5 (Swamp Restoration/Nourishment)
Pre-MRGO closure salinities for these features range from 0.31 to 18 ppt, with average salinities ranging from 8.77 to 9.99 ppt. Post-MRGO closure salinities were only available for feature CC3, and range from 4.52 to 8.86 ppt, with an average salinity of 6.71 ppt.

Because salinities in Lake Borgne are similar to salinities within the footprint of these features,

hydraulic dredging of sediments from Borrow Areas 4 and 5 for swamp nourishment is not expected to result in substantial changes to salinity within the area of these features. Any minor changes in salinity resulting from the hydraulic transport of dredged slurry derived from sediment and water from Borrow Areas 4 and 5 in Lake Borgne would quickly be dispersed and thereby diluted, as no confinement dikes would be constructed for the nourishment components of these features.

For the swamp restoration components of these features, minor, short-term salinity differences may occur within the areas enclosed by confinement dikes as compared to tidal waters outside of feature areas, until dikes are breached following consolidation of dredged sediments. Following the breaching of the confinement dikes and settling of dredged sediments, tidally influenced waters would return salinities to pre-project conditions.

CC4 (Swamp Restoration)
Pre-MRGO closure salinities for this feature range from 3.1 to 18 ppt, with an average salinity of 10.1 ppt, while post-MRGO closure salinities for this feature range from 4.52 to 8.86 ppt, with an average salinity of 6.7 ppt.

Minor, short-term salinity differences may occur within the areas enclosed by confinement dikes as compared to tidal waters outside of the swamp restoration feature area, until dikes are breached following consolidation of dredged sediments. Following the breaching of the confinement dikes and settling of dredged sediments, tidally influenced waters would return salinities to pre-project conditions.

CC6 (Swamp Nourishment)
Pre-MRGO closure salinities for this feature range from 2 to 15.92 ppt, with an average salinity of 9.8 ppt, post-MRGO closure salinities for this feature are not available.

Because salinities in Lake Borgne are similar to salinities within the footprint of this feature, hydraulic dredging of sediments from Borrow Area 4 for swamp nourishment is not expected to result in substantial changes to salinity within the area of this feature. Any minor changes in salinity resulting from the hydraulic transport of dredged slurry derived from sediment and water from Borrow Area 4 in Lake Borgne would quickly be dispersed and thereby diluted, as no confinement dikes would be constructed for the nourishment components of this feature.

CM1 (Marsh Nourishment)
Pre-MRGO closure salinities for this feature range from 2.8 to 18 ppt, with an average salinity of 10.0 ppt, while post-MRGO closure salinities for this feature range from 4.52 to 8.86 ppt, with an average salinity of 6.7 ppt.

Because salinities in Lake Borgne are similar to salinities within the footprint of this feature, hydraulic dredging of sediments from Borrow Area 5 for marsh nourishment is not expected to result in substantial changes to salinity within the area of this feature. Any minor changes in salinity resulting from the hydraulic transport of dredged slurry derived from sediment and water from Borrow Area 5 in Lake Borgne would quickly be dispersed and thereby diluted, as no confinement dikes would be constructed for the nourishment components of this feature.

CM2, CM3, CM4, and CM5 (Marsh Restoration/Nourishment)
Pre-MRGO closure salinities for these features range from 0.31 to 17.52 ppt, with average salinities ranging from 9.9 to 10.5 ppt. Post-MRGO closure salinities for these features range from 4.52 to 17.5 ppt, with average salinities ranging from 6.7 to 10.3 ppt.

Because salinities in Lake Borgne and the MRGO/GIWW Borrow Area are similar to salinities within the footprint of these features, hydraulic dredging of sediments from Lake Borgne Borrow Areas 5 and 6 and the MRGO/GIWW Borrow Area for marsh nourishment is not expected to result in substantial changes to salinity within the area of these features. Any minor changes in salinity resulting from the hydraulic transport of dredged slurry derived from sediment and water from Lake Borgne Borrow Areas 5 and 6 and the GIWW borrow area would quickly be dispersed and thereby diluted, as no confinement dikes would be constructed for the nourishment components of these features.

For the marsh restoration components of these features, minor, short-term salinity differences may occur within the areas enclosed by confinement dikes as compared to tidal waters outside of feature areas, until dikes are breached following consolidation of dredged sediments. Following the breaching of the confinement dikes and settling of dredged sediments, tidally influenced waters would return salinities to pre-project conditions.

East Orleans (EM, ES)

EM1, EM3 and EM4 (Marsh Restoration/Nourishment)
Pre-MRGO closure salinities for these features range from 0.01 to 34 PPT, with average salinities ranging from 5.0 to 6.7 PPT. Post-MRGO closure salinities for these features are not available.

Because the flotation access channel for feature EM1 would be backfilled following the completion of feature construction, no long-term impacts to salinity are anticipated to result from flotation access channel construction.

EM2 (Marsh Nourishment)
Pre-MRGO closure salinities for this feature range from 0.04 to 14.48 PPT, with an average salinity of 5.4 PPT, post-MRGO closure salinities for this feature are not available.

Because salinities in Lake Borgne are similar to salinities within the footprint of this feature, hydraulic dredging of sediments from Borrow Area 8 for marsh nourishment is not expected to result in substantial changes to salinity within the area of this feature. Any minor changes in salinity resulting from the hydraulic transport of dredged slurry derived from sediment and water from Borrow Area 8 in Lake Borgne would quickly be dispersed and thereby diluted, as no confinement dikes would be constructed for the nourishment components of this feature.

Because the flotation access channel constructed for this feature would be backfilled following the completion of feature construction, no long-term impacts to salinity are anticipated to result from flotation access channel construction.

ES1, ES2, and ES3 (Shoreline Protection)
Pre-MRGO closure salinities for these features range from 0.3 to 34 PPT, with average salinities ranging from 6.1 to 6.5 PPT. Post-MRGO closure salinities for these features are not available.

These features would provide a hydraulic barrier for the exchange of water between Lake Borgne (ES3) and Lake Pontchartrain (ES1 and ES2) and the marshes behind the shoreline protection features. This barrier may induce some localized changes to salinities for the area of the marshes immediately behind the shoreline protection features. The polarity of salinity change would be dependent upon salinity conditions in Lake Borgne and Lake Pontchartrain.

Because the flotation access channel constructed for these features would be backfilled following the completion of feature construction, no long-term impacts to salinity are anticipated to result from flotation access channel construction.

South Lake Borgne (LM, LS)

LM1, LM2, LM3, and LM4 (Marsh Restoration/Nourishment)
Pre-MRGO closure salinities for these features range from 6.2 to 21.7 ppt, with average salinities ranging from 9.5 to 14.0 ppt. Post-MRGO closure salinities for these features range from 4.94 to 24.8 ppt, with average salinities ranging from 7.8 to 16.6 ppt.

Because salinities in Lake Borgne are similar to salinities within the footprint of these features, hydraulic dredging of sediments from Lake Borgne Borrow Areas 2, 4, 5, and 6 for marsh nourishment is not expected to result in substantial changes to salinity within the area of these features. Any minor changes in salinity resulting from the hydraulic transport of dredged slurry derived from sediment and water from Lake Borgne Borrow Areas 2, 4, 5, and 6 would quickly be dispersed and thereby diluted, as no confinement dikes would be constructed for the nourishment components of these features.

For the marsh restoration components of these features, minor, short-term salinity differences may occur within the areas enclosed by confinement dikes as compared to tidal waters outside of feature areas, until dikes are breached following consolidation of dredged sediments. Following the breaching of the confinement dikes and settling of dredged sediments, tidally influenced waters would return salinities to pre-project conditions.

LS1 (Shoreline Protection)
Pre-MRGO closure salinities for this feature range from 6.2 to 17.6 PPT, with an average salinity of 9.5 PPT, while post-MRGO closure salinities for this feature range from 5.1 to 11.8 PPT, with an average salinity of 7.8 PPT.

These features would provide a hydraulic barrier for the exchange of water between Lake Borgne and the marsh behind the shoreline protection feature. This barrier may induce some localized changes to salinities for the area of the marsh immediately behind the shoreline protection feature. The polarity of salinity change would be dependent upon salinity conditions in Lake Borgne.

Because the flotation access channel constructed for this feature would be backfilled following the completion of feature construction, no long-term impacts to salinity are anticipated to result from flotation access channel construction.

Terre aux Boeufs (TM)

TM1, TM2, and TM7 (Marsh Restoration/Nourishment)
Pre-MRGO closure salinities for these features range from 0.17 to 22.4 ppt, with average salinities ranging from 6.7 to 13.2 ppt. Post-MRGO closure salinities for these features are not available.

Because salinities in Lake Borgne are similar to salinities within the footprint of these features, hydraulic dredging of sediments from Lake Borgne Borrow Area 2 for marsh nourishment is not expected to result in substantial changes to salinity within the area of these features. Any minor changes in salinity resulting from the hydraulic transport of dredged slurry derived from sediment and water from Lake Borgne Borrow Area 2 would quickly be dispersed and thereby diluted, as no confinement dikes would be constructed for the nourishment components of these features.

For the marsh restoration components of these features, minor, short-term salinity differences may occur within the areas enclosed by confinement dikes as compared to tidal waters outside of feature areas, until dikes are breached following consolidation of dredged sediments. Following the breaching of the confinement dikes and settling of dredged sediments, tidally influenced waters would return salinities to pre-project conditions.

TM8 (Marsh Restoration)
Pre-MRGO closure salinities for this feature range from 0.17 to 19.4 ppt, with an average salinity of 6.7 ppt, post-MRGO closure salinities for this feature are not available.

Minor, short-term salinity differences may occur within the areas enclosed by confinement dikes as compared to tidal waters outside of the marsh restoration feature area, until dikes are breached following consolidation of dredged sediments. Following the breaching of the confinement dikes and settling of dredged sediments, tidally influenced waters would return salinities to pre-project conditions.

Hopedale (HM)

HM1 (Marsh Restoration/Nourishment)
Pre-MRGO closure salinities for this feature range from 8.8 to 22.4 ppt, with an average salinity of 13.5 ppt, post-MRGO closure salinities for this feature range are not available.

Because salinities in Lake Borgne are similar to salinities within the footprint of this feature, hydraulic dredging of sediments from Lake Borgne Borrow Area 2 for marsh nourishment is not expected to result in substantial changes to salinity within the area of this feature. Any minor changes in salinity resulting from the hydraulic transport of dredged slurry derived from sediment and water from Lake Borgne Borrow Area 2 would quickly be dispersed and thereby

diluted, as no confinement dikes would be constructed for the nourishment components of this feature.

For the marsh restoration component of this feature, minor, short-term salinity differences may occur within the areas enclosed by confinement dikes as compared to tidal waters outside of the feature area, until dikes are breached following consolidation of dredged sediments. Following the breaching of the confinement dikes and settling of dredged sediments, tidally influenced waters would return salinities to pre-project conditions.

2.2.2 Water Chemistry

2.2.2.1 pH

Data table 2.2.2-1 depicts average monthly pH levels for all project features. LDEQ and EPA water quality criteria for pH (minimum and maximum values) are also included within **data table 2.2.2-1**. Dredging and placement of dredged sediments may result in short term effects on pH. Factors typically associated with dredging activities may cause pH in receiving area waters to shift toward more acidic conditions. These factors include increased turbidity, organic enrichment, chemical leaching, reduced dissolved oxygen, and elevated carbon dioxide levels, among others.

Biloxi Marsh (BM, BS, BR)

BM1 (Marsh Nourishment)
Monthly average pH levels in the vicinity of feature BM1 range from 6.14 to 8.01.

Hydraulic placement of dredged sediments for marsh nourishment for this feature would result in a localized and temporary reduction in pH for effluent receiving waters. Tidal currents present in effluent receiving waters would help to minimize changes to ambient pH levels by dispersing effluent discharging from the marsh nourishment site. Following construction activities and breaching of confinement dikes, pH levels in the area of feature BM1 would return to those observed prior to feature construction.

BR1 (Ridge Restoration)
Monthly average pH levels in the vicinity of feature CM1 range from 7.55 to 8.03.

The placement of dewatered sediments and flotation access channel sediments for ridge restoration for this feature may result in a temporary reduction in pH within adjacent waters if sufficient effluent is generated from sediments and is allowed to reach adjacent surface waters. Tidal currents in the vicinity of feature BR1 would help to reduce any minor pH effects that would occur by dispersing these effluent waters. Following construction activities for this feature, pH levels would be expected to return to those observed prior to feature construction.

BS1 (Shoreline Protection)
Monthly average pH levels in the vicinity of feature BS1 range from 7.15 to 8.01.

Placement of rock for shoreline protection and the stockpiling and backfilling of flotation access channel sediments for this feature would result in a localized and temporary reduction in pH. Tidal currents present in the feature area would serve to disperse and thereby dilute localized changes to pH resulting from rock placement and stockpiling and backfill of flotation access channel sediments. Following construction activities, pH levels in the area of feature BS1 would return to those observed prior to feature construction.

BS2 (Oyster Reef)
Monthly average pH levels in the vicinity of feature BS2 range from 6.30 to 8.13.

Placement of materials for oyster reef construction for this feature would result in a localized and temporary reduction in pH. Tidal currents present in the feature area would serve to disperse and thereby dilute localized changes to pH resulting from oyster reef construction. Following construction activities, pH levels in the area of feature BS2 would return to those observed prior to feature construction.

MRGO Channel (MRGO)

MRGO1 and MRGO6 (Shoreline Protection)
Minimum monthly average pH levels in the vicinity of features MRGO1 and MRGO6 are 6.46 and 6.32, respectively.

Maximum monthly average pH levels in the vicinity of features MRGO1 and MRGO6 are 7.79 and 7.95, respectively.

Placement of rock for shoreline protection and the stockpiling and backfilling of flotation access channel sediments for this feature would result in a localized and temporary reduction in pH. Tidal currents present in the feature area would serve to disperse and thereby dilute localized changes to pH resulting from rock placement and stockpiling and backfill of flotation access channel sediments. Following construction activities, pH levels in the area of feature BS1 would return to those observed prior to feature construction.

MRGO2, MRGO3, and MRGO4 (Shoreline Protection Repairs/Maintenance)
Minimum monthly average pH levels in the vicinity of features MRGO2, MRGO3 and MRGO4 are 6.41, 6.46 and 6.32 respectively.

Maximum monthly average pH levels in the vicinity of features MRGO2, MRGO3 and MRGO4 are 8.36, 7.74 and 7.95 respectively.

Placement of rock for shoreline protection repairs and maintenance for these features would result in a localized and temporary reduction in pH. Tidal currents present in feature areas would serve to disperse and thereby dilute localized changes to pH resulting from rock placement. Following construction activities, pH levels in the area of features MRGO2, MRGO3 and MRGO4 would return to those observed prior to feature construction.

MRGO5, MRGO7, and MRGO8 (Shoreline Protection & Marsh Restoration)
Minimum monthly average pH levels in the vicinity of features MRGO5, MRGO7 and MRGO8 are 6.59, 6.50 and 6.41 respectively.

Maximum monthly average pH levels in the vicinity of features MRGO5, MRGO7 and MRGO8 are 8.36, 7.90 and 8.36 respectively.

The placement of rock for shoreline protection and the hydraulic placement of dredged sediments for marsh nourishment would result in a localized and temporary reduction in pH within adjacent waters. Tidal currents present in the feature areas of MRGO5, MRGO7 and MRGO8 would serve to disperse and thereby dilute localized changes to pH resulting from rock and hydraulically transported dredged slurry placement. Following construction activities, pH levels in the area of these features would return to those observed prior to feature construction.

Placement of dredged sediments for marsh restoration and nourishment for feature MRGO5 would result in a localized and temporary reduction in pH for effluent receiving waters. Tidal currents present in effluent receiving waters would help to minimize changes to ambient pH levels by dispersing effluent discharging from the marsh restoration site. Following construction activities and breaching of confinement dikes, pH levels in the area of feature MRGO5 would return to those observed prior to feature construction.

Central Wetlands (CC, CM)

CC1, CC2, CC3, and CC5 (Swamp Restoration/Nourishment)
Minimum monthly average pH levels in the vicinity of features CC1, CC2, CC3 and CC5 are 7.04, 7.04, 7.27 and 6.83 respectively.

Maximum monthly average pH levels in the vicinity of features CC1, CC2, CC3 and CC5 are 7.72, 7.72, 7.81 and 7.66 respectively.

Hydraulic placement of dredged sediments for swamp restoration and nourishment for this feature would result in a localized and temporary reduction in pH for effluent receiving waters. Tidal currents present in effluent receiving waters would help to minimize changes to ambient pH levels by dispersing effluent discharging from the swamp restoration and nourishment site. Following construction activities and breaching of confinement dikes, pH levels in the area of feature CC1, CC2, CC3 and CC5 would return to those observed prior to feature construction.

CC4 (Swamp Restoration)
Monthly average pH levels in the vicinity of feature CC4 range from 7.29 to 7.85 SU.

Hydraulic placement of dredged sediments for swamp restoration for this feature would result in a localized and temporary reduction in pH for effluent receiving waters. Tidal currents present in effluent receiving waters would help to minimize changes to ambient pH levels by dispersing effluent discharging from the swamp restoration site. Following construction activities and breaching of confinement dikes, pH levels in the area of feature CC4 would return to those

observed prior to feature construction.

CC6 (Swamp Nourishment)
Monthly average pH levels in the vicinity of feature CC6 range from 6.89 to 7.44.

Hydraulic placement of dredged sediments for swamp nourishment for this feature would result in a temporary reduction in pH within adjacent waters. Tidal currents in the vicinity of feature CC6 would help to reduce pH effects by dispersing effluent waters generated from settlement of solids present in dredged slurry. Following construction activities for this feature, pH levels would be expected to return to those observed prior to feature construction.

CM1 (Marsh Nourishment)
Monthly average pH levels in the vicinity of feature CM1 range from 7.27 to 7.81.

Hydraulic placement of dredged sediments for marsh nourishment for this feature would result in a temporary reduction in pH within adjacent waters. Tidal currents in the vicinity of feature CM1 would help to reduce pH effects by dispersing effluent waters generated from settlement of solids present in dredged slurry. Following construction activities for this feature, pH levels would be expected to return to those observed prior to feature construction.

CM2, CM3, CM4, and CM5 (Marsh Restoration/Nourishment)
Minimum monthly average pH levels in the vicinity of features CM2, CM3, CM4 and CM5 are 7.29, 6.92, 6.77 and 7.29 respectively.

Maximum monthly average pH levels in the vicinity of features CM2, CM3, CM4 and CM5 are 7.85, 7.60, 7.60 and 7.85 respectively.

Hydraulic placement of dredged sediments for marsh restoration and nourishment for this feature would result in a localized and temporary reduction in pH for effluent receiving waters. Tidal currents present in effluent receiving waters would help to minimize changes to ambient pH levels by dispersing effluent discharging from the marsh restoration site. Following construction activities and breaching of confinement dikes, pH levels in the area of features CM2, CM3, CM4 AND CM5 would return to those observed prior to feature construction.

East Orleans (EM, ES)

EM1, EM3 and EM4 (Marsh Restoration/Nourishment)
Minimum monthly average pH levels in the vicinity of features EM1, EM3 and EM4 are 7.07, 6.93 and 6.87 respectively.

Maximum monthly average pH levels in the vicinity of features EM1, EM3 and EM4 are 7.49, 7.98 and 7.79 respectively.

Hydraulic placement of dredged sediments for marsh restoration and nourishment for this feature would result in a localized and temporary reduction in pH for effluent receiving waters. Tidal currents present in effluent receiving waters would help to minimize changes to ambient pH

levels by dispersing effluent discharging from the marsh restoration site. Following construction activities and breaching of confinement dikes, pH levels in the area of features EM1, EM3 and EM4 would return to those observed prior to feature construction.

The stockpiling and backfilling of flotation access channel sediments for feature EM1 would result in a localized and temporary reduction in pH. Tidal currents present near the feature area would serve to disperse and thereby dilute localized changes to pH resulting from the stockpiling and backfill of the flotation access channel. Following backfill of the flotation access channel, pH levels in the area of feature EM1 would return to those observed prior to feature construction.

EM2 (Marsh Nourishment)
Monthly average pH levels in the vicinity of feature EM2 range from 6.30 to 8.09.

Hydraulic placement of dredged sediments for marsh nourishment for this feature would result in a temporary reduction in pH within adjacent waters. Tidal currents in the vicinity of feature EM2 would help to reduce pH effects by dispersing effluent waters generated from settlement of solids present in dredged slurry. Following construction activities for this feature, pH levels would be expected to return to those observed prior to feature construction.

The stockpiling and backfilling of flotation access channel sediments for feature EM2 would result in a localized and temporary reduction in pH. Tidal currents present near the feature area would serve to disperse and thereby dilute localized changes to pH resulting from the stockpiling and backfill of the flotation access channel. Following backfill of the flotation access channel, pH levels in the area of feature EM2 would return to those observed prior to feature construction.

ES1, ES2, and ES3 (Shoreline Protection)
Minimum monthly average pH levels in the vicinity of features ES1, ES2 and ES3 are 7.09, 7.00 and 7.14 respectively.

Maximum monthly average pH levels in the vicinity of features ES1, ES2 and ES3 are 7.50, 7.51 and 7.71 respectively.

Placement of rock for shoreline protection and the stockpiling and backfilling of flotation access channel sediments for these features would result in a localized and temporary reduction in pH. Tidal currents present in the feature area would serve to disperse and thereby dilute localized changes to pH resulting from rock placement and stockpiling and backfill of flotation access channel sediments. Following construction activities, pH levels in the area of features ES1, ES2,and ES3 would return to those observed prior to feature construction.

South Lake Borgne (LM, LS)

LM1, LM2, LM3, and LM4 (Marsh Restoration/Nourishment)
Minimum monthly average pH levels in the vicinity of features LM1, LM2, LM3 and LM4 are 7.42, 7.23, 7.49 and 6.54 respectively.

Maximum monthly average pH levels in the vicinity of features LM1, LM2, LM3 and LM4 are 7.84, 7.72, 8.36 and 7.84 respectively.

Hydraulic placement of dredged sediments for marsh restoration and nourishment for this feature would result in a localized and temporary reduction in pH for effluent receiving waters. Tidal currents present in effluent receiving waters would help to minimize changes to ambient pH levels by dispersing effluent discharging from the marsh restoration site. Following construction activities and breaching of confinement dikes, pH levels in the area of features LM1, LM2, LM3 and LM4 would return to those observed prior to feature construction.

LS1 (Shoreline Protection)
Monthly average pH levels in the vicinity of feature LS1 range from 7.23 to 7.72.

Placement of rock for shoreline protection and the stockpiling and backfilling of flotation access channel sediments for this feature would result in a localized and temporary reduction in pH. Tidal currents present in the feature area would serve to disperse and thereby dilute localized changes to pH resulting from rock placement and stockpiling and backfill of flotation access channel sediments. Following construction activities, pH levels in the area of feature BS1 would return to those observed prior to feature construction.

Terre aux Boeufs (TM)

TM1, TM2, and TM7 (Marsh Restoration/Nourishment)
Minimum monthly average pH levels in the vicinity of features TM1, TM2 and TM7 are 7.69, 7.57 and 7.69 respectively.

Maximum monthly average pH levels in the vicinity of features TM1, TM2 and TM7 are 8.24, 8.02 and 8.24 respectively.

Hydraulic placement of dredged sediments for marsh restoration and nourishment for this feature would result in a localized and temporary reduction in pH for effluent receiving waters. Tidal currents present in effluent receiving waters would help to minimize changes to ambient pH levels by dispersing effluent discharging from the marsh restoration site. Following construction activities and breaching of confinement dikes, pH levels in the area of features TM1, TM2 and TM7 would return to those observed prior to feature construction.

TM8 (Marsh Restoration)
Monthly average pH levels in the vicinity of feature TM8 range from 7.69 to 8.24 SU.

Hydraulic placement of dredged sediments for marsh restoration for this feature would result in a localized and temporary reduction in pH for effluent receiving waters. Tidal currents present in effluent receiving waters would help to minimize changes to ambient pH levels by dispersing effluent discharging from the marsh restoration site. Following construction activities and breaching of confinement dikes, pH levels in the area of feature TM8 would return to those observed prior to feature construction.

Hopedale (HM)

HM1 (Marsh Restoration/Nourishment)
Monthly average pH levels in the vicinity of feature HM1 range from 7.36 to 8.08.

Hydraulic placement of dredged sediments for marsh restoration and nourishment for this feature would result in a localized and temporary reduction in pH for effluent receiving waters. Tidal currents present in effluent receiving waters would help to minimize changes to ambient pH levels by dispersing effluent discharging from the marsh restoration site. Following construction activities and breaching of confinement dikes, pH levels in the area of feature HM1 would return to those observed prior to feature construction.

2.2.2.2 Water Column Impacts

Overview

Water column impacts resulting from the placement of dredged or fill material for the MRGO Ecosystem Restoration project will differ for each type of feature included in the project. For placement of rock for shoreline protection and shoreline protection repairs and maintenance, very little impact to the water column would be expected, as rocks are expected to be relatively free of contamination, and disturbances to water bottom substrate associated with rock placement would be minimal and short-lived. For oyster reef construction, impacts to the water column would likewise be minimal due to the expected lack of contamination in materials to be used as bedding for oyster reef construction. Construction of the Violet Freshwater Diversion may result in a localized and minor disturbance of water bottom sediments during feature construction; however, the currents of the Mississippi River would quickly disperse and dilute any resuspended sediments. In addition, construction materials for this feature are also expected to be relatively free of contamination. The stockpiling and subsequent backfilling of mechanically dredged flotation access channel material may result in minor, temporary water column impacts, particularly for features which require substantial access channel dredging. Because the method of dredging for construction and backfilling of access channels is not expected to induce a significant release of dissolved contaminants, because sediments proposed for excavation for flotation access channel construction are not in the proximity of any known sources of contaminants (most flotation access channels would be constructed along the Lakes Borgne and Pontchartrain shorelines, as well as along the left descending bank of the MRGO channel south of Bayou Bienvenue), and because flotation access channels would be constructed in waterbodies with the capacity to quickly disperse and dilute any concentrations of contaminants released during dredged material placement activities, associated water column impacts are anticipated to be minimal and short-lived. The major restoration types for which there is a potential for adverse water column impacts appear to be wetlands restoration and/or nourishment—which include marsh restoration, marsh nourishment, swamp restoration, and swamp nourishment—and ridge restoration.

For wetlands restoration and/or nourishment features, the border of each feature would be comprised of a confinement dike which would prevent the uncontrolled dispersion of dredged slurry while allowing suspended solids associated with the slurry to settle within the footprint of

the feature. An effluent weir located along the alignment of the confinement dike would allow supernatant water to exit the footprint of the feature following adequate settlement of suspended solids (EPA/USACE, 1998). Effluent would be expected to contain low levels of suspended solids, and also would likely contain concentrations of dissolved contaminants resulting from the mixing of borrow area water and sediments. For ridge restoration, dewatered sediments would be placed atop of the existing Bayou La Loutre Ridge. Ridge restoration would generate very little effluent due to the dewatered nature of borrow sediments; however, as a worst-case scenario, sediments are assumed to contain sufficient water content to result in a discharge into adjacent wetlands or waterbodies during placement activities.

Several water quality criteria and standards exist which apply to the discharge of dredged material effluent into the aquatic environment in waters of the United States, in order to ensure that dissolved contaminant concentrations released as a result of these discharges do not result in adverse impacts to aquatic life. Federal and State water quality criteria applicable to the MRGO Ecosystem Restoration project are promulgated by the U.S. Environmental Protection Agency (EPA) and State of Louisiana Department of Environmental Quality (LDEQ). Federal aquatic life criteria are published by the EPA pursuant to section 304(a) of the Clean Water Act (CWA); numerical criteria are available for approximately 150 contaminants, and the application of criteria for each contaminant is dependent on salinity regime (freshwater and marine) and duration of effect (acute and chronic) (EPA, 2010). State aquatic life criteria for toxic substances, metals, and inorganics published by the LDEQ have been derived mostly from EPA publications for water quality criteria, but also consider background conditions of state waterbodies (Louisiana Administrative Code (LAC) Title 33, Part IX, Subpart 1, Section 1113). These numerical criteria have been derived primarily for the attainment of fish and wildlife propagation use. Similar to EPA criteria, the application of State numerical criteria for each contaminant is dependent on salinity regime (freshwater, brackish, and marine) and duration of effect (acute and chronic).

For restoration features included in the MRGO Ecosystem Restoration project, applicable salinity regimes for comparison to State and Federal water quality criteria were determined based on the average salinity of water samples in the vicinity of each feature. Salinity regimes as they are defined in LAC Title 33, Part IX, Subpart 1, Section 1105 were used to define the applicable salinity regime for each feature. Features whose surface waters had an average salinity between 0 and 2 parts per thousand (ppt) were defined as having a freshwater salinity regime, and water column impacts associated with the construction of these features were compared to State and Federal freshwater criteria. Features whose surface waters had an average salinity between 2 and 10 ppt were defined as having a brackish salinity regime, and water column impacts associated with the construction of these features were compared to State brackish and Federal marine criteria. Features whose surface waters had an average salinity greater than 10 ppt were defined as having a marine salinity regime, and water column impacts associated with the construction of these features were compared to State and Federal marine criteria.

In order to meet compliance with State of Louisiana water quality standards, the discharge of dredged material effluent for the construction of wetlands restoration and/or nourishment features is required to meet all State and Federal aquatic life criteria beyond the State-defined mixing zone, which is defined as "those portions of water bodies where effluent waters are

dispersed into receiving waters" (LAC Title 33, Part IX, Subpart 1, Section 1115). The mixing zone for any particular effluent discharge is dependent on the receiving waterbody. Table 2a in LAC Title 33, Part IX, Subpart 1, Section 1115 describes each category of waterbody and its applicable mixing zone. For many of the wetlands restoration and/or nourishment features included in the MRGO Ecosystem Restoration project, the location of effluent discharge associated with these features is not clearly defined; in some cases, the receiving waterbody for discharged effluent is defined as 'adjacent marsh' and 'adjacent waterbodies' (MRGO Ecosystem Restoration DEIS). Under these assumptions, and as a screening step, all mixing zones are assumed to be minimal, such that very little dilution will be available in waterbodies receiving effluent discharge in order to dilute any exceedances of water quality criteria down to levels below criteria prior to reaching the edge of the mixing zone. Inversely, this assumption implies that dissolved concentrations of contaminants could only be allowed to marginally exceed both acute and chronic aquatic life criteria in order for these exceedances to be diluted to levels below water quality criteria before reaching the edge of the State-defined mixing zone.

The estimation of dissolved contaminant concentrations for effluent discharged from wetlands restoration and/or nourishment features can be accomplished through one of two approaches. The first approach is to use available sediment chemistry, sediment physical properties, and water chemistry representative of borrow area surface water and substrate, as well as available water chemistry representative of the water quality conditions in the restoration feature footprint, to screen for any exceedances of water quality associated with the effluent discharge activity. Technical documentation providing instruction for this method of estimating water column impacts from the discharge of dredged material effluent are available in ERDC (2006). The second approach is to collect project-specific sediment and water samples in order to prepare for a modified elutriates test in accordance with methodology established in the Upland Testing Manual (UTM; USACE [2003]).

For dewatered, mechanically dredged sediments proposed as borrow material for ridge restoration, effluent generated is assumed to contain characteristics similar to runoff from hydraulically dredged sediments placed in a confined disposal facility. Dissolved contaminant concentrations associated with effluent resulting from placement of sediments for ridge restoration was therefore estimated based on principles for the estimation of upland confined disposal facility surface runoff quality included in USACE (2008). This Army Technical Note provides guidance for estimating dredged material runoff quality based on available sediment chemistry, sediment physical properties, and water chemistry representative of borrow area surface water and substrate, as well as water chemistry representative of water quality conditions in the restoration feature footprint.

Lake Borgne Borrow Areas: For these borrow areas (Borrow Areas 2, 3, 4, 5, 6, and 8), no modified elutriate tests were performed on borrow area sediments in order to predict dissolved concentrations of contaminants during hydraulic placement of dredged sediments. However, sufficient data was available to provide a screen for exceedances of water quality criteria based on ERDC (2006). For the screening evaluation, both the average of average representative sediment contaminant concentrations for each of these borrow areas, and the maximum representative sediment contaminant concentration within all of these borrow areas was used as input data for Lake Borgne borrow areas. Surface water chemistry for both the Lake Borgne

borrow areas and associated restoration features was taken to be the highest representative average between these borrow areas, as well as the highest representative average between all restoration features. Borrow area sediment physical properties were taken to be the average of representative physical properties for all Lake Borgne borrow areas.

The screening evaluation was divided based upon the feature salinities; all features to receive borrow sediments from Lake Borgne were collectively grouped based on where their representative water chemistry data contained an average salinity that was either brackish or marine. Within each of these two groupings, screening evaluations were further divided based on the representative sediment data used (average of average representative contaminant concentrations for each of the Lake Borgne borrow areas, or maximum representative contaminant concentration within all Lake Borgne borrow areas) and based on whether results of the screen would be compared to acute or chronic water quality criteria.

The screen could only be conducted for parameters for which representative sediment chemistry data was available for one or more of the Lake Borgne borrow areas, and for which water quality criteria existed. For parameters for which representative sediment chemistry data was available, but for which no representative borrow area and/or restoration feature water chemistry data was available, concentrations in water were estimated by one of two methods. For the first, where no water chemistry data was available for any feature, representative water chemistry for both borrow area and restoration feature waters were estimated to be slightly below the water quality criteria selected for comparison (either acute or chronic), such that if the release of the contaminant from sediments was expected to be at levels exceeding criteria, the contaminant would be flagged for further review. For the second, where representative water chemistry data was available for any of the borrow areas or restoration features included in the MRGO Ecosystem Restoration project, the maximum concentration from all borrow areas and restoration features was used. The lesser of the State and Federal criteria for a given parameter was utilized for the screen. Where the representative average for a restoration feature grouping exceeded the applicable water quality criteria, the dilution required to achieve a concentration 5 percent greater than the representative average was instead determined. For most contaminants, a release from sediments was predicted to be at levels below the water quality criteria selected for comparison.

A summary of the results of the screening evaluation are included in **data table 2.2.2-2**, which is based on a series of spreadsheets that accompanies ERDC (2006). The parameters for which representative sediment chemistry data for the Lake Borgne borrow areas and for which water quality criteria were available, and therefore for which a screening evaluation could be conducted, included the metals arsenic, cadmium, copper, lead, mercury, nickel, selenium, silver, and zinc, as well as the pesticides aldrin, gamma-BHC, alpha-chlordane, p,p'-DDD, p,p'-DDE, p,p'-DDT, dieldrin, alpha-endosulfan, beta-endosulfan, endrin, heptachlor, heptachlor epoxide, mirex, and tozaphene. Copper was the only parameter for which a dilution requirement was obtained based on representative sediment chemistry results for borrow areas which were not below the laboratory detection limit, and based upon representative water chemistry results for borrow areas and restoration areas which were not below the laboratory detection limit. The highest dilution requirement was determined to be for the brackish restoration features which will utilize borrow sediments from Lake Borgne, where screening based on the average of

average representative copper concentrations for each of the borrow areas and based on the lesser of LDEQ brackish chronic and EPA marine chronic criteria indicated a dilution requirement of 1.94. However, for both marine and brackish feature groups, there were also several contaminants for which their release from sediments would initially (prior to mixing with water from borrow areas) enter the water column at levels exceeding the applicable water quality criteria, including selenium, alpha-endosulfan, beta-endosulfan, and toxaphene. For selenium, concentrations were detected in representative borrow area sediments, but no representative water chemistry results were available for either the Lake Borgne borrow areas or associated restoration areas, while for alpha-endosulfan, beta-endosulfan, and toxaphene, concentrations in representative borrow area sediments were all below the laboratory detection limit.

Mississippi River Borrow Area: For the Bayou La Loutre Ridge restoration feature (feature BR1), it was conservatively assumed that dewatered and mechanically dredged Mississippi River borrow area sediments would contain sufficient water to result in a discharge into adjacent waterbodies and wetlands during dredged material placement, and that effluent quality would resemble the water quality for unoxidized (wet) confined disposal facility runoff. To estimate dissolved concentrations of contaminants associated with effluent, a screen was conducted in accordance with methodology included in the Army Technical Note Screening Evaluations for Upland Confined Disposal Facility Surface Runoff Quality (ERDC, 2008). The technical note provides methodology for the estimation of unoxidized (wet) confined disposal facility surface runoff quality based on sediment chemistry, sediment physical properties, and water chemistry representative of borrow area surface water and substrate, as well as water chemistry representative of water quality conditions in the restoration feature footprint.

Data table 2.2.2-3 depicts effluent dilution requirements for parameters for which borrow area sediment chemistry results and State or Federal chronic water quality criteria were available, which is based on results for Mississippi River borrow area sediments. Copper was the only contaminant detected in borrow area sediment and water, as well as feature area water, that required a dilution in order to comply with water quality criteria. The dilution required for copper is 0.441.

MRGO/GIWW Borrow Area: **Data table 2.2.2-4** depicts the dilution requirements necessary to meet the most stringent State/Federal acute and chronic water quality criteria for modified elutriate results. The maximum modified elutriate concentration observed for ammonia would require a dilution factor of 5.56 to meet the most stringent State/Federal water quality criteria. For copper, the maximum modified elutriate concentration observed would require a dilution factor of 3.30 to meet the most stringent State/Federal chronic water quality criteria. For total PCBs, the minimum and maximum modified elutriate concentrations observed would require dilution factors of 139 and 187, respectively, to meet the most stringent State/Federal chronic water quality criteria.

Biloxi Marsh (BM, BS, BR)

BM1 (Marsh Nourishment)

Representative water chemistry data indicates that the salinity regime of feature BM1 is marine.

Data table 2.2.2-2 depicts dilution requirements for parameters for which representative borrow area sediment chemistry data and water quality criteria were available for both brackish and marine features whose borrow sediment will be acquired from one of the Lake Borgne borrow areas. For marine features, where the average representative contaminant concentrations from each borrow area were averaged for the purpose of screening, copper was the only parameter which required a dilution based on detectible concentrations in representative borrow area water and sediment, as well as representative water chemistry. In order to meet marine acute criteria, the dilution required for copper was 0.160, while in order to meet marine chronic criteria, the required dilution was 0.473. Where the maximum contaminant concentrations from all borrow areas were utilized for the purpose of screening, copper was the only parameter which required a dilution based on detectible concentrations in representative borrow area water and sediment, as well as representative water chemistry. In order to meet marine acute criteria, the dilution required for copper was 0.290, while in order to meet marine chronic criteria, the required dilution was 0.637. Based on the screening evaluation for marine restoration features, it is anticipated that very little dilution would be required to meet water quality criteria for any marine features.

BR1 (Ridge Restoration)

Data table 2.2.2-3 depicts effluent dilution requirements for parameters for which borrow area sediment chemistry results and State or Federal chronic water quality criteria were available. Copper was the only contaminant detected in borrow area sediment and water, as well as feature area water, that required a dilution in order to comply with water quality criteria. The dilution required for copper is 0.441. Because it is expected that this dilution factor can be achieved, and because the approach for estimating water column impacts associated with feature BR1 conservatively estimates that dewatered sediments would still generate effluent in sufficient quantities to be able to migrate to adjacent surface waters, the placement of dewatered sediments from the Mississippi River borrow area for ridge restoration is not anticipated to result in any adverse water column impacts for adjacent waterbodies or wetland areas.

The sidecasting of mechanically dredged flotation access channel material within the footprint of feature BR1 may result in minor, temporary water column impacts. Because the method of dredging for flotation access channel construction is not expected to induce a significant release of dissolved contaminants, and because sediments proposed for excavation for flotation access channel construction are not in proximity to any known sources of contaminants, water column impacts associated with placement of flotation access channel material are anticipated to be minimal and short-lived.

BS1 (Shoreline Protection)

For placement of rock for shoreline protection for feature BS1, very little impact to the water column would be expected, as rocks are expected to be relatively free of contamination, and disturbances to water bottom substrate associated with rock placement would be minimal and short-lived.

The stockpiling and subsequent backfilling of mechanically dredged flotation access channel material for feature BS1 may result in minor, temporary water column impacts. Because the method of dredging for flotation access channel construction and backfilling is not expected to

induce a significant release of dissolved contaminants, because sediments proposed for excavation for flotation access channel construction are not in proximity to any known sources of contaminants, and because the flotation access channel would be constructed within a waterbody with the capacity to quickly disperse and dilute any concentrations of contaminants released during dredged material placement activities, associated water column impacts are anticipated to be minimal and short-lived.

BS2 (Oyster Reef)
For placement of materials to construct oyster reef habitat for feature BS2, very little impact to the water column would be expected, as materials are expected to be relatively free of contamination, and disturbances to water bottom substrate associated with oyster reef construction would be minimal and short-lived.

MRGO Channel (MRGO)

MRGO1 and MRGO6 (Shoreline Protection)
For placement of rock for shoreline protection for feature MRGO6, very little impact to the water column would be expected, as rocks are expected to be relatively free of contamination, and disturbances to water bottom substrate associated with rock placement would be minimal and short-lived.

The stockpiling and subsequent backfilling of mechanically dredged flotation access channel material for features MRGO1 and MRGO6 may result in minor, temporary water column impacts. Because the method of dredging for flotation access channel construction and backfilling is not expected to induce a significant release of dissolved contaminants, because sediments proposed for excavation for flotation access channel construction are not in proximity to any known sources of contaminants, and because the flotation access channel would be constructed within a waterbody with the capacity to quickly disperse and dilute any concentrations of contaminants released during dredged material placement activities, associated water column impacts are anticipated to be minimal and short-lived.

MRGO2, MRGO3, and MRGO4 (Shoreline Protection Repairs/Maintenance)
For placement of rock for shoreline protection for these features, very little impact to the water column would be expected, as rocks are expected to be relatively free of contamination, and disturbances to water bottom substrate associated with rock placement would be minimal and short-lived.

MRGO5, MRGO7, and MRGO8 (Shoreline Protection & Marsh Restoration)
Representative water chemistry data indicates that the salinity regime for features MRGO5 and MRGO7 is marine, while the salinity regime for feature MRGO8 is brackish.

Data table 2.2.2-2 depicts dilution requirements for parameters for which representative borrow area sediment chemistry data and water quality criteria were available for both brackish and marine features whose borrow sediment will be acquired from one of the Lake Borgne borrow areas. For marine features, where the average representative contaminant concentrations from each borrow area were averaged for the purpose of screening, copper was the only parameter

which required a dilution based on detectible concentrations in representative borrow area water and sediment, as well as representative water chemistry. In order to meet marine acute criteria, the dilution required for copper was 0.160, while in order to meet marine chronic criteria, the required dilution was 0.473. Where the maximum contaminant concentrations from all borrow areas were utilized for the purpose of screening, copper was the only parameter which required a dilution based on detectible concentrations in representative borrow area water and sediment, as well as representative water chemistry. In order to meet marine acute criteria, the dilution required for copper was 0.290, while in order to meet marine chronic criteria, the required dilution was 0.637. Based on the screening evaluation for marine restoration features, it is anticipated that very little dilution would be required to meet water quality criteria for any marine features.

For brackish features, where the average representative contaminant concentrations from each borrow area were averaged for the purpose of screening, copper was the only parameter which required a dilution based on detectible concentrations in representative borrow area water and sediment, as well as representative water chemistry. In order to meet brackish acute criteria, the dilution required for copper was 0.397, while in order to meet brackish chronic criteria, the required dilution was 1.94. For brackish features, where the maximum contaminant concentrations from all borrow areas were utilized for the purpose of screening, no parameters required dilution. Based on the screening evaluation for brackish restoration features, it is anticipated that very little dilution would be required to meet water quality criteria for any marine features.

For placement of rock for shoreline protection for these features, very little impact to the water column would be expected, as rocks are expected to be relatively free of contamination, and disturbances to water bottom substrate associated with rock placement would be minimal and short-lived.

Placement of mechanically dredged flotation access channel material within the footprint of feature MRGO5 may result in minor, temporary water column impacts. Because the method of dredging for flotation access channel construction is not expected to induce a significant release of dissolved contaminants, and because sediments proposed for excavation for flotation access channel construction are not in proximity to any known sources of contaminants, associated water column impacts are anticipated to be minimal and short-lived.

Central Wetlands (CC, CM)

CC1, CC2, CC3, and CC5 (Swamp Restoration/Nourishment)
Representative water chemistry data indicates that the salinity regimes of features CC1, CC2, CC3, and CC5 are all brackish.

Data table 2.2.2-2 depicts dilution requirements for parameters for which representative borrow area sediment chemistry data and water quality criteria were available for both brackish and marine features whose borrow sediment will be acquired from one of the Lake Borgne borrow areas. For brackish features, where the average representative contaminant concentrations from each borrow area were averaged for the purpose of screening, copper was the only parameter

which required a dilution based on detectible concentrations in representative borrow area water and sediment, as well as representative water chemistry. In order to meet brackish acute criteria, the dilution required for copper was 0.397, while in order to meet brackish chronic criteria, the required dilution was 1.94. For brackish features, where the maximum contaminant concentrations from all borrow areas were utilized for the purpose of screening, no parameters required dilution. Based on the screening evaluation for brackish restoration features, it is anticipated that very little dilution would be required to meet water quality criteria for any marine features.

CC4 (Swamp Restoration)
Representative water chemistry data indicates that the salinity regime of feature CC4 is brackish.

Data table 2.2.2-2 depicts dilution requirements for parameters for which representative borrow area sediment chemistry data and water quality criteria were available for both brackish and marine features whose borrow sediment will be acquired from one of the Lake Borgne borrow areas. For brackish features, where the average representative contaminant concentrations from each borrow area were averaged for the purpose of screening, copper was the only parameter which required a dilution based on detectible concentrations in representative borrow area water and sediment, as well as representative water chemistry. In order to meet brackish acute criteria, the dilution required for copper was 0.397, while in order to meet brackish chronic criteria, the required dilution was 1.94. For brackish features, where the maximum contaminant concentrations from all borrow areas were utilized for the purpose of screening, no parameters required dilution. Based on the screening evaluation for brackish restoration features, it is anticipated that very little dilution would be required to meet water quality criteria for any marine features.

CC6 (Swamp Nourishment)
Representative water chemistry data indicates that the salinity regime of feature CC6 is brackish.

Data table 2.2.2-2 depicts dilution requirements for parameters for which representative borrow area sediment chemistry data and water quality criteria were available for both brackish and marine features whose borrow sediment will be acquired from one of the Lake Borgne borrow areas. For brackish features, where the average representative contaminant concentrations from each borrow area were averaged for the purpose of screening, copper was the only parameter which required a dilution based on detectible concentrations in representative borrow area water and sediment, as well as representative water chemistry. In order to meet brackish acute criteria, the dilution required for copper was 0.397, while in order to meet brackish chronic criteria, the required dilution was 1.94. For brackish features, where the maximum contaminant concentrations from all borrow areas were utilized for the purpose of screening, no parameters required dilution. Based on the screening evaluation for brackish restoration features, it is anticipated that very little dilution would be required to meet water quality criteria for any marine features.

CM1 (Marsh Nourishment)
Representative water chemistry data indicates that the salinity regime of feature CM1 is brackish.

Data table 2.2.2.-2 depicts dilution requirements for parameters for which representative borrow area sediment chemistry data and water quality criteria were available for both brackish and marine features whose borrow sediment will be acquired from one of the Lake Borgne borrow areas. For brackish features, where the average representative contaminant concentrations from each borrow area were averaged for the purpose of screening, copper was the only parameter which required a dilution based on detectible concentrations in representative borrow area water and sediment, as well as representative water chemistry. In order to meet brackish acute criteria, the dilution required for copper was 0.397, while in order to meet brackish chronic criteria, the required dilution was 1.94. For brackish features, where the maximum contaminant concentrations from all borrow areas were utilized for the purpose of screening, no parameters required dilution. Based on the screening evaluation for brackish restoration features, it is anticipated that very little dilution would be required to meet water quality criteria for any marine features.

CM2, CM3, CM4, and CM5 (Marsh Restoration/Nourishment)

Representative water chemistry data indicates that the salinity regimes of features CM2 and CM3 are brackish, while the salinity regimes of features CM4 and CM5 are marine.

Data table 2.2.2-4 depicts the dilution requirements necessary to meet the most stringent State/Federal acute and chronic water quality criteria for modified elutriate results for the MRGO/GIWW borrow area (the proposed borrow area for feature CM2). The maximum modified elutriate concentration observed for ammonia would require a dilution factor of 5.56 to meet the most stringent State/Federal water quality criteria. For copper, the maximum modified elutriate concentration observed would require a dilution factor of 3.30 to meet the most stringent State/Federal chronic water quality criteria. For total PCBs, the minimum and maximum modified elutriate concentrations observed would require dilution factors of 139 and 187, respectively, to meet the most stringent State/Federal chronic water quality criteria. Although a determination of available dilution for feature CM2 is not available, it is not predicted that the effluent water receiving area for this feature would have sufficient dilution available to allow effluent to meet both acute and chronic water quality criteria for total PCBs at the edge of the State mixing zone, as very little dilution is expected to be available in the Central Wetlands Area.

Data table 2.2.2-2 depicts dilution requirements for parameters for which representative borrow area sediment chemistry data and water quality criteria were available for both brackish and marine features whose borrow sediment will be acquired from one of the Lake Borgne borrow areas. For marine features, where the average representative contaminant concentrations from each borrow area were averaged for the purpose of screening, copper was the only parameter which required a dilution based on detectible concentrations in representative borrow area water and sediment, as well as representative water chemistry. In order to meet marine acute criteria, the dilution required for copper was 0.160, while in order to meet marine chronic criteria, the required dilution was 0.473. Where the maximum contaminant concentrations from all borrow areas were utilized for the purpose of screening, copper was the only parameter which required a dilution based on detectible concentrations in representative borrow area water and sediment, as well as representative water chemistry. In order to meet marine acute criteria, the dilution required for copper was 0.290, while in order to meet marine chronic criteria, the required

dilution was 0.637. Based on the screening evaluation for marine restoration features, it is anticipated that very little dilution would be required to meet water quality criteria for any marine features.

For brackish features, where the average representative contaminant concentrations from each borrow area were averaged for the purpose of screening, copper was the only parameter which required a dilution based on detectible concentrations in representative borrow area water and sediment, as well as representative water chemistry. In order to meet brackish acute criteria, the dilution required for copper was 0.397, while in order to meet brackish chronic criteria, the required dilution was 1.94. For brackish features, where the maximum contaminant concentrations from all borrow areas were utilized for the purpose of screening, no parameters required dilution. Based on the screening evaluation for brackish restoration features, it is anticipated that very little dilution would be required to meet water quality criteria for any marine features.

East Orleans (EM, ES)

EM1, EM3 and EM4 (Marsh Restoration/Nourishment)
Representative water chemistry data indicates that the salinity regimes of features EM1, EM3, and EM4 are brackish.

Data table 2.2.2-2 depicts dilution requirements for parameters for which representative borrow area sediment chemistry data and water quality criteria were available for both brackish and marine features whose borrow sediment will be acquired from one of the Lake Borgne borrow areas. For brackish features, where the average representative contaminant concentrations from each borrow area were averaged for the purpose of screening, copper was the only parameter which required a dilution based on detectible concentrations in representative borrow area water and sediment, as well as representative water chemistry. In order to meet brackish acute criteria, the dilution required for copper was 0.397, while in order to meet brackish chronic criteria, the required dilution was 1.94. For brackish features, where the maximum contaminant concentrations from all borrow areas were utilized for the purpose of screening, no parameters required dilution. Based on the screening evaluation for brackish restoration features, it is anticipated that very little dilution would be required to meet water quality criteria for any marine features.

The stockpiling and subsequent backfilling of mechanically dredged flotation access channel material for feature EM1 may result in minor, temporary water column impacts. Because the method of dredging for flotation access channel construction and backfilling is not expected to induce a significant release of dissolved contaminants, because sediments proposed for excavation for flotation access channel construction are not in proximity to any known sources of contaminants, and because the flotation access channel would be constructed within a waterbody with the capacity to quickly disperse and dilute any concentrations of contaminants released during dredged material placement activities, associated water column impacts are anticipated to be minimal and short-lived.

EM2 (Marsh Nourishment)
Representative water chemistry data indicates that the salinity regime of feature EM2 is brackish.

Data table 2.2.2-2 depicts dilution requirements for parameters for which representative borrow area sediment chemistry data and water quality criteria were available for both brackish and marine features whose borrow sediment will be acquired from one of the Lake Borgne borrow areas. For brackish features, where the average representative contaminant concentrations from each borrow area were averaged for the purpose of screening, copper was the only parameter which required a dilution based on detectible concentrations in representative borrow area water and sediment, as well as representative water chemistry. In order to meet brackish acute criteria, the dilution required for copper was 0.397, while in order to meet brackish chronic criteria, the required dilution was 1.94. For brackish features, where the maximum contaminant concentrations from all borrow areas were utilized for the purpose of screening, no parameters required dilution. Based on the screening evaluation for brackish restoration features, it is anticipated that very little dilution would be required to meet water quality criteria for any marine features.

The stockpiling and subsequent backfilling of mechanically dredged flotation access channel material for feature EM2 may result in minor, temporary water column impacts. Because the method of dredging for flotation access channel construction and backfilling is not expected to induce a significant release of dissolved contaminants, because sediments proposed for excavation for flotation access channel construction are not in proximity to any known sources of contaminants, and because the flotation access channel would be constructed within a waterbody with the capacity to quickly disperse and dilute any concentrations of contaminants released during dredged material placement activities, associated water column impacts are anticipated to be minimal and short-lived.

ES1, ES2, and ES3 (Shoreline Protection)
For placement of rock for shoreline protection for these features, very little impact to the water column would be expected, as rocks are expected to be relatively free of contamination, and disturbances to water bottom substrate associated with rock placement would be minimal and short-lived.

The stockpiling and subsequent backfilling of mechanically dredged flotation access channel material for these features may result in minor, temporary water column impacts. Because the method of dredging for flotation access channel construction and backfilling is not expected to induce a significant release of dissolved contaminants, because sediments proposed for excavation for flotation access channel construction are not in proximity to any known sources of contaminants, and because the flotation access channel would be constructed within a waterbody with the capacity to quickly disperse and dilute any concentrations of contaminants released during dredged material placement activities, associated water column impacts are anticipated to be minimal and short-lived.

South Lake Borgne (LM, LS)

LM1, LM2, LM3, and LM4 (Marsh Restoration/Nourishment)
Representative water chemistry data indicates that the salinity regimes of features LM1 and LM3 are brackish, while the salinity regimes of features LM2 and LM4 are marine.

Data table 2.2.2-2 depicts dilution requirements for parameters for which representative borrow area sediment chemistry data and water quality criteria were available for both brackish and marine features whose borrow sediment will be acquired from one of the Lake Borgne borrow areas. For marine features, where the average representative contaminant concentrations from each borrow area were averaged for the purpose of screening, copper was the only parameter which required a dilution based on detectible concentrations in representative borrow area water and sediment, as well as representative water chemistry. In order to meet marine acute criteria, the dilution required for copper was 0.160, while in order to meet marine chronic criteria, the required dilution was 0.473. Where the maximum contaminant concentrations from all borrow areas were utilized for the purpose of screening, copper was the only parameter which required a dilution based on detectible concentrations in representative borrow area water and sediment, as well as representative water chemistry. In order to meet marine acute criteria, the dilution required for copper was 0.290, while in order to meet marine chronic criteria, the required dilution was 0.637. Based on the screening evaluation for marine restoration features, it is anticipated that very little dilution would be required to meet water quality criteria for any marine features.

For brackish features, where the average representative contaminant concentrations from each borrow area were averaged for the purpose of screening, copper was the only parameter which required a dilution based on detectible concentrations in representative borrow area water and sediment, as well as representative water chemistry. In order to meet brackish acute criteria, the dilution required for copper was 0.397, while in order to meet brackish chronic criteria, the required dilution was 1.94. For brackish features, where the maximum contaminant concentrations from all borrow areas were utilized for the purpose of screening, no parameters required dilution. Based on the screening evaluation for brackish restoration features, it is anticipated that very little dilution would be required to meet water quality criteria for any marine features.

LS1 (Shoreline Protection)
For placement of rock for shoreline protection for feature LS1, very little impact to the water column would be expected, as rocks are expected to be relatively free of contamination, and disturbances to water bottom substrate associated with rock placement would be minimal and short-lived.

The stockpiling and subsequent backfilling of mechanically dredged flotation access channel material for feature LS1 may result in minor, temporary water column impacts. Because the method of dredging for flotation access channel construction and backfilling is not expected to induce a significant release of dissolved contaminants, because sediments proposed for excavation for flotation access channel construction are not in proximity to any known sources of contaminants, and because the flotation access channel would be constructed within a waterbody

with the capacity to quickly disperse and dilute any concentrations of contaminants released during dredged material placement activities, associated water column impacts are anticipated to be minimal and short-lived.

Terre aux Boeufs (TM)

TM1, TM2, and TM7 (Marsh Restoration/Nourishment)
Representative water chemistry data indicates that the salinity regimes of features TM1 and TM7 are brackish, while the salinity regime of feature TM2 is marine.

Data table 2.2.2-2 depicts dilution requirements for parameters for which representative borrow area sediment chemistry data and water quality criteria were available for both brackish and marine features whose borrow sediment will be acquired from one of the Lake Borgne borrow areas. For marine features, where the average representative contaminant concentrations from each borrow area were averaged for the purpose of screening, copper was the only parameter which required a dilution based on detectible concentrations in representative borrow area water and sediment, as well as representative water chemistry. In order to meet marine acute criteria, the dilution required for copper was 0.160, while in order to meet marine chronic criteria, the required dilution was 0.473. Where the maximum contaminant concentrations from all borrow areas were utilized for the purpose of screening, copper was the only parameter which required a dilution based on detectible concentrations in representative borrow area water and sediment, as well as representative water chemistry. In order to meet marine acute criteria, the dilution required for copper was 0.290, while in order to meet marine chronic criteria, the required dilution was 0.637. Based on the screening evaluation for marine restoration features, it is anticipated that very little dilution would be required to meet water quality criteria for any marine features.

For brackish features, where the average representative contaminant concentrations from each borrow area were averaged for the purpose of screening, copper was the only parameter which required a dilution based on detectible concentrations in representative borrow area water and sediment, as well as representative water chemistry. In order to meet brackish acute criteria, the dilution required for copper was 0.397, while in order to meet brackish chronic criteria, the required dilution was 1.94. For brackish features, where the maximum contaminant concentrations from all borrow areas were utilized for the purpose of screening, no parameters required dilution. Based on the screening evaluation for brackish restoration features, it is anticipated that very little dilution would be required to meet water quality criteria for any marine features.

TM8 (Marsh Restoration)
Representative water chemistry data indicates that the salinity regime of feature TM8 is brackish.

Data table 2.2.2-2 depicts dilution requirements for parameters for which representative borrow area sediment chemistry data and water quality criteria were available for both brackish and marine features whose borrow sediment will be acquired from one of the Lake Borgne borrow areas. For brackish features, where the average representative contaminant concentrations from each borrow area were averaged for the purpose of screening, copper was the only parameter

which required a dilution based on detectible concentrations in representative borrow area water and sediment, as well as representative water chemistry. In order to meet brackish acute criteria, the dilution required for copper was 0.397, while in order to meet brackish chronic criteria, the required dilution was 1.94. For brackish features, where the maximum contaminant concentrations from all borrow areas were utilized for the purpose of screening, no parameters required dilution. Based on the screening evaluation for brackish restoration features, it is anticipated that very little dilution would be required to meet water quality criteria for any marine features.

Hopedale (HM)

HM1 (Marsh Restoration/Nourishment)
Representative water chemistry data indicates that the salinity regime of feature HM1 is marine.

Data table 2.2.2-2 depicts dilution requirements for parameters for which representative borrow area sediment chemistry data and water quality criteria were available for both brackish and marine features whose borrow sediment will be acquired from one of the Lake Borgne borrow areas. For marine features, where the average representative contaminant concentrations from each borrow area were averaged for the purpose of screening, copper was the only parameter which required a dilution based on detectible concentrations in representative borrow area water and sediment, as well as representative water chemistry. In order to meet marine acute criteria, the dilution required for copper was 0.160, while in order to meet marine chronic criteria, the required dilution was 0.473. Where the maximum contaminant concentrations from all borrow areas were utilized for the purpose of screening, copper was the only parameter which required a dilution based on detectible concentrations in representative borrow area water and sediment, as well as representative water chemistry. In order to meet marine acute criteria, the dilution required for copper was 0.290, while in order to meet marine chronic criteria, the required dilution was 0.637. Based on the screening evaluation for marine restoration features, it is anticipated that very little dilution would be required to meet water quality criteria for any marine features.

2.2.3 Clarity/Turbidity

Data table 2.2.3-1 depicts turbidity levels in the vicinity of each feature (including borrow areas). Turbidity affects water quality in several ways. Suspended sedimentary particles decrease light penetration and interferes with the photosynthetic production of oxygen. At the same time, these particles absorb solar energy from the sunlight and transform this energy into heat, thus elevating the temperature of the water. The fact that oxygen is less soluble in warm water than in cold water coupled with the decreased photosynthetic oxygen production can result in decreased oxygen levels.

Biloxi Marsh (BM, BS, BR)

BM1 (Marsh Nourishment)
Turbidity levels in the vicinity of feature BM1 range between 2.6 and 28 Nephelometric Turbidity Units (NTU), and average 11.5 NTU.

Dredged slurry generated from hydraulic placement of dredged material for marsh nourishment for feature BM1 would result in elevated turbidity and a reduction in water clarity due to the unconfined nature of the dredged material placement activity. Elevated turbidity levels, as well as decreased water clarity, would continue in the feature area during dredged material placement activities, and would dissipate following the completion of placement activities.

BR1 (Ridge Restoration)
Turbidity levels in the vicinity of feature BR1 range between 2.6 and 19 NTU, and average 9.5 NTU.

The placement of material for the proposed ridge restoration feature is not expected to contribute directly to turbidity of any waters. Dredging of borrow materials and potential access channels would result in elevated turbidity and a reduction in water clarity at the construction sites. Elevated turbidity levels, as well as decreased water clarity, would continue in the feature area during construction, and would dissipate following the completion of the activities.

Because flotation access channel sediments to be placed in the footprint of feature BR1 would be mechanically dredged, and would therefore minimize the quantities of dredging site water placed along with sediments, only minimal amounts of water would be placed within the footprint of this feature, allowing very little potential for waters carrying elevated turbidity levels to reach adjacent surface waters.

BS1 (Shoreline Protection)
Turbidity levels in the vicinity of feature BS1 range between 1.8 and 56 NTU, and average 13.5 NTU.

The placement of rock for shoreline protection is expected to result in the disturbance of water bottom, causing a minor, temporary, and localized increase in turbidity levels and decrease in water clarity. Following construction activities, turbidity levels and water clarity in the vicinity of feature BS1 would return to those which existed prior to construction activities.

The stockpiling and backfilling of flotation access channel sediments would be expected to have a localized and temporary effect on turbidity levels and water clarity in the vicinity of feature BS1. However, because the means of dredging (mechanical) would minimize resuspension of water bottom sediments, and because tidal action would serve to disperse and dilute waters with elevated levels of turbidity, these effects would be short-lived.

BS2 (Oyster Reef)
Turbidity levels in the vicinity of feature BS2 range between 2.6 and 45 NTU, and average 15.2 NTU.

The placement of material such as concrete rings, metal frames, geotextile filled bags, etc. for oyster reef restoration is expected to result in the disturbance of water bottom, causing a minor, temporary, and localized increase in turbidity levels and decrease in water clarity. Following construction activities, turbidity levels and water clarity in the vicinity of feature BS2 would return to those which existed prior to construction activities. The establishment of oyster reefs

would be expected to reduce suspended sediments in the water column by oysters filtering the water and depositing particles as substrate.

MRGO Channel (MRGO)

MRGO1 and MRGO6 (Shoreline Protection)
Turbidity levels in the vicinity of feature MRGO1 range between 3.2 and 36.5 NTU, and average 13.4 NTU.

Turbidity levels in the vicinity of feature MRGO6 range between 2.6 and 45 NTU, and average 13.7 NTU.

The placement of rock for shoreline protection is expected to result in the disturbance of water bottom, causing a minor, temporary, and localized increase in turbidity levels and decrease in water clarity. Following construction activities, turbidity levels and water clarity in the vicinity of features MRGO1 and MRGO6 would return to those which existed prior to construction activities.

The stockpiling and backfilling of flotation access channel sediments would be expected to have a localized and temporary effect on turbidity levels and water clarity in the vicinity of features MRGO1 and MRGO6. However, because the means of dredging (mechanical) would minimize resuspension of water bottom sediments, and because tidal action would serve to disperse and dilute waters with elevated levels of turbidity, these effects would be short-lived.

MRGO2, MRGO3, and MRGO4 (Shoreline Protection Repairs/Maintenance)
Turbidity levels in the vicinity of feature MRGO2 range between 2.6 and 19 NTU, and average 9.5 NTU.

Turbidity levels in the vicinity of feature MRGO3 range between 3.2 and 36.5 NTU, and average 13.4 NTU.

Turbidity levels in the vicinity of feature MRGO4 range between 2.6 and 45 NTU, and average 13.7 NTU.

The placement of rock for shoreline protection repairs and maintenance is expected to result in the disturbance of water bottom, causing a minor, temporary, and localized increase in turbidity levels and decrease in water clarity. Following construction activities, turbidity levels and water clarity in the vicinity of features MRGO2, MRGO 3, and MRGO4 would return to those which existed prior to construction activities.

MRGO5, MRGO7, and MRGO8 (Shoreline Protection & Marsh Restoration)
Turbidity levels in the vicinity of feature MRGO5 range between 2.6 and 19 NTU, and average 9.5 NTU.

Turbidity levels in the vicinity of feature MRGO7 range between 3.7 and 32 NTU, and average 11.9 NTU.

Turbidity levels in the vicinity of feature MRGO8 range between 2.6 and 19 NTU, and average 9.5 NTU.

The placement of rock for shoreline protection is expected to result in the disturbance of water bottom, causing a minor, temporary, and localized increase in turbidity levels and decrease in water clarity. Following construction activities, turbidity levels and water clarity in the vicinity of features MRGO5, MRGO7, and MRGO8 would return to those which existed prior to construction activities.

Dredged slurry generated from hydraulic placement of dredged material for marsh creation for features MRGO5, MRGO7, and MRGO8 would result in elevated turbidity and a reduction in water clarity due to the unconfined nature of the dredged material placement activity. Elevated turbidity levels, as well as decreased water clarity, would continue in the feature area during dredged material placement activities, and would dissipate following the completion of placement activities.

Flotation access channel material placed within the footprint of feature MRGO5 would generate very little addition effluent due to the means of dredging and placement (mechanical), and would therefore have little to no impact on the turbidity levels of effluent waters discharging from the marsh restoration area for this feature.

Central Wetlands (CC, CM)

CC1, CC2, CC3, and CC5 (Swamp Restoration/Nourishment)

Turbidity levels in the vicinity of feature CC1 range between 3.8 and 100 NTU, and average 16.7 NTU.

Turbidity levels in the vicinity of feature CC2 range between 3.8 and 100 NTU, and average 16.7 NTU.

Turbidity levels in the vicinity of feature CC3 range between 1 and 140 NTU, and average 12.3 NTU.

Turbidity levels in the vicinity of feature CC5 range between 3.2 and 100 NTU, and average 17.4 NTU.

Dredged sediments that are hydraulically placed within the confinement dikes of features CC1, CC2, CC3, and CC5 for swamp restoration would be retained to allow the settling of suspended materials. Effluent discharges from within the confines of this feature would be unlikely to significantly affect the clarity or turbidity of receiving waters.

Dredged slurry generated from hydraulic placement of dredged material for swamp nourishment for features CC1, CC2, CC3, and CC5 would result in elevated turbidity and a reduction in water clarity due to the unconfined nature of the dredged material placement activity. Elevated turbidity levels, as well as decreased water clarity, would continue in the feature area during

dredged material placement activities, and would dissipate following the completion of placement activities.

CC4 (Swamp Restoration)
Turbidity levels in the vicinity of feature CC4 range between 1 and 140 NTU, and average 12.3 NTU.

Dredged sediments that are hydraulically placed within the confinement dikes of feature CC4 would be retained to allow the settling of suspended materials. Effluent discharges from within the confines of this feature would be unlikely to significantly affect the clarity or turbidity of receiving waters.

CC6 (Swamp Nourishment)
Turbidity levels in the vicinity of feature CC6 range between 3.2 and 41.3 NTU, and average 13.2 NTU.

Dredged slurry generated from hydraulic placement of dredged material for swamp nourishment for feature CC6 would result in elevated turbidity and a reduction in water clarity due to the unconfined nature of the dredged material placement activity. Elevated turbidity levels, as well as decreased water clarity, would continue in the feature area during dredged material placement activities, and would dissipate following the completion of placement activities.

CM1 (Marsh Nourishment)
Turbidity levels in the vicinity of feature CM1 range between 1 and 140 NTU, and average 12.3 NTU.

Dredged slurry generated from hydraulic placement of dredged material for marsh nourishment for feature CM1 would result in elevated turbidity and a reduction in water clarity due to the unconfined nature of the dredged material placement activity. Elevated turbidity levels, as well as decreased water clarity, would continue in the feature area during dredged material placement activities, and would dissipate following the completion of placement activities.

CM2, CM3, CM4, and CM5 (Marsh Restoration/Nourishment)
Turbidity levels in the vicinity of feature CM2 range between 1 and 140 NTU, and average 12.3 NTU.

Turbidity levels in the vicinity of feature CM3 range between 3.6 and 100 NTU, and average 14.9 NTU.

Turbidity levels in the vicinity of feature CM4 range between 3.2 and 41.3 NTU, and average 14.0 NTU.

Turbidity levels in the vicinity of feature CM5 range between 1 and 140 NTU, and average 12.3 NTU.

Dredged slurry generated from hydraulic placement of dredged material for marsh nourishment for features CM2, CM3, CM4, and CM5 would result in elevated turbidity and a reduction in water clarity due to the unconfined nature of the dredged material placement activity. Elevated turbidity levels, as well as decreased water clarity, would continue in the feature area during dredged material placement activities, and would dissipate following the completion of placement activities.

East Orleans (EM, ES)

EM1, EM3 and EM4 (Marsh Restoration/Nourishment)
Turbidity levels in the vicinity of feature EM1 range between 1.6 and 190 NTU, and average 12.7 NTU.

Turbidity levels in the vicinity of feature EM3 range between 4 and 130 NTU, and average 16.4 NTU.

Turbidity levels in the vicinity of feature EM4 range between 2.8 and 130 NTU, and average 17.9 NTU.

Dredged slurry generated from hydraulic placement of dredged material for marsh nourishment for features EM1, EM3, and EM4 would result in elevated turbidity and a reduction in water clarity due to the unconfined nature of the dredged material placement activity. Elevated turbidity levels, as well as decreased water clarity, would continue in the feature area during dredged material placement activities, and would dissipate following the completion of placement activities.

The stockpiling and backfilling of flotation access channel sediments would be expected to have a localized and temporary effect on turbidity levels and water clarity in the vicinity of feature EM1. However, because the means of dredging (mechanical) would minimize resuspension of water bottom sediments, and because tidal action would serve to disperse and dilute waters with elevated levels of turbidity, these effects would be short-lived.

EM2 (Marsh Nourishment)
Turbidity levels in the vicinity of feature EM2 range between 2.8 and 45 NTU, and average 19.4 NTU.

Dredged slurry generated from hydraulic placement of dredged material for marsh nourishment for feature EM2 would result in elevated turbidity and a reduction in water clarity due to the unconfined nature of the dredged material placement activity. Elevated turbidity levels, as well as decreased water clarity, would continue in the feature area during dredged material placement activities, and would dissipate following the completion of placement activities.

The stockpiling and backfilling of flotation access channel sediments would be expected to have a localized and temporary effect on turbidity levels and water clarity in the vicinity of feature EM2. However, because the means of dredging (mechanical) would minimize resuspension of

water bottom sediments, and because tidal action would serve to disperse and dilute waters with elevated levels of turbidity, these effects would be short-lived.

ES1, ES2, and ES3 (Shoreline Protection)
Turbidity levels in the vicinity of feature ES1 range between 1.6 and 190 NTU, and average 12.9 NTU.

Turbidity levels in the vicinity of feature ES2 range between 1.6 and 190 NTU, and average 12.7 NTU.

Turbidity levels in the vicinity of feature ES3 range between 2.8 and 50 NTU, and average 11.8 NTU.

The placement of rock for shoreline protection is expected to result in the disturbance of water bottom, causing a minor, temporary, and localized increase in turbidity levels and decrease in water clarity. Following construction activities, turbidity levels and water clarity in the vicinity of features ES1, ES2, and ES3 would return to those which existed prior to construction activities.

The stockpiling and backfilling of flotation access channel sediments would be expected to have a localized and temporary effect on turbidity levels and water clarity in the vicinity of features ES1, ES2, and ES3. However, because the means of dredging (mechanical) would minimize resuspension of water bottom sediments, and because tidal action would serve to disperse and dilute waters with elevated levels of turbidity, these effects would be short-lived.

South Lake Borgne (LM, LS)

LM1, LM2, LM3, and LM4 (Marsh Restoration/Nourishment)
Turbidity levels in the vicinity of feature LM1 range between 3.2 and 36.5 NTU, and average 12.7 NTU.

Turbidity levels in the vicinity of feature LM2 range between 3.2 and 36.5 NTU, and average 13.4 NTU.

Turbidity levels in the vicinity of feature LM3 range between 2.6 and 19 NTU, and average 9.5 NTU.

Turbidity levels in the vicinity of feature LM4 range between 3.2 and 36.5 NTU, and average 12.7 NTU.

Dredged slurry generated from hydraulic placement of dredged material for marsh nourishment for features LM1, LM2, LM3, and LM4 would result in elevated turbidity and a reduction in water clarity due to the unconfined nature of the dredged material placement activity. Elevated turbidity levels, as well as decreased water clarity, would continue in the feature area during dredged material placement activities, and would dissipate following the completion of placement activities.

LS1 (Shoreline Protection)
Turbidity levels in the vicinity of feature LS1 range between 3.2 and 36.5 NTU, and average 13.4 NTU.

The placement of rock for shoreline protection is expected to result in the disturbance of water bottom, causing a minor, temporary, and localized increase in turbidity levels and decrease in water clarity. Following construction activities, turbidity levels and water clarity in the vicinity of feature LS3 would return to those which existed prior to construction activities.

The stockpiling and backfilling of flotation access channel sediments would be expected to have a localized and temporary effect on turbidity levels and water clarity in the vicinity of feature LS1. However, because the means of dredging (mechanical) would minimize resuspension of water bottom sediments, and because tidal action would serve to disperse and dilute waters with elevated levels of turbidity, these effects would be short-lived.

Terre aux Boeufs (TM)

TM1, TM2, and TM7 (Marsh Restoration/Nourishment)
Turbidity levels in the vicinity of feature TM1 range between 3.8 and 89.6 NTU, and average 15.7 NTU.

Turbidity levels in the vicinity of feature TM2 range between 3 and 40 NTU, and average 12.6 NTU.

Turbidity levels in the vicinity of feature TM7 range between 3.8 and 89.6 NTU, and average 15.7 NTU.

Dredged slurry generated from hydraulic placement of dredged material for marsh nourishment for features TM1, TM2, and TM7 would result in elevated turbidity and a reduction in water clarity due to the unconfined nature of the dredged material placement activity. Elevated turbidity levels, as well as decreased water clarity, would continue in the feature area during dredged material placement activities, and would dissipate following the completion of placement activities.

TM8 (Marsh Restoration)
Turbidity levels in the vicinity of feature TM8 range between 3.8 and 89.6 NTU, and average 15.7 NTU.

Dredged slurry generated from hydraulic placement of dredged material for marsh restoration for features TM8 would result in elevated turbidity and a reduction in water clarity due to the unconfined nature of the dredged material placement activity. Elevated turbidity levels, as well as decreased water clarity, would continue in the feature area during dredged material placement activities, and would dissipate following the completion of placement activities.

Hopedale (HM)

HM1 (Marsh Restoration/Nourishment)
Turbidity levels in the vicinity of feature HM1 range between 3 and 32 NTU, and average 12.1 NTU.

Dredged slurry generated from hydraulic placement of dredged material for marsh nourishment for feature HM1 would result in elevated turbidity and a reduction in water clarity due to the unconfined nature of the dredged material placement activity. Elevated turbidity levels, as well as decreased water clarity, would continue in the feature area during dredged material placement activities, and would dissipate following the completion of placement activities.

2.2.4 Color

Biloxi Marsh (BM, BS, BR)

BM1 (Marsh Nourishment)
During confinement dike construction and hydraulic placement of dredged sediments, temporary changes in water color may occur in the area of feature BM1. Turbidity levels are expected to remain high until shortly after nourishment for this feature is completed. Upon the completion of feature BM1, waters affected by the construction of this feature would gradually clarify, restoring water color to conditions observed prior to construction.

BR1 (Ridge Restoration)
Dewatered Mississippi River sediments placed for ridge restoration would be dewatered, and it is not anticipated that large amounts of runoff would be generated from placement activities. Some minor amounts of runoff from these sediments may reach adjacent wetlands and waterbodies and introduce minor levels of turbidity; however, runoff would be quickly dispersed and diluted by tidal action present in adjacent waterbodies.

Placement of flotation access channel material from Bayou La Loutre for ridge restoration may induce a localized increase in turbidity in adjacent waterbodies; however, turbidity associated with water from mechanically dredged sediments would be quickly dispersed and diluted by tidal action present in adjacent waterbodies.

BS1 (Shoreline Protection)
The disturbance of water bottom substrate during placement of rock for shoreline protection may result in temporary and localized changes to water color. In addition, because shoreline protection would serve to reduce erosion, some minor changes to water color in areas protected by the proposed rock dikes are expected, as the rock dikes would serve to significantly reduce the wave energy-driven resuspension of water bottom substrate for those areas.

Stockpiling and backfill of material excavated for flotation access channel construction would result in temporary and localized increases in turbidity levels. Tidal action would serve to dilute and disperse increased turbidity levels shortly after construction activities are completed, allowing water color to return to background conditions.

BS2 (Oyster Reef)
The disturbance of water bottom substrate during placement of materials for oyster reef construction may result in temporary and localized changes to water color. However, no long-term changes to water color are expected from the placement of materials for oyster reef construction for feature BS2.

MRGO Channel (MRGO)

MRGO1 and MRGO6 (Shoreline Protection)
The disturbance of water bottom substrate during placement of rock for shoreline protection may result in temporary and localized changes to water color. In addition, because shoreline protection would serve to reduce erosion, some minor changes to water color in areas protected by the proposed rock dikes are expected, as the rock dikes would serve to significantly reduce the wave energy-driven resuspension of water bottom substrate for those areas.

Stockpiling and backfill of material excavated for flotation access channel construction for these features would result in temporary and localized increases in turbidity levels. Tidal action would serve to dilute and disperse increased turbidity levels shortly after construction activities are completed, allowing water color to return to background conditions.

MRGO2, MRGO3, and MRGO4 (Shoreline Protection Repairs/Maintenance)
The disturbance of water bottom substrate during placement of rock for shoreline protection repairs and maintenance may result in temporary and localized changes to water color. In addition, because these features would serve to further reduce erosion, some minor changes to water color in areas protected by the proposed rock dikes are expected, as the rock dikes would aid in reducing the wave energy-driven resuspension of water bottom substrate for those areas.

MRGO5, MRGO7, and MRGO8 (Shoreline Protection & Marsh Restoration)
The disturbance of water bottom substrate during placement of rock for shoreline protection may result in temporary and localized changes to water color. In addition, because shoreline protection would serve to reduce erosion, some minor changes to water color in areas protected by the proposed rock dikes are expected, as the rock dikes would serve to significantly reduce the wave energy-driven resuspension of water bottom substrate for those areas.

During confinement dike construction for the marsh restoration component of MRGO5, MRGO7, and MRGO8, temporary changes in water color may occur in the vicinity of these features. Turbidity levels are expected to remain high until construction of confinement dikes is completed, following which waters affected by the construction of these features would gradually clarify, restoring water color to conditions observed prior to construction. Effluent discharge from these features is not anticipated to significantly affect water color, as effluent water leaving confined marsh restoration areas would be the clarified supernatant resulting from solids settlement following hydraulic dredged material placement.

Central Wetlands (CC, CM)

CC1, CC2, CC3, and CC5 (Swamp Restoration/Nourishment)
During confinement dike construction for the swamp restoration component of CC1, CC2, CC3, and CC5, temporary changes in water color may occur in the vicinity of these features. Turbidity levels are expected to remain high until construction of confinement dikes is completed, following which waters affected by the construction of these features would gradually clarify, restoring water color to conditions observed prior to construction. Effluent discharge from these features is not anticipated to significantly affect water color, as effluent water leaving confined swamp restoration areas would be the clarified supernatant resulting from solids settlement following hydraulic dredged material placement.

For swamp nourishment for features CC1, CC2, CC3, and CC5, during confinement dike construction and hydraulic placement of dredged sediments, temporary changes in water color may occur. Turbidity levels are expected to remain high until shortly after nourishment for these features is completed. Upon the completion of nourishment for these features, waters affected by nourishment activities would gradually clarify, restoring water color to conditions observed prior to construction.

CC4 (Swamp Restoration)
During confinement dike construction, temporary changes in water color may occur in the vicinity of feature CC4. Turbidity levels are expected to remain high until construction of confinement dikes is completed, following which waters affected by the construction of this feature would gradually clarify, restoring water color to conditions observed prior to construction. Effluent discharge from this feature is not anticipated to significantly affect water color, as effluent water leaving the confined marsh restoration area would be the clarified supernatant resulting from solids settlement following hydraulic dredged material placement.

CC6 (Swamp Nourishment)
During confinement dike construction and hydraulic placement of dredged sediments, temporary changes in water color may occur in the area of feature CC6. Turbidity levels are expected to remain high until shortly after nourishment for this feature is completed. Upon the completion of feature CC6, waters affected by the construction of this feature would gradually clarify, restoring water color to conditions observed prior to construction.

CM1 (Marsh Nourishment)
During confinement dike construction and hydraulic placement of dredged sediments, temporary changes in water color may occur in the area of feature CM1. Turbidity levels are expected to remain high until shortly after nourishment for this feature is completed. Upon the completion of feature CM1, waters affected by the construction of this feature would gradually clarify, restoring water color to conditions observed prior to construction.

CM2, CM3, CM4, and CM5 (Marsh Restoration/Nourishment)
During confinement dike construction for the marsh restoration component of CM2, CM3, CM4, and CM5, temporary changes in water color may occur in the vicinity of these features. Turbidity levels are expected to remain high until construction of confinement dikes is

completed, following which waters affected by the construction of these features would gradually clarify, restoring water color to conditions observed prior to construction. Effluent discharge from these features is not anticipated to significantly affect water color, as effluent water leaving confined marsh restoration areas would be the clarified supernatant resulting from solids settlement following hydraulic dredged material placement.

For marsh nourishment for features CM2, CM3, CM4, and CM5, during confinement dike construction and hydraulic placement of dredged sediments, temporary changes in water color may occur. Turbidity levels are expected to remain high until shortly after nourishment for these features is completed. Upon the completion of nourishment for these features, waters affected by nourishment activities would gradually clarify, restoring water color to conditions observed prior to construction.

East Orleans (EM, ES)

EM1, EM3 and EM4 (Marsh Restoration/Nourishment)
During confinement dike construction for the marsh restoration component of EM1, EM3, and EM4, temporary changes in water color may occur in the vicinity of these features. Turbidity levels are expected to remain high until construction of confinement dikes is completed, following which waters affected by the construction of these features would gradually clarify, restoring water color to conditions observed prior to construction. Effluent discharge from these features is not anticipated to significantly affect water color, as effluent water leaving confined marsh restoration areas would be the clarified supernatant resulting from solids settlement following hydraulic dredged material placement.

For marsh nourishment for features EM1, EM3, and EM4, during confinement dike construction and hydraulic placement of dredged sediments, temporary changes in water color may occur. Turbidity levels are expected to remain high until shortly after nourishment for these features is completed. Upon the completion of nourishment for these features, waters affected by nourishment activities would gradually clarify, restoring water color to conditions observed prior to construction.

Stockpiling and backfill of material excavated for flotation access channel construction for feature EM1 would result in temporary and localized increases in turbidity levels. Tidal action would serve to dilute and disperse increased turbidity levels shortly after construction activities are completed, allowing water color to return to background conditions.

EM2 (Marsh Nourishment)
During confinement dike construction and hydraulic placement of dredged sediments, temporary changes in water color may occur in the area of feature EM2. Turbidity levels are expected to remain high until shortly after nourishment for this feature is completed. Upon the completion of feature EM2, waters affected by the construction of this feature would gradually clarify, restoring water color to conditions observed prior to construction.

Stockpiling and backfill of material excavated for flotation access channel construction for feature EM2 would result in temporary and localized increases in turbidity levels. Tidal action

would serve to dilute and disperse increased turbidity levels shortly after construction activities are completed, allowing water color to return to background conditions.

ES1, ES2, and ES3 (Shoreline Protection)
The disturbance of water bottom substrate during placement of rock for shoreline protection may result in temporary and localized changes to water color. In addition, because shoreline protection would serve to reduce erosion, some minor changes to water color in areas protected by the proposed rock dikes are expected, as the rock dikes would serve to significantly reduce the wave energy-driven resuspension of water bottom substrate for those areas.

Stockpiling and backfill of material excavated for flotation access channel construction for these features would result in temporary and localized increases in turbidity levels. Tidal action would serve to dilute and disperse increased turbidity levels shortly after construction activities are completed, allowing water color to return to background conditions.

South Lake Borgne (LM, LS)

LM1, LM2, LM3, and LM4 (Marsh Restoration/Nourishment)
During confinement dike construction for the marsh restoration component of LM1, LM2, LM3, and LM4, temporary changes in water color may occur in the vicinity of these features. Turbidity levels are expected to remain high until construction of confinement dikes is completed, following which waters affected by the construction of these features would gradually clarify, restoring water color to conditions observed prior to construction. Effluent discharge from these features is not anticipated to significantly affect water color, as effluent water leaving confined marsh restoration areas would be the clarified supernatant resulting from solids settlement following hydraulic dredged material placement.

For marsh nourishment for features LM1, LM2, LM3, and LM4, during confinement dike construction and hydraulic placement of dredged sediments, temporary changes in water color may occur. Turbidity levels are expected to remain high until shortly after nourishment for these features is completed. Upon the completion of nourishment for these features, waters affected by nourishment activities would gradually clarify, restoring water color to conditions observed prior to construction.

LS1 (Shoreline Protection)
The disturbance of water bottom substrate during placement of rock for shoreline protection may result in temporary and localized changes to water color. In addition, because shoreline protection would serve to reduce erosion, some minor changes to water color in areas protected by the proposed rock dikes are expected, as the rock dikes would serve to significantly reduce the wave energy-driven resuspension of water bottom substrate for those areas.

Stockpiling and backfill of material excavated for flotation access channel construction for feature EM2 would result in temporary and localized increases in turbidity levels. Tidal action would serve to dilute and disperse increased turbidity levels shortly after construction activities are completed, allowing water color to return to background conditions.

Terre aux Boeufs (TM)

TM1, TM2, and TM7 (Marsh Restoration/Nourishment)
During confinement dike construction for the marsh restoration component of TM1, TM2, and TM7, temporary changes in water color may occur in the vicinity of these features. Turbidity levels are expected to remain high until construction of confinement dikes is completed, following which waters affected by the construction of these features would gradually clarify, restoring water color to conditions observed prior to construction. Effluent discharge from these features is not anticipated to significantly affect water color, as effluent water leaving confined marsh restoration areas would be the clarified supernatant resulting from solids settlement following hydraulic dredged material placement.

For marsh nourishment for features TM1, TM2, and TM7, during confinement dike construction and hydraulic placement of dredged sediments, temporary changes in water color may occur. Turbidity levels are expected to remain high until shortly after nourishment for these features is completed. Upon the completion of nourishment for these features, waters affected by nourishment activities would gradually clarify, restoring water color to conditions observed prior to construction.

TM8 (Marsh Restoration)
During confinement dike construction, temporary changes in water color may occur in the vicinity of feature TM8. Turbidity levels are expected to remain high until construction of confinement dikes is completed, following which waters affected by the construction of this feature would gradually clarify, restoring water color to conditions observed prior to construction. Effluent discharge from this feature is not anticipated to significantly affect water color, as effluent water leaving the confined marsh restoration area would be the clarified supernatant resulting from solids settlement following hydraulic dredged material placement.

Hopedale (HM)

HM1 (Marsh Restoration/Nourishment)
During confinement dike construction for the marsh restoration component of HM1, temporary changes in water color may occur in the vicinity of this feature. Turbidity levels are expected to remain high until construction of confinement dikes is completed, following which waters affected by the construction of this feature would gradually clarify, restoring water color to conditions observed prior to construction. Effluent discharge from this feature is not anticipated to significantly affect water color, as effluent water leaving the confined marsh restoration area would be the clarified supernatant resulting from solids settlement following hydraulic dredged material placement.

For marsh nourishment for feature HM1, during confinement dike construction and hydraulic placement of dredged sediments, temporary changes in water color may occur. Turbidity levels are expected to remain high until shortly after nourishment for this feature is completed. Upon the completion of nourishment for this feature, waters affected by nourishment activities would gradually clarify, restoring water color to conditions observed prior to construction.

2.2.5 Odor

Biloxi Marsh (BM, BS, BR)

BM1 (Marsh Nourishment)
Placement of dredged sediments for marsh nourishment will result in the exposure of previously undisturbed, organic and reduced sediments, which is expected to result in an odor which would persist until nourishment is complete and any dredged sediments that are not submerged become vegetated.

BR1 (Ridge Restoration)
Placement of Mississippi River Borrow Area sediments for ridge restoration is not expected to result in any significant odors, as sediments are not expected to be highly organic and would be dewatered prior to placement. Placement of flotation access channel sediments for ridge restoration will result in the exposure of previously undisturbed, organic and reduced sediments, which is expected to result in an odor which would persist until sediments become dewatered.

BS1 (Shoreline Protection)
Placement of rock for shoreline protection is not expected to result in any significant odors, as any disturbance of water bottom sediments resulting from rock placement would be minimal and would be concealed below the water surface.

The placement of previously undisturbed, organic and reduced sediments for flotation access channel stockpiling and backfill may result in a slightly noticeable odor during dredged material placement activities; however, as sediments would remain submerged, odors would be largely concealed below the water surface.

BS2 (Oyster Reef)
Placement of materials for oyster reef construction is not expected to result in any significant odors, as any disturbance of water bottom sediments resulting from material placement would be minimal and would be concealed below the water surface.

MRGO Channel (MRGO)

MRGO1 and MRGO6 (Shoreline Protection)
Placement of rock for shoreline protection is not expected to result in any significant odors, as any disturbance of water bottom sediments resulting from rock placement would be minimal and would be concealed below the water surface.

The placement of previously undisturbed, organic and reduced sediments for flotation access channel stockpiling and backfill may result in a slightly noticeable odor during dredged material placement activities; however, as sediments would remain submerged, odors would be largely concealed below the water surface.

MRGO2, MRGO3, and MRGO4 (Shoreline Protection Repairs/Maintenance)
Placement of rock for shoreline protection repairs and maintenance is not expected to result in any significant odors, as any disturbance of water bottom sediments resulting from rock placement would be minimal and would be concealed below the water surface.

MRGO5, MRGO7, and MRGO8 (Shoreline Protection & Marsh Restoration)
Placement of dredged sediments for marsh restoration will result in the exposure of previously undisturbed, organic and reduced sediments, which is expected to result in an odor which would persist until the marsh restoration site becomes vegetated.

Placement of rock for shoreline protection is not expected to result in any significant odors, as any disturbance of water bottom sediments resulting from rock placement would be minimal and would be concealed below the water surface.

Central Wetlands (CC, CM)

CC1, CC2, CC3, and CC5 (Swamp Restoration/Nourishment)
Placement of dredged sediments for swamp restoration and nourishment will result in the exposure of previously undisturbed, organic and reduced sediments, which is expected to result in an odor which would persist until the swamp restoration and nourishment site becomes vegetated.

CC4 (Swamp Restoration)
Placement of dredged sediments for swamp restoration will result in the exposure of previously undisturbed, organic and reduced sediments, which is expected to result in an odor which would persist until the swamp restoration site becomes vegetated.

CC6 (Swamp Nourishment)
Placement of dredged sediments for swamp nourishment will result in the exposure of previously undisturbed, organic and reduced sediments, which is expected to result in an odor which would persist until the swamp nourishment site becomes vegetated.

CM1 (Marsh Nourishment)
Placement of dredged sediments for marsh nourishment will result in the exposure of previously undisturbed, organic and reduced sediments, which is expected to result in an odor which would persist until the marsh nourishment site becomes vegetated.

CM2, CM3, CM4, and CM5 (Marsh Restoration/Nourishment)
Placement of dredged sediments for marsh restoration will result in the exposure of previously undisturbed, organic and reduced sediments, which is expected to result in an odor which would persist until the marsh restoration site becomes vegetated.

East Orleans (EM, ES)

EM1, EM3 and EM4 (Marsh Restoration/Nourishment)
Placement of dredged sediments for marsh restoration and nourishment will result in the exposure of previously undisturbed, organic and reduced sediments, which is expected to result in an odor which would persist until the marsh restoration and nourishment site becomes vegetated.

For feature EM1, the placement of previously undisturbed, organic and reduced sediments for flotation access channel stockpiling and backfill may result in a slightly noticeable odor during dredged material placement activities; however, as sediments would remain submerged, odors would be largely concealed below the water surface.

EM2 (Marsh Nourishment)
Placement of dredged sediments for marsh nourishment will result in the exposure of previously undisturbed, organic and reduced sediments, which is expected to result in an odor which would persist until the marsh nourishment site becomes vegetated.

The placement of previously undisturbed, organic and reduced sediments for flotation access channel stockpiling and backfill may result in a slightly noticeable odor during dredged material placement activities; however, as sediments would remain submerged, odors would be largely concealed below the water surface.

ES1, ES2, and ES3 (Shoreline Protection)
Placement of rock for shoreline protection is not expected to result in any significant odors, as any disturbance of water bottom sediments resulting from rock placement would be minimal and would be concealed below the water surface.

The placement of previously undisturbed, organic and reduced sediments for flotation access channel stockpiling and backfill may result in a slightly noticeable odor during dredged material placement activities; however, as sediments would remain submerged, odors would be largely concealed below the water surface.

South Lake Borgne (LM, LS)

LM1, LM2, LM3, and LM4 (Marsh Restoration/Nourishment)
Placement of dredged sediments for marsh restoration and nourishment will result in the exposure of previously undisturbed, organic and reduced sediments, which is expected to result in an odor which would persist until the marsh restoration and nourishment site becomes vegetated.

LS1 (Shoreline Protection)
Placement of rock for shoreline protection is not expected to result in any significant odors, as any disturbance of water bottom sediments resulting from rock placement would be minimal and would be concealed below the water surface.

The placement of previously undisturbed, organic and reduced sediments for flotation access channel stockpiling and backfill may result in a slightly noticeable odor during dredged material placement activities; however, as sediments would remain submerged, odors would be largely concealed below the water surface.

Terre aux Boeufs (TM)

TM1, TM2, and TM7 (Marsh Restoration/Nourishment)
Placement of dredged sediments for marsh restoration and nourishment will result in the exposure of previously undisturbed, organic and reduced sediments, which is expected to result in an odor which would persist until the marsh restoration and nourishment site becomes vegetated.

TM8 (Marsh Restoration)
Placement of dredged sediments for marsh restoration will result in the exposure of previously undisturbed, organic and reduced sediments, which is expected to result in an odor which would persist until the marsh restoration site becomes vegetated.

Hopedale (HM)

HM1 (Marsh Restoration/Nourishment)
Placement of dredged sediments for marsh restoration and nourishment will result in the exposure of previously undisturbed, organic and reduced sediments, which is expected to result in an odor which would persist until the marsh restoration and nourishment site becomes vegetated.

2.2.6 Taste

Because the project features are not located nearby any drinking water intakes, no impacts to taste are anticipated from construction of these features.

2.2.7 Dissolved Oxygen Levels

Data table 2.2.7-1 displays monthly average dissolved oxygen levels for all project features and borrow areas. Average monthly dissolved oxygen levels that fall below the LDEQ/EPA minimum dissolved oxygen concentration limit are highlighted within the table. Short-term decreases in dissolved oxygen could occur due to introduction of organics from the sediment into the water column, as well as the release of nutrients. Turbidity affects water quality in several ways, one which may markedly affect dissolved oxygen levels. The introduction of nutrients and organic material to the water column as a result of the discharge can lead to a high biochemical oxygen demand (BOD), which in turn can lead to reduced dissolved oxygen, thereby potentially affecting the survival of aquatic organisms. Proposed borrow sediments—particularly sediments from the Lake Borgne borrow areas and the MRGO/GIWW borrow area—area highly organic, and therefore there is potential for temporarily lowering dissolved oxygen levels at some of the disposal areas.

Biloxi Marsh (BM, BS, BR)

BM1 (Marsh Nourishment)
Average monthly ambient dissolved oxygen levels in the vicinity of feature BM1 range between 4.41 and 10.6 mg/L.

Because of the high organic carbon content of sediment from the Lake Borgne borrow areas, the discharge of hydraulically dredged material for marsh nourishment at feature BM1 may have a short-term impact on dissolved oxygen levels in the vicinity of this feature. In addition, there is a possibility that effects related to the release of ammonia from borrow area sediment pore water could occur. Management of dredged sediment during placement, including the use of a baffle plate at the end of the discharge pipeline, would introduce oxygen to the dredged material slurry and dissipate ammonia. Additional management strategies would be employed within the disposal areas, as needed, to further dissipate ammonia.

BR1 (Ridge Restoration)
Average monthly ambient dissolved oxygen levels in the vicinity of feature BR1 range between 4.98 and 10.39 mg/L.

The placement of material for the proposed ridge restoration feature is not expected to contribute directly to changes in dissolved gas levels of any waters. Dredging of borrow materials and potential access channels could result in minor, localized, and short-term reductions in dissolved oxygen levels.

BS1 (Shoreline Protection)
Average monthly ambient dissolved oxygen levels in the vicinity of feature BS1 range between 6.43 and 11.2 mg/L.

Placement of rock for shoreline protection may result in disturbances of water bottom substrate along the footprint of feature BS1; because of the high organic carbon content in substrate, this disturbance may result in minor, localized, and short-term reductions in dissolved oxygen levels. In addition, placement of material excavated for flotation access channel construction would result in the discharge of sediment with high organic content along the Lake Borgne shoreline, prompting a localized, short-term reduction in dissolved oxygen levels. Tidal currents are expected to quickly disperse waters affected by feature BS1 such that no significant impacts to dissolved oxygen levels are anticipated.

BS2 (Oyster Reef)
Average monthly ambient dissolved oxygen levels in the vicinity of feature BS2 range between 6.09 and 11.20 mg/L.

Placement of material for oyster reef construction may result in disturbances of water bottom substrate along the footprint of feature BS2; because of the high organic carbon content in substrate, this disturbance may result in minor, localized, and short-term reductions in dissolved oxygen levels. Tidal currents are expected to quickly disperse waters affected by feature BS2

such that no significant impacts to dissolved oxygen levels are anticipated. The establishment of oyster reefs would be expected to reduce suspended sediments in the water column by oysters filtering the water and depositing particles as substrate, which could increase dissolved oxygen levels.

MRGO Channel (MRGO)

MRGO1 and MRGO6 (Shoreline Protection)
Average monthly ambient dissolved oxygen levels in the vicinity of feature MRGO1, range between 5.03 and 10.27 mg/L.

Average monthly ambient dissolved oxygen levels in the vicinity of feature MRGO6 range between 3.98 and 10.61 mg/L.

Placement of rock for shoreline protection may result in disturbances of water bottom substrate along the footprint of features MRGO1 and MRGO6; because of the high organic carbon content in substrate, this disturbance may result in minor, localized, and short-term reductions in dissolved oxygen levels. In addition, placement of material excavated for flotation access channel construction would result in the discharge of sediment with high organic content, prompting a localized, short-term reduction in dissolved oxygen levels. Tidal currents are expected to quickly disperse waters affected by features MRGO1 and MRGO6 such that no significant impacts to dissolved oxygen levels are anticipated.

MRGO2, MRGO3, and MRGO4 (Shoreline Protection Repairs/Maintenance)
Average monthly ambient dissolved oxygen levels in the vicinity of feature MRGO2 range between 3.85 and 12.35 mg/L.

Average monthly ambient dissolved oxygen levels in the vicinity of feature MRGO3 range between 4.80 and 10.15 mg/L.

Average monthly ambient dissolved oxygen levels in the vicinity of feature MRGO4 range between 3.98 and 10.61 mg/L.

Placement of rock for shoreline protection repairs and maintenance may result in disturbances of water bottom substrate along the footprint of features MRGO2, MRGO3, and MRGO4; because of the high organic carbon content in substrate, this disturbance may result in minor, localized, and short-term reductions in dissolved oxygen levels. In addition, placement of material excavated for flotation access channel construction would result in the discharge of sediment with high organic content, prompting a localized, short-term reduction in dissolved oxygen levels. Tidal currents are expected to quickly disperse waters affected by features MRGO2, MRGO3, and MRGO4 such that no significant impacts to dissolved oxygen levels are anticipated.

MRGO5, MRGO7, and MRGO8 (Shoreline Protection & Marsh Restoration)
Average monthly ambient dissolved oxygen levels in the vicinity of feature MRGO5 range between 4.33 and 10.49 mg/L.

Average monthly ambient dissolved oxygen levels in the vicinity of feature MRGO7 range between 5.46 and 74.75 mg/L.

Average monthly ambient dissolved oxygen levels in the vicinity of feature MRGO8 range between 3.85 and 12.35 mg/L.

Placement of rock for shoreline protection may result in disturbances of water bottom substrate along the footprint of features MRGO5, MRGO7, and MRGO8; because of the high organic carbon content in substrate, this disturbance may result in minor, localized, and short-term reductions in dissolved oxygen levels. In addition, placement of material excavated for flotation access channel construction would result in the discharge of sediment with high organic content, prompting a localized, short-term reduction in dissolved oxygen levels. Tidal currents are expected to quickly disperse waters affected by features MRGO5, MRGO7, and MRGO8 such that no significant impacts to dissolved oxygen levels are anticipated.

Because of the high organic carbon content of sediment from the Lake Borgne borrow areas, the discharge of hydraulically dredged material for marsh restoration at features MRGO5, MRGO7, and MRGO8 may have a short-term impact on dissolved oxygen levels for effluent waters discharging from the confines of this feature. In addition, there is a possibility that effects related to the release of ammonia from borrow area sediment pore water could occur. These effects would last until effluent production resulting from dredged material placement were to cease, but would not be as significant if management strategies (such as use of baffle plates) were adopted to reduce ammonia levels in dredged slurry during hydraulic placement of sediment.

Central Wetlands (CC, CM)

CC1, CC2, CC3, and CC5 (Swamp Restoration/Nourishment)

Average monthly ambient dissolved oxygen levels in the vicinity of feature CC1 range between 3.06 and 10.14 mg/L.

Average monthly ambient dissolved oxygen levels in the vicinity of feature CC2 range between 3.06 and 10.14 mg/L.

Average monthly ambient dissolved oxygen levels in the vicinity of feature CC3 range between 3.82 and 9.16 mg/L.

Average monthly ambient dissolved oxygen levels in the vicinity of feature CC5 range between 2.34 and 9.95 mg/L.

Because of the high organic carbon content of sediment from the Lake Borgne borrow areas, the discharge of hydraulically dredged material for swamp restoration at features CC1, CC2, CC3, and CC5 may have a short-term impact on dissolved oxygen levels for effluent waters discharging from the confines of this feature. In addition, considering the lack of mixing available within the Central Wetlands Area, there is a possibility that effects related to the release

of ammonia from borrow area sediment pore water could occur. These effects would last until effluent production resulting from dredged material placement were to cease, but would not be as significant if management strategies (such as use of baffle plates) were adopted to reduce ammonia levels in dredged slurry during hydraulic placement of sediment.

CC4 (Swamp Restoration)
Average monthly ambient dissolved oxygen levels in the vicinity of feature CC4 range between 3.92 and 9.35 mg/L.

Because of the high organic carbon content of sediment from the Lake Borgne borrow areas, the discharge of hydraulically dredged material for swamp restoration at feature CC4 may have a short-term impact on dissolved oxygen levels for effluent waters discharging from the confines of this feature. In addition, considering the lack of mixing available within the Central Wetlands Area, there is a possibility that effects related to the release of ammonia from borrow area sediment pore water could occur. These effects would last until effluent production resulting from dredged material placement were to cease, but would not be as significant if management strategies (such as use of baffle plates) were adopted to reduce ammonia levels in dredged slurry during hydraulic placement of sediment.

CC6 (Swamp Nourishment)
Average monthly ambient dissolved oxygen levels in the vicinity of feature CC6 range between 2.45 and 9.56 mg/L.

Because of the high organic carbon content of sediment from the Lake Borgne borrow areas, the discharge of hydraulically dredged material for swamp nourishment at feature CC6 may have a short-term impact on dissolved oxygen levels in the vicinity of this feature. In addition, there is a possibility that effects related to the release of ammonia from borrow area sediment pore water could occur. These effects would last until effluent production resulting from dredged material placement were to cease, but would not be as significant if management strategies (such as use of baffle plates) were adopted to reduce ammonia levels in dredged slurry during hydraulic placement of sediment.

CM1 (Marsh Nourishment)
Average monthly ambient dissolved oxygen levels in the vicinity of feature CM1 range between 3.82 and 9.16 mg/L.

Because of the high organic carbon content of sediment from the Lake Borgne borrow areas, the discharge of hydraulically dredged material for marsh nourishment at feature CM1 may have a short-term impact on dissolved oxygen levels in the vicinity of this feature. In addition, there is a possibility that effects related to the release of ammonia from borrow area sediment pore water could occur. These effects would last until effluent production resulting from dredged material placement were to cease, but would not be as significant if management strategies (such as use of baffle plates) were adopted to reduce ammonia levels in dredged slurry during hydraulic placement of sediment.

CM2, CM3, CM4, and CM5 (Marsh Restoration/Nourishment)
Average monthly ambient dissolved oxygen levels in the vicinity of feature CM2 range between 3.92 and 9.35 mg/L.

Average monthly ambient dissolved oxygen levels in the vicinity of feature CM3 range between 3.94 and 9.64 mg/L.

Average monthly ambient dissolved oxygen levels in the vicinity of feature CM4 range between 3.67 and 9.72 mg/L.

Average monthly ambient dissolved oxygen levels in the vicinity of feature CM5 range between 3.92 and 9.35 mg/L.

Because of the high organic carbon content of sediment from the Lake Borgne borrow areas, the discharge of hydraulically dredged material for marsh restoration at features CM2, CM3, CM4, and CM5 may have a short-term impact on dissolved oxygen levels for effluent waters discharging from the confines of this feature. In addition, considering the lack of mixing available within the Central Wetlands Area, there is a possibility that effects related to the release of ammonia from borrow area sediment pore water could occur. These effects would last until effluent production resulting from dredged material placement were to cease, but would not be as significant if management strategies (such as use of baffle plates) were adopted to reduce ammonia levels in dredged slurry during hydraulic placement of sediment.

East Orleans (EM, ES)

EM1, EM3 and EM4 (Marsh Restoration/Nourishment)
Average monthly ambient dissolved oxygen levels in the vicinity of feature EM1 range between 6.45 and 10.38 mg/L.

Average monthly ambient dissolved oxygen levels in the vicinity of feature EM3 range between 3.56 and 9.15 mg/L.

Average monthly ambient dissolved oxygen levels in the vicinity of feature EM4 range between 4.99 and 9.18 mg/L.

Because of the high organic carbon content of sediment from the Lake Borgne borrow areas, the discharge of hydraulically dredged material for marsh restoration at features EM1, EM3, and EM4 may have a short-term impact on dissolved oxygen levels for effluent waters discharging from the confines of this feature. In addition, considering the lack of mixing available within the Central Wetlands Area, there is a possibility that effects related to the release of ammonia from borrow area sediment pore water could occur. These effects would last until effluent production resulting from dredged material placement were to cease, but would not be as significant if management strategies (such as use of baffle plates) were adopted to reduce ammonia levels in dredged slurry during hydraulic placement of sediment.

EM2 (Marsh Nourishment)
Average monthly ambient dissolved oxygen levels in the vicinity of feature EM2 range between 5.70 and 9.21 mg/L.

Because of the high organic carbon content of sediment from the Lake Borgne borrow areas, the discharge of hydraulically dredged material for marsh nourishment at feature EM2 may have a short-term impact on dissolved oxygen levels in the vicinity of this feature. In addition, there is a possibility that effects related to the release of ammonia from borrow area sediment pore water could occur. These effects would last until effluent production resulting from dredged material placement were to cease, but would not be as significant if management strategies (such as use of baffle plates) were adopted to reduce ammonia levels in dredged slurry during hydraulic placement of sediment.

ES1, ES2, and ES3 (Shoreline Protection)
Average monthly ambient dissolved oxygen levels in the vicinity of feature ES1 range between 6.65 and 10.43 mg/L.

Average monthly ambient dissolved oxygen levels in the vicinity of feature ES2 range between 6.52 and 10.31 mg/L.

Average monthly ambient dissolved oxygen levels in the vicinity of feature ES3 range between 3.93 and 9.72 mg/L.

Placement of rock for shoreline protection may result in disturbances of water bottom substrate along the footprint of features ES1, ES2, and ES3; because of the high organic carbon content in substrate, this disturbance may result in minor, localized, and short-term reductions in dissolved oxygen levels. In addition, placement of material excavated for flotation access channel construction would result in the discharge of sediment with high organic content along the Lake Borgne shoreline, prompting a localized, short-term reduction in dissolved oxygen levels. Tidal currents are expected to quickly disperse waters affected by features ES1, ES2, and ES3 such that no significant impacts to dissolved oxygen levels are anticipated.

South Lake Borgne (LM, LS)

LM1, LM2, LM3, and LM4 (Marsh Restoration/Nourishment)
Average monthly ambient dissolved oxygen levels in the vicinity of feature LM1 range between 5.51 and 61.68 mg/L.

Average monthly ambient dissolved oxygen levels in the vicinity of feature LM2 range between 5.71 and 9.69 mg/L.

Average monthly ambient dissolved oxygen levels in the vicinity of feature LM3 range between 4.33 and 10.49 mg/L.

Average monthly ambient dissolved oxygen levels in the vicinity of feature LM4 range between 5.51 and 61.68 mg/L.

Because of the high organic carbon content of sediment from the Lake Borgne borrow areas, the discharge of hydraulically dredged material for marsh restoration at features LM1, LM2, LM3, and LM4 may have a short-term impact on dissolved oxygen levels for effluent waters discharging from the confines of this feature. In addition, there is a possibility that effects related to the release of ammonia from borrow area sediment pore water could occur. These effects would last until effluent production resulting from dredged material placement were to cease, but would not be as significant if management strategies (such as use of baffle plates) were adopted to reduce ammonia levels in dredged slurry during hydraulic placement of sediment.

LS1 (Shoreline Protection)

Average monthly ambient dissolved oxygen levels in the vicinity of feature LS1 range between 5.71 and 9.69 mg/L.

Placement of rock for shoreline protection may result in disturbances of water bottom substrate along the footprint of feature LS1; because of the high organic carbon content in substrate, this disturbance may result in minor, localized, and short-term reductions in dissolved oxygen levels. In addition, placement of material excavated for flotation access channel construction would result in the discharge of sediment with high organic content along the Lake Borgne shoreline, prompting a localized, short-term reduction in dissolved oxygen levels. Tidal currents are expected to quickly disperse waters affected by feature LS1 such that no significant impacts to dissolved oxygen levels are anticipated.

Terre aux Boeufs (TM)

TM1, TM2, and TM7 (Marsh Restoration/Nourishment)

Average monthly ambient dissolved oxygen levels in the vicinity of feature TM1 range between 4.38 and 10.22 mg/L.

Average monthly ambient dissolved oxygen levels in the vicinity of feature TM2 range between 5.14 and 10.71 mg/L.

Average monthly ambient dissolved oxygen levels in the vicinity of feature TM7 range between 4.38 and 10.22 mg/L.

Because of the high organic carbon content of sediment from the Lake Borgne borrow areas, the discharge of hydraulically dredged material for marsh restoration at features TM1, TLM2, and TM7 may have a short-term impact on dissolved oxygen levels for effluent waters discharging from the confines of this feature. In addition, there is a possibility that effects related to the release of ammonia from borrow area sediment pore water could occur. These effects would last until effluent production resulting from dredged material placement were to cease, but would not be as significant if management strategies (such as use of baffle plates) were adopted to reduce ammonia levels in dredged slurry during hydraulic placement of sediment.

TM8 (Marsh Restoration)
Average monthly ambient dissolved oxygen levels in the vicinity of feature TM8 range between 4.38 and 10.22 mg/L.

Because of the high organic carbon content of sediment from the Lake Borgne borrow areas, the discharge of hydraulically dredged material for marsh restoration at features TM8 may have a short-term impact on dissolved oxygen levels for effluent waters discharging from the confines of this feature. In addition, there is a possibility that effects related to the release of ammonia from borrow area sediment pore water could occur. These effects would last until effluent production resulting from dredged material placement were to cease, but would not be as significant if management strategies (such as use of baffle plates) were adopted to reduce ammonia levels in dredged slurry during hydraulic placement of sediment.

Hopedale (HM)

HM1 (Marsh Restoration/Nourishment)
Average monthly ambient dissolved oxygen levels in the vicinity of feature HM1 range between 4.49 and 10.27 mg/L.

Because of the high organic carbon content of sediment from the Lake Borgne borrow areas, the discharge of hydraulically dredged material for marsh restoration at feature HM1 may have a short-term impact on dissolved oxygen levels for effluent waters discharging from the confines of this feature. In addition, there is a possibility that effects related to the release of ammonia from borrow area sediment pore water could occur. These effects would last until effluent production resulting from dredged material placement were to cease, but would not be as significant if management strategies (such as use of baffle plates) were adopted to reduce ammonia levels in dredged slurry during hydraulic placement of sediment.

2.2.8 Nutrients and Eutrophication

Biloxi Marsh (BM, BS, BR)

BM1 (Marsh Nourishment)
Sediments proposed as borrow material for feature BM1 are expected to contain variable levels of organic material, which may release elevated concentrations of ammonia during construction activities related to marsh nourishment. Management strategies would be employed to assist in the transformation of ammonia into non-toxic nitrate. Nitrogen as either ammonia or nitrate may result in temporary increases in algal production within the vicinity of feature BM1. However, adverse or persistent algal blooms are not expected following the completion of construction activities.

BR1 (Ridge Restoration)
The placement of material for the proposed ridge restoration feature is not expected to contribute directly to eutrophication of any waters. Dredging of borrow materials and potential access channels would may result in the disturbance of water bottom substrate, which may expose variable levels of organic matter to the water column, resulting in the release of minor amounts

of ammonia into the water column. Elevated turbidity levels, as well as decreased water clarity, would continue in the feature area during construction, and would dissipate following the completion of the activities. However, as these releases are expected to be minor, and because there is expected to be adequate dissolved oxygen levels in the water column for converting ammonia into non-toxic nitrate, any effects associated with construction activities are expected to be short-lived and would altogether cease following feature construction.

BS1 (Shoreline Protection)
Placement of rock for shoreline protection for feature BS1 may result in the disturbance of water bottom substrate, which may expose variable levels of organic matter to the water column, resulting in the release of minor amounts of ammonia into the water column. In addition, the placement of dredged sediments for access channel construction is likely to expose additional organic matter in sediments to the water column, resulting in additional releases of ammonia. However, as these releases are expected to be minor, and because there is expected to be adequate dissolved oxygen levels in the water column for converting ammonia into non-toxic nitrate, any effects associated with construction activities associated with feature BS1 are expected to be short-lived and would altogether cease following feature construction.

BS2 (Oyster Reef)
Placement of material for oyster reef construction for feature BS2 may result in the disturbance of water bottom substrate, which may expose variable levels of organic matter to the water column, resulting in the release of minor amounts of ammonia into the water column. However, as these releases are expected to be minor, and because there is expected to be adequate dissolved oxygen levels in the water column for converting ammonia into non-toxic nitrate, any effects associated with construction activities associated with feature BS2 are expected to be short-lived and would altogether cease following feature construction. The establishment of oyster reefs would be expected to reduce nutrients in the water column by oysters filtering the water and depositing particles as substrate.

MRGO Channel (MRGO)

MRGO1 and MRGO6 (Shoreline Protection)
Placement of rock for shoreline protection for features MRGO1 and MRGO6 may result in the disturbance of water bottom substrate, which may expose variable levels of organic matter to the water column, resulting in the release of minor amounts of ammonia into the water column. In addition, the placement of dredged sediments for access channel construction is likely to expose additional organic matter in sediments to the water column, resulting in additional releases of ammonia. However, as these releases are expected to be minor, and because there is expected to be adequate dissolved oxygen levels in the water column for converting ammonia into non-toxic nitrate, any effects associated with construction activities associated with features MRGO1 and MRGO6 are expected to be short-lived and would altogether cease following feature construction.

MRGO2, MRGO3, and MRGO4 (Shoreline Protection Repairs/Maintenance)
Placement of rock for shoreline protection and maintenance for features MRGO2, MRGO3, and MRGO4 may result in the disturbance of water bottom substrate, which may expose variable

levels of organic matter to the water column, resulting in the release of minor amounts of ammonia into the water column. In addition, the placement of dredged sediments for access channel construction is likely to expose additional organic matter in sediments to the water column, resulting in additional releases of ammonia. However, as these releases are expected to be minor, and because there is expected to be adequate dissolved oxygen levels in the water column for converting ammonia into non-toxic nitrate, any effects associated with construction activities associated with features MRGO2, MRGO3, and MRGO4 are expected to be short-lived and would altogether cease following feature construction.

MRGO5, MRGO7, and MRGO8 (Shoreline Protection & Marsh Restoration)
Placement of rock for shoreline protection for features MRGO5, MRGO7, and MRGO8 may result in the disturbance of water bottom substrate, which may expose variable levels of organic matter to the water column, resulting in the release of minor amounts of ammonia into the water column. In addition, the placement of dredged sediments for access channel construction is likely to expose additional organic matter in sediments to the water column, resulting in additional releases of ammonia. However, as these releases are expected to be minor, and because there is expected to be adequate dissolved oxygen levels in the water column for converting ammonia into non-toxic nitrate, any effects associated with construction activities associated with features MRGO5, MRGO7, and MRGO8 are expected to be short-lived and would altogether cease following feature construction.

Sediments proposed as borrow material for features MRGO5, MRGO7, and MRGO8 are expected to contain variable levels of organic material, which may release elevated concentrations of ammonia during construction activities related to marsh restoration. Management strategies would be employed to assist in the transformation of ammonia into non-toxic nitrate. Nitrogen as either ammonia or nitrate may result in temporary increases in algal production within the vicinity of features MRGO5, MRGO7, and MRGO8. However, adverse or persistent algal blooms are not expected following the completion of construction activities.

Central Wetlands (CC, CM)

CC1, CC2, CC3, and CC5 (Swamp Restoration/Nourishment)
Sediments proposed as borrow material for features CC1, CC2, CC3, and CC5 are expected to contain variable levels of organic material, which may release elevated concentrations of ammonia during construction activities related to swamp restoration and nourishment. Management strategies would be employed to assist in the transformation of ammonia into non-toxic nitrate. Nitrogen as either ammonia or nitrate may result in temporary increases in algal production within the vicinity of features CC1, CC2, CC3, and CC5. However, adverse or persistent algal blooms are not expected following the completion of construction activities.

CC4 (Swamp Restoration)
Sediments proposed as borrow material for feature CC4 are expected to contain variable levels of organic material, which may release elevated concentrations of ammonia during construction activities related to swamp restoration. Management strategies would be employed to assist in the transformation of ammonia into non-toxic nitrate. Nitrogen as either ammonia or nitrate may result in temporary increases in algal production within the vicinity of feature CC4. However,

adverse or persistent algal blooms are not expected following the completion of construction activities.

CC6 (Swamp Nourishment)
Sediments proposed as borrow material for feature CC6 are expected to contain variable levels of organic material, which may release elevated concentrations of ammonia during construction activities related to swamp nourishment. Management strategies would be employed to assist in the transformation of ammonia into non-toxic nitrate. Nitrogen as either ammonia or nitrate may result in temporary increases in algal production within the vicinity of feature CC6. However, adverse or persistent algal blooms are not expected following the completion of construction activities.

CM1 (Marsh Nourishment)
Sediments proposed as borrow material for feature CM1 are expected to contain variable levels of organic material, which may release elevated concentrations of ammonia during construction activities related to marsh nourishment. Management strategies would be employed to assist in the transformation of ammonia into non-toxic nitrate. Nitrogen as either ammonia or nitrate may result in temporary increases in algal production within the vicinity of feature CM1. However, adverse or persistent algal blooms are not expected following the completion of construction activities.

CM2, CM3, CM4, and CM5 (Marsh Restoration/Nourishment)
Sediments proposed as borrow material for features CM2, CM3, CM4, and CM5 are expected to contain variable levels of organic material, which may release elevated concentrations of ammonia during construction activities related to marsh restoration and nourishment. Management strategies would be employed to assist in the transformation of ammonia into non-toxic nitrate. Nitrogen as either ammonia or nitrate may result in temporary increases in algal production within the vicinity of features CM2, CM3, CM4, and CM5. However, adverse or persistent algal blooms are not expected following the completion of construction activities.

East Orleans (EM, ES)

EM1, EM3 and EM4 (Marsh Restoration/Nourishment)
Sediments proposed as borrow material for features EM1, EM3, and EM4 are expected to contain variable levels of organic material, which may release elevated concentrations of ammonia during construction activities related to marsh restoration and nourishment. Management strategies would be employed to assist in the transformation of ammonia into non-toxic nitrate. Nitrogen as either ammonia or nitrate may result in temporary increases in algal production within the vicinity of features EM1, EM3, and EM4. However, adverse or persistent algal blooms are not expected following the completion of construction activities.

EM2 (Marsh Nourishment)
Sediments proposed as borrow material for feature EM2 are expected to contain variable levels of organic material, which may release elevated concentrations of ammonia during construction activities related to marsh nourishment. Management strategies would be employed to assist in the transformation of ammonia into non-toxic nitrate. Nitrogen as either ammonia or nitrate may

result in temporary increases in algal production within the vicinity of feature EM2. However, adverse or persistent algal blooms are not expected following the completion of construction activities.

ES1, ES2, and ES3 (Shoreline Protection)
Placement of rock for shoreline protection for features ES1, ES2, and ES3 may result in the disturbance of water bottom substrate, which may expose variable levels of organic matter to the water column, resulting in the release of minor amounts of ammonia into the water column. In addition, the placement of dredged sediments for access channel construction is likely to expose additional organic matter in sediments to the water column, resulting in additional releases of ammonia. However, as these releases are expected to be minor, and because there is expected to be adequate dissolved oxygen levels in the water column for converting ammonia into non-toxic nitrate, any effects associated with construction activities associated with features ES1, ES2, and ES3 are expected to be short-lived and would altogether cease following feature construction.

South Lake Borgne (LM, LS)

LM1, LM2, LM3, and LM4 (Marsh Restoration/Nourishment)
Sediments proposed as borrow material for features LM1, LM2, LM3, and LM4 are expected to contain variable levels of organic material, which may release elevated concentrations of ammonia during construction activities related to marsh restoration and nourishment. Management strategies would be employed to assist in the transformation of ammonia into non-toxic nitrate. Nitrogen as either ammonia or nitrate may result in temporary increases in algal production within the vicinity of features LM1, LM2, LM3, and LM4. However, adverse or persistent algal blooms are not expected following the completion of construction activities.

LS1 (Shoreline Protection)
Placement of rock for shoreline protection for feature LS1 may result in the disturbance of water bottom substrate, which may expose variable levels of organic matter to the water column, resulting in the release of minor amounts of ammonia into the water column. In addition, the placement of dredged sediments for access channel construction is likely to expose additional organic matter in sediments to the water column, resulting in additional releases of ammonia. However, as these releases are expected to be minor, and because there is expected to be adequate dissolved oxygen levels in the water column for converting ammonia into non-toxic nitrate, any effects associated with construction activities associated with feature LS1 are expected to be short-lived and would altogether cease following feature construction.

Terre aux Boeufs (TM)

TM1, TM2, and TM7 (Marsh Restoration/Nourishment)
Sediments proposed as borrow material for features TM1, TM2, and TM7 are expected to contain variable levels of organic material, which may release elevated concentrations of ammonia during construction activities related to marsh restoration and nourishment. Management strategies would be employed to assist in the transformation of ammonia into non-toxic nitrate. Nitrogen as either ammonia or nitrate may result in temporary increases in algal

production within the vicinity of features TM1, TM2, and TM7. However, adverse or persistent algal blooms are not expected following the completion of construction activities.

TM8 (Marsh Restoration)
Sediments proposed as borrow material for feature TM8 are expected to contain variable levels of organic material, which may release elevated concentrations of ammonia during construction activities related to marsh restoration. Management strategies would be employed to assist in the transformation of ammonia into non-toxic nitrate. Nitrogen as either ammonia or nitrate may result in temporary increases in algal production within the vicinity of feature TM8. However, adverse or persistent algal blooms are not expected following the completion of construction activities.

Hopedale (HM)

HM1 (Marsh Restoration/Nourishment)
Sediments proposed as borrow material for feature HM1 are expected to contain variable levels of organic material, which may release elevated concentrations of ammonia during construction activities related to marsh restoration and nourishment. Management strategies would be employed to assist in the transformation of ammonia into non-toxic nitrate. Nitrogen as either ammonia or nitrate may result in temporary increases in algal production within the vicinity of feature HM1. However, adverse or persistent algal blooms are not expected following the completion of construction activities.

2.2.9 Actions Taken to Minimize Adverse Impacts

Biloxi Marsh (BM, BS, BR)

BM1 (Marsh Nourishment)
Confinement dikes would allow solids to settle from dredged slurry prior to discharging from the feature area, and Inlets and outlets of the marsh nourishment area would be aligned so as to minimize effluent suspended solids.

BR1 (Ridge Restoration)
Material used for ridge restoration would be dewatered prior to placement, and is expected to generate minimal effluent during placement activities, thereby minimizing turbidity- and water quality-related impacts associated with feature construction.

Mechanical excavation of material for flotation access channel construction would serve to minimize the turbidity- and water quality-related impacts associated with access channel construction.

BS1 (Shoreline Protection)
Mechanical excavation of material for flotation access channel construction would serve to minimize the turbidity- and water quality-related impacts associated with access channel construction.

BS2 (Oyster Reef)
No actions taken.

MRGO Channel (MRGO)

MRGO1 and MRGO6 (Shoreline Protection)
Mechanical excavation of material for flotation access channel construction would serve to minimize the turbidity- and water quality-related impacts associated with access channel construction.

MRGO2, MRGO3, and MRGO4 (Shoreline Protection Repairs/Maintenance)
No actions taken.

MRGO5, MRGO7, and MRGO8 (Shoreline Protection & Marsh Restoration)
Confinement dikes would allow solids to settle from dredged slurry prior to discharging from feature areas, and Inlets and outlets of marsh restoration areas would be aligned so as to minimize effluent suspended solids.

Mechanical excavation of material for flotation access channel construction for feature MRGO5 would serve to minimize the turbidity- and water quality-related impacts associated with access channel construction.

Central Wetlands (CC, CM)

CC1, CC2, CC3, and CC5 (Swamp Restoration/Nourishment)
Confinement dikes would allow solids to settle from dredged slurry prior to discharging from feature areas, and Inlets and outlets of marsh restoration and nourishment areas would be aligned so as to minimize effluent suspended solids.

CC4 (Swamp Restoration)
Confinement dikes would allow solids to settle from dredged slurry prior to discharging from the feature area, and Inlets and outlets of the swamp restoration area would be aligned so as to minimize effluent suspended solids.

CC6 (Swamp Nourishment)
Confinement dikes would allow solids to settle from dredged slurry prior to discharging from the feature area, and Inlets and outlets of the swamp nourishment area would be aligned so as to minimize effluent suspended solids.

CM1 (Marsh Nourishment)
Confinement dikes would allow solids to settle from dredged slurry prior to discharging from the feature area, and Inlets and outlets of the marsh nourishment area would be aligned so as to minimize effluent suspended solids.

CM2, CM3, CM4, and CM5 (Marsh Restoration/Nourishment)
Confinement dikes would allow solids to settle from dredged slurry prior to discharging from feature areas, and Inlets and outlets of marsh restoration and nourishment areas would be aligned so as to minimize effluent suspended solids.

East Orleans (EM, ES)

EM1, EM3 and EM4 (Marsh Restoration/Nourishment)
Confinement dikes would allow solids to settle from dredged slurry prior to discharging from feature areas, and Inlets and outlets of marsh restoration and nourishment areas would be aligned so as to minimize effluent suspended solids.

Mechanical excavation of material for flotation access channel construction for feature EM1would serve to minimize the turbidity- and water quality-related impacts associated with access channel construction.

EM2 (Marsh Nourishment)
Confinement dikes would allow solids to settle from dredged slurry prior to discharging from the feature area, and Inlets and outlets of the marsh nourishment area would be aligned so as to minimize effluent suspended solids.
Mechanical excavation of material for flotation access channel construction would serve to minimize the turbidity- and water quality-related impacts associated with access channel construction.

ES1, ES2, and ES3 (Shoreline Protection)
Mechanical excavation of material for flotation access channel construction for these features would serve to minimize the turbidity- and water quality-related impacts associated with access channel construction.

South Lake Borgne (LM, LS)

LM1, LM2, LM3, and LM4 (Marsh Restoration/Nourishment)
Confinement dikes would allow solids to settle from dredged slurry prior to discharging from feature areas, and Inlets and outlets of marsh restoration and nourishment areas would be aligned so as to minimize effluent suspended solids.

LS1 (Shoreline Protection)
Mechanical excavation of material for flotation access channel construction would serve to minimize the turbidity- and water quality-related impacts associated with access channel construction.

Terre aux Boeufs (TM)

TM8 (Marsh Restoration)
Confinement dikes would allow solids to settle from dredged slurry prior to discharging from the feature area, and Inlets and outlets of the marsh restoration area would be aligned so as to minimize effluent suspended solids.

Hopedale (HM)

HM1 (Marsh Restoration/Nourishment)
Confinement dikes would allow solids to settle from dredged slurry prior to discharging from the feature area, and Inlets and outlets of the marsh nourishment and nourishment areas would be aligned so as to minimize effluent suspended solids.

2.3 Water Circulation, Fluctuation, and Salinity Gradient Determination

Water circulation, fluctuation and salinity gradient are largely influenced by tidal action.

If the deposited material is enclosed within a confinement dike whose crown is above the tidally-influenced elevation, then water circulation and fluctuation within the feature would be restricted, and the interior of the feature would be isolated from the influence of the salinity of the surrounding waters. Dikes would be breached, either naturally or manually, following consolidation and colonization of dredged material by vegetation, thereby reestablishing water circulation, fluctuation, and salinity gradients.

If temporary enclosure structures are used within the feature to expedite the wetland restoration, the discharge would be allowed to nourish the adjacent wetlands, which would alter water circulation and fluctuation. If the vicinity wetlands are not located at the tidal influenced area, the salinity gradient alteration would be minor.

Biloxi Marsh (BM, BS, BR)

BM1 (Marsh Nourishment)
For feature BM1, there would be significant short-term effects to water circulation for the areas inside and outside of the feature's confinement dikes (and for water levels inside of dikes). This would be an indirect impact associated with the construction of confinement dikes. Following the degradation of confinement dikes, water circulation and water level fluctuations in the feature area would be restored to conditions similar to pre-project, although the higher substrate elevations resulting from feature construction may slightly reduce throughput of water for the footprint of this feature.

Because waters within the footprint of feature BM1 are relatively shallow (generally less than ten feet deep), and because no major coastal channels will be obstructed by this feature after confinement dikes are degraded, no significant affects to salinity gradients are anticipated as a result of feature construction.

BR1 (Ridge Restoration)
Because feature BR1 is located on an upland site, no affects to water circulation, water level fluctuations, or salinity gradients are expected as a result of feature BR1.

The proposed access channel for construction of feature BR1 is not expected to be large enough to significantly impact existing water circulations patterns, water level fluctuations, or salinity gradients in Bayou La Loutre.

BS1 (Shoreline Protection)
Because shoreline protection would be segmented where bayous and canals meet Lake Borgne, main conduits for tidal flows would remain unimpeded by this feature. Shoreline protection would reduce the tidal exchange between contiguous marsh areas between bayous and canals that would otherwise be in direct interface with Lake Borgne; however, the benefits of shoreline protection are expected to far outweigh the effects to water circulation resulting from this feature.

Because waters within the area of feature BM1 are relatively shallow (generally less than ten feet deep), and because no major coastal channels will be obstructed by this feature after confinement dikes are degraded, no significant affects to salinity gradients are anticipated as a result of feature construction.

Because the access channel associated with construction of feature BS1 will be backfilled following the completion of feature construction, no net change in water circulation, water level fluctuations, or salinity gradients is expected to occur as a result of access channel construction.

BS2 (Oyster Reef)
Depending on the material chosen for oyster reef construction, the extent to which feature BS2 will protrude above the water bottom may vary; however, it is not anticipated that oyster reef materials would extent into the water column to heights that would result in any significant effects to water circulation. Because this feature is located adjacent to the Gulf of Mexico and is not hydraulically isolating any areas, it would not have any effect on water level fluctuations.

Because waters within the area of this feature are relatively shallow (generally less than ten feet deep), no significant affects to salinity gradients are anticipated as a result of feature construction.

MRGO Channel

MRGO1 and MRGO6 (Shoreline Protection)
Because shoreline protection would be segmented where bayous and canals meet the MRGO channel, main conduits for tidal flows would remain unimpeded by this feature. Shoreline protection would reduce the tidal exchange between contiguous marsh areas between bayous and canals that would otherwise be in direct interface with the MRGO channel; however, the benefits of shoreline protection are expected to far outweigh the effects to water circulation resulting from this feature.

The cumulative effect of all shoreline protection and shoreline protection repairs/maintenance features along the left descending bank of the MRGO channel may generate a minor effect on salinity gradients within the channel by impeding flow between the channel and the marsh areas north of the proposed features. However, because these features would be segmented where bayous and canals meet the MRGO channel, drainage patterns for marsh separated by these features would not be significantly altered to the extent that salinity gradients existing in the MRGO channel would be impacted.

Because the access channels associated with construction of features MRGO1 and MRGO6 will be backfilled following the completion of feature construction, no net change in water circulation, water level fluctuations, or salinity gradients is expected to occur as a result of access channel construction.

MRGO2, MRGO3, and MRGO4 (Shoreline Protection Repairs/Maintenance)
Because shoreline protection would be segmented where bayous and canals meet the MRGO channel, main conduits for tidal flows would remain unimpeded by this feature. Shoreline protection would reduce the tidal exchange between contiguous marsh areas between bayous and canals that would otherwise be in direct interface with the MRGO channel; however, the benefits of shoreline protection are expected to far outweigh the effects to water circulation resulting from this feature.

The cumulative effect of all shoreline protection and shoreline protection repairs/maintenance features along the left descending bank of the MRGO channel may generate a minor effect on salinity gradients within the channel by impeding flow between the channel and the marsh areas north of the proposed features . However, because these features would be segmented where bayous and canals meet the MRGO channel, drainage patterns for marsh separated by these features would not be significantly altered to the extent that salinity gradients existing in the MRGO channel would be impacted.

MRGO5, MRGO7, and MRGO8 (Shoreline Protection & Marsh Restoration)
Because shoreline protection would be segmented where bayous and canals meet the MRGO channel, main conduits for tidal flows would remain unimpeded by this feature. Shoreline protection would reduce the tidal exchange between contiguous marsh areas between bayous and canals that would otherwise be in direct interface with the MRGO channel; however, the benefits of shoreline protection are expected to far outweigh the effects to water circulation resulting from this feature.

The cumulative effect of all shoreline protection and shoreline protection repairs/maintenance features along the left descending bank of the MRGO channel may generate a minor effect on salinity gradients within the channel by impeding flow between the channel and the marsh areas north of the proposed features. However, because these features would be segmented where bayous and canals meet the MRGO channel, drainage patterns for marsh separated by these features would not be significantly altered to the extent that salinity gradients existing in the MRGO channel would be impacted.

For the marsh restoration component of these features, there would be significant short-term effects to water circulation for the areas inside and outside of the features' confinement dikes (and for water levels inside of dikes). This would be an indirect impact associated with the construction of confinement dikes. Following the degradation of confinement dikes, water level fluctuations in the area of these features would be restored to conditions similar to pre-project; however, because construction of these features would result in the replacement of open water habitat with contiguous wetlands habitat, significant impacts to water circulation are anticipated.

The proposed access channel for construction of feature MRGO5 is not expected to be large enough to significantly impact existing water circulations patterns, water level fluctuations, or salinity gradients in the MRGO channel.

Central Wetlands (CC, CM)

CC1, CC2, CC3, and CC5 (Cypress Swamp Restoration/Nourishment)
For the swamp nourishment component of these features, there would be significant short-term effects to water circulation for the areas inside and outside of the features' confinement dikes (and for water levels inside of dikes). This would be an indirect impact associated with the construction of confinement dikes. Following the degradation of confinement dikes, water circulation and water level fluctuations in the area of these features would be restored to conditions similar to pre-project, although the higher substrate elevations resulting from the construction of these features may slightly reduce throughput of water in and around feature footprints.

For the swamp restoration component of these features, there would be significant short-term effects to water circulation for the areas inside and outside of the features' confinement dikes (and for water levels inside of dikes). This would be an indirect impact associated with the construction of confinement dikes. Following the degradation of confinement dikes, water level fluctuations in the area of these features would be restored to conditions similar to pre-project; however, because construction of these features would result in the replacement of open water habitat with contiguous wetlands habitat, significant impacts to water circulation are anticipated.

Because waters within the footprint of these features are relatively shallow (generally less than ten feet deep), and because no major coastal channels are being obstructed by these features, no significant affects to salinity gradients are anticipated as a result of feature construction.

CC4 (Cypress Swamp Restoration)
For feature CC4, there would be significant short-term effects to water circulation for the areas inside and outside of the feature's confinement dikes (and for water levels inside of dikes). This would be an indirect impact associated with the construction of confinement dikes. Following the degradation of confinement dikes, water level fluctuations in the feature area would be restored to conditions similar to pre-project; however, because feature construction would result in the replacement of open water habitat with contiguous wetlands habitat, significant impacts to water circulation are anticipated.

CC6 (Cypress Swamp Nourishment)
For feature CC6, there would be significant short-term effects to water circulation for the areas inside and outside of the feature's confinement dikes (and for water levels inside of dikes). This would be an indirect impact associated with the construction of confinement dikes. Following the degradation of confinement dikes, water circulation and water level fluctuations in the feature area would be restored to conditions similar to pre-project, although the higher substrate elevations resulting from feature construction may slightly reduce throughput of water for the footprint of this feature.

CM1 (Marsh Nourishment)
For feature CM1, there would be significant short-term effects to water circulation for the areas inside and outside of the feature's confinement dikes (and for water levels inside of dikes). This would be an indirect impact associated with the construction of confinement dikes. Following the degradation of confinement dikes, water circulation and water level fluctuations in the feature area would be restored to conditions similar to pre-project, although the higher substrate elevations resulting from feature construction may slightly reduce throughput of water for the footprint of this feature.

CM2, CM3, CM4, and CM5 (Marsh Restoration/Nourishment)
For the marsh nourishment component of these features, there would be significant short-term effects to water circulation for the areas inside and outside of the features' confinement dikes (and for water levels inside of dikes). This would be an indirect impact associated with the construction of confinement dikes. Following the degradation of confinement dikes, water circulation and water level fluctuations in the area of these features would be restored to conditions similar to pre-project, although the higher substrate elevations resulting from the construction of these features may slightly reduce throughput of water in and around feature footprints.

For the marsh restoration component of these features, there would be significant short-term effects to water circulation for the areas inside and outside of the features' confinement dikes (and for water levels inside of dikes). This would be an indirect impact associated with the construction of confinement dikes. Following the degradation of confinement dikes, water level fluctuations in the area of these features would be restored to conditions similar to pre-project; however, because construction of these features would result in the replacement of open water habitat with contiguous wetlands habitat, significant impacts to water circulation are anticipated.

Because waters within the footprint of these features are relatively shallow (generally less than ten feet deep), and because no major coastal channels are being obstructed by these features, no significant affects to salinity gradients are anticipated as a result of feature construction.

East Orleans (EM, ES)

EM1, EM3 and EM4 (Marsh Restoration/Nourishment)
For the marsh nourishment component of these features, there would be significant short-term effects to water circulation for the areas inside and outside of the features' confinement dikes (and for water levels inside of dikes). This would be an indirect impact associated with the

construction of confinement dikes. Following the degradation of confinement dikes, water circulation and water level fluctuations in the area of these features would be restored to conditions similar to pre-project, although the higher substrate elevations resulting from the construction of these features may slightly reduce throughput of water in and around feature footprints.

For the marsh restoration component of these features, there would be significant short-term effects to water circulation for the areas inside and outside of the features' confinement dikes (and for water levels inside of dikes). This would be an indirect impact associated with the construction of confinement dikes. Following the degradation of confinement dikes, water level fluctuations in the area of these features would be restored to conditions similar to pre-project; however, because construction of these features would result in the replacement of open water habitat with contiguous wetlands habitat, significant impacts to water circulation are anticipated.

Because waters within the footprint of these features are relatively shallow (generally less than ten feet deep), and because no major coastal channels are being obstructed by these features, no significant affects to salinity gradients are anticipated as a result of feature construction.

Because the access channel associated with construction of feature EM1 will be backfilled following the completion of feature construction, no net change in water circulation, water level fluctuations, or salinity gradients is expected to occur as a result of access channel construction.

EM2 (Marsh Nourishment)
For feature EM2, there would be significant short-term effects to water circulation for the areas inside and outside of the feature's confinement dikes (and for water levels inside of dikes). This would be an indirect impact associated with the construction of confinement dikes. Following the degradation of confinement dikes, water circulation and water level fluctuations in the feature area would be restored to conditions similar to pre-project, although the higher substrate elevations resulting from feature construction may slightly reduce throughput of water for the footprint of this feature.

Because waters within the footprint of feature EM2 are relatively shallow (generally less than ten feet deep), and because no major coastal channels are being obstructed by these features, no significant affects to salinity gradients are anticipated as a result of feature construction.

Because the access channel associated with construction of feature EM2 will be backfilled following the completion of feature construction, no net change in water circulation, water level fluctuations, or salinity gradients is expected to occur as a result of access channel construction.

ES1, ES2, and ES3 (Shoreline Protection)
Because shoreline protection would be segmented where bayous and canals meet Lakes Borgne and Ponchartrain, main conduits for tidal flows would remain unimpeded by these features. Shoreline protection would reduce the tidal exchange between contiguous marsh areas between bayous and canals that would otherwise be in direct interface with Lake Borgne; however, the benefits of shoreline protection are expected to far outweigh the effects to water circulation resulting from this feature.

Because waters within the area of these features are predominantly relatively shallow (with the exception of reaches of shoreline protection features adjacent to Chef Menteur Pass and Pass Rigolets, features are generally adjacent to waters less than ten feet deep), and because no major coastal channels will be obstructed by this feature after confinement dikes are degraded, no significant affects to salinity gradients are anticipated as a result of feature construction.

Because the access channels associated with construction of these features will be backfilled following the completion of feature construction, no net change in water circulation, water level fluctuations, or salinity gradients is expected to occur as a result of access channel construction.

South Lake Borgne (LM, LS)

LM1, LM2, LM3, and LM4 (Marsh Restoration/Nourishment)

For the marsh nourishment component of these features, there would be significant short-term effects to water circulation for the areas inside and outside of the features' confinement dikes (and for water levels inside of dikes). This would be an indirect impact associated with the construction of confinement dikes. Following the degradation of confinement dikes, water circulation and water level fluctuations in the area of these features would be restored to conditions similar to pre-project, although the higher substrate elevations resulting from the construction of these features may slightly reduce throughput of water in and around feature footprints.

For the marsh restoration component of these features, there would be significant short-term effects to water circulation for the areas inside and outside of the features' confinement dikes (and for water levels inside of dikes). This would be an indirect impact associated with the construction of confinement dikes. Following the degradation of confinement dikes, water level fluctuations in the area of these features would be restored to conditions similar to pre-project; however, because construction of these features would result in the replacement of open water habitat with contiguous wetlands habitat, significant impacts to water circulation are anticipated.

Because waters within the footprint of these features are relatively shallow (generally less than ten feet deep), and because no major coastal channels are being obstructed by these features, no significant affects to salinity gradients are anticipated as a result of feature construction.

LS1 (Shoreline Protection)

Because shoreline protection would be segmented where bayous and canals meet Lake Borgne, main conduits for tidal flows would remain unimpeded by this feature. Shoreline protection would reduce the tidal exchange between contiguous marsh areas between bayous and canals that would otherwise be in direct interface with Lake Borgne; however, the benefits of shoreline protection are expected to far outweigh the effects to water circulation resulting from this feature.

Because waters within the footprint of feature LS1 are relatively shallow (generally less than ten feet deep), and because no major coastal channels are being obstructed by this feature, no significant affects to salinity gradients are anticipated as a result of feature construction.

Because the access channel associated with construction of feature LS1 will be backfilled following the completion of feature construction, no net change in water circulation, water level fluctuations, or salinity gradients is expected to occur as a result of access channel construction.

Terre aux Boeufs (TM)

TM1, TM2, and TM7 (Marsh Restoration/Nourishment)
For the marsh nourishment components of these features, there would be significant short-term effects to water circulation for the areas inside and outside of the feature's confinement dikes (and for water levels inside of dikes). This would be an indirect impact associated with the construction of confinement dikes. Following the degradation of confinement dikes, water circulation and water level fluctuations in the feature area would be restored to conditions similar to pre-project, although the higher substrate elevations resulting from feature construction may slightly reduce throughput of water for the footprint of this feature.

For the marsh restoration component of these features, there would be significant short-term effects to water circulation for the areas inside and outside of the features' confinement dikes (and for water levels inside of dikes). This would be an indirect impact associated with the construction of confinement dikes. Following the degradation of confinement dikes, water level fluctuations in the area of these features would be restored to conditions similar to pre-project; however, because construction of these features would result in the replacement of open water habitat with contiguous wetlands habitat, significant impacts to water circulation are anticipated.

Because waters within the footprint of these features are relatively shallow (generally less than ten feet deep), and because no major coastal channels are being obstructed by these features, no significant affects to salinity gradients are anticipated as a result of feature construction.

TM8 (Marsh Restoration)
For feature TM8, there would be significant short-term effects to water circulation for the areas inside and outside of the feature's confinement dikes (and for water levels inside of dikes). This would be an indirect impact associated with the construction of confinement dikes. Following the degradation of confinement dikes, water level fluctuations in the feature area would be restored to conditions similar to pre-project; however, because feature construction would result in the replacement of open water habitat with contiguous wetlands habitat, significant impacts to water circulation are anticipated.

Because waters within the footprint of feature TM8 are relatively shallow (generally less than ten feet deep), and because no major coastal channels are being obstructed by this feature, no significant affects to salinity gradients are anticipated as a result of feature construction.

Hopedale (HM)

HM1 (Marsh Restoration/Nourishment)
For the marsh nourishment component of feature HM1, there would be significant short-term effects to water circulation for the areas inside and outside of the feature's confinement dikes

(and for water levels inside of dikes). This would be an indirect impact associated with the construction of confinement dikes. Following the degradation of confinement dikes, water circulation and water level fluctuations in the feature area would be restored to conditions similar to pre-project, although the higher substrate elevations resulting from feature construction may slightly reduce throughput of water for the footprint of this feature.

For the marsh restoration component of feature HM1, there would be significant short-term effects to water circulation for the areas inside and outside of the feature's confinement dikes (and for water levels inside of dikes). This would be an indirect impact associated with the construction of confinement dikes. Following the degradation of confinement dikes, water level fluctuations in the area of this feature would be restored to conditions similar to pre-project; however, because construction of this feature would result in the replacement of open water habitat with contiguous wetlands habitat, significant impacts to water circulation are anticipated.

Because waters within the footprint of feature HM1 are relatively shallow (generally less than ten feet deep), and because no major coastal channels are being obstructed by this feature, no significant affects to salinity gradients are anticipated as a result of feature construction.

2.3.1 Actions Taken to Minimize Impacts

Biloxi Marsh (BM, BS, BR)

BM1 (Marsh Restoration/Nourishment)
No actions taken.

BR1 (Ridge Restoration)
No actions taken.

BS1 (Shoreline Protection)
Gaps would be left in shoreline protection feature BS1 to allow for water circulation.

Material excavated for flotation access channel construction will be used to backfill the access channel. Therefore, flotation access channel construction would have no long term effect on water circulation.

BS2 (Oyster Reef)
No actions taken.

MRGO Channel (MRGO)

MRGO1 and MRGO6 (Shoreline Protection)
Material excavated for flotation access channel construction will be used to backfill the access channel. Therefore, flotation access channel construction would have no long term effect on water circulation.

MRGO2, MRGO3, and MRGO4 (Shoreline Protection Repairs/Maintenance)
No actions taken.

MRGO5, MRGO7, and MRGO8 (Shoreline Protection & Marsh Restoration)
Confinement dikes would be utilized to prevent dredged material from flowing from these features.

Material excavated for flotation access channel construction will be used to backfill the access channel. Therefore, flotation access channel construction would have no long term effect on water circulation.

Central Wetlands (CC, CM)

CC1, CC2, CC3, and CC5 (Swamp Restoration/Nourishment)
No actions taken.

CC4 (Swamp Restoration)
No actions taken.

CC6 (Swamp Nourishment)
No actions taken.

CM1 (Marsh Nourishment)
Upon completion of construction activities for this feature, all closures would be removed, thereby restoring water circulation for affected waterbodies.

CM2, CM3, CM4, and CM5 (Marsh Restoration/Nourishment)
Confinement dikes would be utilized to prevent dredged material from flowing from these features.

Upon completion of construction activities for features CM3 and CM4, all closures would be removed, thereby restoring water circulation for affected waterbodies.

East Orleans (EM, ES)

EM1, EM3 and EM4 (Marsh Restoration/Nourishment)
For feature EM1, material excavated for flotation access channel construction will be used to backfill the access channel.

EM2 (Marsh Nourishment)
For feature EM2, material excavated for flotation access channel construction will be used to backfill the access channel.

ES1, ES2, and ES3 (Shoreline Protection)
Gaps would be left in shoreline protection feature BS1 to allow for water circulation. Gaps will also be left in the rock dike to allow boat access into the Irish Bayou Community, and at the I-10 and I-11 corridor.

Material excavated for flotation access channel construction will be used to backfill the access channel. Therefore, flotation access channel construction would have no long term effect on water circulation.

South Lake Borgne (LM, LS)

LM1, LM2, LM3, and LM4 (Marsh Restoration/Nourishment)
Upon completion of construction activities for features LM1, LM2, and LM4, all closures would be removed, thereby restoring water circulation for affected waterbodies.

For Feature LM2, based upon preliminary lake bottom classification surveys, approximately 3 acres of hard bottom surface falls within the northern-most access corridor leading from the borrow sites in Lake Borgne Site No 4. As excavation for flotation access will not be performed, marsh buggy access will simply be required within this 3 acres area in order to access the marsh restoration sites.

LS1 (Shoreline Protection)
Gaps would be left in shoreline protection feature BS1 to allow for fish passage and water circulation.

Material excavated for flotation access channel construction will be used to backfill the access channel. Therefore, flotation access channel construction would have no long term effect on water circulation.

Terre aux Boeufs (TM)

TM1, TM2, and TM7 (Marsh Restoration/Nourishment)
Upon completion of construction activities for features TM1 and TM7, all closures would be removed, thereby restoring water circulation for affected waterbodies.

TM8 (Marsh Restoration)
Upon completion of construction activities for this feature, all closures would be removed, thereby restoring water circulation for affected waterbodies.

Hopedale (HM)

HM1 (Marsh Restoration/Nourishment)
No actions taken.

2.4 Contaminant Determinations

Representative sediment chemistry for all wetlands restoration and/or nourishment features and borrow areas for which chemical analysis of nearby sediment samples was available was compared with the sediment screening benchmarks provided in the National Oceanic and Atmospheric Administration (NOAA) Screening Quick Reference Tables (SQuiRTs) (NOAA, 2008). The suite of screening benchmarks provided in these tables are for different biological and toxicological endpoints, some of which (such as PEL, T50, and ERM criteria) represent levels at which a high probability of adverse effects or toxicity for benthic organisms exposed to sediment are expected. Further definitions of screening benchmarks are available at http://response.restoration.noaa.gov/faq_topic.php?faq_topic_id=6#tecpec. Although they are not regulated, these benchmarks provide a useful means of assessing sediment chemistry to determine whether or not acute or chronic exposure of benthic organisms to sediment may result in adverse biological effects or mortality.

Data tables 2.4-1 through **2.4-32** depict minimum, maximum, and average representative sediment concentrations for wetlands restoration and/or nourishment features and borrow areas for which chemical analysis of nearby sediment samples was available, and includes a comparison of these concentrations to the marine NOAA sediment screening benchmarks. Results which are shaded exceed at least one screening benchmark, and the color which a given exceedance is shaded represents the highest screening benchmark exceeded. **Data table 2.4-33** depicts the factor of difference between representative average sediment concentrations for each wetlands restoration and/or nourishment feature for which chemical analysis of nearby sediment samples was available and their respective borrow areas (in other words, values in these tables depict the representative average concentration for sediments in the vicinity of a feature's borrow area divided by the representative average concentration in sediments from nearby that feature).

Lake Borgne Borrow Areas (Borrow Areas 2, 3, 4, 5, 6, and 8): The maximum concentrations in all sediment samples within the vicinity of Lake Borgne borrow areas were compared to sediment screening benchmarks, the results of which are available in **data tables 2.4-2** through **2.4-7**. Maximum sediment concentrations exceeded screening benchmarks for the following benchmark classes (arranged by increasing order of predicted toxicity gradient) and parameters:

- T_{20}: antimony, arsenic, cadmium, nickel, and silver
- TEL: arsenic, cadmium, nickel, tin, gamma-BHC, toxaphene, acenaphthene, acenaphthylene, and dibenzo(a,h)anthracene
- ERL: cadmium and dieldrin
- T_{50}: None
- PEL: None
- ERM: None
- AET: iron, manganese, selenium, tin, and heptachlor
- Eco Tox EqP: None

No screening values for which probable effects (PEL and ERM) or elevated mortality rates (T50) were exceeded for the maximum sediment concentrations observed in the vicinity of Lake Borgne borrow areas.

Mississippi River Borrow Area: Concentrations for sediment samples extracted from within the vicinity of the Mississippi River borrow area are available in **data table 2.4-27**. Sediment concentrations exceeded screening benchmarks (arranged by increasing order of predicted toxicity gradient) for the following benchmark classes and parameters:

- T_{20}: cadmium, nickel, dieldrin, and heptachlor epoxide
- TEL: nickel, tin, gamma-BHC, p,p'-DDD, p,p'-DDT, dieldrin, and toxaphene
- ERL: p,p'-DDD, p,p'-DDT, and dieldrin
- T_{50}: None
- PEL: gamma-BHC and heptachlor epoxide
- ERM: None
- AET: dieldrin, heptachlor, and benzoic acid
- Eco Tox EqP: diazinon and toxaphene

For p,p'-DDD, p,p'-DDT, dieldrin, gamma-BHC, heptachlor, heptachlor epoxide, and toxaphene, concentrations were measured below laboratory detection limits which were 19 times higher than the detection limits requested for the analysis of Mississippi River sediments. For all of the previously listed chemicals except for toxaphene, results were reported as being below a detection limit of 6.6 µg/kg, and results for the purposes of evaluating sediment were estimated as half of the reporting limit, or 3.3 µg/kg. For toxaphene, results were reported as being below a detection limit of 260 µg/kg, and results for the purposes of evaluating sediment were estimated as half of the reporting limit, or 130 µg/kg.

Actual results for these parameters are expected to be lower; however, because of elevated detection limits, the estimated concentrations of gamma-BHC and heptachlor epoxide exceed PEL screening values, which are indicative of probable effects to benthic organisms.

MRGO/GIWW Borrow Area: The maximum concentrations in all sediment samples in the vicinity of the western extent of the MRGO/GIWW borrow area are available in **data table 2.4-28**. Maximum sediment concentrations exceeded screening benchmarks for the following benchmark classes (arranged by increasing order of predicted toxicity gradient) and parameters:

- T_{20}: mercury, nickel, silver, zinc, dieldrin, heptachlor epoxide, acenaphthene, acenaphthylene, anthracene, benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(g,h,i)perylene, benzo(k)fluoranthene, phenanthrene, chrysene, bibenzo(a,h)anthracene, fluoranthene, fluorine, 2-methylnaphthalene, naphthalene, pyrene, and indeno(1,2,3-cd)pyrene
- TEL: arsenic, barium, cadmium, copper, lead, mercury, nickel, tin, zinc, gamma-BHC, p,p'-DDD, p,p'-DDE, p,p'-DDT, dieldrin, toxaphene, acenaphthene, acenaphthylene, anthracene, benzo(a)anthracene, benzo(a)pyrene,

phenanthrene, bis(2-ethylhexyl)phthalate, chrysene, dibenzo(a,h)anthracene, fluoranthene, fluorene, 2-methylnaphthalene, naphthalene, and pyrene

- ERL: arsenic, cadmium, copper, lead, mercury, nickel, zinc, p,p'-DDD, p,p'-DDE, p,p'-DDT, dieldrin, acenaphthene, acenaphthylene, anthracene, benzo(a)anthracene, benzo(a)pyrene, phenanthrene, chrysene, dibenzo(a,h)anthracene, fluoranthene, fluorene, 2-methylnaphthalene, and pyrene
- T_{50}: cadmium, lead, acenaphthene, acenaphthylene, anthracene, benzo(a)anthracene, benzo(a)pyrene, benzo(g,h,i)perylene, phenanthrene, chrysene, dibenzo(a,h)anthracene, fluoranthene, fluorence, 2-methylphenanthrene, and indeno(1,2,3-cd)pyrene
- PEL: lead, gamma-BHC, p,p'-DDD, acenaphthene, acenaphthylene, anthracene, benzo(a)anthracene, benzo(a)pyrene, phenanthrene, bis(2-ethylhexyl)phthalate, chrysene, dibenzo(a,h)anthracene, fluoranthene, fluorene, and pyrene
- ERM: lead, p,p'-DDD, acenaphthene, and phenanthrene
- AET: selenium, tin, aldrin, p,p'-DDD, heptachlor, acenaphthene, acenaphthylene, anthracene, benzo(g,h,i)perylene, phenanthrene, benzoic acid, bis(2-ethylhexyl)phthalate, butyl benzyl phthalate, chrysene, p-cresol, dibenzo(a,h)anthracene, dibenzofuran, 2,4-dimethylphenol, fluoranthene, fluorene, hexachlorobenzene, 2-methylnaphthalene, nitrobenzene, and indeno(1,2,3-cd)pyrene
- Eco Tox EqP: diazinon, methoxyclor, toxaphene, and benzene

For several parameters included in analysis of sediment in the vicinity of the western extent of the MRGO/GIWW borrow area, concentrations were measured below laboratory detection limits which were between 5 and 13 times higher than the laboratory detection limits requested for the analysis of these sediments. Reanalysis of sediments for several parameters and samples was conducted to compensate for this error; however, reanalysis was not conducted for all samples or parameters with elevated detection limits. Actual results for these parameters are expected to be lower; however, because of elevated detection limits, the screening of maximum concentrations in sediments—where concentrations measured below the detection limit are estimated as being one half of the detection limit—indicated exceedances of AET screening benchmarks for 2,4-dimethylphenol, benzoic acid, butyl benzyl phthalate, hexachlorobenzene, and nitrobenzene, and the exceedance of the Eco Tox EqP benchmark for diazinon. Nonetheless, maximum sediment concentrations between these samples reveal exceedances of screening benchmarks emblematic of probable effects or toxicity for benthic organisms exposed to sediment. In addition, results from whole sediment toxicity testing for exposure of the estuarine organism L. plumulosus to sediment sampled for the same region of the GIWW resulted in significant mortality rates (USACE, 2005). Therefore, results from sediment chemistry and sediment toxicity testing on sediments in proximity to the western end of the MRGO/GIWW borrow area indicate that using material from the western end of the borrow area may adversely affect benthic organisms. Because no information is available regarding the remainder of the borrow area, and in light of available information for the western end of the borrow area, there is no clear understanding of the chemical nature of sediments proposed for marsh restoration and nourishment from a majority of this borrow area.

Biloxi Marsh (BM, BS, BR)

BM1 (Marsh Nourishment)
See discussion of the Lake Borgne borrow areas for information and determinations pertaining to the sediment chemistry of these borrow areas, which includes the borrow area for feature BM1 (Borrow Area 2).

Because no screening values for which probable effects (PEL and ERM) or elevated mortality rates (T50) were exceeded for the maximum sediment concentrations observed in the vicinity of Lake Borgne borrow areas, it is not anticipated that the use of material from Borrow Area 2 for marsh nourishment at feature BM1 would result in adverse impacts for benthic organisms in the vicinity of this feature. In addition, because no contaminants were discovered for which the average concentration in the vicinity of Borrow Area 2 exceeded the average concentration in the vicinity of feature BM1 by a factor greater than ten, no significant changes in sediment chemistry resulting from construction of the proposed feature using material from this borrow area is anticipated.

BR1 (Ridge Restoration)
The borrow area associated with feature BR1 is the Mississippi River borrow area. Sediment Chemistry results for this borrow area reveal levels of gamma-BHC and heptachlor epoxide that exceed PEL screening values. Actual results for these parameters are expected to be lower; however, because of elevated detection limits, the estimated concentrations of gamma-BHC and heptachlor epoxide exceed these screening values, which are indicative of probable effects to benthic organisms. All contaminants measured at detectable levels did not indicate probable adverse effect or mortality for benthic organisms. Based on detectable levels of contaminants in Mississippi River borrow area sediments, no adverse effects are expected from placement of borrow area sediments for ridge restoration.

Several contaminants were discovered for which the average concentration in the Mississippi River borrow area sediments exceeded the average concentration in the vicinity of feature BR1 by a factor greater than ten. However, these exceedances were all based on Mississippi River borrow area sediment chemistry results which were below elevated laboratory detection limits.

The chemical nature of flotation access channel material sidecast in the footprint of feature BR1 is unknown. However, as this area is not located near any known sources of contamination, it is not believed that flotation access channel material contains significant levels of contaminants, and therefore should not result in changes to substrate chemistry that would adversely affect benthic organisms for any wetlands areas that may be included in the footprint of feature BR1.

BS1 (Shoreline Protection)
Because rock used for the construction of shoreline protection for feature BS1 is expected to be free of contaminants, the placement of rock for shoreline protection for this feature is not anticipated to result in changes to substrate chemistry that would adversely affect benthic organisms.

Because sediments excavated for flotation access channel construction will be used to backfill the flotation access channel after construction is completed, no net change in sediment chemical properties is expected to occur from flotation access channel construction.

BS2 (Oyster Reef)
Because materials used for the construction of oyster reef for feature BS2 are expected to be free of contaminants, the placement of material for oyster reef construction for this feature is not anticipated to result in changes to substrate chemistry that would adversely affect benthic organisms.

MRGO Channel (MRGO)

MRGO1 and MRGO6 (Shoreline Protection)
Because rock used for the construction of shoreline protection for features MRGO1 and MRGO6 is expected to be free of contaminants, the placement of rock for shoreline protection for this feature is not anticipated to result in changes to substrate chemistry that would adversely affect benthic organisms.

Because sediments excavated for flotation access channel construction for these features will be used to backfill the flotation access channel after construction is completed, no net change in sediment chemical properties is expected to occur from flotation access channel construction.

MRGO2, MRGO3, and MRGO4 (Shoreline Protection Repairs/Maintenance)
Because rock used for the construction of shoreline protection repairs and maintenance for features MRGO2, MRGO2, and MRGO4 is expected to be free of contaminants, the placement of rock for shoreline protection for these features is not anticipated to result in changes to substrate chemistry that would adversely affect benthic organisms.

MRGO5, MRGO7, and MRGO8 (Shoreline Protection & Marsh Restoration)
See discussion of the Lake Borgne borrow areas for information and determinations pertaining to the sediment chemistry of these borrow areas, which includes the borrow area for feature MRGO5 and MRGO8 (Borrow Area 3) and MRGO7 (Borrow Area 5).

Because no screening values for which probable effects (PEL and ERM) or elevated mortality rates (T50) were exceeded for the maximum sediment concentrations observed in the vicinity of Lake Borgne borrow areas, it is not anticipated that the use of material from Borrow Areas 3 and 5 for shoreline protection & marsh restoration at features MRGO5, MRGO7, and MRGO8 would result in adverse impacts for benthic organisms in the vicinity of this feature. In addition, because no contaminants were discovered for which the average concentration in the vicinity of Borrow Areas 3 and 5 exceeded the average concentration in the vicinity of features MRGO5, MRGO7, and MRGO8 by a factor greater than ten, no significant changes in sediment chemistry resulting from construction of the proposed feature using material from this borrow area is anticipated.

The chemical nature of flotation access channel material that will be placed for marsh restoration for feature MRGO5 is unknown. However, as this area is not located near any known sources of

contamination, it is not believed that flotation access channel material contains significant levels of contaminants, and therefore should not result in changes to substrate chemistry that would adversely affect benthic organisms.

Central Wetlands (CC, CM)

CC1, CC2, CC3, and CC5 (Swamp Restoration/Nourishment)
See discussion of the Lake Borgne borrow areas for information and determinations pertaining to the sediment chemistry of these borrow areas, which includes the borrow area for features CC1 (Borrow Area 5), CC2 (Borrow Area 5), CC3 (Borrow Area 5), and CC5 (Borrow Area 4).

Because no screening values for which probable effects (PEL and ERM) or elevated mortality rates (T50) were exceeded for the maximum sediment concentrations observed in the vicinity of Lake Borgne borrow areas, it is not anticipated that the use of material from Borrow Areas 4 and 5 for swamp restoration/nourishment at features CC1, CC2, CC3, and CC5 would result in adverse impacts for benthic organisms in the vicinity of this feature. In addition, because no contaminants were discovered for which the average concentration in the vicinity of Borrow Areas 4 and 5 exceeded the average concentration in the vicinity of features CC1, CC2, CC3, and CC5 by a factor greater than ten, no significant changes in sediment chemistry resulting from construction of the proposed feature using material from this borrow area is anticipated.

CC4 (Swamp Restoration)
See discussion of the Lake Borgne borrow areas for information and determinations pertaining to the sediment chemistry of these borrow areas, which includes the borrow area for feature CC4 (Borrow Area 6).

Because no screening values for which probable effects (PEL and ERM) or elevated mortality rates (T50) were exceeded for the maximum sediment concentrations observed in the vicinity of Lake Borgne borrow areas, it is not anticipated that the use of material from Borrow Area 6 for swamp restoration at feature CC4 would result in adverse impacts for benthic organisms in the vicinity of this feature. In addition, because no contaminants were discovered for which the average concentration in the vicinity of Borrow Area 6 exceeded the average concentration in the vicinity of feature CC4 by a factor greater than ten, no significant changes in sediment chemistry resulting from construction of the proposed feature using material from this borrow area is anticipated.

CC6 (Swamp Nourishment)
See discussion of the Lake Borgne borrow areas for information and determinations pertaining to the sediment chemistry of these borrow areas, which includes the borrow area for feature CC6 (Borrow Area 4).

Because no screening values for which probable effects (PEL and ERM) or elevated mortality rates (T50) were exceeded for the maximum sediment concentrations observed in the vicinity of Lake Borgne borrow areas, it is not anticipated that the use of material from Borrow Area 6 for swamp nourishment at feature CC6 would result in adverse impacts for benthic organisms in the vicinity of this feature. In addition, because no contaminants were discovered for which the

average concentration in the vicinity of Borrow Area 6 exceeded the average concentration in the vicinity of feature CC6 by a factor greater than ten, no significant changes in sediment chemistry resulting from construction of the proposed feature using material from this borrow area is anticipated.

CM1 (Marsh Nourishment)

See discussion of the Lake Borgne borrow areas for information and determinations pertaining to the sediment chemistry of these borrow areas, which includes the borrow area for feature CM1 (Borrow Area 5).

Because no screening values for which probable effects (PEL and ERM) or elevated mortality rates (T50) were exceeded for the maximum sediment concentrations observed in the vicinity of Lake Borgne borrow areas, it is not anticipated that the use of material from Borrow Area 5 for marsh nourishment at feature CM1 would result in adverse impacts for benthic organisms in the vicinity of this feature. In addition, because no contaminants were discovered for which the average concentration in the vicinity of Borrow Area 5 exceeded the average concentration in the vicinity of feature CM1 by a factor greater than ten, no significant changes in sediment chemistry resulting from construction of the proposed feature using material from this borrow area is anticipated.

CM2, CM3, CM4, and CM5 (Marsh Restoration/Nourishment)

See discussion of the MRGO/GIWW borrow area for information and determinations pertaining to the sediment chemistry of this borrow area, which is the proposed borrow source for feature CM2.

Results from sediment chemistry and sediment toxicity testing on sediments in proximity to the western end of the MRGO/GIWW borrow area indicate that using material from the western end of the borrow area may adversely affect benthic organisms. Because no information is available regarding the remainder of the borrow area, and in light of available information for the western end of the borrow area, there is no clear understanding of the chemical nature of sediments proposed for marsh restoration and nourishment from a majority of this borrow area. Therefore, further characterization of MRGO/GIWW borrow area sediments is required in order to determine whether any reaches of this borrow area contain sediments suitable for use for feature CM2.

See discussion of the Lake Borgne borrow areas for information and determinations pertaining to the sediment chemistry of these borrow areas, which includes the borrow area for features CM3 (Borrow Area 5), CM4 (Borrow Area 4), and CM5 (Borrow Area 6).

Because no screening values for which probable effects (PEL and ERM) or elevated mortality rates (T50) were exceeded for the maximum sediment concentrations observed in the vicinity of Lake Borgne borrow areas, it is not anticipated that the use of material from Borrow Areas 4, 5, and 6 for marsh restoration/nourishment at features CM3, CM4, and CM5 would result in adverse impacts for benthic organisms in the vicinity of this feature. In addition, because no contaminants were discovered for which the average concentration in the vicinity of Borrow Areas 4, 5, and 6 exceeded the average concentration in the vicinity of features CM3 and CM4

by a factor greater than ten, no significant changes in sediment chemistry resulting from construction of the proposed feature using material from this borrow area is anticipated.

East Orleans (EM, ES)

EM1, EM3, and EM4 (Marsh Restoration/Nourishment)
See discussion of the Lake Borgne borrow areas for information and determinations pertaining to the sediment chemistry of these borrow areas, which includes the borrow area for features EM1 (Borrow Area 6), EM3 (Borrow Area 8), and EM4 (Borrow Area 8).

Because no screening values for which probable effects (PEL and ERM) or elevated mortality rates (T50) were exceeded for the maximum sediment concentrations observed in the vicinity of Lake Borgne borrow areas, it is not anticipated that the use of material from Borrow Areas 6 and 8 for marsh restoration/nourishment at features EM1, EM3, and EM4 would result in adverse impacts for benthic organisms in the vicinity of this feature. In addition, because no contaminants were discovered for which the average concentration in the vicinity of Borrow Areas 6 and 8 exceeded the average concentration in the vicinity of features EM1, EM3 and EM4 by a factor greater than ten, no significant changes in sediment chemistry resulting from construction of the proposed feature using material from this borrow area is anticipated.

Because sediments excavated for flotation access channel construction for feature EM1 will be used to backfill the flotation access channel after construction is completed, no net change in sediment chemical properties is expected to occur from flotation access channel construction.

EM2 (Marsh Nourishment)
See discussion of the Lake Borgne borrow areas for information and determinations pertaining to the sediment chemistry of these borrow areas, which includes the borrow area for feature EM2 (Borrow Area 8).

Because no screening values for which probable effects (PEL and ERM) or elevated mortality rates (T50) were exceeded for the maximum sediment concentrations observed in the vicinity of Lake Borgne borrow areas, it is not anticipated that the use of material from Borrow Area 8 for marsh nourishment at feature EM2 would result in adverse impacts for benthic organisms in the vicinity of this feature. In addition, because no contaminants were discovered for which the average concentration in the vicinity of Borrow Area 8 exceeded the average concentration in the vicinity of feature EM2 by a factor greater than ten, no significant changes in sediment chemistry resulting from construction of the proposed feature using material from this borrow area is anticipated.

Because sediments excavated for flotation access channel construction will be used to backfill the flotation access channel after construction is completed, no net change in sediment chemical properties is expected to occur from flotation access channel construction.

ES1, ES2, and ES3 (Shoreline Protection)
Because rock used for the construction of shoreline protection for features ES1, ES2, and ES3 is expected to be free of contaminants, the placement of rock for shoreline protection for these

features is not anticipated to result in changes to substrate chemistry that would adversely affect benthic organisms.

Because sediments excavated for flotation access channel construction for these features will be used to backfill the flotation access channel after construction is completed, no net change in sediment chemical properties is expected to occur from flotation access channel construction.

South Lake Borgne (LM, LS)

LM1, LM2, LM3, and LM4 (Marsh Restoration/Nourishment)
See discussion of the Lake Borgne borrow areas for information and determinations pertaining to the sediment chemistry of these borrow areas, which includes the borrow area for feature LM1 and LM4 (Borrow Area 6), LM2 (Borrow Area 4), and LM3 (Borrow Area 2).

Because no screening values for which probable effects (PEL and ERM) or elevated mortality rates (T50) were exceeded for the maximum sediment concentrations observed in the vicinity of Lake Borgne borrow areas, it is not anticipated that the use of material from Borrow Areas 2, 4, and 6 for marsh restoration/nourishment at features LM1, LM2, LM3, and LM4 would result in adverse impacts for benthic organisms in the vicinity of this feature. In addition, because no contaminants were discovered for which the average concentration in the vicinity of Borrow Areas 2, 4, and 6 exceeded the average concentration in the vicinity of features LM1, LM2, LM3, and LM4 by a factor greater than ten, no significant changes in sediment chemistry resulting from construction of the proposed feature using material from this borrow area is anticipated.

LS1 (Shoreline Protection)
Because rock used for the construction of shoreline protection for feature LS1 is expected to be free of contaminants, the placement of rock for shoreline protection for this feature is not anticipated to result in changes to substrate chemistry that would adversely affect benthic organisms.

Because sediments excavated for flotation access channel construction for will be used to backfill the flotation access channel after construction is completed, no net change in sediment chemical properties is expected to occur from flotation access channel construction.

Terre aux Boeufs (TM)

TM1, TM2, and TM7 (Marsh Restoration/Nourishment)
See discussion of the Lake Borgne borrow areas for information and determinations pertaining to the sediment chemistry of these borrow areas, which includes the borrow area for feature TM1, TM2, and TM7 (Borrow Area 2).

Because no screening values for which probable effects (PEL and ERM) or elevated mortality rates (T50) were exceeded for the maximum sediment concentrations observed in the vicinity of Lake Borgne borrow areas, it is not anticipated that the use of material from Borrow Area 2 for marsh restoration/nourishment at features TM1, TM2, and TM7 would result in adverse impacts

for benthic organisms in the vicinity of this feature. In addition, because no contaminants were discovered for which the average concentration in the vicinity of Borrow Area 2 exceeded the average concentration in the vicinity of features TM1, TM2, and TM7 by a factor greater than ten, no significant changes in sediment chemistry resulting from construction of the proposed feature using material from this borrow area is anticipated.

TM8 (Marsh Restoration)

See discussion of the Lake Borgne borrow areas for information and determinations pertaining to the sediment chemistry of these borrow areas, which includes the borrow area for feature TM8 (Borrow Area 2).

Because no screening values for which probable effects (PEL and ERM) or elevated mortality rates (T50) were exceeded for the maximum sediment concentrations observed in the vicinity of Lake Borgne borrow areas, it is not anticipated that the use of material from Borrow Area 2 for marsh restoration at feature TM8 would result in adverse impacts for benthic organisms in the vicinity of this feature. In addition, because no contaminants were discovered for which the average concentration in the vicinity of Borrow Area 2 exceeded the average concentration in the vicinity of feature TM8 by a factor greater than ten, no significant changes in sediment chemistry resulting from construction of the proposed feature using material from this borrow area is anticipated.

Hopedale (HM)

HM1 (Marsh Restoration/Nourishment)

See discussion of the Lake Borgne borrow areas for information and determinations pertaining to the sediment chemistry of these borrow areas, which includes the borrow area for feature HM1 (Borrow Area 2).

Because no screening values for which probable effects (PEL and ERM) or elevated mortality rates (T50) were exceeded for the maximum sediment concentrations observed in the vicinity of Lake Borgne borrow areas, it is not anticipated that the use of material from Borrow Area 2 for marsh restoration/nourishment at feature HM1 would result in adverse impacts for benthic organisms in the vicinity of this feature.

The average concentration in the vicinity of Borrow Area 2 exceeded the average concentration in the vicinity of feature HM1 by a factor greater than ten (16.7) for tin. Levels of tin in Borrow Area 2 are similar to those of all other Lake Borgne borrow areas, and do not exceed any screening values for which probable effects (PEL and ERM) or elevated mortality rates (T50). With the exception of tin, no significant changes in sediment chemistry resulting from construction of the proposed feature using material from this borrow area is anticipated.

2.5 Aquatic Ecosystem Organism Determination

2.5.1 Effects on Plankton

Biloxi Marsh (BM, BS, BR)

BM1 (Marsh Nourishment)
Temporary and localized impacts (decreased dissolved oxygen, increased turbidity) to plankton communities are expected in project areas during construction activities; however, projected long-term effects are beneficial to productivity. Plankton communities would be temporarily displaced at deposition locations proposed for marsh and swamp restoration and nourishment. Also, any dredged materials that enter shallow water may produce sufficient turbidity to inhibit the photosynthesis of phytoplankton.

Long-term effects are primarily positive. The overall project goals involve a general shift from open water to wetland, mudflat, and shallow water communities as well as a restoration of the natural elevation and salinity gradient of estuarine systems. The result would be an increase in suitable plankton foraging habitat and a greater diversity of food sources for zooplankton provided through the increased productivity expected in emergent and submerged vegetation restoration.

BS1 (Shoreline Protection)
Shoreline protection measures would protect wetland habitats and improve the quality of the wetlands with respect to viable plankton habitat. Improvements to plankton habitats may include an increase in suitable plankton foraging habitat and a greater diversity of food sources for zooplankton.

BS2 (Oyster Reef)
Artificial oyster reefs offer protection measures for surrounding wetlands and as such, impacts to plankton are anticipated to similar to those discussed in **section 2.5.1** for BM1. Additionally, oysters feed upon planktonic resources, which would result in a positive feedback cycle beneficial to both the oyster reef and the plankton populations.

BR1 (Ridge Restoration)
No impacts to plankton populations are expected from ridge restoration actions.

MRGO Channel (MRGO)

MRGO2, MRGO3, and MRGO4 (Shoreline Protection Repairs/Maintenance)
Impacts to plankton are anticipated to similar to those discussed in **section 2.5.1** for BS1.

MRGO1 and MRGO6 (Shoreline Protection)
Impacts to plankton are anticipated to similar to those discussed in **section 2.5.1** for BS1.

MRGO5, MRGO7, and MRGO8 (Shoreline Protection & Marsh Restoration)
Impacts to plankton are anticipated to similar to those discussed in **section 2.5.1** for BM1 and BS1.

Central Wetlands (CC, CM)

CC1, CC2, CC3, and CC5 (Swamp Restoration/Nourishment)
Impacts to plankton are anticipated to similar to those discussed in **section 2.5.1** for BM1.

CC4 (Swamp Restoration)
Impacts to plankton are anticipated to similar to those discussed in **section 2.5.1** for BM1.

CC6 (Swamp Nourishment)
Impacts to plankton are anticipated to similar to those discussed in **section 2.5.1** for BM1.

CM1 (Marsh Nourishment)
Impacts to plankton are anticipated to similar to those discussed in **section 2.5.1** for BM1.

CM2, CM3, CM4, and CM5 (Marsh Restoration/Nourishment)
Impacts to plankton are anticipated to similar to those discussed in **section 2.5.1** for BM1.

East Orleans (EM, ES)

EM1, EM3 and EM4 (Marsh Restoration/Nourishment)
Impacts to plankton are anticipated to similar to those discussed in **section 2.5.1** for BM1.

EM2 (Marsh Nourishment)
Impacts to plankton are anticipated to similar to those discussed in **section 2.5.1** for BM1.

ES1, ES2, and ES3 (Shoreline Protection)
Impacts to plankton are anticipated to similar to those discussed in **section 2.5.1** for BS1.

South Lake Borgne (LM, LS)

LM1, LM2, LM3, and LM4 (Marsh Restoration/Nourishment)
Impacts to plankton are anticipated to similar to those discussed in **section 2.5.1** for BM1.

LS1 (Shoreline Protection)
Impacts to plankton are anticipated to similar to those discussed in **section 2.5.1** for BS1.

Terre aux Boeufs (TM)

TM1, TM2, and TM7 (Marsh Restoration/Nourishment)
Impacts to plankton are anticipated to similar to those discussed in **section 2.5.1** for BM1.

TM8 (Marsh Restoration)
Impacts to plankton are anticipated to similar to those discussed in **section 2.5.1** for BM1.

Hopedale (HM)

HM1 (Marsh Restoration/Nourishment)
Impacts to plankton are anticipated to similar to those discussed in **section 2.5.1** for BM1.

Violet Diversion (D)

D05
The proposed release of river water through the Violet diversion canal and into the Lake Borgne and Biloxi Marsh ecosystems would result in a greater reduction of ambient salinity in the adjacent Lake Borgne region than in the more distant Biloxi Marsh. Projected salinity changes of 2 to 3 ppt resulting from maximum diversion flows would have only minor temporal and spatial effect on plankton in Lake Borgne and little to no impact in the Biloxi Marsh. With only minor projected salinity changes in Lake Borgne and the well flushed nature of the Lake Borgne system and the Biloxi marsh ecosystem, no substantial impacts are anticipated from the influx of freshwater.

Effects on phytoplankton have been correlated more with the high nutrient-laden waters released from the Mississippi River than reductions in salinity. However, there appears to be no compelling evidence that changes in water quality would adversely affect plankton within these ecosystems. A study addressing water quality concluded that levels of suspended solids and nutrients would increase in Lake Borgne due to the existing shallow and well-flushed nature of the lake system. Increased detritus flushed from marsh areas into open water by diversion flows would provide additional food sources for zooplankton.

2.5.2 Effects on Benthos

Biloxi Marsh (BM, BS, BR)

BM1 (Marsh Nourishment)
The overall project would result in a shift from open water to wetland, mudflat, and shallow water communities as well as a restored natural elevation and salinity gradient. The net result would be an increase in suitable benthic habitat, especially due to wetland restoration. Wetland habitats protected, created, and nourished by the project indirectly benefit benthic resources by providing increased dissolved organic compounds and detritus that would in turn provide food and energy resources for benthic organisms.

Effects to the benthos would be related primarily to localized and temporary disturbance of water bottoms dredging and placement of borrow materials. These activities may directly impact and bury slow-moving or sessile benthic organisms within the proposed borrow areas, floatation access channels, wetland restoration, and shoreline protection footprints. Disturbance to benthic species would likely occur from increased turbidity, temperature, and biological oxygen demand and decreased dissolved oxygen caused by construction activities. It is expected that there would be a negligible impact on the regional benthic ecosystem because; (1) the benthic assemblages within the borrow sites are not unique and are similar to assemblages in adjacent areas and (2) the spatial extent of the dredged area is small compared to the broad area of the nearshore coastal

environment. Once construction is completed it is anticipated that waters would return to ambient conditions and benthic organisms would likely re-colonize disturbed areas.

BS1 (Shoreline Protection)
Effects to the benthos would be related primarily to localized and temporary disturbance of water bottoms during placement of shoreline protection features. These activities would have similar impacts to those discussed in **section 2.5.2** for BS1.

BS2 (Oyster Reef)
Effects to the benthos would be related primarily to localized and temporary disturbance of water bottoms during placement of artificial reefs. These activities would have similar impacts to those discussed in **section 2.5.2** for BS1.

BR1 (Ridge Restoration)
No impacts to benthic populations are expected from ridge restoration actions.

MRGO Channel (MRGO)

MRGO2, MRGO3, and MRGO4 (Shoreline Protection Repairs/Maintenance)
Impacts to the benthos are anticipated to similar to those discussed in **section 2.5.2** for BS1.

MRGO1 and MRGO6 (Shoreline Protection)
Impacts to the benthos are anticipated to similar to those discussed in **section 2.5.2** for BS1.

MRGO5, MRGO7, and MRGO8 (Shoreline Protection & Marsh Restoration)
Impacts to the benthos are anticipated to similar to those discussed in **section 2.5.2** for BM1.

Central Wetlands (CC, CM)

CC1, CC2, CC3, and CC5 (Swamp Restoration/Nourishment)
Impacts to the benthos are anticipated to similar to those discussed in **section 2.5.2** for BM1.

CC4 (Swamp Restoration)
Impacts to the benthos are anticipated to similar to those discussed in **section 2.5.2** for BM1.

CC6 (Swamp Nourishment)
Impacts to the benthos are anticipated to similar to those discussed in **section 2.5.2** for BM1.

CM1 (Marsh Nourishment)
Impacts to the benthos are anticipated to similar to those discussed in **section 2.5.2** for BM1.

CM2, CM3, CM4, and CM5 (Marsh Restoration/Nourishment)
Impacts to the benthos are anticipated to similar to those discussed in **section 2.5.2** for BM1.

East Orleans (EM, ES)

EM1, EM3 and EM4 (Marsh Restoration/Nourishment)
Impacts to the benthos are anticipated to similar to those discussed in **section 2.5.2** for BM1.

EM2 (Marsh Nourishment)
Impacts to the benthos are anticipated to similar to those discussed in **section 2.5.2** for BM1.

ES1, ES2, and ES3 (Shoreline Protection)
Impacts to the benthos are anticipated to similar to those discussed in **section 2.5.2** for BS1.

South Lake Borgne (LM, LS)

LM1, LM2, LM3, and LM4 (Marsh Restoration/Nourishment)
Impacts to the benthos are anticipated to similar to those discussed in **section 2.5.2** for BM1.

LS1 (Shoreline Protection
Impacts to the benthos are anticipated to similar to those discussed in **section 2.5.2** for BS1.

Terre aux Boeufs (TM)

TM1, TM2, and TM7 (Marsh Restoration/Nourishment)
Impacts to the benthos are anticipated to similar to those discussed in **section 2.5.2** for BM1.

TM8 (Marsh Restoration)
Impacts to the benthos are anticipated to similar to those discussed in **section 2.5.2** for BM1.

Hopedale (HM)

HM1 (Marsh Restoration/Nourishment)
Impacts to the benthos are anticipated to similar to those discussed in **section 2.5.2** for BM1.

Violet Diversion (D)

D05
Increases in freshwater, sediment, and nutrients would have positive effects on benthic communities. The re-establishment of the salinity gradient essential to diverse and productive wetland communities would increase wetland productivity, thereby increasing habitat and available food sources for benthic communities. A study addressing water quality concluded that levels of suspended solids and nutrients would increase in Lake Borgne due to the existing shallow and well-flushed nature of the lake system. Increased detritus flushed from marsh areas into open water by diversion flows would provide additional food sources for benthic organisms.

2.5.2.1 Physical Effect on Benthos

Biloxi Marsh (BM, BS, BR)

BM1 (Marsh Nourishment)
There may be some detrimental effects to benthic zones due to water bottom disturbance in dredge borrow areas and placement areas. Through the physical removal of the surficial sediment, dredging exposes sediment that has different physical and geochemical properties than the pre-dredged sediment. The changes to the surficial sediment characteristics may change its suitability for burrowing, feeding, and larval settlement of benthic organisms. Dredging exposes anaerobic sediment that may affect benthic organism recolonization of the dredged area and changes the rate of nutrient exchange between the sediment and water column. The rate at which benthic communities recover after dredging varies widely depending on the habitat (Newell et al. 1998). Low dissolved oxygen concentrations caused by dredging could prevail if current flow is reduced as a result of the dredge material removal. Current flow reduction can be avoided or ameliorated by increasing the surface area of the borrow pits. Borrow pits have been designed with a large width to depth ratio to increase the surface area and increase the success of benthic habitat recovery.

Low dissolved oxygen (DO) levels could be a potential impact during construction activities in Lake Borgne and continue to persist after construction. Additionally, there is the potential that the Violet Freshwater Diversion could exacerbate low DO condition in Lake Borgne due to the high level of nutrients causing algal blooms. The potential for this impact could be monitored in the future after implementation and addressed with adaptive management.

The overall project goals would result in a shift from open water to wetland, mudflat, and shallow water communities as well as a restored natural elevation and salinity gradient. The result would be an increase in suitable benthic habitat, especially due to wetland restoration. Physical effects to the benthos will be related primarily to localized and temporary disturbance of water bottoms during dredging and placement of borrow materials. Once construction is completed it is anticipated that benthic habitats and communities would return to ambient conditions.

BS1 (Shoreline Protection)
Physical effects to the benthos would be related primarily to localized and temporary disturbance of water bottoms during placement of shoreline protection features. Impacts would be similar to those discussed in **section 2.5.2.1** for BM1.

BS2 (Oyster Reef)
Oysters are part of the epibenthic community (i.e., living on the surface of the substrate). The restoration of artificial oyster reefs would re-establish the epibenthic community, which is necessary to help regulate or modify most physical, chemical, geological, and biological processes throughout the entire estuarine.

BR1 (Ridge Restoration)
No impacts to the physical benthos are expected from ridge restoration actions.

MRGO Channel (MRGO)

MRGO2, MRGO3, and MRGO4 (Shoreline Protection Repairs/Maintenance)
Impacts to the benthos are anticipated to similar to those discussed in **section 2.5.2.1** for BS1.

MRGO1and MRGO6 (Shoreline Protection)
Impacts to the benthos are anticipated to similar to those discussed in **section 2.5.2.1** for BS1.

MRGO5, MRGO7, and MRGO8 (Shoreline Protection & Marsh Restoration)
Impacts to the benthos are anticipated to similar to those discussed in **section 2.5.2.1** for BM1 and BS1.

Central Wetlands (CC, CM)

CC1, CC2, CC3, and CC5 (Swamp Restoration/Nourishment)
Impacts to the benthos are anticipated to similar to those discussed in **section 2.5.2.1** for BM1.

CC4 (Swamp Restoration)
Impacts to the benthos are anticipated to similar to those discussed in **section 2.5.2.1** for BM1.

CC6 (Swamp Nourishment)
Impacts to the benthos are anticipated to similar to those discussed in **section 2.5.2.1** for BM1.

CM1 (Marsh Nourishment)
Impacts to the benthos are anticipated to similar to those discussed in **section 2.5.2.1** for BM1.

CM2, CM3, CM4, and CM5 (Marsh Restoration/Nourishment)
Impacts to the benthos are anticipated to similar to those discussed in **section 2.5.2.1** for BM1.

East Orleans (EM, ES)

EM1, EM3 and EM4 (Marsh Restoration/Nourishment)
Impacts to the benthos are anticipated to similar to those discussed in **section 2.5.2.1** for BM1.

EM2 (Marsh Nourishment)
Impacts to the benthos are anticipated to similar to those discussed in **section 2.5.2.1** for BM1.

ES1, ES2, and ES3 (Shoreline Protection)
Impacts to the benthos are anticipated to similar to those discussed in **section 2.5.2.1** for BS1.

South Lake Borgne (LM, LS)

LM1, LM2, LM3, and LM4 (Marsh Restoration/Nourishment)
Impacts to the benthos are anticipated to similar to those discussed in **section 2.5.2.1** for BM1.

LS1 (Shoreline Protection)
Impacts to the benthos are anticipated to similar to those discussed in **section 2.5.2.1** for BS1.

Terre aux Boeufs (TM)

TM1, TM2, and TM7 (Marsh Restoration/Nourishment)
Impacts to the benthos are anticipated to similar to those discussed in **section 2.5.2.1** for BM1.

TM8 (Marsh Restoration)
Impacts to the benthos are anticipated to similar to those discussed in **section 2.5.2.1** for BM1.

Hopedale (HM)

HM1 (Marsh Restoration/Nourishment)
Impacts to the benthos are anticipated to similar to those discussed in **section 2.5.2.1** for BM1.

Violet Diversion (D)

D05
The restoration of the natural salinity and elevation gradient within the marshes would increase the overall area of benthic habitat within the project area. Preliminary modeling results show a slight decrease in annual net productivity for benthic species in east Lake Pontchartrain at target years 2015 and 2065 and Lake Borgne at target year 2015. However, across the entire project, monthly benthic productivity is higher in the month of September within the Lake Borgne and Biloxi Marsh. Uncertainties associated with the preliminary CASM results are on the order of approximately +/-20 percent. Therefore, the minimal decreases in modeled benthic productivity might be reasonably interpreted as no adverse impact.

2.5.2.2 Toxic Effect and Bioaccumulation on Benthos

For further detailed information regarding contaminant determinations and water column impacts see **sections 2.4 and 2.2.2.2**, respectively.

Biloxi Marsh (BM, BS, BR)

BM1 (Marsh Nourishment)
No toxic effect or bioaccumulation on benthic species is anticipated from the project.

BS1 (Shoreline Protection)
No toxic effect or bioaccumulation on benthic species is anticipated from the project.

BS2 (Oyster Reef)
Oysters can be considered part of the benthos as epibenthic organisms. They feed by filtering microorganisms from the water column; therefore, any toxic materials present in the water can bioaccumulate within an active reef. However, this is a natural process and is not an effect of the project. Oyster reef restoration would not occur in highly contaminated waters.

BR1 (Ridge Restoration)
No toxic effect or bioaccumulation on benthic species is anticipated from the project.

MRGO Channel (MRGO)

MRGO2, MRGO3, and MRGO4 (Shoreline Protection Repairs/Maintenance)
No toxic effect or bioaccumulation on benthic species is anticipated from the project.

MRGO1 and MRGO6 (Shoreline Protection)
No toxic effect or bioaccumulation on benthic species is anticipated from the project.

MRGO5, MRGO7, and MRGO8 (Shoreline Protection & Marsh Restoration)
No toxic effect or bioaccumulation on benthic species is anticipated from the project.

Central Wetlands (CC, CM)

CC1, CC2, CC3, and CC5 (Swamp Restoration/Nourishment)
No toxic effect or bioaccumulation on benthic species is anticipated from the project.

CC4 (Swamp Restoration)
No toxic effect or bioaccumulation on benthic species is anticipated from the project.

CC6 (Swamp Nourishment)
No toxic effect or bioaccumulation on benthic species is anticipated from the project.

CM1 (Marsh Nourishment)
No toxic effect or bioaccumulation on benthic species is anticipated from the project.

CM2, CM3, CM4, and CM5 (Marsh Restoration/Nourishment)
No toxic effect or bioaccumulation on benthic species is anticipated from the project.

East Orleans (EM, ES)

EM1, EM3 and EM4 (Marsh Restoration/Nourishment)
No toxic effect or bioaccumulation on benthic species is anticipated from the project.

EM2 (Marsh Nourishment)
No toxic effect or bioaccumulation on benthic species is anticipated from the project.

ES1, ES2, and ES3 (Shoreline Protection)
No toxic effect or bioaccumulation on benthic species is anticipated from the project.

South Lake Borgne (LM, LS)

LM1, LM2, LM3, and LM4 (Marsh Restoration/Nourishment)
No toxic effect or bioaccumulation on benthic species is anticipated from the project.

LS1 (Shoreline Protection)
No toxic effect or bioaccumulation on benthic species is anticipated from the project.

Terre aux Boeufs (TM)

TM1, TM2, and TM7 (Marsh Restoration/Nourishment)
No toxic effect or bioaccumulation on benthic species is anticipated from the project.

TM8 (Marsh Restoration)
No toxic effect or bioaccumulation on benthic species is anticipated from the project.

Hopedale (HM)

HM1 (Marsh Restoration/Nourishment)
No toxic effect or bioaccumulation on benthic species is anticipated from the project.

Violet Diversion (D)

D05
Long-lasting organochlorine insecticides such as DDT, dieldrin, and endrin, are still detected within the Mississippi River. If the diversion project near Violet is implemented, the occurrence and variety of pesticides and other organic compounds would likely increase in the Central Wetlands, MRGO, and Lake Borgne. This could lead to a possibility of bioaccumulation of these compounds in various filter feeders such as oysters, particularly in the areas nearest to the diversion structure. Chemical spills within the Mississippi River should be detected by the Lower Mississippi River Early Warning Organic Compound Detection System (EVOCS) and the diversion structure could be closed until any potential spill passes by Violet, thus preventing accidental spills from entering the Central Wetlands and MRGO via the diversion structure. Existing programs, such as the National Pollutant Discharge Elimination System (NPDES), the Louisiana Department of Environmental Quality's (LDEQ's) and Mississippi Department of Environmental Quality's (MDEQ's) Nonpoint Source Pollution Program, Louisiana Department of Natural Resources' (LDNR's) Coastal Nonpoint Pollution Program, and Total Maximum Daily Loads (TMDLs), would continue. The Lake Pontchartrain Basin Foundation (LPBF) activities, such as water quality monitoring, habitat protection, environmental education, and public events, are expected to continue.

2.5.3 Effects on Nekton

Biloxi Marsh (BM, BS, BR)

BM1 (Marsh Nourishment)
The placement of material for nourishment and restoration is unlikely to adversely affect nekton populations. Most evidence suggests that nekton utilize the entire marsh surface across the range from low to high elevations, but that the dense vegetation characteristic of high marsh habitats may offer greater protection from natant predators than low marshes. Increases to elevation within the marsh habitat would increase nektonic habitat diversity. Small disruptions to nekton populations may occur during construction; however, most nekton species would relocate temporarily to avoid construction areas and quickly return to their original habitats once construction is completed.

BS1 (Shoreline Protection)
Small disruptions to nekton populations may occur during construction; however, most nekton species would relocate temporarily to avoid construction areas and quickly return to their original habitats once construction is completed.

BS2 (Oyster Reef)
Impacts to nekton communities are anticipated to be slight and similar to those discussed in **section 2.5.3** for BS1. Additionally, nekton species may use the artificial oyster reef as habitat, for shelter and food sources, which would increase nekton populations.

BR1 (Ridge Restoration)
No impacts to nekton populations are expected from ridge restoration actions.

MRGO Channel (MRGO)

MRGO2, MRGO3, and MRGO4 (Shoreline Protection Repairs/Maintenance)
Impacts to nekton communities are anticipated to be slight and similar to those discussed in **section 2.5.3** for BS1.

MRGO1 and MRGO6 (Shoreline Protection)
Impacts to nekton communities are anticipated to be slight and similar to those discussed in **section 2.5.3** for BS1.

MRGO5, MRGO7, and MRGO8 (Shoreline Protection & Marsh Restoration)
Impacts to nekton communities are anticipated to be slight and similar to those discussed in **section 2.5.3** for BM1.

Central Wetlands (CC, CM)

CC1, CC2, CC3, and CC5 (Swamp Restoration/Nourishment)
Impacts to nekton communities are anticipated to be slight and similar to those discussed in **section 2.5.3** for BM1.

CC4 (Swamp Restoration)
Impacts to nekton communities are anticipated to be slight and similar to those discussed in **section 2.5.3** for BM1.

CC6 (Swamp Nourishment)
Impacts to nekton communities are anticipated to be slight and similar to those discussed in **section 2.5.3** for BM1.

CM1 (Marsh Nourishment)
Impacts to nekton communities are anticipated to be slight and similar to those discussed in **section 2.5.3** for BM1.

CM2, CM3, CM4, and CM5 (Marsh Restoration/Nourishment)
Impacts to nekton communities are anticipated to be slight and similar to those discussed in **section 2.5.3** for BM1.

East Orleans (EM, ES)

EM1, EM3 and EM4 (Marsh Restoration/Nourishment)
Impacts to nekton communities are anticipated to be slight and similar to those discussed in **section 2.5.3** for BM1.

EM2 (Marsh Nourishment)
Impacts to nekton communities are anticipated to be slight and similar to those discussed in **section 2.5.3** for BM1.

ES1, ES2, and ES3 (Shoreline Protection)
Impacts to nekton communities are anticipated to be slight and similar to those discussed in **section 2.5.3** for BS1.

South Lake Borgne (LM, LS)

LM1, LM2, LM3, and LM4 (Marsh Restoration/Nourishment)
Impacts to nekton communities are anticipated to be slight and similar to those discussed in **section 2.5.3** for BM1.

LS1 (Shoreline Protection)
Impacts to nekton communities are anticipated to be slight and similar to those discussed in **section 2.5.3** for BS1.

Terre aux Boeufs (TM)

TM1, TM2, and TM7 (Marsh Restoration/Nourishment)
Impacts to nekton communities are anticipated to be slight and similar to those discussed in **section 2.5.3** for BM1.

TM8 (Marsh Restoration)
Impacts to nekton communities are anticipated to be slight and similar to those discussed in **section 2.5.3** for BM1.

Hopedale (HM)

HM1 (Marsh Restoration/Nourishment)
Impacts to nekton communities are anticipated to be slight and similar to those discussed in **section 2.5.3** for BM1.

Violet Diversion (D)

D05
The restoration of the natural salinity gradient due to the Violet Diversion may increase the diversity of food sources for nekton communities.

2.5.4 Effects on Aquatic Food Web

Biloxi Marsh (BM, BS, BR)

BM1 (Marsh Nourishment)
In general, a restoration of the natural elevation and salinity gradient of the wetland ecosystems within the project area would benefit the aquatic food web by increasing habitat and species diversity at base and intermediate levels of the food web. Wetland habitats protected, created, and nourished by the project indirectly benefit benthic resources by providing increased dissolved organic compounds and detritus that would in turn provide food and energy resources for benthic organisms. This would eventually increase local epifauna, which would help reduce turbidity, regenerate ammonia and phosphorus, and serve as sources of food for birds, nekton, and people. The ecosystem would also experience benefits from habitat preservation and increased habitat complexity.

BS1 (Shoreline Protection)
By protecting wetland habitats, shoreline protection would benefit the aquatic food web by increasing habitat and species diversity at base and intermediate levels of the food web, as discussed in **section 2.5.4** for BM1.

BS2 (Oyster Reef)
The restoration of artificial oyster reefs would benefit the aquatic food web. Oysters themselves serve an integral part of the food web as both predator and prey, using base levels as food sources and serving as a food source for higher levels of the food web such as oyster drills, oyster catchers, and even raccoons. No negative impacts to the food web are expected from oyster reef construction.

BR1 (Ridge Restoration)
The forest ecosystem supported by the restored ridge would encourage populations of top tier food web species, such as predators. Top-down pressure from predators can balance the food web by regulating populations at lower trophic levels.

MRGO Channel (MRGO)

MRGO2, MRGO3, and MRGO4 (Shoreline Protection Repairs/Maintenance)
By protecting wetland habitats, shoreline protection would benefit the aquatic food web by increasing habitat and species diversity at base and intermediate levels of the food web, as discussed in **section 2.5.4** for BM1.

MRGO1 and MRGO6 (Shoreline Protection)
By protecting wetland habitats, shoreline protection would benefit the aquatic food web by increasing habitat and species diversity at base and intermediate levels of the food web, as discussed in **section 2.5.4** for BM1.

MRGO5, MRGO7, and MRGO8 (Shoreline Protection & Marsh Restoration)
Impacts to the food web would be similar to those discussed in **section 2.5.4** for BM1.

Central Wetlands (CC, CM)

CC1, CC2, CC3, and CC5 (Swamp Restoration/Nourishment)
Impacts to the food web would be similar to those discussed in **section 2.5.4** for BM1.

CC4 (Swamp Restoration)
Impacts to the food web would be similar to those discussed in **section 2.5.4** for BM1.

CC6 (Swamp Nourishment)
Impacts to the food web would be similar to those discussed in **section 2.5.4** for BM1.

CM1 (Marsh Nourishment)
Impacts to the food web would be similar to those discussed in **section 2.5.4** for BM1.

CM2, CM3, CM4, and CM5 (Marsh Restoration/Nourishment)
Impacts to the food web would be similar to those discussed in **section 2.5.4** for BM1.

East Orleans (EM, ES)

EM1, EM3 and EM4 (Marsh Restoration/Nourishment)
Impacts to the food web would be similar to those discussed in **section 2.5.4** for BM1.

EM2 (Marsh Nourishment)
Impacts to the food web would be similar to those discussed in **section 2.5.4** for BM1.

ES1, ES2, and ES3 (Shoreline Protection)
By protecting wetland habitats, shoreline protection would benefit the aquatic food web by increasing habitat and species diversity at base and intermediate levels of the food web, as discussed in **section 2.5.4** for BM1.

South Lake Borgne (LM, LS)

LM1, LM2, LM3, and LM4 (Marsh Restoration/Nourishment)
Impacts to the food web would be similar to those discussed in **section 2.5.4** for BM1.

LS1 (Shoreline Protection)
By protecting wetland habitats, shoreline protection would benefit the aquatic food web by increasing habitat and species diversity at base and intermediate levels of the food web, as discussed in **section 2.5.4** for BM1.

Terre aux Boeufs (TM)

TM1, TM2, and TM7 (Marsh Restoration/Nourishment)
Impacts to the food web would be similar to those discussed in **section 2.5.4** for BM1.

TM8 (Marsh Restoration)
Impacts to the food web would be similar to those discussed in **section 2.5.4** for BM1.

Hopedale (HM)

HM1 (Marsh Restoration/Nourishment)
Impacts to the food web would be similar to those discussed in **section 2.5.4** for BM1.

Violet Diversion (D)

D05
Diverting freshwater from the Mississippi River would affect the food web by altering salinity, by introducing sediment and nutrient-laden waters to Lake Borgne, and by altering turbidity and current patterns. The restoration of the natural salinity gradient due to the Violet Diversion may increase the diversity of food sources for nekton communities, increase wetland productivity and thereby increasing habitat and available food sources for benthic communities. Salinity modeling predicts the salinity change resulting from the Violet Diversion would not be substantial enough to affect the fisheries population within the project area. Plankton species would not likely be negatively impacted by the higher flows and resulting lower salinities. Effects on phytoplankton have been correlated more with the high nutrient-laden waters released from the Mississippi River than with reductions in salinity. Increased detritus flushed from marsh areas into open water by diversion flows would provide additional food sources for zooplankton and benthic organisms. Impacts to fisheries populations from increased turbidity may include reduced feeding opportunities for visual predators and gill clogging. Impacts to turbidity would increase closer to the source of the diversion during periods of high flow (April

through May, maximum flow of 7,000 cfs). Best management practices (BMPs) would be used during construction to ensure impacts were temporary and localized.

2.5.5 Special Aquatic Sites Effects

2.5.5.1 Sanctuaries and Refuges

Biloxi Marsh (BM, BS, BR)

BM1 (Marsh Nourishment)
BM1 occurs within the Biloxi State Wildlife Management Area (WMA); however, marsh nourishment activities should have positive impacts to wildlife habitat. Negative impacts are anticipated during construction; however, they should be temporary. Wildlife populations displaced during construction should repopulate disrupted areas upon completion of the project. Care should be taken during construction to avoid construction during nesting periods.

BS1 (Shoreline Protection)
Shoreline protection would occur along the northern boundary of the Biloxi State WMA and should have positive impacts to wildlife habitat by discouraging the erosion of marsh habitat. Negative impacts are anticipated during construction; however, they should be temporary. Wildlife populations displaced during construction should repopulate disrupted areas upon completion of the project. Care should be taken during construction to avoid construction during nesting periods.

BS2 (Oyster Reef)
No negative impacts to local sanctuaries or refuges are anticipated.

BR1 (Ridge Restoration)
No negative impacts to local sanctuaries or refuges are anticipated.

MRGO Channel (MRGO)

MRGO2, MRGO3, and MRGO4 (Shoreline Protection Repairs/Maintenance)
No negative impacts to local sanctuaries or refuges are anticipated.

MRGO1 and MRGO6 (Shoreline Protection)
No negative impacts to local sanctuaries or refuges are anticipated.

MRGO5, MRGO7, and MRGO8 (Shoreline Protection & Marsh Restoration)
No negative impacts to local sanctuaries or refuges are anticipated.

Central Wetlands (CC, CM)

CC1, CC2, CC3, and CC5 (Swamp Restoration/Nourishment)
No negative impacts to local sanctuaries or refuges are anticipated.

CC4 (Swamp Restoration)
No negative impacts to local sanctuaries or refuges are anticipated.

CC6 (Swamp Nourishment)
No negative impacts to local sanctuaries or refuges are anticipated.

CM1 (Marsh Nourishment)
No negative impacts to local sanctuaries or refuges are anticipated.

CM2, CM3, CM4, and CM5 (Marsh Restoration/Nourishment)
No negative impacts to local sanctuaries or refuges are anticipated.

East Orleans (EM, ES)

EM1, EM3 and EM4 (Marsh Restoration/Nourishment)
EM1 occurs wholly within Bayou Sauvage National Wildlife Refuge (NWR); however, marsh restoration activities should have positive impacts to wildlife habitat.

EM 3 and EM4 occur south of the Pearl River State WMA; any marsh restoration activities occurring near the WMA should encourage wildlife populations by providing more diverse habitat and greater range. Negative impacts are anticipated during construction; however, they should be temporary. Wildlife populations displaced during construction should repopulate disrupted areas upon completion of the project. Care should be taken during construction to avoid construction during nesting periods.

EM2 (Marsh Nourishment)
EM2 occurs near the Pearl River State WMA; any marsh restoration activities occurring near the WMA should encourage wildlife populations by providing more diverse habitat and greater range. Negative impacts are anticipated during construction; however, they should be temporary. Wildlife populations displaced during construction should repopulate disrupted areas upon completion of the project. Care should be taken during construction to avoid construction during nesting periods.

ES1, ES2, and ES3 (Shoreline Protection)
Shoreline protection proposed for ES1 and ES2 would occur along the edge of the Bayou Sauvage NWR and should have positive impacts to wildlife habitat by discouraging the erosion of marsh habitat. Negative impacts are anticipated during construction; however, they should be temporary. Wildlife populations displaced during construction should repopulate disrupted areas upon completion of the project. Care should be taken during construction to avoid construction during nesting periods.

ES2 occurs near the Fort Pike State Historical Site; shoreline protection measures would protect the Site from erosion. Construction activities would be excluded from historical features and artifacts at the Site.

South Lake Borgne (LM, LS)

LM1, LM2, LM3, and LM4 (Marsh Restoration/Nourishment)
No negative impacts to local sanctuaries or refuges are anticipated.

LS1 (Shoreline Protection)
No negative impacts to local sanctuaries or refuges are anticipated.

Terre aux Boeufs (TM)

TM1, TM2, and TM7 (Marsh Restoration/Nourishment)
No negative impacts to local sanctuaries or refuges are anticipated.

TM8 (Marsh Restoration)
No negative impacts to local sanctuaries or refuges are anticipated.

Hopedale (HM)

HM1 (Marsh Restoration/Nourishment)
No negative impacts to local sanctuaries or refuges are anticipated.

Violet Diversion (D)

D05
No negative impacts to local sanctuaries or refuges are anticipated.

2.5.5.2 Wetlands

Biloxi Marsh (BM, BS, BR)

BM1 (Marsh Nourishment)
In general, wetlands would be created and improved by the project. The project would restore approximately 8,000 acres of marsh habitat in the project area. There will be temporary and localized adverse impacts to wetlands during construction; however, the net effect of the project would be an increase in wetland acreage and quality.

BS1 (Shoreline Protection)
The project includes approximately 50,637 linear feet of shoreline protection, which would protect existing and proposed marshes from future erosion. There will be temporary and localized adverse impacts to wetlands during construction; however, the net effect of the project would be an increase in wetland acreage and quality.

BS2 (Oyster Reef)
The project includes approximately 30,750 linear feet of oyster reef restoration, which would protect existing and proposed marshes from future erosion. The artificial oyster would create a valuable estuarine ecosystem that would benefit area wetlands by stabilizing the substrate and

reducing erosion as well as encouraging nutrient rich sediment to nourish the marsh. There would be temporary and localized adverse impacts to wetlands during construction; however, the net effect of the project would be an increase in wetland acreage and quality.

BR1 (Ridge Restoration)
The project would restore approximately 54 acres of ridge habitat. Upland areas created by ridge restoration would provide a stable substrate to encourage natural marsh nourishment through sedimentation. There would be temporary and localized adverse impacts to wetlands during construction; however, the net effect of the project would be an increase in wetland acreage and quality.

MRGO Channel (MRGO)

MRGO2, MRGO3, and MRGO4 (Shoreline Protection Repairs/Maintenance)
MRGO2, MRGO3, and MRGO4 would repair/maintain 21,630, 26,650, and 11,770 linear feet of shoreline protection, respectively. Wetland impacts from the project would be similar to those discussed in **section 2.5.5.2** for BS1.

MRGO1 and MRGO6 (Shoreline Protection)
MRGO1 and MRGO6 include approximately 3,850 and 8,132 linear feet of shoreline protection, respectively. Wetland impacts from the project would be similar to those discussed in **section 2.5.5.2** for BS1.

MRGO5, MRGO7, and MRGO8 (Shoreline Protection & Marsh Restoration)
MRGO5, MRGO7, and MRGO8 include approximately 13,685, 9,700, and 32,010 linear feet of shoreline protection and marsh restoration, respectively. Wetland impacts from the project would be similar to those discussed in **section 2.5.5.2** for BM1 and BS1.

Central Wetlands (CC, CM)

CC1, CC2, CC3, and CC5 (Swamp Restoration/Nourishment)
CC1, CC2, CC3, and CC5 would restore and nourish 1,955, 500, 1,160, and 2,670 acres of swamp habitat, respectively. Wetland impacts from the project would be similar to those discussed in **section 2.5.5.2** for BM1.

CC4 (Swamp Restoration)
CC4 would restore 1,465 acres of swamp habitat. Wetland impacts from the project would be similar to those discussed in **section 2.5.5.2** for BM1.

CC6 (Swamp Nourishment)
CC6 would nourish 2,568 acres of swamp habitat. Wetland impacts from the project would be similar to those discussed in **section 2.5.5.2** for BM1.

CM1 (Marsh Nourishment)
CM1 would nourish 1,240 acres of marsh habitat. Wetland impacts from the project would be similar to those discussed in **section 2.5.5.2** for BM1.

CM2, CM3, CM4, and CM5 (Marsh Restoration/Nourishment)
CM2, CM3, CM4, and CM5 would restore and nourish 985, 515, 227, and 315 acres of marsh habitat, respectively. Wetland impacts from the project would be similar to those discussed in **section 2.5.5.2** for BM1.

East Orleans (EM, ES)

EM1, EM3, and EM4 (Marsh Restoration/Nourishment)
EM1, EM3, and EM4 would restore and nourish 4,005, 1,041, and 4,080 acres of marsh habitat, respectively. Wetland impacts from the project would be similar to those discussed in **section 2.5.5.2** for BM1.

EM2 (Marsh Nourishment)
EM2 would nourish 1,095 acres of marsh habitat. Wetland impacts from the project would be similar to those discussed in **section 2.5.5.2** for BM1.

ES1, ES2, and ES3 (Shoreline Protection)
ES1, ES2, and ES3 include approximately 20,530, 30,750, 69,900 linear feet of shoreline protection, respectively. Wetland impacts from the project would be similar to those discussed in **section 2.5.5.2** for BS1.

South Lake Borgne (LM, LS)

LM1, LM2, LM3, and LM4 (Marsh Restoration/Nourishment)
LM1, LM2, LM3, and LM4 would restore and nourish 4,317, 2,853, 1,861, and 281 acres of marsh habitat, respectively. Wetland impacts from the project would be similar to those discussed in **section 2.5.5.2** for BM1.

LS1 (Shoreline Protection)
LS1 includes approximately 45,000 linear feet of shoreline protection. Wetland impacts from the project would be similar to those discussed in **section 2.5.5.2** for BS1.

Terre aux Boeufs (TM)

TM1, TM2, and TM7 (Marsh Restoration/Nourishment)
TM1, TM2, and TM7 would restore and nourish 1,021, 4,166, and 4,399 acres of marsh habitat, respectively. Wetland impacts from the project would be similar to those discussed in **section 2.5.5.2** for BM1.

TM8 (Marsh Restoration)
TM8 would restore 1,511 acres of marsh habitat. Wetland impacts from the project would be similar to those discussed in **section 2.5.5.2** for BM1.

Hopedale (HM)

HM1 (Marsh Restoration/Nourishment)
HM1 would restore and nourish 1,730 acres of marsh habitat. Wetland impacts from the project would be similar to those discussed in **section 2.5.5.2** for BM1.

Violet Diversion (D)

D05
Increased freshwater, sediment, and nutrient input into the project area would increase wetland productivity. The influx of fresh water would decrease salinity levels and would encourage habitat shifts and a possible redistribution of the vegetation zones. Changes to the marsh or coastal vegetation zones would be dictated by the salinity tolerances of the dominant vegetation and available nutrients and zone elevation. Preliminary modeling results suggest no adverse impacts to productivity of emergent coastal vegetation would occur in the project vicinity.

2.5.5.3 Mud Flats

Biloxi Marsh (BM, BS, BR)

BM1 (Marsh Nourishment)
In general, mudflats would be created by the project. There would be temporary and localized adverse impacts to mudflats during construction; however, the net effect of the project would be an increase in mudflat acreage and quality.

BS1 (Shoreline Protection)
Shoreline protection measures would protect mudflats created by the project. There would be temporary and localized adverse impacts to mudflats during construction; however, the net effect of the project would be an increase in mudflat acreage and quality.

BS2 (Oyster Reef)
Artificial oyster reefs would provide shoreline protection for mudflats created by the project. There would be temporary and localized adverse impacts to mudflats during construction; however, the net effect of the project would be an increase in mudflat acreage and quality.

BR1 (Ridge Restoration)
Ridge restoration would stabilize area wetland and mudflats and encourage natural sedimentation.

MRGO Channel (MRGO)

MRGO2, MRGO3, and MRGO4 (Shoreline Protection Repairs/Maintenance)
Impacts to mudflats are anticipated to be similar to those described in **section 2.5.5.3** for BS1.

MRGO1 and MRGO6 (Shoreline Protection)
Impacts to mudflats are anticipated to be similar to those described in **section 2.5.5.3** for BS1.

MRGO5, MRGO7, and MRGO8 (Shoreline Protection & Marsh Restoration)
Impacts to mudflats are anticipated to be similar to those described in **section 2.5.5.3** for BS1 and BM1.

Central Wetlands (CC, CM)

CC1, CC2, CC3, and CC5 (Swamp Restoration/Nourishment)
Impacts to mudflats are anticipated to be similar to those described in **section 2.5.5.3** for BM1.

CC4 (Swamp Restoration)
Impacts to mudflats are anticipated to be similar to those described in **section 2.5.5.3** for BM1.

CC6 (Swamp Nourishment)
Impacts to mudflats are anticipated to be similar to those described in **section 2.5.5.3** for BM1.

CM1 (Marsh Nourishment)
Impacts to mudflats are anticipated to be similar to those described in **section 2.5.5.3** for BM1.

CM2, CM3, CM4, and CM5 (Marsh Restoration/Nourishment)
Impacts to mudflats are anticipated to be similar to those described in **section 2.5.5.3** for BM1.

East Orleans (EM, ES)

EM1, EM3 and EM4 (Marsh Restoration/Nourishment)
Impacts to mudflats are anticipated to be similar to those described in **section 2.5.5.3** for BM1.

EM2 (Marsh Nourishment)
Impacts to mudflats are anticipated to be similar to those described in **section 2.5.5.3** for BM1.

ES1, ES2, and ES3 (Shoreline Protection)
Impacts to mudflats are anticipated to be similar to those described in **section 2.5.5.3** for BS1.

South Lake Borgne (LM, LS)

LM1, LM2, LM3, and LM4 (Marsh Restoration/Nourishment)
Impacts to mudflats are anticipated to be similar to those described in **section 2.5.5.3** for BM1.

LS1 (Shoreline Protection)
Impacts to mudflats are anticipated to be similar to those described in **section 2.5.5.3** for BS1.

Terre aux Boeufs (TM)

TM1, TM2, and TM7 (Marsh Restoration/Nourishment)
Impacts to mudflats are anticipated to be similar to those described in **section 2.5.5.3** for BM1.

TM8 (Marsh Restoration)
Impacts to mudflats are anticipated to be similar to those described in **section 2.5.5.3** for BM1.

Hopedale (HM)

HM1 (Marsh Restoration/Nourishment)
Impacts to mudflats are anticipated to be similar to those described in **section 2.5.5.3** for BM1.

Violet Diversion (D)

D05
The freshwater diversion would allow nutrient rich sediment from the Mississippi River to flow into Lake Borgne and surrounding wetlands and mudflats, encouraging accumulation through sedimentation.

2.5.5.4 Vegetated Shallows

Biloxi Marsh (BM, BS, BR)

BM1 (Marsh Nourishment)
Temporary and localized adverse effects to communities of submerged aquatic vegetation (SAV) are expected due to increased sediment from dredging and dredge placement. However, after restoration is complete there should be an increase in suitable SAV habitat available for recruitment.

BS1 (Shoreline Protection)
Shoreline protection measures would protect vegetated shallows to allow for natural recruitment of SAV species.

BS2 (Oyster Reef)
Oyster reefs would stabilize and protect the substrate to allow for natural recruitment of SAV species.

BR1 (Ridge Restoration)
Forested upland areas would have little effect on vegetated shallows; however, they would help to create the natural elevational gradient of the marsh ecosystem which would encourage sedimentation and allow for the natural recruitment of SAV species.

MRGO Channel (MRGO)

MRGO2, MRGO3, and MRGO4 (Shoreline Protection Repairs/Maintenance)
Impacts to vegetated shallows are anticipated to be similar to those described in **section 2.5.5.4** for BS1.

MRGO1 and MRGO6 (Shoreline Protection)
Impacts to vegetated shallows are anticipated to be similar to those described in **section 2.5.5.4** for BS1.

MRGO5, MRGO7, and MRGO8 (Shoreline Protection & Marsh Restoration)
Impacts to vegetated shallows are anticipated to be similar to those described in **section 2.5.5.4** for BS1 and BM1.

Central Wetlands (CC, CM)

CC1, CC2, CC3, and CC5 (Swamp Restoration/Nourishment)
Impacts to vegetated shallows are anticipated to be similar to those described in **section 2.5.5.4** for BM1.

CC4 (Swamp Restoration)
Impacts to vegetated shallows are anticipated to be similar to those described in **section 2.5.5.4** for BM1.

CC6 (Swamp Nourishment)
Impacts to vegetated shallows are anticipated to be similar to those described in **section 2.5.5.4** for BM1.

CM1 (Marsh Nourishment)
Impacts to vegetated shallows are anticipated to be similar to those described in **section 2.5.5.4** for BM1.

CM2, CM3, CM4, and CM5 (Marsh Restoration/Nourishment)
Impacts to vegetated shallows are anticipated to be similar to those described in **section 2.5.5.4** for BM1.

East Orleans (EM, ES)

EM1, EM3 and EM4 (Marsh Restoration/Nourishment)
Impacts to vegetated shallows are anticipated to be similar to those described in **section 2.5.5.4** for BM1.

EM2 (Marsh Nourishment)
Impacts to vegetated shallows are anticipated to be similar to those described in **section 2.5.5.4** for BM1.

ES1, ES2, and ES3 (Shoreline Protection)
Impacts to vegetated shallows are anticipated to be similar to those described in **section 2.5.5.4** for BS1.

South Lake Borgne (LM, LS)

LM1, LM2, LM3, and LM4 (Marsh Restoration/Nourishment)
Impacts to vegetated shallows are anticipated to be similar to those described in **section 2.5.5.4** for BM1.

LS1 (Shoreline Protection)
Impacts to vegetated shallows are anticipated to be similar to those described in **section 2.5.5.4** for BS1.

Terre aux Boeufs (TM)

TM1, TM2, and TM7 (Marsh Restoration/Nourishment)
Impacts to vegetated shallows are anticipated to be similar to those described in **section 2.5.5.4** for BM1.

TM8 (Marsh Restoration)
Impacts to vegetated shallows are anticipated to be similar to those described in **section 2.5.5.4** for BM1.

Hopedale (HM)

HM1 (Marsh Restoration/Nourishment)
Impacts to vegetated shallows are anticipated to be similar to those described in **section 2.5.5.4** for BM1.

Violet Diversion (D)

D05
The area impacted by the diversion is expected to experience a revitalization of SAVs, such as pondweed, southern naiad, coontail, and wild celery. Changes to currents, temperature, salinity, and turbidity resulting from the proposed activities may alter SAV species assemblage. A minimal reduction in salinity is well within the tolerance of the SAV species found in the fringing coastal marshes and seagrass beds. Impacts would decrease as the distance from the point of disturbance increases.

2.5.5.5 Coral Reefs.

Biloxi Marsh (BM, BS, BR)

BM1 (Marsh Nourishment)
There are no coral reefs within the project area.

BS1 (Shoreline Protection)
There are no coral reefs within the project area.

BS2 (Oyster Reef)
There are no coral reefs within the project area.

BR1 (Ridge Restoration)
There are no coral reefs within the project area.

MRGO Channel (MRGO)

MRGO2, MRGO3, and MRGO4 (Shoreline Protection Repairs/Maintenance)
There are no coral reefs within the project area.

MRGO1 and MRGO6 (Shoreline Protection)
There are no coral reefs within the project area.

MRGO5, MRGO7, and MRGO8 (Shoreline Protection & Marsh Restoration)
There are no coral reefs within the project area.

Central Wetlands (CC, CM)

CC1, CC2, CC3, and CC5 (Swamp Restoration/Nourishment)
There are no coral reefs within the project area.

CC4 (Swamp Restoration)
There are no coral reefs within the project area.

CC6 (Swamp Nourishment)
There are no coral reefs within the project area.

CM1 (Marsh Nourishment)
There are no coral reefs within the project area.

CM2, CM3, CM4, and CM5 (Marsh Restoration/Nourishment)
There are no coral reefs within the project area.

East Orleans (EM, ES)

EM1, EM3 and EM4 (Marsh Restoration/Nourishment)
There are no coral reefs within the project area.

EM2 (Marsh Nourishment)
There are no coral reefs within the project area.

ES1, ES2, and ES3 (Shoreline Protection)
There are no coral reefs within the project area.

South Lake Borgne (LM, LS)

LM1, LM2, LM3, and LM4 (Marsh Restoration/Nourishment)
There are no coral reefs within the project area.

LS1 (Shoreline Protection)
There are no coral reefs within the project area.

Terre aux Boeufs (TM)

TM1, TM2, and TM7 (Marsh Restoration/Nourishment)
There are no coral reefs within the project area.

TM8 (Marsh Restoration)
There are no coral reefs within the project area.

Hopedale (HM)

HM1 (Marsh Restoration/Nourishment)
There are no coral reefs within the project area.

Violet Diversion (D)

D05
There are no coral reefs within the project area.

2.5.5.6 Riffle Pool Complexes.

Biloxi Marsh (BM, BS, BR)

BM1 (Marsh Nourishment)
There are no riffle pool complexes within the project area.

BS1 (Shoreline Protection)
There are no riffle pool complexes within the project area.

BS2 (Oyster Reef)
There are no riffle pool complexes within the project area.

BR1 (Ridge Restoration)
There are no riffle pool complexes within the project area.

MRGO Channel (MRGO)

MRGO2, MRGO3, and MRGO4 (Shoreline Protection Repairs/Maintenance)
There are no riffle pool complexes within the project area.

MRGO1 and MRGO6 (Shoreline Protection)
There are no riffle pool complexes within the project area.

MRGO5, MRGO7, and MRGO8 (Shoreline Protection & Marsh Restoration)
There are no riffle pool complexes within the project area.

Central Wetlands (CC, CM)

CC1, CC2, CC3, and CC5 (Swamp Restoration/Nourishment)
There are no riffle pool complexes within the project area.

CC4 (Swamp Restoration)
There are no riffle pool complexes within the project area.

CC6 (Swamp Nourishment)
There are no riffle pool complexes within the project area.

CM1 (Marsh Nourishment)
There are no riffle pool complexes within the project area.

CM2, CM3, CM4, and CM5 (Marsh Restoration/Nourishment)
There are no riffle pool complexes within the project area.

East Orleans (EM, ES)

EM1, EM3 and EM4 (Marsh Restoration/Nourishment)
There are no riffle pool complexes within the project area.

EM2 (Marsh Nourishment)
There are no riffle pool complexes within the project area.

ES1, ES2, and ES3 (Shoreline Protection)
There are no riffle pool complexes within the project area.

South Lake Borgne (LM, LS)

LM1, LM2, LM3, and LM4 (Marsh Restoration/Nourishment)
There are no riffle pool complexes within the project area.

LS1 (Shoreline Protection)
There are no riffle pool complexes within the project area.

Terre aux Boeufs (TM)

TM1, TM2, and TM7 (Marsh Restoration/Nourishment)
There are no riffle pool complexes within the project area.

TM8 (Marsh Restoration)
There are no riffle pool complexes within the project area.

Hopedale (HM)

HM1 (Marsh Restoration/Nourishment)
There are no riffle pool complexes within the project area.

Violet Diversion (D)

D05
There are no riffle pool complexes within the project area.

2.5.6 Effects on Threatened and Endangered Species

Biloxi Marsh (BM, BS, BR)

BM1 (Marsh Nourishment)
In general, the proposed action is designed to create, protect, and nourish wetlands, which would have a positive impact on important wildlife or fishery breeding and nursery areas. This is also considered to be positive for unique and valuable habitats. Coordination with the United States Fish and Wildlife Service (USFWS) and National Marine Fisheries Service (NMFS) is in progress. Initial findings indicate that the project may affect, but is not likely to adversely affect any listed species.

Since Lake Borgne dredging raises issues because it is designated critical habitat for the threatened Gulf sturgeon, a trade off analysis has been conducted. Due to the public acceptability factor, the lake is the preferred choice while recognizing some higher costs and environmental impacts. A consultation with NMFS on the critical habitat impacts is ongoing with a final Biological Assessment being submitted prior to the EIS. The plan that is presented may be further refined as a result of this consultation. Regarding dredge areas in Lake Borgne, it is important to note the following regarding listed species:

Gulf Sturgeon (*Acipenser oxyrhynchus desotoi*). Approximately 11.0 mcy borrow material would be removed from Gulf sturgeon critical habitat within Lake Borgne. To limit potential impacts to critical habitat for the Gulf sturgeon, areas determined to have sandy, shell, or hard bottoms were removed from consideration as borrow sites; however, limited research shows that some prey species are found in muddy habitats similar to those found in Lake Borgne borrow pit areas. Although foraging habitat may be impacted by the project, the effects would be temporary and localized, and there is an abundance of similar habitat in the immediate area. Sturgeon are likely

to find prey sources elsewhere during construction and would recolonize dredged areas once the action is completed.

BS1 (Shoreline Protection)
Shoreline protection measures would protect wetlands, which would have a positive impact on important wildlife or fishery breeding and nursery areas. Coordination with USFWS and NMFS is in progress. Initial findings indicate that the project may affect, but is not likely to adversely affect any listed species.

Since Lake Borgne dredging raises issues because it is designated critical habitat for the threatened Gulf sturgeon, a trade off analysis has been conducted. Due to the public acceptability factor, the lake is the preferred choice while recognizing some higher costs and environmental impacts. A consultation with NMFS on the critical habitat impacts is ongoing with a final Biological Assessment being submitted prior to the EIS. The plan that is presented may be further refined as a result of this consultation. Regarding dredge acres in Lake Borgne, it is important to note the following regarding listed species:

Gulf Sturgeon (Acipenser oxyrhynchus desotoi). Shoreline protection features are proposed along the southeast shore of Lake Borgne, which is critical habitat for the Gulf Sturgeon. However, the critical habitat within Lake Borgne is primarily foraging habitat for the Gulf sturgeon and does not include the shoreline. Sturgeon foraging behaviors may be disrupted during construction but are likely to find prey sources elsewhere and would recolonize project areas once the action is completed.

BS2 (Oyster Reef)
The proposed action may affect, but is not likely to adversely affect any listed species. Restoration of oyster reefs would create valuable habitat for prey species to listed species, benefit the aquatic food web by increasing habitat and species diversity at base and intermediate levels of the food web, and provide protection to foraging habitat of listed species.

BR1 (Ridge Restoration)
The proposed action may affect, but is not likely to adversely affect any listed species.

MRGO Channel (MRGO)

MRGO2, MRGO3, and MRGO4 (Shoreline Protection Repairs/Maintenance)
The proposed action may affect, but is not likely to adversely affect any listed species.

MRGO1 and MRGO6 (Shoreline Protection)
The proposed action may affect, but is not likely to adversely affect any listed species.

MRGO5, MRGO7, and MRGO8 (Shoreline Protection & Marsh Restoration)
MRGO5, MRGO7, and MRGO8 would obtain 3.0 mcy, 1.7 mcy, and 3.5 mcy of material from Lake Borgne, respectively. Impacts to listed species would be similar to those discussed in **section 2.5.6** for BM1. The proposed action may affect, but is not likely to adversely affect any listed species.

Central Wetlands (CC, CM)

CC1, CC2, CC3, and CC5 (Swamp Restoration/Nourishment)
CC1, CC2, CC3, and CC5 would borrow approximately 6.0 mcy, 1.7 mcy, 3.7 mcy, and 7.8 mcy from Lake Borgne, respectively. Impacts to listed species would be similar to those discussed in **section 2.5.6** for BM1. The proposed action would may affect, but is not likely to adversely affect any listed species.

CC4 (Swamp Restoration)
CC4 would borrow approximately 10.4 mcy from Lake Borgne. Impacts to listed species would be similar to those discussed in **section 2.5.6** for BM1. The proposed action may affect, but is not likely to adversely affect any listed species.

CC6 (Swamp Nourishment)
CC6 would borrow approximately 5.2mcy from Lake Borgne. Impacts to listed species would be similar to those discussed in **section 2.5.6** for BM1. The proposed action may affect, but is not likely to adversely affect any listed species.

CM1 (Marsh Nourishment)
CM1 would borrow approximately 1.5 mcy from Lake Borgne. Impacts to listed species would be similar to those discussed in **section 2.5.6** for BM1. The proposed action may affect, but is not likely to adversely affect any listed species.

CM2, CM3, CM4, and CM5 (Marsh Restoration/Nourishment)
CM2, CM3, CM4, and CM5 would borrow approximately 4.72 mcy, 1.6 mcy, 600,000 cy, and 1.0 mcy from Lake Borgne, respectively. Impacts to listed species would be similar to those discussed in **section 2.5.6** for BM1. The proposed action may affect, but is not likely to adversely affect any listed species.

East Orleans (EM, ES)

EM1, EM3 and EM4 (Marsh Restoration/Nourishment)
EM1, EM3, and EM4 would borrow approximately 8.1 mcy, 4.1 mcy, and 9.2 mcy from Lake Borgne, respectively. Impacts to listed species would be similar to those discussed in **section 2.5.6** for BM1. The proposed action may affect, but is not likely to adversely affect any listed species.

EM2 (Marsh Nourishment)
EM2 would borrow approximately 1.3 mcy from Lake Borgne. Impacts to listed species would be similar to those discussed in **section 2.5.6** for BM1. The proposed action may affect, but is not likely to adversely affect any listed species.

ES1, ES2, and ES3 (Shoreline Protection)
Shoreline protection measures would protect wetlands, which would have a positive impact on important wildlife or fishery breeding and nursery areas. Coordination with USFWS and NMFS

is in progress. Initial findings indicate that the project may affect, but is not likely to adversely affect any listed species. However, it is important to note the following:

Gulf Sturgeon (Acipenser oxyrhynchus desotoi). Shoreline protection features are proposed along the northern shore of Lake Borgne, which is critical habitat for the Gulf Sturgeon. However, the critical habitat within Lake Borgne is primarily foraging habitat for the Gulf sturgeon and does not include the shoreline. Sturgeon foraging behaviors may be disrupted during construction but are likely to find prey sources elsewhere and would recolonize project areas once the action is completed.

South Lake Borgne (LM, LS)

LM1, LM2, LM3, and LM4 (Marsh Restoration/Nourishment)

LM1, LM2, LM3, and LM4 would borrow approximately 14.3 mcy, 4.45 mcy, 6.4 mcy, and 1.16 mcy from Lake Borgne, respectively. Impacts to listed species would be similar to those discussed in **section 2.5.6** for BM1. The proposed action would may affect, but is not likely to adversely affect any listed species.

LS1 (Shoreline Protection)

The proposed action may affect, but is not likely to adversely affect any listed species.

Terre aux Boeufs (TM)

TM1, TM2, and TM7 (Marsh Restoration/Nourishment)

TM1, TM2, and TM7 would borrow approximately 3.8 mcy, 3.8 mcy, and possibly 12.4 mcy from Lake Borgne, respectively. Impacts to listed species would be similar to those discussed in **section 2.5.6** for BM1. The proposed action would may affect, but is not likely to adversely affect any listed species.

TM8 (Marsh Restoration)

TM8 may borrow approximately 9.7 mcy from Lake Borgne. Impacts to listed species would be similar to those discussed in **section 2.5.6** for BM1. The proposed action may affect, but is not likely to adversely affect any listed species.

Hopedale (HM)

HM1 (Marsh Restoration/Nourishment)

HM1 would borrow approximately 4.5 mcy from Lake Borgne. Impacts to listed species would be similar to those discussed in **section 2.5.6** for BM1. The proposed action may affect, but is not likely to adversely affect any listed species.

Violet Diversion (D)

D05

The proposed freshwater diversion at Violet would be constructed along the eastern side of the Mississippi River at river mile (RM) 84 to discharge freshwater into the Central Wetlands and adjacent open water and wetland areas. The structure would be designed to discharge a

minimum of 1,000 cfs and a maximum of 7,000 cfs. The diversion would be operated to provide freshwater during the months of April and May for four out of ten years to meet the Chatry salinity targets. Impacts near the diversion would include a shift to more freshwater tolerant species near the diversion during the months of operation. Resistance and resilience to periodic habitat disturbance, the presence of natural cycles in distribution and abundance, and the occurrence of alternate community states have to be considered in evaluating habitat quality and restoration status (Poirrier, Spalding, and Franze). The freshwater diversion would reduce the salinity to values that were historically recorded before the MRGO was constructed. The freshwater input would result in prey and predatory fish populations to shift slightly within the project area. The operation of the Violet Freshwater Diversion would mimic historic conditions when Mississippi River experience flood stages and over topped its banks, freshening of the Lake Pontchartrain/Lake Borgne ecosystem. Gulf sturgeon are either making their way to or already in their spawning grounds in the rivers at the time the diversion would be operated in April and May. Any juvenile Gulf sturgeon that could possibly still be in the area would not be affected by the lowered salinities as they typically reside in areas with lower salinity during this part of the year. As such, the CEMVN expects that the reduction in salinity should have little effect on resident populations of Gulf sturgeon as the aquatic modeling suggests.

2.5.7 Other Wildlife

Biloxi Marsh (BM, BS, BR)

BM1 (Marsh Nourishment)
The overall effect of the project is expected to be positive for species and habitats. The project would restore approximately 8,000 acres of habitat in the Biloxi Marsh. Restoration of marsh habitat would create a more contiguous emergent marsh providing important and essential transitional habitats used by fish for spawning, foraging, cover, nursery, and other important life requirements. Any potential adverse impacts from construction are expected to be temporary. During construction, marsh restoration and restoration activities would temporarily affect wildlife by disrupting their activities and displacing them (and their prey) from the immediate construction zone. Once construction is complete, most if not all wildlife and prey species would return to the area. Any habitat impacted during construction would be restored before leaving the area.

Impacts to oysters and oyster leases would be primarily associated with the dredging of borrow material and floatation access due to increased turbidity, siltation, temperature, and biological demand, and decreased dissolved oxygen. Modeling results indicate slight decreases in annual net oyster productivity. Impacts near areas of dredging and construction would be temporary, and would return to ambient conditions following the completion of construction activities. The project would create and nourish emergent wetlands, providing protection and food in the form of nutrients and detritus, a major food source for oysters.

BS1 (Shoreline Protection)
The overall effect of the project is expected to be positive for species and habitats. The project would create approximately 50,637 linear feet of shoreline protection, vital to neotropical migratory birds; colonial nesting birds, waterfowl and mammals. Furthermore, shoreline

protection measures protect marsh habitat which are important and essential transitional habitats used by fish for spawning, foraging, cover, nursery, and other important life requirements. Any potential adverse impacts from construction are expected to be temporary. During construction, shoreline protection construction activities would temporarily affect wildlife by disrupting their activities and displacing them (and their prey) from the immediate construction zone. Once construction is complete, most if not all wildlife and prey species would return to the area. Any habitat impacted during construction would be restored before leaving the area.

BS2 (Oyster Reef)
The plan includes the restoration of 30,750 linear feet (5.8 miles) of artificial oyster reef development on the Chandeleur Sound side of the Biloxi Marsh from Eloi Point and the mouth of Bayou La Loutre. The restoration of the artificial oyster reef would provide a viable substrate to which oyster larvae would attach, eventually forming a reef, which acts as a natural coastal buffer. The oyster habitat created by the recommended plan would far outweigh any oysters inadvertently covered by dredge material for wetland restoration and nourishment. Additionally, oyster reef ecosystems provide food sources for many important bird and fish species.

BR1 (Ridge Restoration)
The forested habitat supported by the restored ridge would provide habitat for many important wildlife species.

MRGO Channel (MRGO)

MRGO2, MRGO3, and MRGO4 (Shoreline Protection Repairs/Maintenance)
Impacts to wildlife are anticipated to similar to those discussed in **section 2.5.7** for BS1.

MRGO1 and MRGO6 (Shoreline Protection)
Impacts to wildlife are anticipated to similar to those discussed in **section 2.5.7** for BS1.

MRGO5, MRGO7, and MRGO8 (Shoreline Protection & Marsh Restoration)
Impacts to wildlife are anticipated to similar to those discussed in **section 2.5.7** for BS1.

Central Wetlands (CC, CM)

CC1, CC2, CC3, and CC5 (Swamp Restoration/Nourishment)
Impacts to wildlife are anticipated to similar to those discussed in **section 2.5.7** for BM1.

CC4 (Swamp Restoration)
Impacts to wildlife are anticipated to similar to those discussed in **section 2.5.7** for BM1.

CC6 (Swamp Nourishment)
Impacts to wildlife are anticipated to similar to those discussed in **section 2.5.7** for BM1.

CM1 (Marsh Nourishment)
Impacts to wildlife are anticipated to similar to those discussed in **section 2.5.7** for BM1.

CM2, CM3, CM4, and CM5 (Marsh Restoration/Nourishment)
Impacts to wildlife are anticipated to similar to those discussed in **section 2.5.7** for BM1.

East Orleans (EM, ES)

EM1, EM3 and EM4 (Marsh Restoration/Nourishment)
Impacts to wildlife are anticipated to similar to those discussed in **section 2.5.7** for BM1.

EM2 (Marsh Nourishment)
Impacts to wildlife are anticipated to similar to those discussed in **section 2.5.7** for BM1.

ES1, ES2, and ES3 (Shoreline Protection)
Impacts to wildlife are anticipated to similar to those discussed in **section 2.5.7** for BS1.

South Lake Borgne (LM, LS)

LM1, LM2, LM3, and LM4 (Marsh Restoration/Nourishment)
Impacts to wildlife are anticipated to similar to those discussed in **section 2.5.7** for BM1.

LS1 (Shoreline Protection)
Impacts to wildlife are anticipated to similar to those discussed in **section 2.5.7** for BS1.

Terre aux Boeufs (TM)

TM1, TM2, and TM7 (Marsh Restoration/Nourishment)
Impacts to wildlife are anticipated to similar to those discussed in **section 2.5.7** for BM1.

TM8 (Marsh Restoration)
Impacts to wildlife are anticipated to similar to those discussed in **section 2.5.7** for BM1.

Hopedale (HM)

HM1 (Marsh Restoration/Nourishment)
Impacts to wildlife are anticipated to similar to those discussed in **section 2.5.7** for BM1.

Violet Diversion (D)

D05
The freshwater diversion would influence approximately 529 acres of habitat, improving wildlife habitat and introducing fresh water into the project area. Based upon salinity modeling, this change would not be substantial enough to affect the fisheries population within this given area. This change in salinity could result in slight shifts in oyster productivity by altering isohalines in and near the project area. However, restoration, protection, and nourishment of emergent wetlands in the project area in conjunction with other actions proposed and implemented in the vicinity would increase the productivity of planktonic resources upon which oysters feed. No net adverse impacts are expected to occur to oyster leases from the diversion caused by

sedimentation or such slight changes in salinity within the Lake Borgne area as well as the entire project area.

2.6 Proposed Discharge Site Determinations

Because the highest dilution requirement predicted for effluent from the Mississippi River borrow area and the Lake Borgne borrow areas was minimal (the maximum determined dilution requirement, based on detectable levels in elutriates and restoration feature surface waters, was 1.94 parts site (restoration feature) water per 1 part dredged material effluent), it was assumed that all discharge sites associated with these borrow areas would provide adequate dilution for meeting compliance with State of Louisiana mixing zone standards as included in LAC Title 33, Part IX, Subpart 1, Section 1115. For the MRGO/GIWW borrow area, a high ratio of dilution was predicted to be required to meet State and Federal water quality criteria. Because tidal influence in the Central Wetlands Area is reduced as a result of levee construction, it is not anticipated that the restoration feature to receive sediments from the MRGO/GIWW borrow area (feature CM2) would have adequate dilution available for levels of total PCBs to meet water quality criteria at the edge of the State mixing zone. See **section 2.2.2.2** for further details regarding compliance with applicable water quality standards as they pertain to proposed discharge site determinations.

2.7 Determination of Cumulative Effects on the Aquatic Ecosystem

2.7.1 Potential Effects on Aquatic Ecosystems

Biloxi Marsh (BM, BS, BR)

BM1 (Marsh Nourishment)
Marsh habitats restored are vital to commercially and restorationally important fisheries species. The project would provide a net benefit to wetlands and aid in maintaining valuable habitat vital for providing foraging, breeding, spawning, and cover from predators for all stages of fisheries life cycles.

BS1 (Shoreline Protection)
Shoreline protection measures would protect wetlands and thereby aid in maintaining valuable habitat vital for providing foraging, breeding, spawning, and cover from predators for all stages of fisheries life cycles. By implementing access features in the shoreline protection measures, fish would be allowed access to the protected wetlands within the project area.

BS2 (Oyster Reef)
Installation of the artificial oyster reef would restore a naturally occurring ecosystem important to aquatic ecosystems.

BR1 (Ridge Restoration)
No negative impacts to aquatic ecosystems are anticipated from the ridge restoration.

MRGO Channel (MRGO)

MRGO2, MRGO3, and MRGO4 (Shoreline Protection Repairs/Maintenance)
Impacts to aquatic ecosystems are anticipated to similar to those discussed in **section 2.7.1** for BS1.

MRGO1 and MRGO6 (Shoreline Protection)
Impacts to aquatic ecosystems are anticipated to similar to those discussed in **section 2.7.1** for BS1.

MRGO5, MRGO7, and MRGO8 (Shoreline Protection & Marsh Restoration)
Impacts to aquatic ecosystems are anticipated to similar to those discussed in **section 2.7.1** for BS1.

Central Wetlands (CC, CM)

CC1, CC2, CC3, and CC5 (Swamp Restoration/Nourishment)
Impacts to aquatic ecosystems are anticipated to similar to those discussed in **section 2.7.1** for BM1.

CC4 (Swamp Restoration)
Impacts to aquatic ecosystems are anticipated to similar to those discussed in **section 2.7.1** for BM1.

CC6 (Swamp Nourishment)
Impacts to aquatic ecosystems are anticipated to similar to those discussed in **section 2.7.1** for BM1.

CM1 (Marsh Nourishment)
Impacts to aquatic ecosystems are anticipated to similar to those discussed in **section 2.7.1** for BM1.

CM2, CM3, CM4, and CM5 (Marsh Restoration/Nourishment)
Impacts to aquatic ecosystems are anticipated to similar to those discussed in **section 2.7.1** for BM1.

East Orleans (EM, ES)

EM1, EM3 and EM4 (Marsh Restoration/Nourishment)
Impacts to aquatic ecosystems are anticipated to similar to those discussed in **section 2.7.1** for BM1.

EM2 (Marsh Nourishment)
Impacts to aquatic ecosystems are anticipated to similar to those discussed in **section 2.7.1** for BM1.

ES1, ES2, and ES3 (Shoreline Protection)
Impacts to aquatic ecosystems are anticipated to similar to those discussed in **section 2.7.1** for BS1.

South Lake Borgne (LM, LS)

LM1, LM2, LM3, and LM4 (Marsh Restoration/Nourishment)
Impacts to aquatic ecosystems are anticipated to similar to those discussed in **section 2.7.1** for BM1.

LS1 (Shoreline Protection)
Impacts to aquatic ecosystems are anticipated to similar to those discussed in **section 2.7.1** for BS1.

Terre aux Boeufs (TM)

TM1, TM2, and TM7 (Marsh Restoration/Nourishment)
Impacts to aquatic ecosystems are anticipated to similar to those discussed in **section 2.7.1** for BM1.

TM8 (Marsh Restoration)
Impacts to aquatic ecosystems are anticipated to similar to those discussed in **section 2.7.1** for BM1.

Hopedale (HM)

HM1 (Marsh Restoration/Nourishment)
Impacts to aquatic ecosystems are anticipated to similar to those discussed in **section 2.7.1** for BM1.

Violet Diversion (D)

D05
The Violet Freshwater Diversion would mimic natural processes and enhance the sustainability of the system through the input of freshwater, nutrients, and sediment. Inputs of freshwater are necessary to provide vital sediment and nutrients essential to aquatic ecosystems. Net impacts are anticipated to be positive. The restoration of the natural salinity gradient due to the Violet Diversion may increase the diversity of food sources for nekton communities, increase wetland productivity and thereby increasing habitat and available food sources for benthic communities. Plankton species would not likely be negatively impacted by the higher flows and resulting lower salinities. Increased detritus flushed from marsh areas into open water by diversion flows would provide additional food sources for zooplankton and benthic organisms. Salinity modeling predicts the salinity change resulting from the Violet Diversion would not be substantial enough to affect the fisheries population within the project area; however, impacts to fisheries populations from increased turbidity may include reduced feeding opportunities for visual predators and gill clogging. The area impacted by the diversion is expected to experience a

revitalization of SAVs, such as pondweed, southern naiad, coontail, and wild celery; although, changes to currents, temperature, salinity, and turbidity resulting from the proposed activities may alter SAV species assemblage. Impacts would decrease as the distance from the point of disturbance increases.

2.7.2 Potential Effects on Human Use Characteristics

2.7.2.1 Municipal and Private Water Supply

The nearest drinking water intake in the MRGO ecosystem restoration territory is located in the Mississippi River at river mile marker 80.9. The restoration feature which has any possibility of impacting a drinking water intake along the Mississippi River is the Violet Diversion. The proposed diversion control structure is located near the river mile marker 85.7, which is approximately 5 miles upstream of the drinking water intake. Any possible effects to the raw water quality associated with construction activities near the diversion control structure would diminish long before reaching this intake.

2.7.2.2 Water Related Restoration

The cumulative beneficial effects of ongoing and planned measures as well as the proposed project measures would be the restoration, restoration, nourishment, and protection of important marsh, swamp and ridge habitat to support fish and wildlife, and the increase in freshwater habitat for waterfowl and birds. This in turn is expected to increase freshwater-based restorational activities while maintaining and stabilizing saltwater based restoration activities. Potential impacts would be the need to travel further towards the Gulf of Mexico for saltwater-based opportunities and a temporary reduction in the restorational activity during high flow periods associated with the diversion due to increased turbidity.

Together these ongoing, planned and proposed measures for the study area would help to maintain, stabilize, and potentially enhance economic benefits relative to restoration.

2.8 Determination of Secondary Effects on the Aquatic Ecosystem

Biloxi Marsh (BM, BS, BR)

BM1 (Marsh Nourishment)
No adverse significant secondary effects on the aquatic ecosystem should occur as a result of the project.

BS1 (Shoreline Protection)
No adverse significant secondary effects on the aquatic ecosystem should occur as a result of the project.

BS2 (Oyster Reef)
No adverse significant secondary effects on the aquatic ecosystem should occur as a result of the project.

BR1 (Ridge Restoration)
No adverse significant secondary effects on the aquatic ecosystem should occur as a result of the project.

MRGO Channel (MRGO)

MRGO2, MRGO3, and MRGO4 (Shoreline Protection Repairs/Maintenance)
No adverse significant secondary effects on the aquatic ecosystem should occur as a result of the project.

MRGO1 and MRGO6 (Shoreline Protection)
No adverse significant secondary effects on the aquatic ecosystem should occur as a result of the project.
MRGO5, MRGO7, and MRGO8 (Shoreline Protection & Marsh Restoration)
No adverse significant secondary effects on the aquatic ecosystem should occur as a result of the project.

Central Wetlands (CC, CM)

CC1, CC2, CC3, and CC5 (Swamp Restoration/Nourishment)
No adverse significant secondary effects on the aquatic ecosystem should occur as a result of the project.

CC4 (Swamp Restoration)
No adverse significant secondary effects on the aquatic ecosystem should occur as a result of the project.

CC6 (Swamp Nourishment)
No adverse significant secondary effects on the aquatic ecosystem should occur as a result of the project.

CM1 (Marsh Nourishment)
No adverse significant secondary effects on the aquatic ecosystem should occur as a result of the project.

CM2, CM3, CM4, and CM5 (Marsh Restoration/Nourishment)
No adverse significant secondary effects on the aquatic ecosystem should occur as a result of the project.

East Orleans (EM, ES)

EM1, EM3 and EM4 (Marsh Restoration/Nourishment)
No adverse significant secondary effects on the aquatic ecosystem should occur as a result of the project.

EM2 (Marsh Nourishment)
No adverse significant secondary effects on the aquatic ecosystem should occur as a result of the project.

ES1, ES2, and ES3 (Shoreline Protection)
No adverse significant secondary effects on the aquatic ecosystem should occur as a result of the project.

South Lake Borgne (LM, LS)

LM1, LM2, LM3, and LM4 (Marsh Restoration/Nourishment)
No adverse significant secondary effects on the aquatic ecosystem should occur as a result of the project.

LS1 (Shoreline Protection)
No adverse significant secondary effects on the aquatic ecosystem should occur as a result of the project.

Terre aux Boeufs (TM)

TM1, TM2, and TM7 (Marsh Restoration/Nourishment)
No adverse significant secondary effects on the aquatic ecosystem should occur as a result of the project.

TM8 (Marsh Restoration)
No adverse significant secondary effects on the aquatic ecosystem should occur as a result of the project.

Hopedale (HM)

HM1 (Marsh Restoration/Nourishment)
No adverse significant secondary effects on the aquatic ecosystem should occur as a result of the project.

Violet Diversion (D)

D05
No adverse significant secondary effects on the aquatic ecosystem should occur as a result of the project.

3.0 FINDINGS OF COMPLIANCE OR NON-COMPLIANCE WITH THE RESTRICTIONS ON DISCHARGE

3.1 Adaption of the Section 404(b)(1) Guidelines to this Evaluation

No significant adaptations of the guidelines were made relative to this evaluation.

3.2 Evaluation of Availability of Practicable Alternatives to the Proposed Discharge that Would Have Less Adverse Impact on the Aquatic Ecosystem

Alternatives to the proposed project are presented in the MRGO Ecosystem Restoration Plan Feasibility Study. A geographic information system (GIS) database was used to catalogue study information including individual management measures, existing and authorized water projects, and study area existing conditions.

3.3 Determination of Compliance with Applicable Water Quality Standards

Because the highest dilution requirement predicted for effluent from the Mississippi River borrow area and the Lake Borgne borrow areas was minimal (the maximum determined dilution requirement, based on detectable levels in elutriates and restoration feature surface waters, was 1.94 parts site (restoration feature) water per 1 part dredged material effluent), it was assumed that all discharge sites associated with these borrow areas would provide adequate dilution for meeting compliance with State of Louisiana mixing zone standards as included in LAC Title 33, Part IX, Subpart 1, Section 1115. For the MRGO/GIWW borrow area, a high ratio of dilution was predicted to be required to meet State and Federal water quality criteria. Because tidal influence in the Central Wetlands Area is reduced as a result of levee construction, it is not anticipated that the restoration feature to receive sediments from the MRGO/GIWW borrow area (feature CM2) would have adequate dilution available for levels of total PCBs to meet water quality criteria at the edge of the State mixing zone. See **section 2.2.2.2** for further details regarding compliance with applicable water quality standards as they pertain to proposed discharge site determinations.

3.4 Compliance with Applicable Toxic Effluent Standard of Prohibition Under Section 307 of the Clean Water Act

The project is expected to be in compliance of Section 307 of the Clean Water Act and would not violate the Toxic Effluent Standards for all features except feature CM2. Chemical constituents of dredged material released during dredging and disposal operations are not expected to exceed Louisiana Water Quality Standards with the exception of feature CM2, whose borrow source (the MRGO/GIWW Borrow Area) would require a high ratio of dilution in order to meet all State and Federal water quality criteria at the edge of the State mixing zone. See **section 2.2.2.2** for further details regarding compliance with applicable water quality standards as they pertain to proposed discharge site determinations.

Existing programs, such as the National Pollutant Discharge Elimination System (NPDES),

LDEQ's and MDEQ's Nonpoint Source Pollution Program, LDNR's Coastal Nonpoint Pollution Program, and Total Maximum Daily Loads (TMDLs), would continue. The Lake Pontchartrain Basin Foundation (LPBF) activities, such as water quality monitoring, habitat protection, environmental education, and public events, are expected to continue. Water quality certification was granted by LDEQ on xxxx; public notice comment period was held xxxxxxxx; a NPDES non-point source permit would be required and obtained before construction commences.

3.5 Compliance with the Endangered Species Act of 1973

Compliance with the Endangered Species Act (7 U.S.C. 136; 16 U.S.C. 460 *et seq.*) is being coordinated with the USFWS and the National Oceanic and Atmospheric Administration (NOAA) for those species under their respective jurisdictions. A BA will be included with the public release of the EIS in **appendix G**. The USACE has provided a copy of the BA to the USFWS and NOAA and has requested the initiation of formal consultation with the USFWS on potential impacts to the endangered pallid sturgeon (*Scaphirhynchus albus)*, and requested the initiation of formal consultation with NOAA on potential impacts to the threatened Gulf sturgeon (*(Acipenser oxyrhynchus desotoi)* and its critical habitat.

3.6 Compliance with the Specified Protection Measures for Marine Sanctuaries Designated by the Marine Protection, Research, and Sanctuaries Act of 1972

The proposed action is compliant with specific protection measures for marine sanctuaries designated by the Marine Protection, Research, and Sanctuaries Act of 1972. All disposal sites and effects will occur in inland waters. No effects will occur in ocean waters beyond the Shoreline of the Gulf of Mexico.

3.7 Evaluation of Extent of Degradation of the Waters of the Unites States

The proposed placement of dredged material would not contribute to significant degradation of waters of the United States. Nor would it result in significant adverse effects on human health and welfare, including municipal and private water supplies; restoration and commercial fishing; life stages or organisms dependent on the aquatic ecosystem; ecosystem diversity, productivity, and stability; or restorational, aesthetic or economic values.

3.8 Appropriate and Practicable Steps Taken to Minimize Potential Adverse Impacts of the Discharge on the Aquatic Ecosystem

Borrow Areas

Borrow material for most wetlands restoration and/or nourishment features would come from Lake Borgne Borrow Areas. Borrow pit dimensions may influence the potential formation of dissolved oxygen deficits. The tendency for a borrow pit to accumulate organic material can be reduced by: 1) limiting the depth of the pit; 2) increasing the surface area of the pit; and 3) decreasing side-slopes that transition from the pit to adjacent water bottoms. A shallow and

broad "pan-shaped" borrow pit would facilitate circulation with adjacent waters, thereby decreasing the likelihood that organic material would become entrained, as well as allow for periodic flushing of the pit during storm events. In contrast, narrow and deep pits would be less influenced by circulation in the overlying water column and would require greater energy for flushing of organic material. Shallower pits would require less energy to mix the water column and would facilitate the mixing with adjacent waters.

Borrow pits in Lake Borgne that would be utilized as a sediment source for marsh restoration projects would have dimensions restrictive of DO deficit formation. Borrow pits would be pan-shaped with large surface area (acreages would differ by borrow site locations) and relatively shallow depths (not to exceed 10 feet below existing depth) and would gradually transition from adjacent water bottoms to project depth (side slopes of 2:1). The borrow pits would be located some distance from sources of rock inputs for shoreline protection measures (1,000 feet minimum distance from shoreline or tidal passes), and sedimentation rates within the project area are relatively low without the presence of predominant organic layers. Moreover, circulation within Lake Borgne is not restricted by physical barriers, and storm fronts generating considerable wave energy commonly occur. Proposed borrow pit dimensions combined with observed characteristics of the project area would therefore not be expected to favor the formation of dissolved oxygen deficits.

Biloxi Marsh (BM, BS, BR)

BM1 (Marsh Nourishment)
Confinement dikes would be utilized to prevent dredged material from flowing from this feature, and would allow solids to settle from dredged slurry prior to discharging from the feature area. Inlets and outlets of the marsh nourishment area would be aligned so as to minimize effluent suspended solids.

BS1 (Shoreline Protection)
Gaps would be left in shoreline protection feature BS1 to allow for fish passage and water circulation. Material excavated for flotation access channel construction will be used to backfill the access channel. The flotation access channel will be limited to an 80 feet bottom width channel not to exceed an elevation of -8 feet.

Mechanical excavation of material for flotation access channel construction would serve to minimize the turbidity- and water quality-related impacts associated with access channel construction. Material excavated for flotation access channel construction will be used to backfill the access channel. Therefore, flotation access channel construction would have no long term effect on water circulation.

BS2 (Oyster Reef)
The material used to create the reef would be placed on geotextile fabric to minimize settlement. Where the oyster shells will be used for reef construction, shells would be placed in mesh bags to minimize material losses and structure migration.

BR1 (Ridge Restoration)
Material used for ridge restoration would be dewatered prior to placement, and is expected to generate minimal effluent during placement activities, thereby minimizing turbidity- and water quality-related impacts associated with feature construction. Material excavated for flotation access channel construction would be placed in the footprint of feature BR1 for ridge restoration. The flotation access channel will be limited to a 60 feet bottom width channel not to exceed an elevation of -6 feet. Mechanical excavation of material for flotation access channel construction would serve to minimize the turbidity- and water quality-related impacts associated with access channel construction.

MRGO Channel

MRGO1 and MRGO6 (Shoreline Protection)
For features MRGO1 and MRGO6, material excavated for flotation access channel construction will be used to backfill the access channels. Therefore, flotation access channel construction would have no long term effect on water circulation. The flotation access channels will be limited to an 80 feet bottom width channel not to exceed an elevation of -8 feet. Mechanical excavation of material for flotation access channel construction would serve to minimize the turbidity- and water quality-related impacts associated with access channel construction.

MRGO2, MRGO3, and MRGO4 (Shoreline Protection Repairs/Maintenance)
No action taken.

MRGO5, MRGO7, and MRGO8 (Shoreline Protection & Marsh Creation)
Confinement dikes would be utilized to prevent dredged material from flowing from these features. Confinement dikes would allow solids to settle from dredged slurry prior to discharging from feature areas, and Inlets and outlets of marsh restoration areas would be aligned so as to minimize effluent suspended solids. Material excavated for flotation access channel construction would be placed within the footprint of feature MRGO5 for marsh restoration. The flotation access channel will be limited to an 80 feet bottom width channel not to exceed an elevation of -8 feet. Mechanical excavation of material for flotation access channel construction for feature MRGO5 would serve to minimize the turbidity- and water quality-related impacts associated with access channel construction. Material excavated for flotation access channel construction will be used to backfill the access channel. Therefore, flotation access channel construction would have no long term effect on water circulation.

Central Wetlands (CC, CM)

CC1, CC2, CC3, and CC5 (Cypress Swamp Creation/Nourishment)
Confinement dikes would be utilized to prevent dredged material from flowing from these features. Confinement dikes would allow solids to settle from dredged slurry prior to discharging from feature areas, and Inlets and outlets of marsh restoration and nourishment areas would be aligned so as to minimize effluent suspended solids.

CC4 (Cypress Swamp Creation)
Confinement dikes would be utilized to prevent dredged material from flowing from this feature. Confinement dikes would allow solids to settle from dredged slurry prior to discharging from the feature area, and Inlets and outlets of the swamp restoration area would be aligned so as to minimize effluent suspended solids.

CC6 (Cypress Swamp Nourishment)
Confinement dikes would be utilized to prevent dredged material from flowing from this feature. Confinement dikes would allow solids to settle from dredged slurry prior to discharging from the feature area, and Inlets and outlets of the swamp nourishment area would be aligned so as to minimize effluent suspended solids.

CM1 (Marsh Nourishment)
Confinement dikes would be utilized to prevent dredged material from flowing from this feature. Confinement dikes would allow solids to settle from dredged slurry prior to discharging from the feature area, and Inlets and outlets of the marsh nourishment area would be aligned so as to minimize effluent suspended solids. Upon completion of construction activities for this feature, all closures would be removed, thereby restoring water circulation for affected waterbodies.

CM2, CM3, CM4, and CM5 (Marsh Creation/Nourishment)
Confinement dikes would be utilized to prevent dredged material from flowing from these features. Confinement dikes would allow solids to settle from dredged slurry prior to discharging from feature areas, and Inlets and outlets of marsh restoration and nourishment areas would be aligned so as to minimize effluent suspended solids. Upon completion of construction activities for features CM3 and CM4, all closures would be removed with dynamite, thereby restoring water circulation for affected waterbodies.

East Orleans (EM, ES)

EM1, EM3 and EM4 (Marsh Creation/Nourishment)
Confinement dikes would be utilized to prevent dredged material from flowing from these features. Confinement dikes would allow solids to settle from dredged slurry prior to discharging from feature areas, and Inlets and outlets of marsh restoration and nourishment areas would be aligned so as to minimize effluent suspended solids.

For feature EM1, material excavated for flotation access channel construction will be used to backfill the access channel. Mechanical excavation of material for flotation access channel construction for feature EM1 would serve to minimize the turbidity- and water quality-related impacts associated with access channel construction.

EM2 (Marsh Nourishment)
Confinement dikes would be utilized to prevent dredged material from flowing from this feature. Confinement dikes would allow solids to settle from dredged slurry prior to discharging from the feature area, and Inlets and outlets of the marsh nourishment area would be aligned so as to minimize effluent suspended solids. Material excavated for flotation access channel construction will be used to backfill the access channel. Mechanical excavation of material for flotation

access channel construction would serve to minimize the turbidity- and water quality-related impacts associated with access channel construction.

ES1, ES2, and ES3 (Shoreline Protection)
Gaps would be left in shoreline protection features to allow for fish passage and water circulation. Gaps will also be left in the rock dike to allow boat access into the Irish Bayou Community, and at the I-10 and I-11 corridor. Material excavated for flotation access channel construction will be used to backfill access channels. Flotation access channels will be limited to an 80 ft. bottom width channel not to exceed an elevation of -8 feet. Mechanical excavation of material for flotation access channel construction for these features would serve to minimize the turbidity- and water quality-related impacts associated with access channel construction. Material excavated for flotation access channel construction will be used to backfill the access channel. Therefore, flotation access channel construction would have no long term effect on water circulation.

For Feature ES1, the northern half appears to front a fairly unbroken shoreline. As such the alignment will be placed immediately fronting this shoreline, with all required flotation material being cast lakeward. The southern half of the project alignment offers a more broken shoreline. The required flotation excavation will be cast landward of the dike alignment in an effort to beneficially use this material to restore the shoreline embankment.

For Feature ES2, The project alignment offers a fairly broken shoreline. The required flotation excavation will be cast landward of the dike alignment in an effort to beneficially use this material to restore the shoreline embankment where possible.

South Lake Borgne (LM, LS)

LM1, LM2, LM3, and LM4 (Marsh Creation/Nourishment)
Confinement dikes would be utilized to prevent dredged material from flowing from these features. Confinement dikes would allow solids to settle from dredged slurry prior to discharging from feature areas, and Inlets and outlets of marsh restoration and nourishment areas would be aligned so as to minimize effluent suspended solids.

Upon completion of construction activities for features LM1, LM2, and LM4, all closures would be removed.

For Feature LM2, based upon preliminary lake bottom classification surveys, approximately 3 acres of hard bottom surface falls within the northern-most access corridor leading from the borrow sites in Lake Borgne Site No 4. As excavation for flotation access will not be performed, marsh buggy access will simply be required within this 3 acres area in order to access the marsh restoration sites.

LS1 (Shoreline Protection))
Gaps would be left in shoreline protection feature LS1 to allow for fish passage and water circulation. Material excavated for flotation access channel construction will be used to backfill the access channel. The flotation access channel will be limited to an 80 feet bottom width

channel not to exceed an elevation of -8 feet. Mechanical excavation of material for flotation access channel construction would serve to minimize the turbidity- and water quality-related impacts associated with access channel construction.

Terre aux Boeufs (TM)

TM1, TM2, and TM7 (Marsh Creation/Nourishment)
Confinement dikes would be utilized to prevent dredged material from flowing from these features.

Upon completion of construction activities for features TM1 and TM7, all closures would be removed, thereby restoring water circulation for affected waterbodies.
TM8 (Marsh Creation)
Confinement dikes would be utilized to prevent dredged material from flowing from this feature. Confinement dikes would allow solids to settle from dredged slurry prior to discharging from the feature area, and Inlets and outlets of the marsh restoration area would be aligned so as to minimize effluent suspended solids. Upon completion of construction activities for this feature, all closures would be removed, thereby restoring water circulation for affected waterbodies.

Hopedale (HM)

HM1 (Marsh Creation/Nourishment)
Confinement dikes would be utilized to prevent dredged material from flowing from this feature. Confinement dikes would allow solids to settle from dredged slurry prior to discharging from the feature area, and Inlets and outlets of the marsh nourishment and nourishment areas would be aligned so as to minimize effluent suspended solids.

4.0 EVALUATION RESPONSIBILITY

Evaluation Prepared By:
Eric Glisch, Environmental Engineer, U.S. Army Corps of Engineers, New Orleans District
Tzenge-Huey (Jerry) Shih, Environmental Engineer, U.S. Army Corps of Engineers, New Orleans District
Erica Buschel, Hydraulic Technician, U.S. Army Corps of Engineers, New Orleans District
Jeff Pollock, URS Corporation
Jonathan Martinez, URS Corporation

Evaluation Reviewed By:
Rodney Mach, Supervisory Hydraulic Engineer, U.S. Army Corps of Engineers, New Orleans District
Sandra Stiles, Environmental Manager, U.S. Army Corps of Engineers, New Orleans District

The proposed discharges of dredged material, fill, and effluent comply with the requirements of the 404(b)(1) guidelines, with the inclusion of appropriate and practicable methods to minimize adverse effects to the aquatic ecosystem.

Date:_____ _____

Edward J. Fleming,
Colonel, U.S. Army
District Commander

5.0 REFERENCES

The following documents have been used and/or referenced as source material in the preparation of this 404 Permit.

Correction of Significant Figures in Aggregate Ecoregional Criteria Recommendations

--- 1989. Soil Survey of Orleans Parish, Louisiana. Soil Conservation Service.

--- 1989. Soil Survey of St. Bernard Parish, Louisiana. Soil Conservation Service.

--- 1990. Soil Survey of St. Tammany Parish, Louisiana. Soil Conservation Service.

Federal Register. December 24, 1980. Guidelines for Specification of Disposal Sites for Dredged or Fill Material. 40 CFR Part 230, Appendix A, Vol. 45, No. 249, pp. 85336.

Guilherme R. Lotufo, Trudy J. Estes, and Paul R. Schroeder. August 2010. Water Quality and Sediment Evaluation for Inner Harbor Navigation Canal Lock Replacement Project, New Orleans, Louisiana. ERDC/EL TR-10-X Final Report.

Paul Schroeder, Trudy Estes, and Susan Bailey. August 2006. Screening Evaluations for Upland Confined Disposal Facility Effluent Quality. ERDC TN-DOER-R11.

U.S. Army Corps of Engineers. January 2003. Evaluation of Dredged Material Proposed for Disposal at Island, Nearshore, or Upland Confined Disposal Facilities – Testing Manual. ERDC/EL TR-03-1 Final Report prepared by Research and Development Center, Vicksburg, MS.

U.S. Environmental Protection Agency. December 1999. 1999 Update of Ambient Water Quality Criteria for Ammonia. EPA-822-R-99-014 prepared by Office of Water - Office of Science and Technology, Washington, DC and Office of Research and Development – Mid-Continent Ecology Division, Duluth, MN.

--- April 1989. Ambient Water Quality Criteria for Ammonia (Saltwater) – 1989. EPA 440/5-88-004 prepared by Office of Research and Development – Environmental Research Laboratory, Narragansette, RI.

--- February 2007. Aquatic Life Ambient Freshwater Quality Criteria – Copper. EPA-822-R-07-001 prepared by Office of Water – Office of Science and Technology, Washington, DC.

--- 2009. National Recommended Water Quality Criteria. Office of Water – Office of Science and Technology.

APPENDIX F

Basis for Analysis

Following the identification of the tentatively selected plan (TSP), a construction sequence was developed. Assumptions factoring into the construction sequence include production rates for building rock projects, dredge equipment availability, land loss rates, and the limitation of alternating dredging cycles in the lobes of Lake Borgne. The Agency coordination for the MRGO plan was based on this construction sequence and without the incorporation of Operation and maintenance (O&M). However, due to uncertainties associated with the timing and availability of funding for the plan, only those features that are sustainable without the implementation of any other feature (such as a diversion) are recommended for construction at this time. A tiered implementation approach has been developed for the TSP (Table 2-28 of EIS) based on these uncertainties. In addition, O&M has been included in the TSP. The benefits have been recalculated by tier utilizing the previously developed construction sequence and without O&M. Due to the uncertainty of when each feature will be implemented, analysis may require updating in later phases of the project. The USACE will continue to coordinate with the agencies throughout the project study and implementation.

Draft Implementation Plan (used to calculate benefits without O&M)	
Measure	**Description**
Construction Year 1	
LS1	47,000 linear feet (8.9 miles) of shoreline protection beginning at the terminus of the Bayou Dupre supplemental shoreline project, extending around Proctor Point to the West of Shell Beach supplemental funding shoreline protection.
MRGO1	3,850 feet of new foreshore protection between MRGO miles 56.6 and 57.4. This stone protection feature is embedded within the limits of MRGO7.
MRGO6	8,132 linear feet of new, non-continuous foreshore protection between MRGO miles 36.0 and 34.2, immediately east of the existing stone closure of the MRGO. MRGO6 ties into an existing foreshore dike immediately downstream.
LM1	3,240 acres of marsh restoration from open water and nourishment of 777 adjacent acres in the Golden Triangle, south of the IHNC Surge Barrier. Approximately 12.8 million cubic yards of borrow to be obtained from Lake Borgne Borrow Area 6.
LM4	289 acres of marsh restoration and nourishment of 95 adjacent acres of marsh in the portion of the Golden Triangle bordered by the GIWW, the IHNC Surge Barrier, and the MRGO. Approximately 1.4 million cubic yards of borrow material would be obtained from Lake Borgne Area 6.
LM2	422 acres of marsh restoration and 2,523 acres of marsh nourishment in the area between Proctor Point and the MRGO. Approximately 4.9 million cubic yards of borrow material to be obtained from Lake Borgne Borrow Area 3.

Draft Implementation Plan (used to calculate benefits without O&M)	
Measure	**Description**
Construction Year 2	
BS1	Approximately 51,000 linear feet (9.7 miles) of shoreline protection along the southeast shore of Lake Borgne. This feature begins at the northern terminus of the Biloxi Marsh Shoreline Protection Project (PO-72) south of Point aux Marchettes and extends north to Malheureax Point.
BS2	Approximately 39,600 linear feet (7.5 miles) of artificial oyster reef development on the Chandeleur Sound side of the Biloxi Marsh between Eloi Point and the mouth of Bayou La Loutre.
CC4-A	420 acres of cypress restoration in the Bienvenue Triangle. Approximately 2.9 million cubic yards of material to be obtained from the Mississippi River.
BR1	Approximately 48 acres of ridge restoration on the south bank of Bayou La Loutre. 425,000 cubic yards of silty sand material to be obtained from the Mississippi River.
CM2	795 acres of marsh restoration and 190 acres of marsh nourishment north of Paris Road. 3.3 million cubic yards of material are required, 2.6 million cubic yards of which can be obtained from the adjacent reach of the GIWW. The remaining material would be obtained from the Michoud Canal.
Construction Year 3	
ES1	24,000 linear feet (4.6 miles) of shoreline protection from the south shore of Lake Pontchartrain to the terminus of the existing Bayou Chevee shoreline protection feature.
ES2	30,750 linear feet of shoreline protection in Lake Pontchartrain between Chef Menteur Pass and The Rigolets.
ES3	70,000 feet of foreshore protection along Lake Borgne between Alligator Point and The Rigolets.
Construction Year 4	
HM1	757 acres of marsh restoration and the nourishment of 973 acres of adjacent marsh, located in the Hopedale area bordered by MRGO to the northeast. 4.1 million cubic yards of dredged material would be obtained from Lake Borgne Borrow Area 2.
TM1	760 acres of marsh restoration and 223 acres of marsh nourishment, requiring approximately 3.2 million cubic yards of material to be obtained from Lake Borgne Borrow Site 2.
TM2	770 acres of marsh restoration and 3,400 acres of marsh nourishment in the vicinity of Lake Ameda. Approximately 7.4 million cubic yards of borrow material would be obtained from Lake Borgne Borrow Area 2.
MRGO5	188 acres of marsh would be restored behind 14,485 linear feet of vinyl sheet pile wall to establish the shoreline. 2.7 million cubic yards of material would be obtained from Lake Borgne.

Draft Implementation Plan (used to calculate benefits without O&M)	
Measure	**Description**
MRGO8	200 acres of marsh restoration adjacent to approximately 20,640 linear feet of bank reclamation constructed using vinyl sheet pile wall. 3.2 million cubic yards of material would be obtained from Lake Borgne. Approximately 13,572 linear feet of new foreshore protection would also be included between approximate channel miles 51.0 and 48.3
Construction Year 5	
MRGO7	91 acres of marsh restoration adjacent to approximately 9,700 linear feet of bankline reclamation, consisting of 9,700 linear feet of vinyl sheet pile wall. 1.3 million cubic yards of material would be obtained from Lake Borgne.
EM1	1,175 acres of marsh restoration and nourishment of 2,830 acres of surrounding marsh in the area bounded by the Lake Pontchartrain shoreline, Chef Menteur Pass, and the levee. Approximately 8.1 million cubic yards of material would be obtained from Lake Borgne Borrow Area 6.
Construction Year 6	
LM3	911 acres of marsh creation and 950 acres of marsh nourishment in South Lake Borgne north of Lena Lagoon in the area bounded by the lake, Bayou St. Malo, MRGO, and Doulets Canal. Approximately 4.6 million cubic yards of borrow to be obtained from Lake Borgne Borrow Area 2.
BM1	8,295 acres of marsh nourishment along the south shore of Lake Borgne. 10.8 million cubic yards of material would be obtained from Lake Borgne Borrow Area 2.
Construction Year 7	
CM1	1,240 acres of marsh nourishment south of Paris Road between cypress restoration feature CC3 and the Chalmette Loop Levee. Approximately 3.0 million cubic yards of material would be dredged from Lake Borgne Borrow Area 5 for this feature.
CM3	300 acres of marsh restoration and 215 acres of marsh nourishment in the area north of Bayou Dupre and south of MRGO. 1.9 million cubic yards of borrow material would be obtained from Lake Borgne Borrow Area 5.
CM4	98 acres of marsh restoration and 129 acres of marsh nourishment south of Bayou Dupre. 900,000 cubic yards of dredged material would be obtained from Lake Borgne Borrow Area 4.
CM5	245 acres of marsh restoration and 70 acres of marsh nourishment in the area north of Bayou Bienvenue and Paris Road. 1.2 million cubic yards of material would be obtained from Lake Borgne Borrow Area 4.
Construction Year 8	
TM7	2,255 acres of marsh restoration and up to 3,338 acres of adjacent marsh nourishment on the east side of Bayou Terre aux Boeufs. 11.5 million cubic yards of material would be obtained from Lake Lery if available, but it is currently assumed that material will be obtained from Lake Borgne Borrow Area 2.

Draft Implementation Plan (used to calculate benefits without O&M)	
Measure	**Description**
TM8	1,511 acres of marsh restoration on the east side of Bayou Terre aux Boeufs in the vicinity of Delacroix. 5.5 million cubic yards of material would be dredged from Lake Lery if possible, but it is currently assumed that material will be obtained from Lake Borgne Borrow Area 2.
EM2	1,095 acres of marsh nourishment on Hog Island, located between the west and east mouth of the West Pearl River. Approximately 2.2 million cubic yards of dredged material would be obtained from Lake Borgne Borrow Area 8.
EM3	861 acres of marsh restoration and 180 acres of adjacent marsh nourishment in the area bounded by Highway 433, Little Lagoon, Salt Bayou and Highway 90. Approximately 3.5 million cubic yards of dredged material would be obtained from Lake Borgne Borrow Area 8.
EM4	2,625 acres of marsh restoration and 1,455 acres of adjacent marsh nourishment in the area bounded by Salt Bayou to the north, the West Pearl River to the east, the Rigolets to the south and Highway 80 to the north. Approximately 10.6 million cubic yards of material would be obtained from Lake Borgne Borrow Area 8.
Construction Year 9	
CC1	1,020 acres of cypress swamp restoration and 953 acres of cypress swamp nourishment in the area north of the existing Violet Canal along the Forty Arpent levee. 8.5 million cubic yards of borrow material to be obtained from Lake Borgne Borrow Area 5.
CC2	250 acres of cypress swamp restoration and 250 acres of swamp nourishment to the northeast of CC1. 2.4 million cubic yards of borrow material to be obtained from Lake Borgne Borrow Area 5.
CC3	370 acres of cypress swamp restoration and 790 acres of swamp nourishment along the Forty Arpent Levee south of Paris Road. Approximately 5.3 million cubic yards of material to be obtained from Lake Borgne Borrow Area 5.
CC4	1,465 acres of cypress swamp restoration in the open water areas adjacent to the Forty Arpent Levee north of Paris Road, including the Bienvenue Triangle area in Orleans Parish. 11.3 million cubic yards of borrow material to be obtained from Lake Borgne Borrow Area 6.
Construction Year 10	
CC5	1,120 acres of swamp restoration and 1,645 acres of swamp nourishment south of the Violet Canal along the Forty Arpent Levee and the Chalmette Loop Levee. 9.6 million cubic yards of borrow material to be obtained from Lake Borgne Borrow Area 4.
CC6	1,028 acres of swamp restoration and 1,540 acres of swamp nourishment in the southwest corner of the Central Wetlands. 11.2 million cubic yards of borrow material would be obtained Lake Borgne Borrow Area 4.
Maintenance As Needed	

Draft Implementation Plan (used to calculate benefits without O&M)	
Measure	**Description**
MRGO2	Repair and maintenance of approximately 15,070 linear feet (2.85 miles) of foreshore protection between Mile 44.4 and 39.9 of the MRGO.
MRGO3	Repair and maintenance of existing approximately 10,420 linear feet (1.97 miles) of foreshore protection between approximately Mile 56 to 51 of the MRGO.
MRGO4	Repair and maintenance of approximately 6,690 linear feet (1.27 miles) of existing retention dike MRGO Miles 36.6 to 37.1 and MRGO Miles 33.9 to 32.9.

BOBBY JINDAL
GOVERNOR

SCOTT A. ANGELLE
SECRETARY

State of Louisiana

DEPARTMENT OF NATURAL RESOURCES
OFFICE OF COASTAL MANAGEMENT

February 8, 2011

Joan M. Exnicios
Chief, Environmental Planning and Compliance Branch
Corps of Engineers- New Orleans District
P.O. Box 60267
New Orleans, LA 70160-0267

RE: **C20100406,** Coastal Zone Consistency
New Orleans District, Corps of Engineers
Direct Federal Action
Mississippi River Gulf Outlet (MRGO) Ecosystem Restoration Project, including the Violet Freshwater Diversion, **Orleans, St. Bernard and St. Tammany Parishes, Louisiana**

Dear Ms. Exnicios:

The above referenced project has been reviewed for consistency with the Louisiana Coastal Resources Program in accordance with Section 307 (c) of the Coastal Zone Management Act of 1972, as amended. The project, as proposed in the application, is consistent with the LCRP. If you have any questions concerning this determination please contact Brian Marcks of the Consistency Section at (225)342-7939 or 1-800-267-4019.

Sincerely yours,

Gregory J. DuCote
Administrator
Interagency Affairs/Field Services Division

GJD/JH/bgm

✓Tammy Gilmore, COE-NOD
David Butler, LDWF
Richard Hartman, NMFS
William McCartney, St. Bernard Parish
Russell Watson, USFWS, Lafayette
Brian Fortson, St. Tammany Parish
Frank Cole, OCM FC
Charles Allen, Orleans Parish

APPENDIX G

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) 824-5312; FAX (727) 824-5309
http://sero.nmfs.noaa.gov

F/SER31:AB

MAY 04 2012

Ms. Joan Exnicios
New Orleans District Corps of Engineers
P.O. Box 60267
New Orleans, Louisiana 70160-0267

Re: Mississippi River-Gulf Outlet Ecosystem Restoration Plan

Dear Ms. Exnicios:

Enclosed is the National Marine Fisheries Service's (NMFS) biological opinion issued in accordance with Section 7 of the Endangered Species Act (ESA) of 1973. The U.S. Army Corps of Engineers New Orleans District (COE) proposes to implement an ecosystem restoration plan in southeastern, coastal Louisiana. This restoration plan intends to restore areas affected by the former Mississippi River-Gulf Outlet canal (MRGO) through wetland creation and shoreline protection projects. This effort will take place within Gulf sturgeon critical habitat.

The biological opinion analyzes the project's effects on five species of sea turtles, Gulf sturgeon, and Gulf sturgeon critical habitat. This opinion is based on project-specific information provided by the COE and our review of published literature. It is NMFS' biological opinion that the action, as proposed, may affect, but is not likely to adversely affect sea turtles and Gulf sturgeon. It is also our opinion that the project is likely to adversely affect Gulf sturgeon critical habitat, but is not likely to destroy or adversely modify it.

We look forward to further cooperation with you on other COE projects to ensure the conservation and recovery of our threatened and endangered marine species. If you have any questions regarding this consultation, please contact Adam Brame, ESA Biologist, at (727) 209-5958, or by e-mail at Adam.Brame@noaa.gov.

Sincerely,

Roy E. Crabtree, Ph.D.
Regional Administrator

Enclosure

File: 1514-22.F.7
Ref: F/SER/2010/04236

Endangered Species Act - Section 7 Consultation
Biological Opinion

Action Agency: U.S. Army Corps of Engineers (COE), New Orleans District

Activity: Mississippi River-Gulf Outlet (MRGO) Ecosystem Restoration (Consultation Number F/SER/2010/04236)

Consulting Agency: National Oceanic and Atmospheric Administration, National Marine Fisheries Service (NMFS), Southeast Regional Office, Protected Resources Division, St. Petersburg, Florida

Approved by: _____
Roy E. Crabtree, Ph.D., Regional Administrator
NMFS, Southeast Regional Office
St. Petersburg, Florida

Date Issued: May 3, 2012

TABLE OF CONTENTS

1 CONSULTATION HISTORY 3
2 DESCRIPTION OF THE PROPOSED ACTION AND ACTION AREA 3
3 STATUS OF LISTED SPECIES AND CRITICAL HABITAT 17
4 ENVIRONMENTAL BASELINE 23
5 EFFECTS OF THE ACTION ON GULF STURGEON CRITICAL HABITAT 27
6 CUMULATIVE EFFECTS 32
7 DESTRUCTION OR ADVERSE MODIFICATION ANALYSIS 33
8 CONCLUSION 33
9 INCIDENTAL TAKE STATEMENT 34
10 CONSERVATION RECOMMENDATIONS 34
11 REINITIATION OF CONSULTATION 34
12 LITERATURE CITED 36
13 APPENDIX A 40
14 APPENDIX B 42

Background

Section 7(a)(2) of the Endangered Species Act (ESA) of 1973, as amended (16 U.S.C. § 1531 *et seq.*), requires that each federal agency shall ensure that any action authorized, funded, or carried out by such agency is not likely to jeopardize the continued existence of any endangered or threatened species or result in the destruction or adverse modification of critical habitat of such species; Section 7(a)(2) requires federal agencies to consult with the appropriate Secretary on any such action. NMFS and the U.S. Fish and Wildlife Service (USFWS) share responsibilities for administering the ESA.

Consultation is required when a federal action agency determines that a proposed action "may affect" listed species or designated critical habitat. Consultation is concluded after NMFS determines the proposed action is not likely to adversely affect listed species or their critical habitat, or issues a biological opinion (opinion) that identifies whether a proposed action is likely to jeopardize the continued existence of a listed species, or destroy or adversely modify critical habitat. The opinion states the amount or extent of incidental take of the listed species that may occur and recommends conservation measures to further conserve the species.

This document represents NMFS' opinion based on our review of impacts associated with the Mississippi River-Gulf Outlet (MRGO) ecosystem restoration (wetland creation and shoreline protection) plan to be conducted in coastal Louisiana. This opinion analyzes project effects on sea turtles, Gulf sturgeon, and Gulf sturgeon critical habitat in accordance with Section 7 of the ESA. This opinion is based on project information provided by the New Orleans District COE and other sources of information including published literature cited herein.

BIOLOGICAL OPINION

1 CONSULTATION HISTORY

The New Orleans District COE is both the permitting authority and the applicant for this particular project. COE requested formal ESA Section 7 consultation with NMFS by letter dated August 19, 2010, for the proposed project. COE determined that the restoration action may affect, but is not likely to adversely affect sea turtles and Gulf sturgeon, but may adversely affect Gulf sturgeon critical habitat. On December 22, 2010, NMFS requested a time extension for this project. COE and NMFS agreed that if information was needed for consultation to proceed, the request would be made by February 16, 2011. After reviewing the COE's Biological Assessment (BA) for the proposed restoration, NMFS had concerns that the BA did not sufficiently demonstrate that resources under our purview would be adequately protected. Specifically, NMFS was concerned that borrow pits created during sand mining for beach restoration and wetlands creation could become hypoxic, adversely effecting a large area of Gulf sturgeon critical habitat. More information was requested via e-mail on February 15, 2011. The COE responded on September 22, October 4, and November 8, 2011, and provided an updated (November 18, 2011) BA on November 23, 2011, that addressed many of the NMFS' concerns. A phone call with the COE on December 19, 2011, resolved all remaining concerns and provided NMFS the information necessary to initiate formal consultation. Formal consultation was initiated on December 19, 2011.

2 DESCRIPTION OF THE PROPOSED ACTION AND ACTION AREA

2.1 Proposed Action

The COE proposes to initiate a 50-year restoration project of wetlands creation and shoreline protection to restore areas affected by the former MRGO navigation channel, as required by Section 7013 of the Water Resources Development Act of 2007. Construction and operation of the MRGO channel increased salinities in portions of the Lower Pontchartrain Sub-basin, affecting the overall ecology of the system by converting freshwater and brackish water marshes to marine marshes or open water. The MRGO channel was closed using a stone closure in late July 2009, restoring the hydrological separation once maintained by Bayou La Loutre Ridge. In addition to effects of the MRGO channel, the Pontchartrain Basin has also suffered marsh habitat degradation from decreased freshwater flows and subsidence associated with reductions in ground water and saltwater intrusion. Water diversion structures and levees built around the Mississippi River and New Orleans have altered the amount and timing of freshwater flows and sediments that historically fed Louisiana's coastal wetlands, resulting in large-scale losses of marsh habitat which became open water. An estimated 63,178 ac of land have been lost in the study area from 1985 through 2010. Further forecasts indicate that approximately 131,091 ac will be lost between 2010 and 2065 if restoration efforts are not made (Source: MRGO land loss workbook).

The action is the implementation and maintenance of the MRGO ecosystem restoration plan over the project's 50-year duration (2015-2065). The plan intends to restore and protect 58,531 ac of emergent and upland habitat in the project area, including 43,567 ac of wetlands in the Lower Pontchartrain Sub-basin, 10,431 ac of cypress swamp, and 48 ac of ridge habitat. The restoration

will also provide approximately 76 miles of shoreline protection. The restoration will consist of several parts and features as follows (Figure 1):

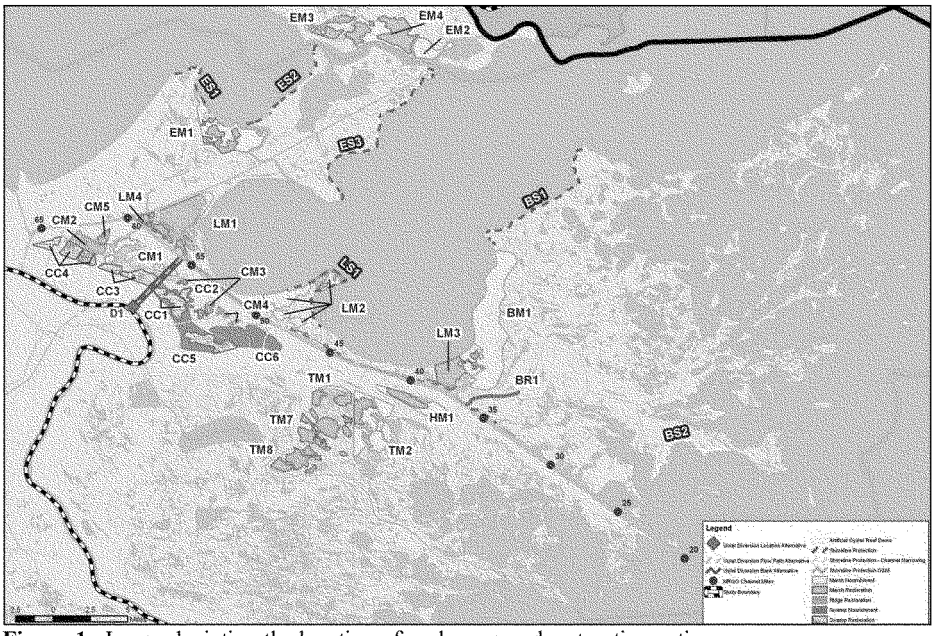


Figure 1. Image depicting the location of each proposed restoration action.

- **Ridge Restoration** – restoration of upland ridges.
  - BR1 – the restoration of a portion of the Bayou La Loutre Ridge. The proposed action involves restoring 17,500 ft of the ridge to an initial elevation of approximately +8 ft North American Vertical Datum 1988 (NAVD88), with a final desired elevation of +6 ft after settlement and consolidation. The proposed ridge will have a crest width of approximately 25 ft and side slopes of 1ft vertical for every 8 ft horizontal (1V to 8H). To restore the ridge, approximately 425,000 cubic yards of silty sand will be dredged from the Mississippi River (between river miles 83R and 85R), the MRGO ODMDS[1] site, or the Bonnet Carre spillway. Access to the site may require the excavation of a floatation channel along Bayou La Loutre, and will require a 50-ft access corridor along the backside of the ridge for equipment. If the floatation channel is necessary it will not exceed 60 ft in width and -6 ft in depth.

- **Shoreline Protection** – construction of rock dikes or oyster reef units to dissipate wave energy and prevent further shoreline erosion. Foreshore dikes will be constructed by placing 1500-lb top size stone on geotextile fabric in a linear mound. These features will

[1] Offshore Dredged Material Disposal Site.

be placed parallel to shore somewhere between the water's edge out to the -3.0 foot depth contour and constructed to a height that exceeds mean high water. Each dike will have a 5-ft crown width and a 1V on 2H side slope (Figure 2). Shoreline protection features will contain 25-ft gaps every 1000 ft to create passages for nekton[2] movements, navigation, and water exchange. Gaps will also be included in the shoreline protection features where natural bayous, creeks, or other water features exist. The construction of many of these features will require floatation channels for barging in heavy equipment (e.g., dredging equipment, bulldozers, diggers) to the site(s). Floatation channels will not exceed 80-ft in bottom width and -8 ft NAVD88. Floatation channels will be mechanically dredged from a shallow-draft barge. Material will be stockpiled landward of the channel unless otherwise stated for the individual feature. Access corridors may also be needed to accommodate barge movement during construction. Corridors, if used, will be spaced approximately 1 mile apart, with a bottom width not to exceed 100 ft. Material dredged during access corridor construction will be side cast and the same material used for backfilling the corridors upon project completion. This component will contain six features as follows:

- BS1 – An approximately 10-mile-long nearshore dike will be constructed along the northeast shoreline of Lake Borgne. The proposed dike will be located at the approximate -2.0 to -3.0 foot depth contour and constructed to an elevation of +4.0 ft NAVD88. It is estimated that 550,000 tons of stone and 240,000 sq yd of separator geotextile fabric will be required for this feature. The construction of this feature will likely require the dredging of flotation channels for site access. In conjunction with past projects, this proposed work will complete shoreline protection of the entire south lobe of Lake Borgne.
- BS2 – Approximately 4 miles of oyster habitat construction is proposed for this area. To promote oyster recruitment, bio-engineered oyster reef units will be placed in the area. These features could include but are not limited to such things as limestone pads, concrete rings, metal frames, and geotextile filled bags.
- ES1 – The construction of approximately 4.6 miles of shoreline protection in the form of a foreshore rock dike, located in eastern Lake Pontchartrain. The feature will connect with an existing shoreline protection feature to the north and the existing Coastal Wetlands Planning, Protection, and Restoration Act (CWPPRA) project (Bayou Chevee shoreline protection) to the south. The dike will be constructed to an elevation of +3.5 ft NAVD88. The project will require an estimated 223,000 tons of stone and 104,000 sq yd of separator fabric. A floatation channel will be necessary for barge access to the proposed site. Dredged material from the channel will be cast lakeward in the north section of the site and landward in the southern portion of the site.
- ES2 – approximately 6 miles of intermittent foreshore rock dikes along the land bridge between Lake Pontchartrain and Lake Catherine. The work area is bounded by Chef Pass to the south and the Rigolets to the north. The dike will be constructed along the current water edge to an elevation of +3.5 ft NAVD88. It is estimated that the proposed project will require 218,000 tons of stone and 120,000 sq yd of separator fabric. Material dredged from the floatation channel will be cast landward in an effort to use the spoil for shoreline embankment

[2] Actively swimming marine animals.

restoration. Corridors to gain access to the project site may require additional channel dredging. These channels will not exceed a bottom width of 100 ft and will be backfilled after the completion of the rock dike.

- ES3 – an approximately 14-mile foreshore rock dike positioned along the -2.0 to -3.0 depth contour from Alligator Point and extending north to the Rigolets in the northwestern portion of Lake Borgne. The dike will be constructed to an elevation of +4.0 ft NAVD88 and require an estimated 575,000 tons of stone and 290,000 sq yd of geotextile fabric. It is anticipated that floatation channels will be necessary along the proposed dike to allow access for barges and construction equipment.
- LS1 – an approximately 8.9-mile foreshore rock dike to be constructed along the perimeter of Proctor Point in Lake Borgne. The dike will be constructed between the -1.0 ft and -3.0 ft contours and have a final elevation of +4.0 ft NAVD88. It is estimated that 492,000 tons of stone and 210,000 sq yd of separator fabric will be required for this project. Floatation channel dredging may be required for access.

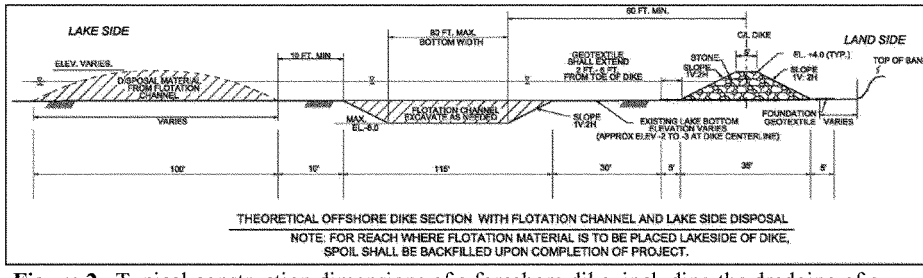


Figure 2. Typical construction dimensions of a foreshore dike, including the dredging of a floatation channel for access.

- **Swamp Restoration/Nourishment** – will consist of pumping hydraulically dredged material from borrow areas into swamps or open water areas to create elevations conducive for swamp development. Swamp restoration/nourishment may require the construction of earthen dikes around the perimeter of the swamps to contain the sediment slurry as the mixture dewaters, earthen weirs within the restoration footprint to assist in the development of the swamp site, or synthetic closures. Earthen dikes will be built from adjacent dredge borrow, contain a crown width of approximately 5 ft and slopes no steeper than 1V on 3H. Weirs will be built in a similar manner but will be lower in elevation. Synthetic closures will consist of vinyl sheet pile between 25 ft and 30 ft in length supported by timber piles spaced every 6 ft to 8 ft. The sediment slurry will be pumped into the swamps to an elevation of +4.5 ft with a final target elevation of +2 ft after dewatering. Swamp restoration will also involve the planting of cypress trees.
    - CC1 – restoration of approximately 1,020 ac of open water to an elevation conducive to swamp creation and the nourishment of approximately 953 ac of adjacent wetlands south of the MRGO within the Central Wetlands of St. Bernard Parish. This feature will require approximately 6 million cubic yards (mcy) of borrow from Lake Borgne. In addition to the earthen dikes, 3 closures totaling

700 ft in length will be required along the west bank of Bayou Dupre in order to retain the dredge slurry.

- CC2 – restoration of approximately 250 ac of open water to elevations conducive to swamp creation, and the nourishment of approximately 250 ac of adjacent wetlands in the Central Wetlands of St. Bernard Parish. This restoration will be directly west of CC1. This restoration feature will require approximately 1.7 mcy of borrow material from Lake Borgne. In addition to the 11,450 ft of earthen dike needed to contain the sediment slurry, 5,900 ft of interior earthen weirs will be constructed from adjacent borrow to assist in the development of the swamp site.
- CC3 – restoration of approximately 370 ac of open water to an elevation conducive to swamp creation and 790 ac of wetland nourishment within the Central Wetlands of St. Bernard Parish. The construction area for this feature will be directly adjacent to the 40 Arpent Levee and Paris Road. This restoration will require approximately 3.7 mcy of borrow material from Lake Borgne, 24,150 ft of earthen retention dike, and the construction of 5,100 ft of closures.
- CC4 - restoration of four open-water areas totaling 1,465 ac to an elevation conducive to swamp creation within the Central Wetlands of St. Bernard Parish. The construction area for this feature will be located between the IHNC and Paris Road, directly adjacent to and north of the 40 Arpent Levee. This restoration will require approximately 10.4 mcy of borrow material from Lake Borgne and the construction of 54,100 ft of earthen retention dike.
- CC5 - restoration of approximately 1,120 ac of open water to an elevation conducive to swamp creation and the nourishment of 1,645 ac of wetlands within the Central Wetlands of St. Bernard Parish. The construction area for this feature is adjacent to and east of the Bayou Dupre/Violet Diversion Channel and the 40 Arpent Levee. This restoration will require approximately 7.8 mcy of borrow material from Lake Borgne and the construction of 37,700 ft of earthen retention dike.
- CC6 – restoration of approximately 1,028 ac of open water to an elevation conducive to swamp creation and the nourishment of 1,540 ac of wetlands within the Central Wetlands of St. Bernard Parish. The construction area for this feature is adjacent to the back canal behind the MRGO south bank disposal area, and Bayou Dupre/Violet Diversion Channel. This restoration will require approximately 5.2 mcy of borrow material from Lake Borgne, the construction of 37,700 ft of earthen retention dike, and the manufacture of 3 closures totaling 1000 ft in length.

- **Marsh Restoration/Nourishment** – will involve raising the elevations of degraded wetlands by pumping hydraulically dredged material into these marsh habitats. It is anticipated that the final result of restoration/nourishment will be a mixture of wetlands, mud flat, and shallow water habitat within each restoration site. Earthen retention dikes, deflection dikes, and/or closures will be necessary to contain the sediment slurry within each project area. Dikes will be constructed from adjacent borrow material and contain a 2-ft freeboard, a minimum of a 5-ft-wide crown, and slopes no steeper than 1V on 3H. Similarly constructed earthen weirs may be necessary on interior portions of the wetlands to enhance wetland development, though these weirs will be constructed to a

slightly lower elevation. The COE will follow best management practices (Appendix A) when constructing earthen dikes to ensure protected species don't become entrapped within the diked area. Earthen dikes and weirs will be allowed to degrade naturally, though if they do not degrade sufficiently following appropriate settlement of dredged material (3 years), they will be mechanically breached or degraded. Closures will typically be built of vinyl sheet piles between 25 and 30 ft in length, supported by timber piles spaced every 6-8 ft. These closures will be removed upon feature completion. In addition to nourishment, marsh restoration efforts will also include the planting of marsh plants native to the area such as *Spartina* and *Juncus* species. This restoration action will require the use of access corridors to gain access to sites and for borrow delivery.

- BM1 – marsh nourishment of approximately 8,000 ac of the Biloxi marshes immediately adjacent to the east shoreline of Lake Borgne. This feature will also result in the shoaling of approximately 295 ac of adjacent waters. Dredged slurry will be placed within the nourishment site to an initial elevation of up to +3.5 ft to reach a final elevation of approximately 1.25 ft after dewatering. This feature will require 9.7 mcy of borrow material from Lake Borgne and the construction of an earthen dike approximately 94,800 ft in length.
- CM1 - marsh nourishment of four wetland areas, totaling approximately 1,240 ac within the Central Wetlands of St. Bernard Parish. More specifically, the feature will be located directly adjacent to the back canal, south of the MRGO. Of the 1,240 ac to be restored 870 ac are existing marsh, while the other 370 ac are open, shallow water. Dredged slurry will be placed within the nourishment sites to a maximum initial elevation of +3.0 ft. This feature will require 1.5 mcy of borrow material which will be hydraulically dredged from the adjacent Gulf Inland Waterway (GIWW)/MRGO channel between miles 66 and 60, as well as the Michoud Canal project which begins at approximately GIWW/MRGO mile 60 and extends east to the Michoud Canal slip. If any additional material is necessary, it will come from Lake Borgne. The feature will require the construction of 35,200 ft of earthen dike and 10 closures measuring 12,100 ft.
- CM2 – marsh creation and nourishment in the Central Wetlands of St. Bernard Parish, immediately adjacent to Bayou Bienvenue, Paris Road, and swamp restoration feature CC 4. The feature will consist of creating 795 ac of marsh and nourishing 190 ac of adjacent wetlands. Borrow material for nourishment will be dredged from Lake Borgne and pumped via a pipeline to the project site. The dredged material will be placed to a maximum slurry elevation of +4 ft. It is estimated that 4.7 mcy of borrow material, and 22,700 ft of earthen retention dikes will be necessary for this restoration feature.
- CM3 - marsh creation and nourishment in the Central Wetlands of St. Bernard Parish, immediately south of the back dike canal and upstream of the Bayou Dupre/Violet Diversion Channel. This feature is also directly adjacent to swamp restoration feature CC 2. The feature will consist of creating 300 ac of marsh and nourishing 215 ac of adjacent wetlands. Borrow material for nourishment will be dredged from Lake Borgne and pumped via a pipeline to the project site. The dredged material will be placed to a maximum slurry elevation of +4 ft. It is estimated that 1.6 mcy of borrow material, and 37,100 ft of earthen retention dikes will be necessary for this restoration feature.
- CM4 - marsh creation and nourishment in the Central Wetlands of St. Bernard

Parish, immediately south of the back dike canal, the Bayou Dupre/Violet Diversion Channel, and swamp restoration feature CC6. The feature will consist of creating 97.5 ac of marsh from open water and nourishing 128.5 ac of adjacent wetlands. Borrow material for nourishment will be dredged from Lake Borgne and pumped via a pipeline to the project site. The dredged material will be placed to a maximum slurry elevation of +4 ft. It is estimated that this feature will require 600,000 cy of borrow material and the construction of 26,560 ft of earthen retention dikes and six enclosures totaling 2,470 ft.

- CM5 - marsh creation and nourishment in the Central Wetlands of St. Bernard Parish, immediately adjacent to Bayou Bienvenue, Paris Road, and wetland restoration feature CM 2. The feature will consist of creating 245 ac of marsh and nourishing 70 ac of adjacent wetlands. Borrow material for nourishment will be dredged from Lake Borgne and pumped via a pipeline to the project site. The dredged material will be placed to a maximum slurry elevation of +4 ft. It is estimated that 1 mcy of borrow material, and 16,100 ft of earthen retention dikes will be necessary for this restoration feature.
- EM1 - marsh creation and nourishment feature in eastern New Orleans along the south shore of Lake Ponchartrain and bounded by Chef Menteur Highway, Highway 11, and Chef Pass. The feature will consist of converting 1,175 ac of open water to marsh habitat and nourishing approximately 2,830 ac of adjacent wetlands. Borrow material for nourishment will be dredged from Lake Borgne and either pumped directly to the project site via a pipeline or transported via barge to the south shore of Lake Pontchartrain, adjacent to the site, and then distributed. The dredged material will be placed to a maximum slurry elevation of +4 ft. It is estimated that 8 mcy of borrow material will be required for the restoration of this feature. The construction of 47,000 ft of earthen retention dikes, 77,000 ft of interior earthen weirs, and 3 closures totaling 4,350 ft in length will also be necessary for the project to retain the slurry.
- EM2 - marsh nourishment of approximately 800 ac of Hog Island and the shallowing of 295 ac of adjacent waterway. The feature is located west of Highway 90 and bounded by the Pearl River, Little Lake, and the Rigolets. Borrow material for nourishment will be dredged from Lake Borgne and pumped directly to the project site via a pipeline. The dredged material will be placed to a maximum slurry elevation of +3.5 ft, with the intent of a final elevation of 1-1.25 ft after dewatering. It is estimated that this feature will require 1.3 mcy of borrow material and 37,150 ft of earthen retention dikes.
- EM3 - marsh creation and nourishment feature in eastern New Orleans along the north shore of Lake Ponchartrain and west of Highway 90. The feature will consist of converting 861 ac of open water to marsh habitat and nourishing approximately 180 ac of adjacent wetlands. Borrow material for nourishment will be dredged from Lake Borgne and either pumped directly to the project site via a pipeline or transported via barge to the north shore of Lake Pontchartrain, adjacent to the site, and then distributed. The dredged material will be placed to a maximum slurry elevation of +4 ft. It is estimated that this feature will require 3.7 mcy of borrow material, 22,300 ft of earthen retention dikes, and 70,500 ft of interior earthen weirs.
- EM4 - marsh creation and nourishment feature in eastern New Orleans along the

north shore of Lake Ponchartrain and immediately east of Highway 90. The feature will consist of converting 2,625 ac of open water to marsh habitat and nourishing approximately 1,455 ac of adjacent wetlands. Borrow material for nourishment will be dredged from Lake Borgne and either pumped directly to the project site via a pipeline or transported via barge to the north shore of Lake Pontchartrain, adjacent to the site, and then distributed. The dredged material will be placed to a maximum slurry elevation of +4 ft and effluent will be returned to the adjacent waterways via spill box weirs. It is estimated that this feature will require approximately 9.2 mcy of borrow material, 75,200 ft of earthen retention dikes, and 60,000 ft of interior earthen weirs.

- LM1 - marsh creation and nourishment feature located just outside the Inner Harbor Navigation Channel Surge Barrier (IHNC), near the confluence of the MRGO and the GIWW. The feature will consist of creating 3,240 ac of marsh habitat and nourishing approximately 777 ac of adjacent existing wetlands. Borrow material for nourishment will be dredged from Lake Borgne and pumped directly to the project site via a pipeline. The dredged material will be placed to a maximum slurry elevation of +4 ft and effluent will be allowed to run over into adjacent marshes and waterways. It is estimated that this feature will require approximately 14.3 mcy of borrow material, 105,700 ft of earthen retention dikes, 92,700 ft of interior earthen weirs, and 7 closures totaling 5,400 ft in length.
- LM2 - marsh creation and nourishment feature located north of the MRGO within St. Bernard Parish. The feature will consist of creating 422 ac of marsh habitat immediately adjacent to and south of Proctor Point, and nourishing approximately 2,523 ac of adjacent existing wetlands. Borrow material for nourishment will be dredged from Lake Borgne and pumped directly to the site via a pipeline. The dredged material will be placed to a maximum slurry elevation of +4 ft and effluent will be allowed to run over into adjacent marshes. It is estimated that this feature will require approximately 5.1 mcy of borrow material, 50,600 ft of interior earthen weirs, and 1 closure totaling 180 ft in length.
- LM3 - marsh creation and nourishment feature located along the south shore of the southern lobe of Lake Borgne and bounded by the MRGO, Lena Lagoon, and Bayou St. Malo. The feature will consist of creating 911 ac of marsh habitat and nourishing approximately 950 ac of adjacent existing wetlands. Borrow material for nourishment will be dredged from Lake Borgne and pumped directly to the site via a pipeline. The dredged material will be placed to a maximum slurry elevation of +4 ft and effluent will be allowed to run over into adjacent marshes and waterways. It is estimated that this feature will require approximately 6.3 mcy of borrow material, 47,200 ft of earthen retention dikes, and 38,700 ft of interior earthen weirs.
- LM4 - marsh creation and nourishment feature located just inside the IHNC surge barrier, at the confluence of the MRGO and the GIWW. The feature will consist of creating 289 ac of marsh habitat and nourishing approximately 95 ac of adjacent existing wetlands. Borrow material for nourishment will be dredged from Lake Borgne and pumped directly to the project site via pipelines or barges. The dredged material will be placed to a maximum slurry elevation of +4 ft and effluent will be allowed to run over into adjacent marshes and waterways. It is

estimated that this feature will require approximately 1.2 mcy of borrow material, 17,200 ft of earthen retention dikes, 13,100 ft of interior earthen weirs, and 3 closures totaling 2,500 ft in length.

- TM1 - marsh creation and nourishment feature located in the vicinity of Yscloskey, Louisiana. More specifically, the feature will be located south of LA 46 between Bayou Terre Aux Boeufs and the Tennessee Gas pipeline canals. The project will consist of creating 760 ac of marsh habitat within 2 proposed wetland creation sites and the nourishing of approximately 223 ac of adjacent existing wetlands. Borrow material for nourishment will be dredged from Lake Borgne and pumped directly to the project site via pipelines. The dredged material will be placed to a maximum slurry elevation of +4 ft and effluent will be allowed to run over into adjacent marshes and waterways. It is estimated that this feature will require approximately 3.7 mcy of borrow material, 20,350 ft of earthen retention dikes, 38,250 ft of interior earthen weirs, and 4 closures totaling 1,200 ft in length.
- TM2 - marsh creation and nourishment feature located in the vicinity of Alluvial City, Louisiana. More specifically, the feature will be located south of Bayou La Loutre between Lake Ameda and the Tennessee Gas pipeline canals. The project will consist of creating 770 ac of marsh habitat and the nourishing of approximately 3,400 ac of adjacent existing wetlands. Borrow material for nourishment will be dredged from Lake Borgne and pumped directly to the project site via pipelines. The dredged material will be placed to a maximum slurry elevation of +4 ft and effluent will be allowed to run over into adjacent marshes and waterways. It is estimated that this feature will require approximately 8.8 mcy of borrow material, 146,000 ft of earthen retention dikes, and 25,500 ft of interior earthen weirs.
- TM7 - marsh creation and nourishment feature located in the vicinity of Delacroix Island and bounded by feature TM 1 on the north, feature TM 8 on the south, Bayou Terre Aux Boeufs on the west and the Tennessee Gas pipeline canals on the east. The feature will consist of creating 2,255 ac of marsh habitat within 7 proposed marsh creation sites and the nourishing of 2,144 - 3,338 ac of adjacent existing wetlands via effluent overflow. Borrow material for nourishment will be dredged from Lake Borgne and pumped directly to the project site via pipelines. The dredged material will be placed to a maximum slurry elevation of +4 ft and effluent will be allowed to run over into adjacent marshes and waterways. It is estimated that this feature will require approximately 12.4 mcy of borrow material, 105,000 ft of earthen retention dikes and weirs, and 4 closures.
- TM8 - marsh creation feature located in the vicinity of Delacroix Island, northeast of Bayou Terre Aux Boeufs and west of the Tennessee Gas pipeline. The feature will consist of creating 1,511 ac of marsh habitat within 5 proposed marsh creation sites. Borrow material for this feature will be dredged from Lake Borgne and pumped directly to the project site via pipelines. The dredged material will be placed to a maximum slurry elevation of +4 ft and effluent will be allowed to run over into adjacent marshes and waterways. It is estimated that this feature will require approximately 10.1 mcy of borrow material, 67,200 ft of earthen retention dikes, 11,600 ft of interior earthen weirs, and 6 closures totaling

approximately 6,200 ft in length.

- HM1 - marsh creation and nourishment feature located in Hopedale, Louisiana and bounded by Bayou La Loutre, Highway 624, Bayou Yscloskey, and the MRGO. The feature will consist of converting 757 ac of open water to marsh habitat and the nourishment of 973 ac of adjacent existing wetlands. Borrow material for nourishment will be dredged from Lake Borgne and pumped directly to the project site via pipelines. The dredged material will be placed to a maximum slurry elevation of +4 ft and effluent will be allowed to run over into adjacent marshes and waterways. It is estimated that this feature will require approximately 4.1 mcy of borrow material, 54,500 ft of earthen retention dikes, and 17,300 ft of interior earthen weirs.

- **MRGO Shoreline Restoration** – will result in the narrowing of the open water width of the MRGO by reestablishing a new north shore bank via construction of a synthetic wall. The proposed restoration will occur along three separate reaches of the MRGO and result in the creation of approximately 480 ac of marsh habitat behind the proposed walls. The walls will be constructed along the -6.0 ft NAVD88 contour using vinyl sheet and timber piles. Seventy-ft of class B treated timber piles will be driven at 4-ft spacing along the proposed wall, with similar piles driven at a 30 degree angle within the marsh creation site for battering. The face of the wall will be comprised of SG 950 vinyl sheet pile driven from +4.0 ft NAVD88 to -38.0 ft NAVD88. The wall will be completed with a double row of 4-in by 6-in timber wales, a 2-in-wide timber cap, and associated hardware. Dredged material will be placed behind the proposed walls for marsh creation. Material will be hydraulically dredged from site specific borrow areas and pumped via pipelines directly to the restoration site. Earthen retention dikes and weirs may be necessary to contain the sediment slurry within each project area for dewatering and settlement. These earthen features will be constructed from adjacent borrow material and contain a 2-ft freeboard, a minimum of a 5-ft-wide crown, and slopes no steeper than 1V on 3H.
    - MRGO 5 – shoreline restoration to be constructed between channel miles 40.0 and 37.3. This feature will consist of 14,485 linear ft of vinyl sheet pile wall, backfilled with earthen material to create approximately 188 ac of new marsh. Borrow material for marsh creation will be dredged from Lake Borgne or possibly the MRGO channel, though this latter option is still being investigated. It is estimated that this feature will require approximately 3 mcy of borrow material and 22,250 linear ft of backside retention dikes. Dredged material will be placed to a maximum slurry elevation of +4.0 ft NAVD88. Strategically placed overflow weirs will be located to allow dredge slurry to overflow and nourish additional existing marsh. This feature may require the dredging of flotation access channels to get equipment to the site. Any material dredged for this purpose will be cast north into the marsh creation site.
    - MRGO 7 - shoreline restoration to be constructed non-continuously between channel miles 58.5 and 55.6. This feature will consist of 9,700 linear ft of vinyl sheet pile wall, backfilled with earthen material to create approximately 91 ac of new marsh. Borrow material for marsh creation will be dredged from Lake Borgne or possibly the MRGO channel, though this latter option is still being investigated. It is estimated that this feature will require approximately 1.65 mcy

of borrow material and 7,100 linear ft of backside retention dikes, and 3,000 ft of earthen weirs. Dredged material will be placed to a maximum slurry elevation of +4.0 ft NAVD88. Strategically placed overflow weirs will be located to allow dredge slurry to overflow and nourish additional existing marsh.

- MRGO 8 - shoreline restoration to be constructed non-continuously between channel miles 48.3 and 44.4. This feature will consist of 20,640 linear ft of vinyl sheet pile wall, backfilled with earthen material to create approximately 200 ac of new marsh. Borrow material for marsh creation will be dredged from Lake Borgne or possibly the MRGO channel, though this latter option is still being investigated. It is estimated that this feature will require approximately 3.6 mcy of borrow material and 29,000 linear ft of backside retention dikes, and 2,800 ft of earthen weirs. Dredged material will be placed to a maximum slurry elevation of +4.0 ft NAVD88. Strategically placed overflow weirs will be located to allow dredge slurry to overflow and nourish additional existing marsh.

- **MRGO Shoreline Protection** – will involve the creation of stone foreshore dikes to protect the existing shoreline alignment from tidal and wind-driven erosion. These dikes will be constructed landward of the -4.0 ft NAVD88 contour to minimize stone quantities. Dikes will be built using rock laid upon geotextile fabric to an elevation of +4.0 ft NAVD88 and be built to contain a 4-ft crown width. These features may require the dredging of flotation access channels (maximum width of 80 ft and depth of -8.0 ft) to get supplies and equipment to the site. Any material dredged for this purpose will be cast toward the channel and backfilled upon project completion.
  - MRGO 1 - stone protection feature proposed for construction between channel miles 56.6 and 57.4. This feature will consist of 3,850 linear ft of foreshore rock dike constructed immediately nearshore of the existing marsh platform. Maximum top stone weight for the proposed feature will be 650 lbs and it is estimated that this feature will require approximately 40,000 tons of stone in addition to 16,000 sq yd of geotextile fabric. It is anticipated that floatation channels for access will be necessary.
  - MRGO 6 - stone protection feature to be non-continuously constructed between channel miles 36.0 and 34.2. This feature will consist of two sections of foreshore rock dike totaling 8,132 linear ft to be constructed immediately nearshore of the existing marsh platform. Maximum top stone weight for the proposed feature will be 2,200 lbs and it is estimated that this feature will require approximately 83,000 tons of stone in addition to 36,000 sq yd of geotextile fabric. It is anticipated that floatation channels for access will be necessary.

- **MRGO Shoreline Repairs** – will involve repairing foreshore rock dikes as needed to repair areas affected by settlement or breaches. This proposed action includes previously described MRGO features 6 and 7 as well as MRGO features 2, 3, and 4 that were installed previously. Repairs may include capping of the existing structures with additional stone and/or modifying the placement of existing stone. Delivery of new stone may require the dredging of floatation access channels ((maximum width of 80 ft and depth of -8.0 ft).

This project proposes significant dredging in Lake Borgne over a period of 10 years. Approximately 150.7 million cubic yards of material will be hydraulically or mechanically dredged from up to 15,439 ac of Lake Borgne for nourishment aspects of this restoration (Table 1). Dredging will also be necessary for access to certain restoration sites in the form of floatation channels, which may impact up to an additional 1,255 ac (648 ac from the dredging and 607 ac due to the stockpiling of material). Since Lake Borgne is critical habitat for Gulf sturgeon several measures are proposed to reduce impacts to critical habitat:

1. All dredging will avoid areas of more consolidated sandy substrate that has been shown to serve as primary Gulf sturgeon forage habitat.
2. Dredging will occur in phases, and will occur in only one lobe of the lake in any given year, so that a portion of Lake Borgne is disturbance free for Gulf sturgeon foraging and/or transiting (Figure 3).
3. Borrow pits will be designed to minimize hypoxia formation. Pits will be dredged to a maximum depth of 12 feet below the current depth (pending the monitoring results discussed below), have gently sloping of sides of 1V to 3H to gradually transition from the adjacent water bottoms, and will be located at least 3,000 ft from the nearest shorelines and tidal passes.
4. To determine the safest depth for which to dig the borrow pits without causing hypoxia, COE will conduct monthly water quality and benthic fauna monitoring at three borrow pits of varying depths. Each of the three borrow pits will be dredged to a different depth during the first year (15, 20, and 25 ft below the water surface) and monitored for a period of two years. Results of the monitoring will dictate how deep all subsequent borrow pits may be dug and therefore the amount of bottom area to be affected by the project.

The COE has intentionally overestimated the area of bottom habitat that may be impacted by the proposed project to insure that sufficient material is available for each project in the event environmental or cultural resources are found within the proposed borrow locations. In the worst case scenario, 15,439 ac could be impacted by dredging borrow pits. However, it is likely that dredging will impact only a portion of that 15,439 ac estimate. This area calculation is based on borrow pits being dug to a maximum depth of -12 feet below the current mud line (approximately 18-21 ft from the water surface). Results of the water quality and benthic fauna study will be used to determine how deep borrow pits can be dug without causing hypoxia, which may result in small changes to all subsequent borrow pit footprints. Prior to any changes in the proposed dredging footprints, NMFS will be notified by the COE of any intended changes and allowed to comment.

The applicant will comply with NMFS' *Sea Turtle and Smalltooth Sawfish Construction Conditions* dated March 23, 2006 (enclosed). The project duration is 50 years. The majority of all in-water construction will occur during the first 10 years (Appendix B) followed by maintenance as needed.

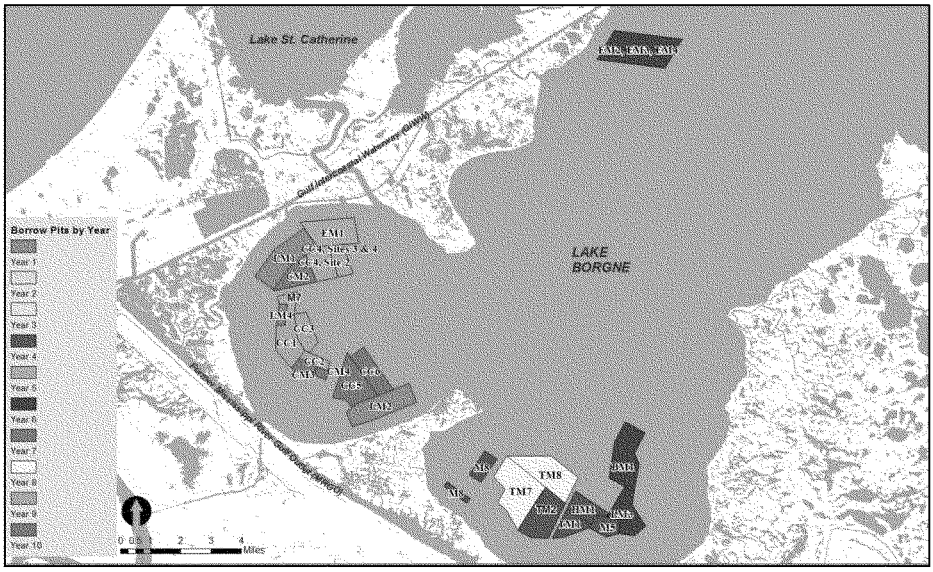


Figure 3. Borrow plan map indicating the location of each proposed borrow pit by year.

Table 1. Borrow plan.

Year	Feature	Borrow Required (cubic yards)	Borrow Depth	Size of Borrow Pit (acres)
1	LM 1*	14,300,000	17	1075
	LM 4*	1,200,000	12	132
	LM 2*	5,100,000	6.5	984
Total		20,600,000		2,191
2	CC4 SITE 1**	2,600,000	0	
	BR 1**	400,000	0	
Total		3,000,000		
3				
Total				
4	TM 1	3,700,000	12	396
	TM 2	8,800,000	12	930
	HM 1	4,100,000	12	438
	M 5	3,000,000	12	322
	M 8	3,600,000	12	385
TOTALS		23,200,000		2,471
5	EM 1	8,000,000	12	846
	M 7	1,650,000	12	180
TOTALS		9,650,000		1,026
6	BM 1	9,700,000	12	1024
	LM 3	6,300,000	12	669
	EM 2	1,300,000	12	142
	EM 3	3,700,000	12	396
	EM 4	9,200,000	12	972
TOTALS		30,200,000		3,203
7	CM 1***	1,500,000		0
	CM 2	4,700,000	12	501
	CM 3	1,600,000	12	174
	CM 4	600,000	12	68
	CM 5***	1,000,000		0
TOTALS		9,400,000		743
8	TM 7	12,400,000	12	1306
	TM 8	10,100,000	12	1066
TOTALS		22,500,000		2,372
9	CC 1	6,000,000	12	637
	CC 2	1,700,000	12	185
	CC 3	3,700,000	12	396
	CC4 SITE 2	4,900,000	12	522
	CC4 SITE 3	2,200,000	12	238
	CC4 SITE 4	700,000	12	78
TOTALS		19,200,000		2,056
10	CC 5	7,800,000	12	825
	CC 6	5,200,000	12	553
TOTALS		13,000,000		1,378
PROJECT TOTALS		**150,750,000**		**15,439**

* Borrow depths vary for these features so that 2 years of monitoring can determine how water quality parameters are affected.

** Borrow material will come from Mississippi River borrow site between miles 85 R and 83 R

*** Borrow material to come from Reach 1 of the MRGO/GIWW, and Michoud Canal if necessary

2.2 Action Area

The proposed project is located within the Middle and Lower Pontchartrain Sub-basins of southeastern coastal Louisiana (east of the Mississippi River, Figure 4). The project area has been greatly influenced by both natural impacts (wind and storm induced erosion) and anthropogenic impacts (the creation of canals and levees). Project activities will be conducted in the southeastern portion of Lake Pontchartrain, Lake Borgne, Biloxi Marsh, the East Orleans Landbridge, and the Terre aux Boeufs Marsh. The action area for this project will include the entire Lower Pontchartrain Sub-basin and the Mississippi Sound, through which materials and barges may pass. This includes all areas necessary for floatation channels, access corridors, temporary storage areas, and barge routes for rock delivery from the Mississippi River.

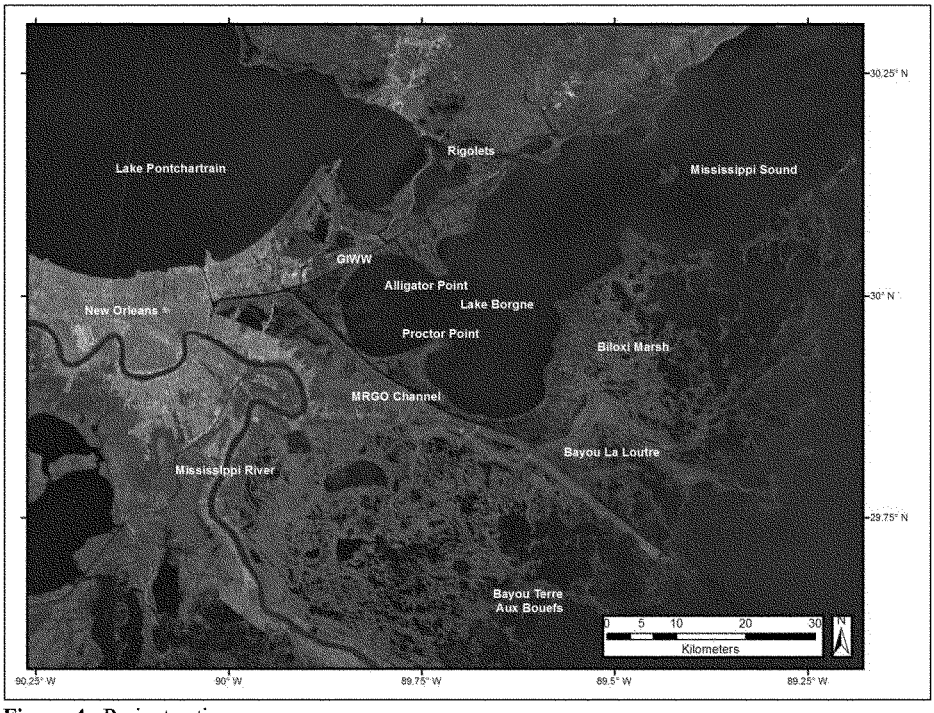


Figure 4. Project action area.

3 STATUS OF LISTED SPECIES AND CRITICAL HABITAT

3.1 Listed Species that May Occur in the Action Area

The following endangered (E) and threatened (T) sea turtle, and fish species, and designated critical habitat under the jurisdiction of NMFS may occur in or near the action area:

Common Name	Scientific Name	ESA Listed Status
Sea Turtle		
Loggerhead sea turtle	*Caretta caretta*[3]	E/T
Hawksbill sea turtle	*Eretmochelys imbricata*	E
Leatherback sea turtle	*Dermochelys coriacea*	E
Kemp's ridley sea turtle	*Lepidochelys kempii*	E
Green sea turtle	*Chelonia mydas*[4]	E/T
Fish		
Gulf sturgeon	*Acipenser oxyrinchus desotoi*	T
Designated Critical Habitat		
Gulf sturgeon – Unit 8 (Lake Pontchartrain to Mississippi Sound)		

3.2 Listed Species Not Likely to be Adversely Affected

Five species of sea turtles (loggerhead, green, hawksbill, Kemp's ridley, and leatherback), and Gulf sturgeon protected by the ESA can be found in or near the action area and may be affected by the project.

Sea turtles and Gulf sturgeon may be affected by construction-related activities such as barge traffic, the deposition of materials during the construction of the shoreline protection barriers, and dredging associated with both the creation of access channels and borrow material. However, due to the operation of vessels at slow speeds, species' mobility, and the implementation of NMFS' *Sea Turtle and Smalltooth Sawfish Construction Conditions*, the risk of injury will be discountable. Mechanical (bucket or clamshell) or hydraulic (cutterhead) dredging is not likely to adversely affect sea turtle and sturgeon species, as interactions are highly unlikely. To date, NMFS has received only one report of a sea turtle interaction with a mechanical dredge (one green captured alive in the bucket at Cape Canaveral, Florida, over the past 20 years) and two reported interactions of sturgeon with mechanical dredges (one Atlantic sturgeon killed by a clamshell dredge in the Cape Fear River, North Carolina, and one shortnose sturgeon killed in 2003 by a clamshell dredge in Maine). Similarly, NMFS has received limited reports of sea turtle or sturgeon interactions with hydraulic dredges (one loggerhead turtle killed in Florida and several juvenile green sea turtles killed in Texas, though the green turtles were strongly affected by a severe cold event). Therefore, due to the rarity of these incidents, NMFS believes that the likelihood of these species being adversely impacted by dredging operations is discountable.

The creation of earthen dikes to retain the slurry used for wetland nourishment has been shown to affect bottlenose dolphins and may similarly affect sea turtles and Gulf sturgeon through entrapment within these areas. However, we believe it is unlikely that sea turtles and Gulf

[3] Northwest Atlantic Ocean (NWA) distinct population segment (DPS). On September 16, 2011, NMFS and USFWS issued a final rule changing the listing of loggerhead sea turtles from a single, threatened species to nine DPSs listed as either threatened or endangered. The NWA DPS was listed as threatened.

[4] Green turtles are listed as threatened except for the Florida and Pacific coast of Mexico breeding populations, which are listed as endangered.

sturgeon will be using the areas where nourishment activities will occur, despite the fact that Gulf sturgeon critical habitat is located just adjacent to many of these proposed areas. Based on stranding data, green, hawksbill, and leatherback sea turtles are largely absent from coastal Louisiana (Table 2). Kemp's ridley turtles, the most abundant sea turtle in coastal Louisiana, have been shown to use nearshore areas as forage habitat. While tracking data shows Kemp's ridley turtles use estuarine embayments (Seney and Landry 2011) and it is possible that juveniles may enter wetland areas for forage (E. Seney, NMFS, pers. comm. to A. Brame, NMFS, March 22, 2012), to date there is no information that suggests turtles (Kemp's ridley or Loggerhead) are regularly using wetlands (satellite tracking data from Seaturtle.org). Further, very few sea turtles have been tracked within the lower Pontchartrain Sub-basin and in the few instances where this occurred turtles did not use any wetland areas (satellite tracking data from Seaturtle.org). Though Gulf sturgeon critical habitat is located directly adjacent to many of the areas proposed for wetland nourishment/creation, wetlands are not considered critical habitat for Gulf sturgeon and it is unlikely that Gulf sturgeon are using these habitats. Gulf sturgeon prefer to use more open water areas as forage grounds and tracking data from fish exiting the Pearl River show that most Gulf sturgeon prefer to use passes along the barrier islands (Rogillio et al. 2007). Very rarely does this species use wetland areas such as those within Lake Borgne or surrounding the MRGO channel (Tim Ruth pers. comm. to A. Brame March 21, 2012, Phil Kirk pers. comm. to A. Brame March 22, 2012). Additionally, the majority of areas to be nourished are shallow water areas ≤1 m in depth, where sturgeon are unlikely to feed given their preference for feeding in waters 2-4 m in depth. To further reduce the risk of entrapment, the COE has agreed to comply with a series of best management practices (Appendix A) to prevent entrapment associated with project implementation. Therefore we believe any effects to protected species from entrapment will be discountable.

Table 2. Reported strandings in Louisiana between 2000 and 2011.

Year	Species				
	Loggerhead	Green	Leatherback	Hawksbill	Kemp's ridley
2000	8	0	5	0	29
2001	9	0	1	0	89
2002	12	0	6	1	54
2003	7	1	0	0	20
2004	2	1	0	0	3
2005	4	0	1	0	6
2006	2	0	0	0	5
2007	2	0	0	0	7
2008	0	0	0	0	29
2009	0	0	0	0	11
2010	9	13	0	0	125
2011	19	6	0	0	104
Totals	**55**	**21**	**13**	**1**	**482**

Sea turtles and Gulf sturgeon may be affected by being temporarily unable to use the project site due to potential avoidance of construction activities and its related noise. However, normal behavior patterns of sea turtles are not expected to be significantly disrupted by project activities

because activities will only occur in single areas of Lake Borgne at any given time. Therefore, sea turtles will still be able to use areas of Lake Borgne unaffected by project construction. Gulf sturgeon are known to use Lake Borgne during the winter months (October - March) and therefore may be affected by the project. However, normal behavior patterns of Gulf sturgeon are not expected to be significantly disrupted by the project because they are not likely to be utilizing the project area for migration, they are not likely to forage extensively in the area given the substrate composition (as discussed in Sections 5 and 7), and their spawning habitat is known to occur in freshwater. Therefore, NMFS has determined that avoidance effects by listed species from construction associated with the restoration of this area are insignificant.

In summary, NMFS concludes green, hawksbill, Kemp's ridley, leatherback, and loggerhead sea turtles, and Gulf sturgeon are not likely to be adversely affected by the proposed action as any effects will be discountable or insignificant. Therefore, these species will not be discussed further in this opinion.

3.3 Critical Habitat Likely to be Adversely Affected

Gulf sturgeon critical habitat was jointly designated by NMFS and USFWS on April 18, 2003 (50 CFR 226.214). Critical habitat is defined in Section 3(5)(A) of the ESA as (1) the specific areas within the geographic area occupied by a species, at the time it is listed in accordance with the Act, on which are found those physical or biological features (a) essential to the conservation of the species and (b) that may require special management considerations or protection; and (2) specific areas outside the geographic area occupied by a species at the time it is listed, upon a determination that such areas are essential for the conservation of the species. The term "conservation" is defined in Section 3(3) of the ESA as the use of all methods and procedures that are necessary to bring any endangered or threatened species to the point at which listing under the ESA is no longer necessary.

Gulf sturgeon critical habitat includes areas within the major river systems that support the seven currently reproducing sub-populations (USFWS et al. 1995), and associated estuarine and marine habitats. Gulf sturgeon use the rivers for spawning, larval and juvenile feeding, adult resting and staging, and to move between the areas that support these components. Gulf sturgeon use the lower riverine, estuarine, and marine environment during winter months primarily for feeding and, more rarely, for inter-river migrations. Estuaries and bays adjacent to the riverine units provide unobstructed passage of Gulf sturgeon from feeding areas to spawning grounds.

Fourteen areas (units) are designated as Gulf sturgeon critical habitat. The project is located in Unit 8, which encompasses parts of Lake Pontchartrain, Lake St. Catherine, the Rigolets, Little Lake, Lake Borgne, and Mississippi Sound. These 14 critical habitat units encompass a total of 2,783 river kilometers (rkm) and 6,042 km^2 of estuarine and marine habitats, and include portions of the following Gulf of Mexico rivers, tributaries, estuarine, and marine areas:

Unit 1	Pearl and Bogue Chitto Rivers in Louisiana and Mississippi;
Unit 2	Pascagoula, Leaf, Bowie, Big Black Creek, and Chickasawhay Rivers in Mississippi;
Unit 3	Escambia, Conecuh, and Sepulga Rivers in Alabama and Florida;
Unit 4	Yellow, Blackwater, and Shoal Rivers in Alabama and Florida;

Unit 5 Choctawhatchee and Pea Rivers in Florida and Alabama;
Unit 6 Apalachicola and Brothers Rivers in Florida;
Unit 7 Suwannee and Withlacoochee Rivers in Florida;
Unit 8 Lake Pontchartrain (east of causeway), Lake Catherine, Little Lake, the Rigolets, Lake Borgne, Pascagoula Bay, and Mississippi Sound systems in Louisiana and Mississippi, and sections of the state waters within the Gulf of Mexico;
Unit 9 Pensacola Bay system in Florida;
Unit 10 Santa Rosa Sound in Florida;
Unit 11 Nearshore Gulf of Mexico in Florida;
Unit 12 Choctawhatchee Bay system in Florida;
Unit 13 Apalachicola Bay system in Gulf and Franklin Counties, Florida; and
Unit 14 Suwannee Sound in Florida.

Critical habitat determinations focus on those physical and biological features that are essential to the conservation of the species (50 CFR 424.12). Federal agencies must ensure that their activities are not likely to result in the destruction or adverse modification of critical habitat through adverse effects to the essential features on which designations are based. Therefore, proposed actions that may impact designated critical habitat require an analysis of potential impacts to each essential feature.

Features identified as essential for the conservation of the Gulf sturgeon consist of:

(1) Abundant food items, such as detritus, aquatic insects, worms, and/or molluscs, within riverine habitats for larval and juvenile life stages; and abundant prey items, such as amphipods, lancelets, polychaetes, gastropods, ghost shrimp, isopods, molluscs and/or crustaceans, within estuarine and marine habitats and substrates for sub-adult and adult life stages;

(2) Riverine spawning sites with substrates suitable for egg deposition and development, such as limestone outcrops and cut limestone banks, bedrock, large gravel or cobble beds, marl, soapstone, or hard clay;

(3) Riverine aggregation areas, also referred to as resting, holding, and staging areas, used by adult, sub-adult, and/or juveniles, generally, but not always, located in holes below normal riverbed depths, believed necessary for minimizing energy expenditures during fresh water residency and possibly for osmoregulatory functions;

(4) A flow regime (i.e., the magnitude, frequency, duration, seasonality, and rate-of-change of fresh water discharge over time) necessary for normal behavior, growth, and survival of all life stages in the riverine environment, including migration, breeding site selection, courtship, egg fertilization, resting, staging, and for maintaining spawning sites in suitable condition for egg attachment, egg sheltering, resting, and larval staging;

(5) Water quality, including temperature, salinity, pH, hardness, turbidity, oxygen content, and other chemical characteristics, necessary for normal behavior, growth, and viability of all life stages;

(6) Sediment quality, including texture and other chemical characteristics, necessary for normal behavior, growth, and viability of all life stages; and

(7) Safe and unobstructed migratory pathways necessary for passage within and between riverine, estuarine, and marine habitats (e.g., an unobstructed river or a dammed river that still allows for passage).

As stated in the final rule designating Gulf sturgeon critical habitat, the following activities, among others, when authorized, funded, or carried out by a federal agency, may destroy or adversely modify critical habitat:

(1) Actions that would appreciably reduce the abundance of riverine prey for larval and juvenile sturgeon, or of estuarine and marine prey for juvenile and adult Gulf sturgeon, within a designated critical habitat unit, such as dredging, dredged material disposal, channelization, in-stream mining, and land uses that cause excessive turbidity or sedimentation;

(2) Actions that would appreciably reduce the suitability of Gulf sturgeon spawning sites for egg deposition and development within a designated critical habitat unit, such as impoundment, hard-bottom removal for navigation channel deepening, dredged material disposal, in-stream mining, and land uses that cause excessive sedimentation;

(3) Actions that would appreciably reduce the suitability of Gulf sturgeon riverine aggregation areas, also referred to as resting, holding, and staging areas, used by adult, sub-adult, and/or juveniles, believed necessary for minimizing energy expenditures and possibly for osmoregulatory functions, such as dredged material disposal upstream or directly within such areas, and other land uses that cause excessive sedimentation;

(4) Actions that would alter the flow regime (the magnitude, frequency, duration, seasonality, and rate-of-change of fresh water discharge over time) of a riverine critical habitat unit such that it is appreciably impaired for the purposes of Gulf sturgeon migration, resting, staging, breeding site selection, courtship, egg fertilization, egg deposition, and egg development, such as impoundment, water diversion, and dam operations;

(5) Actions that would alter water quality within a designated critical habitat unit, including temperature, salinity, pH, hardness, turbidity, oxygen content, and other chemical characteristics, such that it is appreciably impaired for normal Gulf sturgeon behavior, reproduction, growth, or viability, such as dredging, dredged material disposal, channelization, impoundment, in-stream mining, water diversion, dam operations, land uses that cause excessive turbidity, and release of chemicals, biological pollutants, or heated effluents into surface water or connected groundwater via point sources or dispersed non-point sources;

(6) Actions that would alter sediment quality within a designated critical habitat unit such that it is appreciably impaired for normal Gulf sturgeon behavior, reproduction, growth, or viability, such as dredged material disposal, channelization, impoundment, in-stream mining,

land uses that cause excessive sedimentation, and release of chemical or biological pollutants that accumulate in sediments; and

(7) Actions that would obstruct migratory pathways within and between adjacent riverine, estuarine, and marine critical habitat units, such as dams, dredging, point-source-pollutant discharges, and other physical or chemical alterations of channels and passes that restrict Gulf sturgeon movement (68 FR 13399).

Within Unit 8, the following four features are present and may be affected by the proposed action: abundant prey items; water quality and sediment quality necessary for normal behavior, growth, and viability of all life stages; and safe and unobstructed migratory pathways necessary for passage within and between riverine, estuarine, and marine habitats. NMFS expects that the prey abundance and water quality essential features may be adversely affected by the proposed action, as will be discussed in detail further on. However, NMFS expects that, although the proposed action has the potential to affect sediment quality and safe, unobstructed migratory pathways, all effects to these features will be insignificant.

NMFS does not expect any significant changes to sediment quality from the proposed project as the composition of the dredged materials to be removed is expected to be similar to that remaining. A small sample of soil borings collected over the project area indicates the sediments are relatively consistent throughout the area to a depth of 20-25 ft.[5]

While the shoreline protection barriers will exceed mean high water (extend out of the water), resulting in an obstruction to Gulf sturgeon migrations, effects are expected to be insignificant. The primary migration pattern of Gulf sturgeon is parallel to the shoreline in this nearshore area. Therefore, it is not expected that the emergent barriers will significantly impede Gulf sturgeon migratory pathways.

The proposed action will directly impact the water quality and the benthos through dredging activities. Additionally, the creation of riprap structures will permanently remove a portion of water bottom that could serve as foraging habitat for Gulf sturgeon. Therefore, the potential project impacts relative to Gulf sturgeon water quality and prey availability/abundance are presented in the Effects of the Action section (Section 5).

4 ENVIRONMENTAL BASELINE

This section contains a description of the effects of past and ongoing human activities leading to the current status of the species, their habitat, and the ecosystem, within the action area. The environmental baseline is a snapshot of the factors affecting the critical habitat and includes federal, state, tribal, local, and private actions already affecting the critical habitat, or that will occur contemporaneously with the consultation in progress. Unrelated, future federal actions affecting the same critical habitat areas that have completed formal or informal consultation are also part of the environmental baseline, as are implemented and ongoing federal and other actions within the action area that may benefit listed species.

[5] Additional boring surveys will be conducted within each borrow area prior to project construction. If these proposed borings do not conform to the uniformity expressed by the preliminary borings, the COE will be required to reinitiate consultation.

4.1 Status of Critical Habitat Within the Action Area

Of the 14 units designated as Gulf sturgeon critical habitat, only Unit 8 will be affected by the proposed project. Unit 8 encompasses Lake Pontchartrain east of the Lake Pontchartrain Causeway, all of Little Lake, The Rigolets, Lake St. Catherine, and Lake Borgne, including Heron Bay, and Mississippi Sound. Critical habitat follows the shorelines around the perimeter of each included lake. Mississippi Sound includes adjacent open bays including Pascagoula Bay, Point aux Chenes Bay, Grand Bay, Sandy Bay, and barrier island passes, including Ship Island Pass, Dog Keys Pass, Horn Island Pass, and Petit Bois Pass. The northern boundary of the Mississippi Sound is the shoreline of the mainland between Heron Bay Point, Mississippi and Point aux Pins, Alabama. Critical habitat excludes St. Louis Bay, north of the railroad bridge across its mouth; Biloxi Bay, north of the U.S. Highway 90 bridge; and Back Bay of Biloxi. The southern boundary follows along the broken shoreline of Lake Borgne created by low swamp islands from Malheureux Point to Isle au Pitre. From the northeast point of Isle au Pitre, the boundary continues in a straight north-northeast line to the point 1 nautical mile (nmi) seaward of the western most extremity of Cat Island (30°13'N, 89°10'W). The southern boundary continues 1 nmi offshore of the barrier islands and offshore of the 72 COLREGS lines at barrier island passes (defined at 33 CFR 80.815 c)), (d) and (e)) to the eastern boundary. Between Cat Island and Ship Island there is no 72 COLREGS line. NMFS has therefore defined that section of the unit southern boundary as 1 nmi offshore of a straight line drawn from the southern tip of Cat Island to the western tip of Ship Island. The eastern boundary is the line of longitude 88°18.8'W from its intersection with the shore (Point aux Pins) to its intersection with the southern boundary. The lateral extent of Unit 8 is the MHW line on each shoreline of the included water bodies or the entrance to rivers, bayous, and creeks.

Gulf sturgeon critical habitat Unit 8 provides juvenile, sub-adult, and adult feeding, resting, and passage habitat for Gulf sturgeon from the Pascagoula and the Pearl River sub-populations. Unit 8 encompasses a total of 881,421 ac of critical habitat. Incidental captures and recent studies confirm that both Pearl River and Pascagoula River adult Gulf sturgeon winter in the Mississippi Sound (to which Lake Borgne is directly connected), particularly around barrier islands and barrier islands passes (Reynolds 1993, Ross et al. 2001, and Rogillio et al. 2002, Rogillio 2007). Gulf sturgeon exiting the Pascagoula River move both east and west, with telemetry locations as far east as Dauphin Island and as far west as Cat Island and the entrance to Lake Pontchartrain, Louisiana (Ross et al. 2001). Tagged Gulf sturgeon from the Pearl River sub-population have been located between Cat Island, Ship Island, Horn Island, and east of Petit Bois Islands to the Alabama State line (Rogillio et al. 2002).

Coastal Louisiana was created through the deltaic processes of the Mississippi River as sediments were deposited over time. The Lower Pontchartrain Sub-basin contains a number of different biological communities, including seagrass beds, unconsolidated bottom communities, oyster beds, salt marshes, brackish water marshes, freshwater marshes, and freshwater swamps (Lake Pontchartrain Basin Foundation 2006). Natural forces and anthropogenic actions have drastically altered the physical features of the entire Louisiana coast. Hurricanes and strong winter cold fronts produce surges and large wave conditions along the coast and within the coastal lakes (Lake Borgne, Lake Pontchartrain, Lake Maurepas), which tend to increase erosion

rates along the marsh shorelines. Water diversion structures and levees built around the Mississippi River and New Orleans west of Lake Borgne have altered the amount and timing of freshwater flows and sediments that historically fed the Louisiana coastal wetlands, leading to higher salinities and conversion of marsh to open-water habitat. The most notable anthropogenic impact to this region was the construction of the MRGO canal, which altered the tidal circulation and the overall hydrology of the region. The MRGO resulted in increased salinities in the interior marshes of coastal Louisiana, thus affecting the overall ecology of these systems. The MRGO was closed off by a rock barrier in July 2009.

Sediment layers in the Lower Pontchartrain Basin are from the Pliocene, Miocene, Oligocene, and Eocene epoch. These sediments and sedimentary rocks consist of clay, silt, sand, gravel, and limestone. Most sediments are a result of a river system (ancestral to the current Mississippi River) that drained the rising continental interior and deposited sediments from throughout the large continental drainage area into the Gulf of Mexico, although sediments in the south may also be of marine origin. The sediments of the Lower Pontchartrain Sub-basin are relatively uncontaminated. A 1999 EPA study reported that 0 percent of sediments from Lake Borgne, 22 percent of sediments from Lake Pontchartrain, and 6 percent of sediments from Mississippi Sound contained high levels of contaminants.

Four essential features are present in critical habitat Unit 8: abundant prey items for sub-adults and adults, water quality, sediment quality, and safe and unobstructed migratory pathways. Unit 8 of Gulf sturgeon critical habitat encompasses a total of 3,567 km^2 (881,421 ac).

4.2 Factors Affecting Critical Habitat Within the Action Area

4.2.1 Federal Actions

The April 2003 joint designation of Gulf sturgeon critical habitat by NMFS and USFWS benefits the species, through the ESA Section 7 consultation process. Federal agencies that regularly consult on potential impacts to Gulf sturgeon critical habitat include the COE, the Department of Defense (DOD), the Environmental Protection Agency (EPA), and the Bureau of Ocean Energy Management (BOEM), formerly, the Minerals Management Service. Dredging and dredged material disposal and military activities, including training exercises and ordnance detonation, have the potential to impact designated critical habitat. Oil and gas exploration and production also has the potential to impact designated critical habitat typically through dredging or the installation of pipelines.

In 2003, NMFS completed a regional biological opinion on hopper dredging in the Gulf of Mexico that included maintenance dredging in Gulf sturgeon critical habitat Units 8-14 and concluded that when existing navigation channels within designated critical habitat are dredged to only their current depth (i.e., maintenance-dredged), without improvements (e.g., deepening or widening), the project will not destroy or adversely modify Gulf sturgeon critical habitat.

While numerous formal consultations have been conducted on potential impacts to the species, NMFS has conducted about 40 formal consultations on potential impacts to Gulf sturgeon critical habitat since the April 18, 2003, final rule designating Gulf sturgeon critical habitat. Through formal consultation for actions occurring within Unit 8, NMFS has realized adverse

effects in less than 0.001 percent of the area (Unit 8) designated as critical habitat. Meanwhile, USFWS has conducted about 25 total formal consultations to ascertain potential project impacts on designated Gulf sturgeon critical habitat (K. Herrington, USFWS, pers. comm. to Stephania Bolden, NMFS, May 2011). The previous formal consultations conducted by NMFS, mostly with the COE, concluded that proposed actions would not result in the destruction or adverse modification of critical habitat. Also, numerous informal consultations with the DOD, COE, EPA, and BOEM analyzing potential impacts to designated critical habitat have been conducted.

Federally-regulated stormwater and industrial discharges and chemically-treated discharges from sewage treatment systems may impact Gulf sturgeon critical habitat. NMFS continues to consult with EPA to minimize the effects of these activities on both listed species and designated critical habitat. In addition, other federally-permitted construction activities, such as beach restoration, have the potential to impact Gulf sturgeon critical habitat east of the action area.

Actions impacting wetlands abutting Gulf sturgeon critical habitat throughout Mississippi Sound are regulated, managed, and mitigated via numerous COE nationwide permits. Furthermore, federal EFH consultation requirements pursuant to the Magnuson-Stevens Fishery Conservation and Management Act may minimize and mitigate for losses of wetlands and preserve valuable Gulf sturgeon habitat.

4.2.2 State or Private Actions

A number of activities that may indirectly affect Gulf sturgeon critical habitat include discharges from wastewater systems, dredging, ocean pumping and disposal, commercial and recreational fishing, and aquaculture facilities. The impacts from these activities are difficult to measure. However, where possible, conservation actions through the ESA Section 7 process, ESA Section 10 permitting, and state permitting programs are being implemented to monitor or study impacts from these sources.

Commercial and recreational trawling for shrimp is permitted within Lake Borgne and the lower portion of the Pontchartrain Basin. This activity may affect Gulf sturgeon critical habitat through increased turbidity events and the disruption of sediment surface dwelling invertebrates at trawling locations, though these disturbances are temporary and small in spatial scale. Trawling within the state waters of Louisiana is regulated by the State of Louisiana Department of Wildlife and Fisheries.

Increasing coastal development and ongoing beach erosion will result in increased demands by coastal communities, especially beach resort towns, for periodic privately-funded or federally-sponsored beach renourishment projects. These activities may affect Gulf sturgeon critical habitat by burying nearshore habitats that serve as foraging areas.

4.2.3 Deepwater Horizon Oil Spill

On April 20, 2010, while working on an exploratory well approximately 50 miles offshore Louisiana, the floating semi-submersible mobile offshore drilling unit Deepwater Horizon experienced an explosion and fire. The rig subsequently sank and oil and natural gas began leaking into the Gulf of Mexico. At this time the total amount of oil and natural gas that has

escaped into the Gulf of Mexico is unknown, but is currently believed to be approximately 4.9 million barrels according to scientists in the Flow Rate Technical Group that was supervised by the U.S. Geological Survey and the U.S. Department of Energy. The Deepwater Horizon oil spill is the worst environmental disaster in U.S. history and its full environmental impact will not be known for years to come and may never be known. Assessing the impacts of this oil spill on designated critical habitat is difficult because so much remains unknown or unclear about the impacts to the environment and habitat. Given these uncertainties, it is not practical to speculate on spill effects to the environmental baseline of critical habitat at this time. However, we expect the primary route of effects to designated critical habitat from the release of oil and subsequent cleanup efforts is to the benthos and the benthic community it supports. There are at least two routes of exposure: suffocation of infaunal organisms and toxicity of substrate. Both of these effects would impact the abundance of Gulf sturgeon prey. The long term impact to designated critical habitat from exposure to oil and the subsequent response and clean-up efforts is currently unknown.

4.2.4 Other Potential Sources of Impacts in the Environmental Baseline

Other activities that may affect critical habitat in the action area of this consultation include anthropogenic marine debris and pollution. Sources of pollutants along the Gulf of Mexico include atmospheric loading of pollutants such as polychorinated biphenyls (commonly known as PCBs), stormwater runoff from coastal towns and cities into rivers and canals emptying into bays and the ocean (e.g., Mississippi River), oil and tar discharge from tankers using Gulf waters, and groundwater and other discharges. Nutrient loading from land-based sources such as coastal community discharges is known to stimulate plankton blooms in closed or semi-closed estuarine systems. The effects on larger embayments are unknown. The impacts from these activities are difficult to measure. Where possible, conservation actions are being implemented to monitor or study impacts from these sources.

5 EFFECTS OF THE ACTION ON GULF STURGEON CRITICAL HABITAT

This biological opinion does not rely on the regulatory definition of "destruction or adverse modification" of critical habitat at 50 CFR 402.02, which has been invalidated by several Federal, District, and Circuit courts. Instead, we have relied upon the statutory provisions of the ESA to complete our analysis with respect to critical habitat. Actions associated with this restoration project may affect up to 17,067 ac of critical habitat (15,439 ac through the dredging of borrow pits, 1,255 ac through the dredging of floatation channels, and 382 ac through the placement of rock for foreshore protection barriers). It is expected that the majority of all effects will be temporary in duration as most impacted areas will return to pre-disturbance conditions following the completion of construction activities. Furthermore, an implementation schedule that restricts the amount and location (dredging in only one lobe of Lake Borgne in any given year) of dredging on a yearly basis will act to minimize impacts to critical habitat. As discussed in Section 3, two essential features within critical habitat Unit 8 may be adversely affected by the proposed project: abundant prey items and water quality. Potential impacts on these essential features are analyzed below.

5.1 Prey Abundance

The final rule designating Gulf sturgeon critical habitat states that the abundance of prey items, such as amphipods, lancelets, polychaetes, gastropods, ghost shrimp, isopods, mollusks, and/or crustaceans within estuarine and marine habitats and substrates for sub-adult and adult life stages, are essential for the conservation of the species. In other opinions, NMFS has considered and analyzed the following factors to assess direct and indirect effects of projects impacting Gulf sturgeon prey abundance essential to the conservation of the Gulf sturgeon:

1. Gulf sturgeon sub-populations using the affected critical habitat;
2. Gulf sturgeon foraging behavior;
3. Benthic community structure and Gulf sturgeon prey items; and
4. Recovery of benthic biota.

Whether individual factors are relevant to a particular action and analyzed within an opinion is highly site- and project-specific. We assess the relevant factors in order to predict the persistence and resilience of the prey resource with regard to density of current and recovering Gulf sturgeon populations. That is, numerous variables associated with Gulf sturgeon prey are considered to determine the likelihood of appropriate and abundant prey in the critical habitat unit following project construction.

5.1.1 Gulf Sturgeon Sub-populations Using Affected Critical Habitat

The total number of Gulf sturgeon using the affected critical habitat is unknown. There are no current population estimates for the Lower Pontchartrain Sub-basin or the two closest rivers (the Pearl and Pascagoula Rivers). Prior to Hurricanes Ivan (2004) and Katrina (2005), the number of Gulf sturgeon was estimated at about 400 in the Pearl River (Rogillio et al. 2002) and around 200 in the Pascagoula River (Ross et al. 2001). Effects of the hurricanes to the populations within the Pearl and Pascagoula Rivers are unknown as research has since been limited in those systems (USFWS and NMFS 2009).

On August 9, 2011, an overflow of "black liquor" (an extremely alkaline waste byproduct of the paper industry) was accidentally released by a paper mill into the Pearl River near Bogalusa, LA. While paper mills regularly use acid to balance the black liquor's pH before releasing the material, as permitted by the Louisiana Department of Environmental Quality, this material released was not treated. The extreme alkalinity of the untreated black liquor caused it to quickly bond with oxygen (aerobic) to dissociate in water. This reduced the amount of oxygen available within the water column, creating a hypoxic environment (< 1mg/L of dissolved oxygen) lethal to aquatic life. These hypoxic conditions moved downstream of the release site killing fish and mussels in the Pearl River over several days. Within a week after the spill, the dissolved oxygen concentrations returned to normal in all areas of the Pearl River tested by Louisiana Department of Wildlife and Fisheries (LDWF).

The investigation of fish mortality began on August 13, 2011, several days after the spill occurred. Twenty-eight Gulf sturgeon carcasses (38- 168 cm TL) were collected in the Pearl River after the spill (T. Ruth, LDFW, pers. com.) and anecdotal information suggests many other Gulf sturgeon carcasses were not collected. The smaller fish collected represent young-of-the-year and indicate spawning is likely occurring in the Pearl River. The spill occurred during the time when the anadromous Gulf sturgeon was still occupying the freshwater habitat. Because the materials moved downriver after the spill, the entire Pearl River population of Gulf sturgeon

was likely impacted (the Pearl River population is the western-most and likely the smallest population numbering around 300 individuals [USFWS and NMFS 2009]). Telemetry data indicated at least one adult Gulf sturgeon exited the Pearl River in front of the spill as recorded on a receiver located at the mouth of the Pearl River (G. Constant, USFWS, pers. com.). We are not aware of any other data indicating early downstream movement of the Gulf sturgeon.

5.1.2 Gulf Sturgeon Foraging Behavior

Gulf sturgeon have a highly protrusible mouth that extends downward to vacuum up sediments containing their prey (i.e., infaunal macroinvertebrates). This suction feeding requires an expandable mouth cavity and a relatively narrow mouth through which to funnel water and food items (Westneat 2001). Success of suction feeding relies on the ability of the predator's mouth to protrude into the proximity of prey (Westneat 2001). The suction tube of the sturgeon's mouth must be able to maintain contact with the benthos their prey inhabit. Findeis (1997) described sturgeon as exhibiting evolutionary traits adapted for cruising the benthos in search of prey. Notably, their caudal fin morphology has presumably been adapted for benthic cruising. The hypochordal lobe is often reduced to allow sweeping of the tail while close to the substrate (Findeis 1997).

Research supports that Gulf sturgeon are typically found foraging in depths greater than 1 m. Lower energy areas, where water depth is greater than 1 to 2 m, would likely assist foraging success given their feeding biology and the dissipation of wave energy. The protrusible mouth of these suction feeders must make contact with the benthos in order to vacuum prey out of the sediments while benthic cruising. The slightly deeper depths (2 to 4 m) the sturgeon seem to prefer (Fox et al. 2002) would have less wave energy at the substrate compared to the shallower swash zone. Downward cycloidal movement of waves dissipates energy through the water column (i.e., wave energy is exponentially dissipated with depth). A sturgeon attempting to forage in a high-energy, shallow-water environment (i.e., the swash zone) would likely have trouble remaining in place and maintaining contact with the bottom. Therefore, Gulf sturgeon foraging success would likely be greater in the slightly deeper, lower energy areas compared to the high-energy swash zone. The proposed foreshore protection barriers and associated floatation channels will be constructed/dredged in waters shallower (about 3 ft) than the preferred feeding depths of 2-4 m.

As benthic cruisers, sturgeon forage extensively in an area, presumably until preferred prey is depleted/reduced, then relocate, and resume foraging. Tracking observations by Sulak and Clugston (1999), Fox et al. (2002), and Edwards et al. (2003) support that individual Gulf sturgeon move over an area until they encounter suitable prey type and density, at which time they forage for extended periods of time. Individual Gulf sturgeon often remain in localized areas (less than 1 sq km) for extended periods of time (greater than two weeks) and then move rapidly to another area where localized movements occurred again (Fox et al. 2002). In a multi-year study, Ross et al. (2009) found Gulf sturgeon from both the Pascagoula and Pearl Rivers broadly overlap and use the shallow water along the Gulf barrier islands as foraging grounds in the winter. These marine habitats utilized by the Gulf sturgeon were all less than 7 m deep, generally well oxygenated, and with relatively clear water. Bottom substrates were mostly coarse sand and shell fragments or fine sand (Ross et al. 2009). Edwards et al. (2007) also discussed mixing of Gulf sturgeon from different populations and overlap of winter habitat utilization. Gulf sturgeon tagged in seven Florida Panhandle river systems were monitored from Carrabelle, Florida, to Mobile Bay, Alabama, during the winter period in the coastal waters of the Gulf of Mexico; Gulf sturgeon from different river systems were located occupying the same

area of marine habitat (Ross et al. 2009). While the exact amount of benthic area required to sustain Gulf sturgeon health and growth is unknown (and likely dependent on fish size and reproductive status), Gulf sturgeon have been known to travel long distances (greater than 161 km) during their winter feeding period. This supports the likelihood that any Gulf sturgeon in the action area will find appropriate and abundant prey in the areas adjacent to the project location given the proximity to nearby sandy areas that are known to support Gulf sturgeon prey.

5.1.3 Benthic Community Structure and Gulf Sturgeon Prey Items

In general, Lake Borgne has predominantly muddy sediments (75 percent is comprised of silt and clay) dominated by polychaete and nemertean worms that are, in general, tolerant to habitat disturbances (EPA 1999), though there are large areas of sand bottom as well. Craft et al. (2001) found that Gulf sturgeon in Pensacola Bay prefer shallow shoals with unvegetated, fine- to medium-grain sand habitats such as sandbars and sub-tidal energy zones resulting in sediment sorting and a preponderance of sand supporting a variety of prey items. Data collected nearby within Choctawhatchee Bay (Fox and Hightower 1998, Fox et al. 2002, Parauka et al. 2001) indicate that Gulf sturgeon prefer sandy shoreline habitats with the majority of fish being located in areas lacking seagrass. Other nearshore Gulf of Mexico locations where Gulf sturgeon are often located (via telemetry and tag returns) consist of unconsolidated, fine-medium grain sand habitats, including natural inlets and passes that are known to support Gulf sturgeon prey items (Menzel 1971, Abele and Kim 1986, AFS 1989). It has been concluded that Gulf sturgeon are foraging in these sandy areas where they are repeatedly located (Fox et al. 2002), as this habitat supports their prey (see preceding Section 5.1.3 for specifics).

A benthic community structure analysis was recently conducted nearby the action area in a portion of Mississippi Sound called Pass Christian (Rakocinski and Heard 2011). The muddy substrate in that area was found to support a wide array of macrobenthic infauna across taxonomic groups including 30 nominal polychaete taxa (Rakocinski and Heard 2011), a known Gulf sturgeon prey item. Polychaetes comprised nearly 64 percent of the total abundance of macrofauna (Rakocinski and Heard 2011). Other common taxa found were gastropods and bivalves, common inhabitants of muddy areas. These results are similar to a 2007 report submitted to the COE, in which Ray reported a benthic community in Lake Borgne dominated by polycheates (62 percent), bivalves (14 percent), and amphipods (11 percent).

Ontogenetic changes in Gulf sturgeon diet and foraging area have been documented. Young-of-the-year (juveniles in their first year that are generally <42 cm fork length, Huff 1975) forage in freshwater on aquatic invertebrates and detritus (Mason and Clugston 1993, Sulak and Clugston 1999). Small sub-adults (reproductively immature juvenile Gulf sturgeon <5 kg) forage within their natal rivers on aquatic insects (e.g., mayflies and caddis flies), worms (oligochaete), and bivalves (Huff 1975, Mason and Clugston 1993). In contrast, adult and larger sub-adult (those >5 kg) Gulf sturgeon generally fast while in freshwater rivers (Mason and Clugston 1993) and lose a substantial percentage of their total body weight (Wooley and Crateau 1985). Therefore, once Gulf sturgeon leave the rivers after having spent at least six months fasting, it is presumed that they immediately begin feeding in estuarine areas to compensate for the loss (Carr 1983, Wooley and Crateau 1985, Clugston et al. 1995, Morrow et al. 1998, Heise et al. 1999, Sulak and Clugston 1999, Ross et al. 2000, Gu et al. 2001). All adult and sub-adult Gulf sturgeon exit the rivers during the fall and concentrate around the mouths of their natal rivers in lakes, bays, and tidal passes (Fox et al. 2002, Rogillio et al. 2007, Ross et al. 2009). These areas are very important for the Gulf sturgeon as they offer the first foraging opportunity for the Gulf sturgeon

exiting the rivers. While, the sub-adults may stay within these estuarine areas, the adults often move beyond the estuaries to feed (Fox et al. 2002, Ross et al. 2009).

Few data have been collected on the food habits of Gulf sturgeon. Their threatened status limits sampling efforts and gastric lavaging has only recently become successful. Gulf sturgeon have been described as opportunistic and indiscriminate benthivores. Generally, Gulf sturgeon prey are burrowing species (e.g., annelids: polychaetes and oligochaetes, amphipods, isopods, and lancelets) that feed on detritus and/or suspended particles, and inhabit sandy substrate. Their guts generally contain benthic marine invertebrates including amphipods, lancelets, polychaetes, gastropods, shrimp, isopods, mollusks, and crustaceans (Huff 1975, Mason and Clugston 1993, Carr et al. 1996, Fox et al. 2000, Fox et al. 2002). During the early fall and winter, immediately following downstream migration, Gulf sturgeon are most often located and presumed to be foraging in marine or estuarine areas that have depths less than 20 feet and contain sandy substrates that support burrowing macroinvertebrates (Craft et al. 2001, Ross et al. 2001, Fox et al. 2002, Parauka et al. 2001, Ross et al. 2009).

5.1.4 Recovery of Benthic Biota

The action will affect the recovery of benthic biota through the dredging of both access channels (1,255 ac) and borrow pits (15,439 ac) which will temporarily remove prey from up to 16,694 ac of potential foraging habitat within Gulf sturgeon critical habitat Unit 8. This will be a temporary impact as it is expected that benthic invertebrates will re-colonize the disturbed area within a period of 1-2 years, based on the characteristics of the existing benthic community (Ray 2007). Dredging will be spaced out geographically over a period of 10 years, so only smaller areas (up to 3,203 ac) will be inaccessible for forage in any given year. However, since a disturbed area may require 1-2 years for benthic recovery the inaccessible forage area may be the largest three year total. In addition to the temporary effects, benthic biota will be permanently inaccessible from the 328 acres of water bottom that are to be covered with foreshore protection barriers.

5.2 Water Quality

Water quality in the action area will be affected by sediment disturbance associated with dredging activities. Dredging has been shown to increase turbidity and re-suspend both nutrients and pollutants that are trapped in the sediments. This can lead to decreases in the amount of dissolved oxygen available in the water column as: (1) biological oxygen demand increases to break down suspended organic matter (nutrients); and (2) reduced light penetration associated with high turbidity results in decreased oxygen production by phytoplankton. Though we believe these impacts will be temporary in nature and spatially confined, we are unsure of how long any potential impacts may persist. Lake Borgne, where the dredging is proposed to occur, is impacted by storm events, tidal events, and the operation of the Bonnet Carre Spillway, all of which result in temporary events of increased turbidity. However, these events have not resulted in hypoxia (low dissolved oxygen) and since we expect dredging impacts associated with this project will be similar in duration, we do not expect the formation of hypoxia from the proposed actions.

Poorly designed borrow pits can cause hypoxic conditions that persist over time and past studies have shown that sturgeon species are sensitive to hypoxia (Secor and Niklitschek 2001, USFWS and NMFS 2009). Improper borrow pit design can reduce water circulation leading to the accumulation of organic material and stratification within the water column. However, Lake

Borgne is a well mixed water body due to the large hydrological connection with Mississippi Sound and the borrow pits have been designed with gentle slopes and modest depths to protect against hypoxia formation. Because of borrow pit designs and the hydrological nature of Lake Borgne (well mixed), NMFS does not anticipate any significant changes in temperature, salinity, pH, hardness, oxygen content, and other chemical characteristics. However, to ensure no water quality impacts result from the dredging of borrow pits, a monitoring study on the front end of the project will assess water quality and benthic infauna recovery over a 2-year period. If results from this study indicates adverse changes in water quality due to the effects of dredging, COE will be required to reinitiate consultation with NMFS.

5.3 Summary of Effects on Gulf Sturgeon Critical Habitat

Construction associated with the MRGO ecosystem restoration plan will temporarily affect water quality and remove up to 16,694 ac of forage habitat. However, due to the implementation schedule and the estimated rate of benthic fauna recovery, NMFS believes that only the total impacted area from any three consecutive year period will be affected at any given time. The largest three year total of affected habitat would occur during years 4-6 when 6,700 ac would be affected (approximately 4 percent of the total area of Lake Borgne or approximately 0.8 percent of the total area of Unit 8). A variety of benthic invertebrates such as polychaetes and segmented annelids, widespread in Lake Borgne and the Mississippi Sound, may be affected by this action, but it is expected that effects will be temporary.

Three hundred eighty-two acres of potential foraging habitat will be permanently lost as foreshore protection barriers will permanently cover the water bottom. The shoreline protection barriers are not expected to provide opportunities for the recovery of benthic biota. However, the shoreline protection barriers will be built in water depths that are shallower than depths preferred by Gulf sturgeon for foraging (2-4 m); therefore, NMFS believes the impact of these structures will be insignificant.

6 CUMULATIVE EFFECTS

ESA Section 7 regulations require NMFS to consider cumulative effects in formulating their biological opinions (50 CFR 402.14). Cumulative effects include the effects of future state, tribal, local, or private actions that are reasonably certain to occur in the action area considered in this opinion. Within the action area, major future changes are not anticipated in the ongoing human activities described in the environmental baseline. The present, major human uses of the action area are expected to continue at the present levels of intensity in the near future.

Throughout the coastal Gulf of Mexico, the loss of numerous ac of wetlands is occurring due to natural subsidence and erosion, as well as reduced sediment input from the Mississippi River. Impacts caused by residential, commercial, and agricultural developments appear to be the primary causes of wetland loss. The COE is studying and considering a freshwater diversion structure that would seasonally add pulses of freshwater to this coastal region. This structure could potentially aid in the recovery of the region by providing a more natural pulse of freshwater to the marshes. If the COE decides to move forward with the concept of the water diversion structure, they will need to initiate consultation under Section 7 of the ESA prior to implementation.

The actions causing the effects mentioned above are ongoing with some occurring over many years. Despite this, both NMFS and the USFWS determined that the areas affected by these actions contained the physical and biological characteristics essential for the conservation of Gulf sturgeon. Based on this determination, the action area, as well as other areas in the northeastern Gulf of Mexico, was designated critical habitat for Gulf sturgeon on April 18, 2003 (68 FR 13370, March 19, 2003). Many of the future actions affecting the critical habitat involve some degree of federal authorization (e.g., through BOEM or COE) and will require consultation under Section 7 of the ESA. Therefore, NMFS will monitor and consult on actions that may cause future degradation of Gulf sturgeon critical habitat.

7 DESTRUCTION OR ADVERSE MODIFICATION ANALYSIS

This section analyzes the effects of this action relative to the ecological function of the essential features of designated critical habitat within Unit 8 continuing to provide sub-adult and adult feeding habitat and water quality for recovering populations of Gulf sturgeon from the Pearl and Pascagoula Rivers (68 FR 13395). In the following analysis we demonstrate that while construction of the shoreline protection barriers and the dredging of borrow pits will impact prey abundance and potentially water quality, Unit 8 will continue to serve its intended conservation role for Gulf sturgeon.

Dredging for borrow and access channels, and the temporary storage of material will result in the deepening of up to 16,694 ac. The deepening process will result in temporary impacts to water quality through increased turbidity, and the temporary loss of benthic invertebrates that serve as prey for Gulf sturgeon. However, preferred feeding areas (more coarse sandy sediment areas) will be avoided and the work will spread out over a number of years, thus we do not expect the dredging of Lake Borgne water bottoms to adversely affect the essential features of Unit 8. In addition to the temporary loss of forage, the project will also result in the permanent loss of 382 ac of potential foraging habitat due to the construction of shoreline protection barriers. However, we believe this will not appreciably diminish the ecological function of Unit 8 in the conservation of Gulf sturgeon as adequate forage grounds will continue to be available nearby.

Finally, the proposed action will not interfere with recovery objectives, actions, or tasks identified in the Gulf sturgeon recovery plan (USFWS et al. 1995). The proposed action will not affect population size or distribution, disrupt research activities, or interfere with any proposed habitat assessments. NMFS concludes that the direct and indirect effects of the ecosystem restoration will not impact the ecological function of Unit 8, and that it will continue to serve its intended conservation role for Gulf sturgeon.

8 CONCLUSION

After reviewing the current status of the Gulf sturgeon's critical habitat in Unit 8, the environmental baseline, the effects of the proposed action, and the cumulative effects, it is NMFS' biological opinion that the project activities in the Lower Pontchartrain Sub-basin will not reduce the critical habitat's ability to support the Gulf sturgeon's conservation. Following the project activities it is expected that the majority of the benthic community structure in the 16,694 ac to be dredged will return to, or return nearly to, pre-project status (i.e., in terms of species diversity, species richness, species abundance), with some inherent natural variability.

NMFS does not expect the 382 ac of adverse impacts to the abundance of prey items resulting from the construction of foreshore protection barriers to appreciably reduce the value of Gulf sturgeon critical habitat. NMFS concludes the action, as proposed, is not likely to destroy or adversely modify designated Gulf sturgeon critical habitat.

9 INCIDENTAL TAKE STATEMENT

NMFS does not anticipate that the proposed action will incidentally take any protected species and no take is being authorized. However, if such a take occurs, the New Orleans District COE shall immediately notify NMFS by e-mail (takereport.nmfsser@noaa.gov) and reference this biological opinion by its title, issuance date, and Public Consultation Tracking System identifier number F/SER/2010/04236. In addition to e-mail notification, COE may also notify NMFS by phone [(727) 824-5312] and/or fax [(727) 824-5309].

10 CONSERVATION RECOMMENDATIONS

Section 7(a)(1) of the ESA directs federal agencies to utilize their authority to further the purposes of the ESA by carrying out conservation programs for the benefit of endangered and threatened species. Conservation recommendations are discretionary agency activities to minimize or avoid adverse effects of a proposed action on listed species to help implement recovery plans or to develop information. NMFS believes New Orleans District COE should implement the following conservation recommendations.

1. Gather data describing recovery rates of Gulf sturgeon prey species in response to re-colonization of muddy-sand substrate that would assist in future assessments of impacts to Gulf sturgeon prey items.
2. Gather data describing Gulf sturgeon movements within the Lower Pontchartrain Sub-basin.

In order for NMFS to be kept informed of actions minimizing or avoiding adverse effects or benefiting listed species or their habitats, NMFS requests notification of the implementation of any conservation recommendations.

11 REINITIATION OF CONSULTATION

This concludes formal consultation on the MRGO Ecosystem Restoration Project. As provided in 50 CFR 402.16, reinitiation of formal consultation is required where discretionary federal agency involvement or control over the action has been retained (or is authorized by law) and if (1) the amount or extent of taking specified in the incidental take statement is exceeded, (2) new information reveals effects of the action may affect listed species or critical habitat in a manner or to an extent not previously considered, (3) the identified action is subsequently modified in a manner that causes an effect to listed species or critical habitat that was not considered in the biological opinion, or (4) a new species is listed or critical habitat designated that may be affected by the identified action.

If results from the water quality monitoring study or boring surveys within the borrow pits reveal new information not previously considered or change the assumptions on which our determinations were based, reinitiation will be necessary.

12 LITERATURE CITED

Abele, L.G. and W. Kim. 1986. An illustrated guide to the marine crustaceans of Florida. Technical Series Vol. 1 Number 1 Part 1. November 1986. Department of Environmental Regulation, State of Florida. 326 pp.

AFS (American Fisheries Society). 1989. Common and scientific names of aquatic invertebrates from the United States and Canada: decapod crustaceans. Special Publication 17, Bethesda, Maryland. 77 pp.

Bateman, D. H. and M.S. Brim. 1994. Environmental contaminants in Gulf sturgeon of Northwest Florida 1985-1991. U.S. Fish and Wildlife Service. Panama City, Florida. 23 pp.

Carr, A. 1983. All the way down upon the Suwannee River. Audubon Magazine 85: 78-101.

Carr, S.H., F. Tatman, and F.A. Chapman. 1996. Observations on the natural history of the Gulf of Mexico sturgeon *Acipenser oxyrinchus desotoi* Vladykov 1955 in the Suwannee River, southeastern United States. Ecology of Freshwater Fish 5: 169-174.

Clugston, J.P., A.M. Foster, and S.H. Carr. 1995. Gulf sturgeon, *Acipenser oxyrinchus desotoi*, in the Suwannee River, Florida. Pp. 215-224 *In:* A.D. Gershanovich and T.I.J. Smith, eds. Proceedings of International Symposium on Sturgeons. Moscow, Russia. September 6-11, 1993. 370 pp.

Craft, N.M., B. Russell, and S. Travis. 2001. Identification of Gulf sturgeon spawning habitats and migratory patterns in the Yellow and Escambia River systems. Final Report to the Florida Marine Research Institute, Fish and Wildlife Conservation Commission. 19 pp.

Edwards, R.E., K.J. Sulak, M.T. Randall, and C.B. Grimes. 2003. Movements of Gulf sturgeon (*Acipenser oxyrinchus desotoi*) in nearshore habitat as determined by acoustic telemetry. Gulf of Mexico Science 21: 59-70.

Edwards, R.E., F.M. Parauka, and K.J. Sulak. 2007. New insights into marine migration and winter habitat of Gulf sturgeon. American Fisheries Society Symposium 56:183-196.

EPA (Environmental Protection Agency). 1999. The Ecological Condition of Estuaries in the Gulf of Mexico. EPA 620-R-98-004. Office of Research and Development, Gulf Ecology Division, Gulf Breeze, Florida. 71 pp.

Findeis, E. K. 1997. Osteology and phylogenetic interrelationships of sturgeons (Acipenserids). Environmental Biology of Fishes 48: 73-126.

Fox, D.A., J.E. Hightower, and F.M. Parauka. 2002. Estuarine and nearshore marine habitat use by Gulf sturgeon from the Choctawhatchee River system, Florida. American Fisheries Society Symposium 28: 111-126.

Fox, D.A. and J.E. Hightower. 1998. Gulf sturgeon estuarine and nearshore marine habitat use in Choctawhatchee Bay, Florida. Annual Report for 1998 to the National Marine Fisheries Service and the U.S. Fish and Wildlife Service. Panama City, Florida. 29 pp.

Fox, D.A., J.E. Hightower, and F.M. Parauka. 2000. Gulf sturgeon spawning, migration, and habitat in the Choctawhatchee River System, Alabama-Florida. Transactions of the American Fisheries Society 129: 811-826.

Gu, B., D.M. Schell, T. Frazer, M. Hoyer, and F.A. Chapman. 2001. Stable carbon isotope evidence for reduced feeding of Gulf of Mexico sturgeon during their prolonged river residence period. Estuarine, Coastal and Shelf Science 53: 275-280.

Heise, R.J., S.T. Ross, M.F. Cashner, and W.T. Slack. 1999. Movement and habitat use for the Gulf sturgeon *Acipenser oxyrinchus desotoi* in the Pascagoula drainage of Mississippi: year III. Museum Technical Report No. 74. Funded by U.S. Fish and Wildlife Service, Project No. E-1, Segment 14.

Huff, J.A. 1975. Life history of the Gulf of Mexico sturgeon, *Acipenser oxyrhynchus desotoi*, in the Suwannee River, Florida. Marine Resources Publication No. 16. 32 pp.

Jones, A. 1986. The effects of dredging and spoil disposal on macrobenthos, Hawkesbury Estuary, New South Wales. Marine Pollution Bulletin 17: 17-20.

Mason, W.T., Jr. and J.P. Clugston. 1993. Foods of the Gulf sturgeon *Acipenser oxyrhynchus desotoi* in the Suwannee River, Florida. Transactions of the American Fisheries Society 122: 378-385.

Menzel, R.W. 1971. Checklist of the marine fauna and flora of the Apalachee Bay and the St. George Sound area. Third Edition. Department of Oceanography, Florida State University, Tallahassee, Florida. 126 pp.

Morrow, J.V. Jr., K.J. Killgore, J.P. Kirk, and H.E. Rogillio. 1998. Distribution and population attributes of Gulf Sturgeon in the lower Pearl River System, Louisiana. Proceedings of the Annual Conference Southeastern Association of Fish and Wildlife Agencies 50 1996: 79-90.

Parauka, F.M., S.K. Alam, and D.A. Fox. 2001. Movement and habitat use of sub-adult Gulf sturgeon in Choctawhatchee Bay, Florida. Proceedings Annual Conference Southeast Association of Fish and Wildlife Agencies 55: 280-297.

Rakocinski, C.F., R.W. Heard, S.E. LeCroy, J.A. McLelland, and T. Simons. 1996. Responses by macrobenthic assemblages to extensive beach restoration at Perdido Key, Florida, U.S.A. Journal of Coastal Research 12: 326-353.

Rakocinski, C.F. and R.W. Heard. 2011. Baseline benthic inventory of Pass Christian key site in relation to Gulf sturgeon foraging habitat. Final Report to the Mississippi Department of Marine Resources. 16 pp.

Ray, G. 2007. Characterization of benthic habitats associated with potential borrow sites and access channels in Lake Borgne, Louisiana. Report to the U.S. Army Corps of Engineers. 23 pp.

Reynolds, C. R. 1993. "Gulf sturgeon sightings, historic and recent-a summary of public responses." U.S. Fish and Wildlife Service. Panama City, Florida. 40 pp.

Rogillio, H.E., E.A. Rabalais, J.S. Forester, C.N. Doolittle, W.J. Granger, and J.P. Kirk. 2002. Status, movement, and habitat use study of Gulf sturgeon in the Lake Pontchartrain Basin, Louisiana. Louisiana Department of Wildlife and Fisheries. 43 pp.

Rogillio, H.E., R.T. Ruth, E.H. Behrens, C.N. Doolittle, W.J. Granger, and J.P. Kirk. 2007. Gulf sturgeon movements in the Pearl River Drainage and the Mississippi Sound. North American Journal of Fisheries Management 27: 89-95.

Ross, S.T., R.J. Heise, W.T. Slack, and M. Dugo. 2001. Habitat requirements of Gulf sturgeon *Acipenser oxyrinchus desotoi* in the northern Gulf of Mexico. Department of Biological Sciences, University of Southern Mississippi and Mississippi Museum of Natural Science. Funded by the Shell Marine Habitat Program, National Fish and Wildlife Foundation. 26 pp.

Ross, S.T., R.J. Heise, W.T. Slack, J.A. Ewing, III, and M. Dugo. 2000. Movement and habitat use of the Gulf sturgeon *Acipenser oxyrinchus desotoi* in the Pascagoula drainage of Mississippi: year IV. Mississippi Department of Wildlife, Fisheries, and Parks, and Mississippi Museum of Natural Science. Funded by U.S. Fish and Wildlife Service, Project No. E-1, Segment 15. 58 pp.

Ross, S.T., W.T. Slack, R.J. Heise, M.A. Dugo, H. Rogillio, B.R. Bowen, P. Mickle, and R.W. Heard. 2009. Estuarine and coastal habitat use of Gulf Sturgeon (*Acipenser oxyrinchus desotoi*) in the North-Central Gulf of Mexico. Estuaries and Coasts 32:360-374.

Secor, D.H. and E.J. Niklitschek. 2001. Hypoxia and sturgeons. Chesapeake Biological Laboratory, University of Maryland Center for Environmental Science. Technical Report Series No. TS-314-01CBL.

Seney, E.E. and A.M. Landry Jr. 2011. Movement patterns of immature and adult female Kemp's ridley sea turtles in the northwestern Gulf of Mexico. Marine Ecology Progress Series 440: 241-254.

Sulak, K. J. and J.P. Clugston. 1999. Recent advances in life history of Gulf of Mexico sturgeon *Acipenser oxyrinchus desotoi* in the Suwannee River, Florida, U.S.A.: a synopsis. Journal of Applied Ichthyology. 15: 116-128.

USFWS, GSMFC, and NMFS. 1995. U.S. Gulf Sturgeon Recovery/Management Plan. Atlanta, Georgia. 170 pp.

USFWS (U.S. Fish and Wildlife Service) and NMFS (National Marine Fisheries Service. 2009. Gulf sturgeon (*Acipenser oxyrinchus desotoi*) 5-Year Review: Summary and Evaluation. 49 pp.

Westneat, M.W. 2001. Ingestion in fish. Encyclopedia of Life Science 12: 1-6.

Wooley, C.M. and E.J. Crateau. 1985. Movement, microhabitat, exploitation, and management of Gulf of Mexico sturgeon, Apalachicola River, Florida. North American Journal of Fisheries Management 5: 590-605.

13 APPENDIX A

Protected Marine Species Entrapment Prevention Measures

Bottlenose dolphins, sea turtles and Gulf sturgeon (NOAA Trust Species) are known to inhabit coastal Louisiana waters. Bottlenose dolphins are protected under the Marine Mammal Protection Act of 1972 (MMPA) and sea turtles and Gulf sturgeons are protected under the Endangered Species Act (ESA). Because of the potential for these protected species to become entrapped within construction sites in coastal Louisiana waters, projects that utilize shallow open water areas for the construction of enclosed facilities and wetland creation will utilize the following measures to minimize and/or prevent the potential for such entrapment:

1. Prior to construction, the Corps of Engineers (COE) Technical Manager, the Contracting Officer Representative (COR) and the Contractors should conduct a site visit and meeting to develop a mutual understanding relative to compliance with the MMPA and the ESA.

2. Contractors will instruct all personnel associated with the project of the potential presence of Trust Species in the area, and the need to prevent entrapment of these animals. All construction personnel will be advised that there are civil and criminal penalties for harming, harassing, or killing these protected species. The Contractor shall be held responsible for any protected species harassed or killed as a result of construction activities not conducted in accordance with these specifications.

3. Contractor will observe the area to be enclosed for Trust Species at least 24 hours prior to and during closure of any levee, dike or structure. This is best accomplished by small vessel or aerial surveys, with at least two experienced marine observers on board scanning for protected species. Large areas (e.g. >300 acres) will likely require the use of more than one vessel or aerial surveys to insure full coverage of the area. These surveys will occur in a best sea state (BSS) of 3 feet or less, as protected species are difficult to sight in choppy water.

4. Any Trust Species sighted within the area to be enclosed triggers all appropriate precautions to be implemented by the Contractor to ensure protection of the animal(s). These precautions shall include avoiding direct contact with the protected species.

5. Any sightings of Trust Species within an enclosed project site shall be reported immediately to the COE. The point of contact within the COE will be Tammy Gilmore, (504) 862-1002 or email at tammy.h.gilmore@usace.army.mil. Coordination by the COE personnel with the National Marine Fisheries Service (NMFS) Marine Mammal Health and Stranding Response (MMHSRP) and the Louisiana State Coordinator for the Sea Turtle Stranding and Salvage Network (STSSN) will be conducted, as applicable, to determine what further actions may be required.

6. During enclosure construction, the Contractor will leave or construct at least one escape route in retention structures to allow any protected species to exit shallow open water areas during construction activities. Escape routes or gaps in retention structures would be constructed to lead directly to open water outside the disposal site with a minimum

width of 100 feet and have a depth as deep as the deepest natural entrance into the disposal site.

7. Escape routes in retention structures would remain open until visual inspections of the enclosure have determined that no protected species are present within the structure.

8. If observers note entrapped animals are not leaving the area, but are visually disturbed, stressed, or their health is compromised then COE may require any pumping activity to cease until the animals either leave on their own or are moved under the direction of NMFS.

    a. In coordination with the local stranding networks and other experts, NMFS will conduct an initial assessment to determine the number of animals, their size, age (in the case of dolphins), body condition, behavior, habitat, environmental parameters, prey availability and overall risk.
    b. If the animal(s) is/are not in imminent danger they will need to be monitored by the Stranding Network for any significant changes in the above variable.
    c. The contractor may not attempt to scare, herd, disturb, or harass the protected species to encourage them to leave the area. Coordination by the COE with the NMFS SER Stranding Coordinator may result in authorization for these actions.
    d. NMFS may intervene (catch and release and/or rehabilitate) if the Trust Species are in a situation that is life threatening and evidence suggests the animal is unlikely to survive in its immediate surroundings.
    e. Surveys will be conducted throughout the area at least twice or more in calm surface conditions (BSS 3 feet or less), with experienced marine observers, to determine whether protected species are no longer present in the area.

9. Any Trust Species observed dead must immediately be reported to the COE (Tammy Gilmore 504-862-1002) who will then report to NMFS and/or STSSN coordinator.

14 APPENDIX B

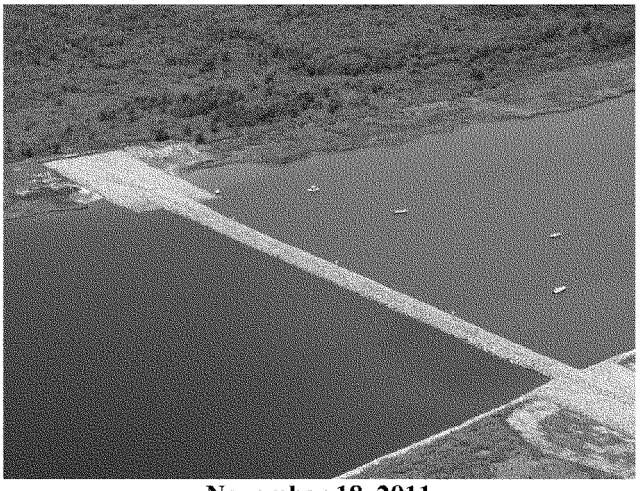
Draft Implementation Plan	
Measure	**Description**
Construction Year 1	
LS1	45,000 linear feet (8.5 miles) of shoreline protection beginning at the terminus of the Bayou Dupre supplemental shoreline project, extending around Proctor Point to the West of Shell Beach supplemental funding shoreline protection.
MRGO1	3,850 feet (0.75 miles) of new foreshore protection between MRGO miles 56.6 and 57.4. This stone protection feature is embedded within the limits of MRGO7.
MRGO6	8,132 linear feet (1.5 miles) of new, non-continuous foreshore protection between MRGO miles 36.0 and 34.4, immediately east of the existing stone closure of the MRGO. MRGO6 ties into an existing foreshore dike immediately downstream.
LM1	3,253 ac of marsh restoration from open water and nourishment of 1,064 adjacent ac in the Golden Triangle, south of the IHNC Surge Barrier. Approximately 14.3 million cubic yards of borrow to be obtained from North Lake Borgne Borrow Cycle 1.
LM4	225.5 ac of marsh restoration and nourishment of 54.8 adjacent ac of marsh in the portion of the Golden Triangle bordered by the GIWW, the IHNC Surge Barrier, and the MRGO. Approximately 1.16 million cubic yards of borrow material would be obtained from North Lake Borgne Borrow Cycle 1.
LM2	225 ac of marsh restoration and 2,628 ac of marsh nourishment in the area between Proctor Point and the MRGO. Approximately 4.45 million cubic yards of borrow material to be obtained from North Lake Borgne Borrow Cycle 1.
Construction Year 2	
BS1	Approximately 50,637 linear feet (9.5 miles) of shoreline protection along the southeast shore of Lake Borgne. This feature begins at the northern terminus of the Biloxi Marsh Shoreline Protection Project (PO-72) south of Point aux Marchettes and extends north to Malheureax Point.
BS2	Approximately 30,750 linear feet (5.8 miles) of artificial oyster reef development on the Chandeleur Sound side of the Biloxi Marsh between Eloi Point and the mouth of Bayou La Loutre.
CC4-A	400 ac of cypress restoration in the Bienvenue Triangle. Approximately 2.6 million cubic yards of silty sand material to be obtained from the Mississippi River between river miles 84.45R and 83R.
BR1	Approximately 54.1 ac of ridge restoration on the south bank of Bayou La Loutre. 400,000 cubic yards of silty sand material to be obtained from the Mississippi River between river miles 83R and 85R.

Draft Implementation Plan	
Measure	**Description**
Construction Year 3	
ES1	20,530 linear feet (3.8 miles) of shoreline protection from the south shore of Lake Pontchartrain to the terminus of the existing Bayou Chevee shoreline protection feature.
ES2	30,750 (5.8 miles) linear feet of shoreline protection in Lake Pontchartrain between Chef Menteur Pass and The Rigolets.
ES3	69,900 linear feet (13.2 miles) of foreshore protection along Lake Borgne between Alligator Point and The Rigolets.
Construction Year 4	
HM1	757 ac of marsh restoration and the nourishment of 973 ac of adjacent marsh, located in the Hopedale area bordered by MRGO to the northeast. 4.5 million cubic yards of dredged material would be obtained from South Lake Borgne Borrow Cycle 4.
TM1	798 ac of marsh restoration and 223 ac of marsh nourishment, requiring approximately 3.8 million cubic yards of material to be obtained from South Lake Borgne Borrow Cycle 4.
TM2	770 ac of marsh restoration and 3,396 ac of marsh nourishment in the vicinity of Lake Ameda. Approximately 8.8 million cubic yards of borrow material would be obtained from South Lake Borgne Borrow Cycle 4.
MRGO5	202 ac of marsh would be restored behind 13,685 linear feet (2.5 miles) of vinyl sheet pile wall to establish the shoreline. 3 million cubic yards of material would be obtained from South Lake Borgne Borrow Cycle 4.
MRGO8	236 ac of marsh restoration adjacent to approximately 17,785 linear feet (3.3 miles) of bank reclamation constructed using vinyl sheet pile wall. 3.5 million cubic yards of material would be obtained from South Lake Borgne Cycle 4.. Approximately 14,225 linear feet (2.6 miles) of new foreshore protection would also be included between approximate channel miles 51.0 and 48.3.
Construction Year 5	
MRGO7	110 ac of marsh restoration adjacent to approximately 9,170 linear feet of bankline reclamation, consisting of 9,700 linear feet (1.8 miles) of vinyl sheet pile wall. 1.65 million cubic yards of material would be obtained from North Lake Borgne borrow cycle 5.
EM1	1,175 ac of marsh restoration and nourishment of 2,830 ac of surrounding marsh in the area bounded by the Lake Pontchartrain shoreline, Chef Menteur Pass, and the levee. Approximately 8.1 million cubic yards of material would be obtained from North Lake Borgne Borrow Cycle 5.
Construction Year 6	
LM3	911 ac of marsh creation and 950 ac of marsh nourishment in South Lake Borgne north of Lena Lagoon in the area bounded by the lake, Bayou St. Malo, MRGO, and Doulets Canal. Approximately 6.4 million cubic yards of borrow to be obtained from South Lake Borgne Borrow Cycle 6.

Draft Implementation Plan	
Measure	**Description**
BM1	8,000 ac of marsh nourishment along the south shore of Lake Borgne. 11 million cubic yards of material would be obtained from South Lake Borgne Borrow Cycle 6.
Construction Year 7	
CM1	1,240 ac of marsh nourishment south of Paris Road between cypress restoration feature CC3 and the Chalmette Loop Levee. Approximately 1.5 million cubic yards of material would be obtained from GIWW/MRGO Reach 1 starting at mile 66, as well as the turning basin at mile 65.5 and the Michoud Canal project that ties into MRGO/GIWW at mile 60.
CM2	795 ac of marsh restoration and 190 ac of marsh nourishment north of Paris Road. Approximately 4.72 million cubic yards of material would be obtained from North Lake Borgne Borrow Cycle 7.
CM3	300 ac of marsh restoration and 215 ac of marsh nourishment in the area north of Bayou Dupre and south of MRGO. 1.6 million cubic yards of borrow material would be obtained from North Lake Borgne Borrow Cycle 7.
CM4	97.5 ac of marsh restoration and 128.5 ac of marsh nourishment south of Bayou Dupre. 600,000 cubic yards of dredged material would be obtained from North Lake Borgne Borrow Cycle 7.
CM5	245 ac of marsh restoration and 70 ac of marsh nourishment in the area north of Bayou Bienvenue and Paris Road. 1million cubic yards of material would be obtained from GIWW/MRGO Reach 1 starting at mile 66, as well as the turning basin at mile 65.5 and the Michoud Canal project that ties into MRGO/GIWW at mile 60.
Construction Year 8	
TM7	2,255 ac of marsh restoration and up to 2,144 ac of adjacent marsh nourishment on the east side of Bayou Terre aux Boeufs. 12.4 million cubic yards of material would be obtained from South Lake Borgne Borrow Cycle 8.
TM8	1,511 ac of marsh restoration on the east side of Bayou Terre aux Boeufs in the vicinity of Delacroix. 9.7 million cubic yards of material will be obtained from South Lake Borgne Borrow Cycle 8.
EM2	1,095 ac of marsh nourishment on Hog Island, located between the west and east mouth of the West Pearl River. Approximately 1.3 million cubic yards of dredged material would be obtained from Northeast Lake Borgne Borrow Cycle 8.
EM3	861 ac of marsh restoration and 180 ac of adjacent marsh nourishment in the area bounded by Highway 433, Little Lagoon, Salt Bayou and Highway 90. Approximately 4.1 million cubic yards of dredged material would be obtained from Northeast Lake Borgne Borrow Cycle 8.

Draft Implementation Plan	
Measure	**Description**
EM4	2,625 ac of marsh restoration and 1,455 ac of adjacent marsh nourishment in the area bounded by Salt Bayou to the north, the West Pearl River to the east, the Rigolets to the south and Highway 80 to the north. Approximately 9.2 million cubic yards of material would be obtained from North east Lake Borgne Borrow Cycle 8.
Construction Year 9	
CC1	1,020 ac of cypress swamp restoration and 935 ac of cypress swamp nourishment in the area north of the existing Violet Canal along the Forty Arpent levee. 6 million cubic yards of borrow material to be obtained from North Lake Borgne Borrow Cycle 9.
CC2	250 ac of cypress swamp restoration and 250 ac of swamp nourishment to the northeast of CC1. 1.7 million cubic yards of borrow material to be obtained from North Lake Borgne Borrow Cycle 9.
CC3	370 ac of cypress swamp restoration and 790 ac of swamp nourishment along the Forty Arpent Levee south of Paris Road. Approximately 3.7 million cubic yards of material to be obtained from North Lake Borgne Borrow Cycle 9.
CC4 (Sites 2,3,4)	1,065 ac of cypress swamp restoration in the open-water areas adjacent to the Forty Arpent Levee north of Paris Road. 7.8 million cubic yards of borrow material to be obtained from North Lake Borgne Borrow Cycle 9.
Construction Year 10	
CC5	1,120 ac of swamp restoration and 1,550 ac of swamp nourishment south of the Violet Canal along the Forty Arpent Levee and the Chalmette Loop Levee. 7.8 million cubic yards of borrow material to be obtained from North Lake Borgne Borrow Cycle 10.
CC6	2,568 ac of swamp nourishment in the southwest corner of the Central Wetlands. 5.2 million cubic yards of borrow material would be obtained from North Lake Borgne Borrow Cycle 10.
Maintenance As Needed	
MRGO2	Repair and maintenance of approximately 21,630 linear feet (4.1 miles) of foreshore protection between Mile 44.5 and 40 of the MRGO.
MRGO3	Repair and maintenance of existing approximately 26,650 linear feet (5 miles) of foreshore protection between approximately Mile 56 to 51 of the MRGO.
MRGO4	Repair and maintenance of approximately 11,770 linear feet (2.2 miles) of existing retention dike MRGO Miles 36.6 to 37.1 and MRGO Miles 33.9 to 32.9.

US ARMY CORPS
OF ENGINEERS
NEW ORLEANS DISTRICT



November 18, 2011

Biological Assessment
Mississippi River Gulf Outlet Ecosystem Restoration Study

Prepared by:

Thomas Parker
U.S. Army Corps of Engineers
New Orleans Environmental Branch
Phone: (504) 862-2526
thomas.w.parker@usace.army.mil

Physical Address:
7400 Leake Ave, Room 363
New Orleans, LA 70118

Elizabeth Behrens
U.S. Army Corps of Engineers
New Orleans Environmental Branch
Phone: (504) 862-2025
elizabeth.h.behrens@usace.army.mil

Mailing Address:
P.O. Box 60267
New Orleans, LA 70160-0267

Basis for Analysis

Following the identification of the tentatively selected plan (TSP), a construction sequence was developed. Assumptions factoring into the construction sequence include production rates for building rock projects, dredge equipment availability, land loss rates, and the limitation of alternating dredging cycles in the lobes of Lake Borgne. The Agency coordination for the MRGO plan was based on this construction sequence and without the incorporation of Operation and maintenance (O&M). However, due to uncertainties associated with the timing and availability of funding for the plan, only those features that are sustainable without the implementation of any other feature (such as a diversion) are recommended for construction at this time. A tiered implementation approach has been developed for the TSP (Table 2-28 of EIS) based on these uncertainties. In addition, O&M has been included in the TSP. The benefits have been recalculated by tier utilizing the previously developed construction sequence and without O&M. Due to the uncertainty of when each feature will be implemented, analysis may require updating in later phases of the project. The USACE will continue to coordinate with the agencies throughout the project study and implementation.

Draft Implementation Plan (used to calculate benefits without O&M)	
Measure	**Description**
Construction Year 1	
LS1	47,000 linear feet (8.9 miles) of shoreline protection beginning at the terminus of the Bayou Dupre supplemental shoreline project, extending around Proctor Point to the West of Shell Beach supplemental funding shoreline protection.
MRGO1	3,850 feet of new foreshore protection between MRGO miles 56.6 and 57.4. This stone protection feature is embedded within the limits of MRGO7.
MRGO6	8,132 linear feet of new, non-continuous foreshore protection between MRGO miles 36.0 and 34.2, immediately east of the existing stone closure of the MRGO. MRGO6 ties into an existing foreshore dike immediately downstream.
LM1	3,240 acres of marsh restoration from open water and nourishment of 777 adjacent acres in the Golden Triangle, south of the IHNC Surge Barrier. Approximately 12.8 million cubic yards of borrow to be obtained from Lake Borgne Borrow Area 6.
LM4	289 acres of marsh restoration and nourishment of 95 adjacent acres of marsh in the portion of the Golden Triangle bordered by the GIWW, the IHNC Surge Barrier, and the MRGO. Approximately 1.4 million cubic yards of borrow material would be obtained from Lake Borgne Area 6.
LM2	422 acres of marsh restoration and 2,523 acres of marsh nourishment in the area between Proctor Point and the MRGO. Approximately 4.9 million cubic yards of borrow material to be obtained from Lake Borgne Borrow Area 3.

Draft Implementation Plan (used to calculate benefits without O&M)	
Measure	**Description**
Construction Year 2	
BS1	Approximately 51,000 linear feet (9.7 miles) of shoreline protection along the southeast shore of Lake Borgne. This feature begins at the northern terminus of the Biloxi Marsh Shoreline Protection Project (PO-72) south of Point aux Marchettes and extends north to Malheureax Point.
BS2	Approximately 39,600 linear feet (7.5 miles) of artificial oyster reef development on the Chandeleur Sound side of the Biloxi Marsh between Eloi Point and the mouth of Bayou La Loutre.
CC4-A	420 acres of cypress restoration in the Bienvenue Triangle. Approximately 2.9 million cubic yards of material to be obtained from the Mississippi River.
BR1	Approximately 48 acres of ridge restoration on the south bank of Bayou La Loutre. 425,000 cubic yards of silty sand material to be obtained from the Mississippi River.
CM2	795 acres of marsh restoration and 190 acres of marsh nourishment north of Paris Road. 3.3 million cubic yards of material are required, 2.6 million cubic yards of which can be obtained from the adjacent reach of the GIWW. The remaining material would be obtained from the Michoud Canal.
Construction Year 3	
ES1	24,000 linear feet (4.6 miles) of shoreline protection from the south shore of Lake Pontchartrain to the terminus of the existing Bayou Chevee shoreline protection feature.
ES2	30,750 linear feet of shoreline protection in Lake Pontchartrain between Chef Menteur Pass and The Rigolets.
ES3	70,000 feet of foreshore protection along Lake Borgne between Alligator Point and The Rigolets.
Construction Year 4	
HM1	757 acres of marsh restoration and the nourishment of 973 acres of adjacent marsh, located in the Hopedale area bordered by MRGO to the northeast. 4.1 million cubic yards of dredged material would be obtained from Lake Borgne Borrow Area 2.
TM1	760 acres of marsh restoration and 223 acres of marsh nourishment, requiring approximately 3.2 million cubic yards of material to be obtained from Lake Borgne Borrow Site 2.
TM2	770 acres of marsh restoration and 3,400 acres of marsh nourishment in the vicinity of Lake Ameda. Approximately 7.4 million cubic yards of borrow material would be obtained from Lake Borgne Borrow Area 2.
MRGO5	188 acres of marsh would be restored behind 14,485 linear feet of vinyl sheet pile wall to establish the shoreline. 2.7 million cubic yards of material would be obtained from Lake Borgne.

Draft Implementation Plan (used to calculate benefits without O&M)	
Measure	**Description**
MRGO8	200 acres of marsh restoration adjacent to approximately 20,640 linear feet of bank reclamation constructed using vinyl sheet pile wall. 3.2 million cubic yards of material would be obtained from Lake Borgne. Approximately 13,572 linear feet of new foreshore protection would also be included between approximate channel miles 51.0 and 48.3
Construction Year 5	
MRGO7	91 acres of marsh restoration adjacent to approximately 9,700 linear feet of bankline reclamation, consisting of 9,700 linear feet of vinyl sheet pile wall. 1.3 million cubic yards of material would be obtained from Lake Borgne.
EM1	1,175 acres of marsh restoration and nourishment of 2,830 acres of surrounding marsh in the area bounded by the Lake Pontchartrain shoreline, Chef Menteur Pass, and the levee. Approximately 8.1 million cubic yards of material would be obtained from Lake Borgne Borrow Area 6.
Construction Year 6	
LM3	911 acres of marsh creation and 950 acres of marsh nourishment in South Lake Borgne north of Lena Lagoon in the area bounded by the lake, Bayou St. Malo, MRGO, and Doulets Canal. Approximately 4.6 million cubic yards of borrow to be obtained from Lake Borgne Borrow Area 2.
BM1	8,295 acres of marsh nourishment along the south shore of Lake Borgne. 10.8 million cubic yards of material would be obtained from Lake Borgne Borrow Area 2.
Construction Year 7	
CM1	1,240 acres of marsh nourishment south of Paris Road between cypress restoration feature CC3 and the Chalmette Loop Levee. Approximately 3.0 million cubic yards of material would be dredged from Lake Borgne Borrow Area 5 for this feature.
CM3	300 acres of marsh restoration and 215 acres of marsh nourishment in the area north of Bayou Dupre and south of MRGO. 1.9 million cubic yards of borrow material would be obtained from Lake Borgne Borrow Area 5.
CM4	98 acres of marsh restoration and 129 acres of marsh nourishment south of Bayou Dupre. 900,000 cubic yards of dredged material would be obtained from Lake Borgne Borrow Area 4.
CM5	245 acres of marsh restoration and 70 acres of marsh nourishment in the area north of Bayou Bienvenue and Paris Road. 1.2 million cubic yards of material would be obtained from Lake Borgne Borrow Area 4.
Construction Year 8	
TM7	2,255 acres of marsh restoration and up to 3,338 acres of adjacent marsh nourishment on the east side of Bayou Terre aux Boeufs. 11.5 million cubic yards of material would be obtained from Lake Lery if available, but it is currently assumed that material will be obtained from Lake Borgne Borrow Area 2.

Draft Implementation Plan (used to calculate benefits without O&M)	
Measure	**Description**
TM8	1,511 acres of marsh restoration on the east side of Bayou Terre aux Boeufs in the vicinity of Delacroix. 5.5 million cubic yards of material would be dredged from Lake Lery if possible, but it is currently assumed that material will be obtained from Lake Borgne Borrow Area 2.
EM2	1,095 acres of marsh nourishment on Hog Island, located between the west and east mouth of the West Pearl River. Approximately 2.2 million cubic yards of dredged material would be obtained from Lake Borgne Borrow Area 8.
EM3	861 acres of marsh restoration and 180 acres of adjacent marsh nourishment in the area bounded by Highway 433, Little Lagoon, Salt Bayou and Highway 90. Approximately 3.5 million cubic yards of dredged material would be obtained from Lake Borgne Borrow Area 8.
EM4	2,625 acres of marsh restoration and 1,455 acres of adjacent marsh nourishment in the area bounded by Salt Bayou to the north, the West Pearl River to the east, the Rigolets to the south and Highway 80 to the north. Approximately 10.6 million cubic yards of material would be obtained from Lake Borgne Borrow Area 8.
Construction Year 9	
CC1	1,020 acres of cypress swamp restoration and 953 acres of cypress swamp nourishment in the area north of the existing Violet Canal along the Forty Arpent levee. 8.5 million cubic yards of borrow material to be obtained from Lake Borgne Borrow Area 5.
CC2	250 acres of cypress swamp restoration and 250 acres of swamp nourishment to the northeast of CC1. 2.4 million cubic yards of borrow material to be obtained from Lake Borgne Borrow Area 5.
CC3	370 acres of cypress swamp restoration and 790 acres of swamp nourishment along the Forty Arpent Levee south of Paris Road. Approximately 5.3 million cubic yards of material to be obtained from Lake Borgne Borrow Area 5.
CC4	1,465 acres of cypress swamp restoration in the open water areas adjacent to the Forty Arpent Levee north of Paris Road, including the Bienvenue Triangle area in Orleans Parish. 11.3 million cubic yards of borrow material to be obtained from Lake Borgne Borrow Area 6.
Construction Year 10	
CC5	1,120 acres of swamp restoration and 1,645 acres of swamp nourishment south of the Violet Canal along the Forty Arpent Levee and the Chalmette Loop Levee. 9.6 million cubic yards of borrow material to be obtained from Lake Borgne Borrow Area 4.
CC6	1,028 acres of swamp restoration and 1,540 acres of swamp nourishment in the southwest corner of the Central Wetlands. 11.2 million cubic yards of borrow material would be obtained Lake Borgne Borrow Area 4.
Maintenance As Needed	

Draft Implementation Plan (used to calculate benefits without O&M)	
Measure	**Description**
MRGO2	Repair and maintenance of approximately 15,070 linear feet (2.85 miles) of foreshore protection between Mile 44.4 and 39.9 of the MRGO.
MRGO3	Repair and maintenance of existing approximately 10,420 linear feet (1.97 miles) of foreshore protection between approximately Mile 56 to 51 of the MRGO.
MRGO4	Repair and maintenance of approximately 6,690 linear feet (1.27 miles) of existing retention dike MRGO Miles 36.6 to 37.1 and MRGO Miles 33.9 to 32.9.

Table of Contents

Introduction 8
Threatened, Endangered, and Proposed Threatened or Endangered Species 8
Sensitive Species and Species of Concern 9
Critical Habitat 9
Previous Consultation 9
Purpose 10
Location of the Proposed Action 11
Description of Proposed Action 11
Ridge Restoration Component 13
Proposed Feature BR-1 14
Shoreline Protection Component 15
Proposed Feature BS-1 16
Proposed Feature BS-2 17
Proposed Feature ES-1 17
Proposed Feature ES-2 18
Proposed Feature ES-3 19
Proposed Feature LS-1 20
Swamp Restoration / Nourishment Component 20
Proposed Feature CC-1 21
Proposed Feature CC-2 21
Proposed Feature CC-3 22
Proposed Feature CC-4 23
Proposed Feature CC-5 24
Proposed Feature CC-6 25
Marsh Restoration/ Nourishment Component 25
Proposed Feature BM-1 26
Proposed Feature CM-1 27
Proposed Feature CM-2 28
Proposed Feature CM-3 29
Proposed Feature CM-4 30
Proposed Feature CM-5 31
Proposed Feature EM-1 31
Proposed Feature EM-2 32
Proposed Feature EM-3 33
Proposed Feature EM-4 34
Proposed Feature LM-1 35
Proposed Feature LM-2 36
Proposed Feature LM-3 37
Proposed Feature LM-4 38
Proposed Feature TM-1 39
Proposed Feature TM-2 40
Proposed Feature TM-7 40

Proposed Feature TM-8 41
Proposed Feature HM-1 42
MRGO Shoreline Restoration Component 43
Proposed Feature MRGO-5 44
Proposed Feature MRGO-7 45
Proposed Feature MRGO-8 45
MRGO Shoreline Protection Component 46
Proposed Feature MRGO-1 46
Proposed Feature MRGO-6 47
MRGO Shoreline Repair Component 47
Proposed Feature MRGO-2, 3, &4 47
Access Corridors Component 48
Weir Component 48
Canal Closures 48
Staging Areas 48
Flotation Access Corridors Component 48
Borrow Component and Implementation Schedule 49
Potential Borrow Sources 51
Viable Borrow Sources 53
Mississippi River 53
Lake Lery 54
GIWW/ Michoud Canal 54
MRGO ODMDS 54
Borrow from Lake Borgne, Gulf Sturgeon Critical Habitat 54
Freshwater Diversion Component 56
Threatened and Endangered Species 56
Gulf Sturgeon 56
Description of Species 56
Distribution and Abundance 58
Offshore 58
Mississippi River 59
Lake Pontchartrain Basin 59
Lake Maurepas, Lake Pontchartrain, Lake Catherine, The Rigolets, Lake Borgne, and Mississippi Sound 60
Pearl River and Bogue Chitto River 61
MRGO 62
Tchefuncte/ Bogue Falaya Rivers 63
Tangipahoa River 63
Tickfaw River 63
Amite River 64
Incidental Captures 64
Movements and Migration 64
Food Habits 66
Habitat Association 67
Status and Cause of Decline 71

Pallid Sturgeon 72
Description of Species 72
Distribution and Abundance 74
Movements and Migration 76
Food Habits 77
Habitat Association 78
Status and Cause of Decline 78
West Indian Manatee 80
Description of Species 80
Distribution and Abundance 80
Movements and Migration 81
Food Habits 81
Habitat Association 82
Status and Cause of Decline 82
Piping Plover 83
Description of Species 83
Distribution and Abundance 83
Movements and Migration 84
Food Habits 84
Habitat Association 85
Status and Cause of Decline 85
Green Sea Turtle 87
Description of Species 87
Distribution and Abundance 88
Movements and Migration 89
Food Habits 90
Habitat Association 90
Status and Cause of Decline 90
Hawksbill Sea Turtle 91
Description of Species 91
Distribution and Abundance 92
Movements and Migration 92
Food Habits 93
Habitat Association 93
Status and Cause of Decline 93
Kemp's Ridley Sea Turtle 94
Description of Species 94
Distribution and Abundance 94
Movements and Migration 95
Food Habits 95
Habitat Association 96
Status and Cause of Decline 96
Leatherback Sea Turtle 100
Description of Species 100

Distribution and Abundance.... 100
Movements and Migration.... 100
Food Habits.... 100
Habitat Association.... 100
Status and Cause of Decline.... 101
Loggerhead Sea Turtle.... 102
Description of Species.... 102
Distribution and Abundance.... 103
Movements and Migration.... 103
Food Habits.... 104
Habitat Association.... 104
Status and Cause of Decline.... 104
Anticipated Effects of the Proposed Action.... 105
Gulf Sturgeon.... 105
Pallid and Shovelnose Sturgeon.... 114
West Indian Manatee.... 114
Piping Plover.... 115
Green Sea Turtle.... 116
Kemp's Ridley Sea Turtle.... 116
Loggerhead Sea Turtle.... 116
Hawksbill Sea Turtle.... 116
Leatherback Sea Turtle.... 117
Conclusion.... 117
Figures.... 118
Figure 1: Annual Average Salinity 1959 to 1961.... 118
Figure 2: Annual Average Salinity 1990 to 2008.... 119
Figure 3: Area of influence of Violet diversion combined with proposed Convent/Blind River diversion Structure.... 120
Figure 4: Sub Units of Study Area.... 121
Figure 5: Tentatively Selected Plan.... 122
Figure 6: Project Footprint Detail: BR1.... 123
Figure 7: Project Footprint Detail: BS1.... 124
Figure 8: Project Footprint Detail: BS2.... 125
Figure 9: Project Footprint Detail: ES1.... 126
Figure 10: Project Footprint Detail: ES2.... 127
Figure 11: Project Footprint Detail: ES3.... 128
Figure 12: Theoretical Section of Shoreline Protection.... 129
Figure 13: Project Footprint Detail: CC1.... 130
Figure 14: Project Footprint Detail: CC2/CM3.... 131
Figure 15: Project Footprint Detail: CC3.... 132
Figure 16: Project Footprint Detail: CC4.... 133
Figure 17: Project Footprint Detail: CC5.... 134
Figure 18: Project Footprint Detail: CC6.... 135
Figure 19: Project Footprint Detail: BM1.... 136
Figure 20: Project Footprint Detail:CM1.... 137

Figure 21: Project Footprint Detail: CM2 138
Figure 22: Project Footprint Detail: CM4 139
Figure 23: Project Footprint Detail: CM5 140
Figure 24: Project Footprint Detail: EM1 141
Figure 25: Project Footprint Detail: EM2 142
Figure 26: Project Footprint Detail: EM3 143
Figure 27: Project Footprint Detail: EM4 144
Figure 28: Project Footprint Detail: LM1 145
Figure 29: Project Footprint Detail: LM2/LS1 146
Figure 30: Project Footprint Detail: LM3 147
Figure 31: Project Footprint Detail: LM4 148
Figure 32: Project Footprint Detail: TM1 149
Figure 33: Project Footprint Detail: TM2 150
Figure 34: Project Footprint Detail: TM7 151
Figure 35: Project Footprint Detail: TM8 152
Figure 36: Project Footprint Detail: HM1 153
Figure 37: Project Footprint Detail: MRGO5 154
Figure 38: Project Footprint Detail: MRGO7 155
Figure 39: Project Footprint Detail: MRGO8 156
Figure 40: Project Footprint Detail: MRGO1 157
Figure 41: Project Footprint Detail: MRGO6 158
Figure 42: Project Footprint Detail: MRGO2 159
Figure 43: Project Footprint Detail: MRGO3 160
Figure 44: Project Footprint Detail: MRGO4 161
Figure 45: Flotation Access Footprints 162
Figure 46: Barge Route for Delivery of MR Sediment to BR1 163
Figure 47: USGS Sand Survey for Lake Pontchartrain and Lake Borgne 164
Figure 48: USGS Sand Survey for Lake Borgne 165
Figure 49: Lake Borgne Borrow Site 166
Figure 50: Gulf Sturgeon Critical Habitat Unit 8 167
Figure 51: Gulf Sturgeon Critical Habitat Unit 1 168
Figure 52: Impediments to Gulf Sturgeon Movements 169
Figure 53: Piping Plover Critical Habitat Unit LA-7 170
Figure 54: Lake Borgne Boring Data 171
Figure 55: Lake Borgne Boring Data 172
Figure 56: Lake Borgne Boring Data 173
Figure 57: Lake Borgne Boring Data 174
Figure 58: Lake Borgne Circulation Modeling 175
Figure 59: Lake Borgne Bathymetry 176
Figure 60: MRGO Water Quality 177
Literature Cited 178
Appendix A 184
Appendix B 185
Appendix C 186

Tables

Table 1: Problems Within Study Area..... 11
Table 2: Rock Placement Features: Impact Acres..... 15
Table 3: Borrow and Implementation Plan..... 49
Table 4: Unit Cost of Dredging and Transportation Via Pipeline..... 53
Table 5: Threatened and Endangered Species..... 56

[Cover Photo: MRGO Closure Structure.]

1.0 INTRODUCTION

Section 7(a)(2) of the Endangered Species Act (ESA) of 1973, as amended, requires that *"Each Federal agency shall, in consultation with and with the assistance of the secretary, insure that any action authorized, funded, or carried out by such agency....Is not likely to jeopardize the continued existence of any endangered species or threatened species or result in the destruction or adverse modification of habitat of such species..."*

This Biological Assessment (BA) provides the information required pursuant to the ESA and implementing regulation (50 CFR 402.14), to comply with the ESA. Additional legal authorities include the National Environmental Policy Act (NEPA) of 1969, 42 U.S.C. section 4321, *et seq.;* the Fish and Wildlife Conservation Act of 1958 (PL 85-624; 16 U.S.C. 661 *et seq.*); the Marine Mammal Protection Act of 1972; and the Migratory Bird Treaty Act of 1918. This Biological Assessment (BA) is submitted to the U.S. Fish and Wildlife Service (USFWS) and the National Marine Fisheries Service (NMFS) by the U.S. Army Corps of Engineers (USACE), New Orleans District (MVN) to initiate formal consultation regarding potential impacts to threatened and endangered species from construction and maintenance of the Mississippi River-Gulf Outlet (MRGO), ecosystem restoration plan. The following BA is promulgated in accordance with Section 7 (Interagency Consultation) of the Endangered Species Act of 1973, as amended (PL 93-205; 16 U.S.C. 1531 et. seq.).

The purpose of this biological assessment is to evaluate the effects of the proposed construction and maintenance of the MRGO plan on threatened, endangered and sensitive species and their habitats. Threatened, endangered and proposed threatened and endangered species are managed under the authority of the ESA (PL 93-205), as amended). Under provisions of the ESA, Federal agencies shall use their authorities to carry out programs for the conservation of listed species, and shall insure any action authorized, funded, or implemented by the agency is not likely to: (1) adversely affect listed species or designated critical habitat; (2) jeopardize the continued existence of proposed species; or (3) adversely modify proposed critical habitat (16 USC 1536).

2.0 THREATENED, ENDANGERED, AND PROPOSED THREATENED OR ENDANGERED SPECIES

Gulf Sturgeon (*Acipenser oxyrhynchus desotoi*), was listed as threatened on September 30, 1991 (56 FR 49653). Critical habitat was designated on March 19, 2003 (68 FR 13370-13495).

Pallid Sturgeon (*Scaphirynchus albus*), was listed as endangered throughout its range on October 9, 1990 (55 FR 36641-36647)

Shovelnose Sturgeon (*Scaphirhynchus platorynchus*), was listed as threatened species under the Similarity of Appearance provisions of the ESA on September 1, 2010.

West Indian Manatee (*Trichechus manatus*), was listed as endangered on June 2, 1970 (35 FR 8491)

Piping Plover (*Charadrius melodus*), was listed as threatened and endangered on December 11, 1985 (50 FR, 50720-50734). Critical habitat was designated on July 6, 2000 (50 FR, 41782-41812)

Green Sea Turtle (*Chelonia mydas*), was listed as threatened in U.S. waters, except for the Florida breeding population which was listed as endangered, on July 28, 1978 (43 FR 32800-32811)

Hawksbill Sea Turtle (*Eretmochelys imbricata*), was listed as endangered throughout its range, on June 2, 1970 (35 FR, 8491).

Kemp's Ridley Sea Turtle (*Lepidochelys kempii*), was listed as endangered throughout its range, on December 2, 1970 (35 FR, 18320)

Leatherback Sea Turtle (*Dermochylys coriacea*), was listed as endangered throughout its range, on December 2, 1970 (35 FR, 8491)

Loggerhead Sea Turtle (*Caretta caretta*) was listed as threatened throughout its range on July 28, 1978 (43 FR 32800-32811).

3.0 CANDIDATE SPECIES

No candidate species are found in the project area.

4.0 CRITICAL HABITAT

Critical habitat for the Gulf sturgeon and the piping plover has been designated within the project area. Gulf sturgeon critical habitat (Unit 8) (**Figure 53**) has been designated in Lake Pontchartrain, Lake St. Catherine, The Rigolets, Little Lake, Lake Borgne, and the Mississippi Sound. Piping plover critical habitat unit (LA-7) (**Figure 55**) has been designated in the Chandeleur Island chain. Impacts to critical habitat features are identified in the proposed plan and are discussed later in this document.

5.0 PREVIOUS CONSULTATION

Informal coordination with the USFWS Lafayette, LA office, for the effects to pallid sturgeon from entrainment through diversion structures, has been ongoing since the 2008 operation of the Bonnet Carré Spillway (BCS). Formal consultation with the NMFS, St. Petersburg, FL office for impacts to sea turtles from maintenance dredging of Federal navigation channels throughout the Gulf of Mexico, was concluded by Biological Opinion on November 19, 2003, with revisions made in 2005 and 2007.

Formal consultation with the NMFS, St. Petersburg, FL office, concluded on June 26, 2008, for the MRGO Deep-Draft De-authorization Study, Louisiana project; and Lake Borgne Wetland Creation and Shoreline Protection Project. NMFS provided a Biological Opinion (BO) for this project which detailed conservation recommendations for projects within Gulf sturgeon critical habitat. Some of the proposed borrow areas and access routes in the MRGO Ecosystem Restoration project overlap with those in the aforementioned studies. To date, informal coordination has been ongoing since September 14, 2010 for the proposed action described in this document.

6.0 PURPOSE

The purpose of this study is for MVN to develop a comprehensive ecosystem restoration plan to restore the areas affected by the former MRGO navigation channel as required by Section 7013 of the Water Resources Development Act (WRDA) 2007. The period of analysis for this project begins at project implementation (2015) and extends 50 years into the future from the estimated first year of construction (2065).

The main water resource problems identified in the study area include:

- Land loss
- Bank/ shoreline erosion
- Habitat switching
- Modification of natural hydrology
- Decreased freshwater
- Sediment and nutrient inputs
- Saltwater intrusion
- Retreating and eroding barrier islands
- Ridge habitat degradation
- Invasive Species
- Herbivory
- Increasing susceptibility to storm surge

The Pontchartrain Basin as a whole has been cut-off from the natural flooding of the Mississippi river by the Mississippi River levee system. The loss of freshwater inflow has led to poor productivity of the wetlands partly due to the lack of vital nutrients and sediments. Poor productivity combined with subsidence has left the wetlands vulnerable to saltwater intrusion and sea level rise. As per USGS website, subsidence of land occurs when large amounts of ground water have been withdrawn from certain types of rocks, such as fine-grained sediments. The rock compacts because the water is partly responsible for holding the ground up. Subsidence is attributed to both natural factors and human induced causes such as soil compactions, oil and gas extraction, and groundwater withdrawal. Accretion (soil build-up) is not keeping pace with subsidence as a result of reduced biological productivity and lack of inorganic sediment.

Wetlands in the project area are deteriorating for several reasons: 1) subsidence, 2) lack of sediment and nutrient deposition, 3) erosion via tidal exchange, 4) channelization, 5) saltwater intrusion and 6) lack of freshwater. Recent hurricanes and tropical storms have also caused significant damage to the project area. These activities and events have resulted in the loss of several thousand acres of previously solid, vegetated marsh. Deterioration will continue unless preventative measures are taken.

The natural flow and drainage patterns have been impacted by a complex of levee systems throughout the area, drainage channels, pipelines and other utilities, roadways and most importantly navigation channels. Navigation channels and other channels serve as a conduit for tidal flows and saltwater intrusion subjecting the sensitive marsh to the erosive forces of wind and wave action. **Table 1** lists the problems identified in the planning subunits.

Table 1 : Problems within Study Area	**Problems**							
	Decreased Freshwater, Sediment and Nutrient Inputs	Hydrologic Modification	Saltwater Intrusion	Wetland Loss	Ridge Habitat Degradation and Destruction	Bank and Shoreline Erosion	Habitat Switching	Invasive Species and Herbivory
East and West Manchac Landbridge	X	X	X	X		X	X	X
Northeast Study Area								
Pearl River Mouth – LA, East Orleans Landbridge, and Bayou Sauvage	X	X	X	X		X	X	X
South Lake Borgne	X	X	X	X	X	X	X	X
Central Wetlands	X	X	X	X			X	X
Eastern Study Area								
Biloxi Marshes Interior and Eloi Bay	X	X	X	X	X	X	X	X
Biloxi Marshes Exterior	X	X	X	X		X	X	X
Chandeleur Islands	X	X						
Southern Study Area								
Florissant and Hopedale	X	X	X	X	X	X	X	X
MRGO Spoil Bank	X	X		X	X	X	X	X
Jean Louis Robin	X	X	X	X	X			
Lake Lery	X	X	X	X		X	X	X
Caernarvon North and South and River aux Chenes	X	X	X	X			X	X

The MRGO wetland creation and shoreline protection project would help restore areas where an altered supply and distribution of freshwater, lack of deltaic forming sediments, navigation induced changes, marsh subsistence, and human development in the vicinity of MRGO have resulted in degraded and unbalanced distribution of swamps, freshwater marsh, brackish marsh, and saltwater marsh habitats. Further, the degradation of the existing marshes has made them more vulnerable to the range of Gulf storm events; extreme and seasonal events have resulted in accelerated degradation, altered hydrology and changed salinity regimes.

Over the past 6,000 to 7,000 years, salinity in the study area has shifted with the major deltaic meandering of the Mississippi River. Modern efforts to control flooding and improve

navigation include numerous bank stabilization, channel alignment, dredging, lock, dam, levee, and spillway projects on the Mississippi River. Such alterations to the Mississippi River and surrounding wetlands have increased salinity in the study area by altering the flow of freshwater in the region (USACE 2004). Salt water intrusion in the area has resulted in significant alteration of the existing habitat within the vicinity of the MRGO. The influence of the MRGO on traversed areas and outward into surrounding wetlands, marshes, and waterways was determined by USACE by comparing the findings of investigations conducted prior to channel construction with data collected from these same areas following completion of construction activities (USACE 1999). Alteration of salinity in waters along the channel and outward in adjacent areas was first observed in studies conducted immediately following channel construction (Gagliano et al. 1970, Dugas 1975). Historic salinity levels from 1959-1961 within the project area that existed prior to the construction of the MRGO ship channel are shown in **Figure 1**.

Observations indicate that the influx of more saline water into these areas following MRGO construction provided a continual salinity increase until a level of stabilization was achieved over time. The magnitude of this increase in salinity across the subjected areas are typically a function of numerous hydrological and ecological factors that include the intensity of saline water influx, variation in circulation patterns, and the sensitivity of the habitat within the impacted area. **Figure 2** shows what salinity levels had stabilized at prior to the construction of the MRGO closure which reconnected a breached ridge located south of Bayou La Loutre.

On June 5, 2008, a stone closure structure was authorized. In late July 2009 the MRGO closure project was completed; restoring the hydrological separation once maintained by the ridge at Bayou La Loutre. Since the completion of MRGO closure salinity levels have begun to decrease in interior marshes of the project area. It is unknown what salinity within these areas will stabilize at without the input of freshwater. To further return salinity levels to those which existed prior to the MRGO construction a freshwater diversion has been included in the proposed action. A fresh water diversion in the vicinity of Violet (FWDV) would ensure that swamp restoration features within the central wetlands area have salinity levels that are tolerated by cypress, tupelo, and other freshwater wetland woodland species. Though a diversion feature has been tentatively selected, the FWDV is being deferred for this component of the proposed action. Once feasibility design is complete a supplemental assessment would be completed. **Figure 3** shows the area of influence that the tentatively selected FWDV would have when combined with other proposed diversions in the study area (i.e. LCA Small Diversion at Convent/Blind River).

The sustainability of the coastal ecosystems is threatened by the inability of many wetlands to maintain their surface elevation. Any alterations which excessively waterlog marsh soils result in soil chemical changes that most marsh plants can't survive. Once plants die, roots no longer provide structure and integrity to marsh soils, and land loss results. Approximately 63,178 acres of land are estimated to have been lost in the study area from 1985 through 2010. Approximately 131,091 acres are projected to be lost between 2010 and 2065 (MRGO land loss workbook) within the study area.

In the absence of supplemental freshwater and sediment from the Mississippi River, subsidence, sea-level rise, wave erosion, and saltwater intrusion will continue to be problems. Protection and enhancement of this area are dependent on providing a hydrologic and sediment regime that minimizes the physiological stress to wetland vegetation from saltwater intrusion and tidal energy and is conducive to the retention of locally provided freshwater and sediments

6.0 LOCATION OF THE PROPOSED ACTION

The study area includes portions of the Mississippi River Deltaic Plain within coastal southeast Louisiana and parts of southwest Mississippi. The study area encompasses approximately 3.86 million acres (over 6,000 square miles). The study area was developed to encompass the Lake Pontchartrain Basin, with a focus on areas that may have been affected by the construction, operation, maintenance, or disposition of the former MRGO navigation channel. The MRGO channel may have affected salinity as far west as Lake Maurepas. To the east, the MRGO channel was dredged through open water between Breton and Grand Gossier Islands (segments of the lower Chandeleur Island chain). The MRGO channel affected portions of the Lake Borgne ecosystem to the north and potentially altered hydrology to the west as far as the Bayou Terre aux Boeuf ridge. In Mississippi, the study area includes the Western Mississippi Sound, its bordering wetlands, and Cat Island. In Louisiana, the study area includes the Pontchartrain Basin which is comprised of the Upper, Middle and Lower Sub-basins. The study area is shown in **Figure 4.**

The restoration measures under consideration for this project are located in the eastern portion, or Lower Pontchartrain sub-basin, of the overall study area. Due to the absence of project related construction features in large portions of the study area, the study area was reduced to facilitate ease of discussion of existing conditions and potential impacts to T&E species from the proposed action. The "smaller" study area that was focused on for discussion in this BA includes: the East Orleans Landbridge, Lake Borgne and associated marsh, the Biloxi Marsh, and Terre aux Boeufs Marsh and is herein referenced as the project area. This area includes subunits 5 through 7, 10 through 15, 17 through 19, 21 through 23, 26, 27, 32, 36a, 38, and 40 as shown in **Figure 4**. Plan C, the tentatively selected plan (TSP) (**Figure 5**), would restore and protect approximately 58,531 acres of habitat in the project area, including 43,567 acres of wetlands in the Lower Pontchartrain sub-basin, 10,431 acres of cypress swamp, and 48 acres of ridge habitat. It would also provide approximately 76 miles or 2,127 acres of shoreline protection.

7.0 DESCRIPTION OF THE PROPOSED ACTION

7.1 Ridge Restoration Component:

A ridge restoration feature is proposed on the south side of Bayou La Loutre. Restoration would consist of the placement of dredged silty sand material to be obtained from the Mississippi River. The initial elevation of the ridge would be approximately +8 feet, with a crown width of 25 feet and 1:8 side slopes. The base width of the ridge would vary, with an average width of approximately 120 feet. A 50 foot access corridor on the south side would be designated for

construction equipment. Access along Bayou La Loutre may require excavation to the channel's authorized depth. If excavation is required material excavated for floatation will be placed in the footprint of the proposed ridge restoration work. The ridge would be planted to develop forested habitat as described in the planting plan for this study.

7.1.1 Proposed Feature BR 1

Feature BR 1 calls for restoration of a portion of the Bayou La Loutre ridge (**Figure 6**). The area designated for ridge restoration is located immediately north of the MRGO, where Bayou La Loutre intersects the MRGO, and extends downstream along the south bank of Bayou La Loutre for a distance of approximately 17,500 feet.

The project will consist of restoring the ridge to an initial elevation of approximate +8' to achieve a desired final design elevation after consolidation of +6'. The ridge would have a crown width of 25' and side slopes of 1V on 8H. While the base width of the ridge will vary with the topography, the average base width would be approximate 120', assuming a natural ground elevation was +2'. A 50' access corridor along the backside would be made available for equipment necessary for hauling, moving and shaping of the material being placed at the site for restoration of the ridge.

The ridge would be constructed of silty sand and the borrow material would come from the Mississippi River, the MRGO ODMDS site, or the Bonnet Carre spillway. For this report, borrow from the Mississippi River, would be used and borrow obtained between river miles 83R and 85R. The excavated material would be loaded on barges and then transported to the ridge restoration site via the IHNC, MRGO/GIWW, Chef Pass, Lake Borgne, Martello Channel and the MRGO downstream to Bayou La Loutre. This would be an approximate 54 mile transit (one way). This one-way transit distance is in line with the distance that would have to be transited if the material were borrowed from the MRGO ODMDS site and transported by barges through Breton Sound to Bayou La Loutre. Approximately 425,000 cubic yards of silty sand would be required.

Access along Bayou La Loutre may require excavation. If excavation is required, excavation for floatation access would be allowed to -6' by 60' width, and the permissible excavation is defined by the theoretical section depicted on the feature drawing. Material excavated for floatation would be placed within the footprint of the proposed ridge restoration work. Access to bayou La Loutre is available via the GIWW, Breton Sound, Lake Borgne, the MRGO, and other navigable waterways, as well as state and local highways.

As surveys were not available for this phase of the study, in order to estimate the amount of cubic yards of borrow and fill required, it was assumed that the average existing natural ground elevation along the reach proposed for restoration was +2'.

7.2 Shoreline Protection Component:

These features consist of either foreshore (shore between high water and low water) rock dikes or rock dikes placed near the existing shoreline to dissipate wave energy before it reached the shoreline as shown in the plan views. Foreshore rock dikes would be constructed by placing rock in a linear mound at the -1.5 to -2.0-foot depth contour, to a height above the water's surface (see **Figure 12** for a theoretical detail view of this detail). Height will be determined based on existing site conditions. Nearshore (beginning at foreshore and extending to the beginning of the offshore zone) rock dikes would be constructed in places where the bathymetry prohibits a foreshore dike (water deepens quickly from the shore). Rock used for dike construction would be graded large enough to resist movement during high energy events, such as frontal passages. Shoreline protection features include 25' gapes every 1000' for organism access, navigation, and water exchange, as noted in the plan view for each feature. Impacts expected from this work are detailed in **Table 2**.

Several different feature alternatives are proposed in the restoration of the project area, including shoreline protection to stabilize existing bank lines to promote plant growth, limit shoreline erosion, reduce bankline recession and interior marsh loss, and provide general stability to the existing topography.

Table 2: ROCK PLACEMENT FEATURES: IMPACT ACRES

MRGO ECOSYSTEM RESTORATION

Element Number	Impact Acres Rock/Marsh Placement	Impact Acres Flotation Excavation	Impact Acres Flotation Placement	Access Corridor	Total Impact Acres
ES1	13	22	22	2	59
ES2	53	83	80	10	226
ES3	121	192	187	19	519
LS1	79	123	120	14	336
BS1	88	138	134	14	374

Preliminary alternative analysis and screening to develop a tentatively selected plan maintained seven (7) shoreline protection features in the final array of alternatives. These shoreline protection features are described in the following pages. Specifically, two (2) features are located in Lake Pontchartrain (ES1 & ES2), three (3) features are located in Lake Borgne (ES3, LS1, & BS1), and two oyster reef (2) features are located in Breton Sound; vicinity of the MRGO Jetty.

The Lake Pontchartrain features assist in protecting existing infrastructure, and the existing land bridge between Lake Pontchartrain and Lake Catherine. The Lake Borgne features will minimize shoreline erosion and provide protection to existing marsh habitat. Historic shoreline erosion rates were obtained from Zganjar et al. The Breton Sound features will be constructed as breakwater features, protecting the interior land features from wind driven waves out of Breton Sound. All completed structures will provide viable habitat and protection for various aquatic species.

Preliminary hydraulic analysis was performed to provide minimal foreshore criteria such as stone size, dike crown width and height. These designs will be advanced upon completion of site specific hydrographic/topographic surveys and analysis of geotechnical considerations; both of which are currently ongoing. Dike alignment will be determined, based on water depths and bankline profile at the proposed placement site. All lake shoreline protection features will be constructed using the following stone proposed stone gradation:

Stone (Weight in Pounds)	Percent Finer by Weight
1500-600	100
650-300	50
330-100	15

Preliminary survey data has been obtained for the Breton Sound shoreline protection reaches. Preliminary geotechnical analysis indicates that rock structures in these water depths would require significant stability berms in addition to additional unanticipated rock quantities to reach desired height of protection. Due to these greater than anticipated water depths at the project sites and associated significant feature construction cost increases, JS1 and BS2 are no longer in any of the plans. This additional stone requirement rendered the features no longer cost-effective. BS2 will now be designated as an oyster reef demo area as a result of significant public comment that artificial oyster reefs should be a component of the plan, as surveys indicate this area would be suitable.

Descriptions of the remaining lake shoreline protection features, and general information on a proposed oyster reef element are as follows:

7.2.1 Proposed Feature BS-1

Element BS1 is located along the northeast shoreline of Lake Borgne (**Figure 7**). The project can be described as a nearshore stone dike, constructed along the existing water's edge for the purpose of shoreline protection. In conjunction with several other completed and proposed shoreline protection efforts, this reach of proposed work will complete shoreline protection of the entire south lobe of Lake Borgne. This rock feature will tie into a reach of shoreline protection proposed under the State DNR CIAP efforts, beginning at Pointe Aux Marchettes and extending north east for approximately 10 miles. This project will halt shoreline erosion, protect an estimated 51,000 feet of shoreline. The foreshore dike alignment intersections several natural bayous and canals which open up into Lake Borgne, and allow tidal interaction. These natural openings will be accommodated with gaps in the foreshore dike to allow continued fish and wildlife access into the interior marshes.

Foreshore rock protection is proposed for construction to stop wind driven wave erosion, and enlargement of natural openings into the marsh platform. Continued erosion along this reach will result in further fragmentation of the shoreline, increased tidal influence into the marsh, and accelerated recession of the shoreline. This area is currently eroding at approximately 2 feet per year due to storm and wind driven wave erosion. The rock protection will be configured as a linear near shore dike section. The proposed dike will be located at the approximate -2.0 to -3.0

foot contour. The dike will be constructed to an elevation of +4.0 NAVD88 with a 5-foot crown width. The dike will be constructed of a graded 1500# top size stone, underlain with a geotextile fabric to minimize settlement. Flotation dredging is anticipated for access to the site for construction equipment and material barges. Flotation excavation along the dike alignment will be limited to an 80-foot bottom width channel not to exceed elevation -8.0 NAVD88. Barge access to the site is available via the GIWW through the Rigolets and across Lake Borgne. It is currently estimated that 550,000 tons of stone and 240,000 square yards of separator geotextile fabric will be required to complete this construction effort. Surveys and borings are currently being analyzed to determine the stability of the proposed dike section, and adequacy of anticipated settlement. Results of this analysis could result in the requirement for stone stability berms, increasing the anticipated cost of this construction feature.

7.2.2 Proposed Feature BS-2

Breton Sound Shoreline Protection features were eliminated from further consideration due to greater than anticipated water depths at the project sites and associated significant feature construction cost increases. In lieu of total elimination, it was decided to replace the proposed stone foreshore feature at BS2 (**Figure 8**) with various bio-engineered oyster reef units. In addition to simple placement of limestone pads to enhance and maintain oyster growth, several technical solutions to oyster reef construction exist that can be implemented into this Element design, including but not limited to concrete rings, metal frames, geotextile filled bags, etc. The Element BS2 footprint encompassed approximately 7 miles of shoreline, north of the MRGO and adjacent to the outer marsh fringe of Eloi Bay immediately south of Bayou La Loutre. It is envisioned that oyster reef units can be established in approximately mile long increments, with appropriate spacing and bedding as required to result in functioning units. Approximately four miles of oyster habitat construction is assumed for this planning effort.

7.2.3 Proposed Feature ES-1

Element ES1 is located in eastern Lake Pontchartrain (**Figure 9**). The actual work limits are bounded by a rail road bridge and existing shoreline protection above the I-10 to the north, and extends south to the existing CWPPRA Bayou Chevee shoreline protection project to the south. The project will be constructed as a nearshore stone dike, constructed along the existing water's edge for the purpose of reducing shoreline erosion and protection of existing infrastructure and adjacent marsh. This project will halt shoreline erosion, protect an estimated 24,100 feet of shoreline. The foreshore dike alignment intersections several natural openings and canals which open up into the Lake Pontchartrain Middle Ground. These natural openings will be accommodated with gaps in the foreshore dike to allow continued fish and wildlife access into the interior marshes, as well as boat access into the Irish Bayou Community. Project alignment will also be gapped at the crossing for the I-10 and US-11 corridor.

A rock foreshore dike will be constructed to a crown elevation of +3.5' with a 5' crown and 1V on 2H side slopes. The dike will be constructed of a graded 1500# top size stone, underlain with a geotextile fabric to minimize settlement. Flotation dredging is anticipated for access to the site for construction equipment and material barges. Flotation excavation along the

dike alignment will be limited to an 80-foot bottom width channel not to exceed elevation -8.0 NAVD88. Barge access to the site is available via the GIWW through Chef Pass or via IHNC and across Lake Pontchartrain. South of the I-10, two gaps in the foreshore dike alignment are proposed; the first a navigation gap at the entrance to the Irish Bayou area, and the second a water access gap to the open water areas west of the existing shoreline. The northern half of this project reach appears to front a fairly unbroken shoreline. As such the alignment will be placed immediately fronting this shoreline, with all required flotation material being cast lakeward. The southern half of the project alignment offers a more broken shoreline. The required flotation excavation will be cast landward of the dike alignment in an effort to beneficially use this material to restore the shoreline embankment. Flotation will be limited to a channel not to exceed 80' bottom width at a maximum depth of -8.0 NAVD88. Access corridors will be allowed to accommodate barge movement during construction. The corridors, if used, will be spaced approximately 1 mile apart, with a bottom width not to exceed 100'. Material from the access corridors will be side cast and backfilled upon completion of construction. It is currently estimated that 223,000 tons of stone and 104,000 square yards of separator fabric will be required to complete this construction effort. Surveys and borings are currently being analyzed to determine the stability of the proposed dike section, and adequacy of anticipated settlement.

7.2.4 Proposed Feature ES-2

Element ES2 is located in eastern Lake Pontchartrain (**Figure 10**), in an area sometimes defined as "Middle Ground". The work limits are bounded by Chef Pass and the Rigolets. The site is broken out into three separate reaches, separated by existing camps and similar structures.

This reach of Lake Pontchartrain shoreline fronts a critical land bridge between Lake Pontchartrain and Lake Catherine, and affords a barrier between Lake Pontchartrain and the GIWW. The project will be constructed as a nearshore stone dike, constructed along the existing water's edge for the purpose of reducing shoreline erosion and protection of existing infrastructure and adjacent marsh. This project will halt shoreline erosion and protect an estimated 30,750 non-continuous feet of shoreline. The foreshore dike alignment intersections several natural openings and canals which open up into the Lake Pontchartrain Middle Ground. These natural openings will be accommodated with gaps in the foreshore dike to allow continued fish and wildlife access into the interior marshes.

A rock foreshore dike will be constructed to a crown elevation of +3.5' with a 5' crown and 1V on 2H side slopes. The dike will be constructed of a graded 1500# top size stone, underlain with a geotextile fabric to minimize settlement. Flotation dredging is anticipated for access to the site for construction equipment and material barges. Flotation excavation along the dike alignment will be limited to an 80-foot bottom width channel not to exceed elevation -8.0 NAVD88. Barge access to the site is available via the GIWW through Chef Pass or the Rigolets. The project alignment offers a fairly broken shoreline. The required flotation excavation will be cast landward of the dike alignment in an effort to beneficially use this material to restore the shoreline embankment where possible. Flotation will be limited to a channel not to exceed 80' bottom width at a maximum depth of -8.0 NAVD88. Access corridors will be allowed to accommodate barge movement during construction. The corridors, if used, will be spaced

approximately 1 mile apart, with a bottom width not to exceed 100'. Material from the access corridors will be side cast and backfilled upon completion of construction. It is currently estimated that 218,000 tons of stone and 120,000 square yards of separator fabric will be required to complete this construction effort. Surveys and borings are currently being analyzed to determine the stability of the proposed dike section, and adequacy of anticipated settlement.

7.2.5 Proposed Feature ES-3

Element ES3 is located in the northwest quadrant of Lake Borgne (**Figure 11**). The project is fronting the GIWW and ultimately Lake Catherine. The project can be described as a nearshore stone dike, constructed along the existing water's edge for the purpose of reducing shoreline erosion and protection of adjacent marsh. In conjunction with several other completed and proposed shoreline protection efforts, this reach of proposed work will complete protection of the entire Lake Borgne shoreline south of the Rigolets. This rock feature will tie into a reach of shoreline protection proposed under the State DNR CIAP efforts (Orleans Land bridge Shoreline Protection Project, PO-36), beginning at Alligator Point and extending north approximately 14 miles to the Rigolets. This project will halt shoreline erosion, protect an estimated 70,300 feet of shoreline. The foreshore dike alignment intersections several natural bayous and canals which open up into Lake Borgne. These natural openings will be accommodated with gaps in the foreshore dike to allow continued fish and wildlife access into the interior marshes.

Foreshore rock protection is proposed for construction to stop wind driven wave erosion, and enlargement of natural openings into the marsh platform. This reach of Lake Borgne shoreline fronts a critical land bridge between Lake Borgne and Lake Catherine, and affords a barrier between Lake Borgne and the GIWW. The bankline of Lake Borgne fronts numerous openings into the marsh, which allow tidal interaction. Continued erosion along this reach will result in further fragmentation of the shoreline, increased tidal influence into the marsh, and accelerated recession of the shoreline. This area is currently eroding at approximately 6-9 feet per year due to storm and wind driven wave erosion. The rock protection will be configured as a linear near shore dike section. The proposed dike will be located at the approximate -2.0 to -3.0 foot contour. The dike will be constructed to an elevation of +4.0 NAVD88 with a 5-foot crown width. The dike will be constructed of a graded 1500# top size stone, underlain with a geotextile fabric to minimize settlement. Flotation dredging is anticipated for access to the site for construction equipment and material barges. Flotation excavation along the dike alignment will be limited to an 80-foot bottom width channel not to exceed elevation -8.0 NAVD88. Barge access to the site is available via the GIWW through the Rigolets and across Lake Borgne. It is currently estimated that 575,000 tons of stone and 290,000 square yards of separator fabric will be required to complete this construction effort. Surveys and borings are currently being analyzed to determine the stability of the proposed dike section, and adequacy of anticipated settlement. Results of this analysis could result in the requirement for stone stability berms, increasing the anticipated cost of this construction feature.

7.2.6 Proposed Feature LS-1

Element LS1 is located in southern Lake Borgne (**Figure 29**), to be constructed along the perimeter of Proctor Point between the eastern and western lobes of Lake Borgne. The project can be described as a nearshore stone dike, constructed along the existing water's edge for the purpose of shoreline protection. This rock feature is bounded by the proposed $75 million supplemental Bayou Dupre rock project to the west, and the proposed $75 million supplemental West of Shell Beach shoreline protection project to the east; extending along the lake shoreline for approximately 8.9 miles. This project will halt shoreline erosion, protect an estimated 46,000 feet of shoreline, and assist in retention of dredged material for future proposed marsh creation/nourishment efforts on Proctor Point (Element LM2).

Foreshore rock protection is proposed for construction to stop wind driven wave erosion. The bankline of Lake Borgne in this area is eroding at approximately 4 feet per year due to storm and wind driven wave erosion. Critical breaches in the shoreline are impacting interior wetland habitat including shallow water ponds and vegetated marshes. The rock protection will be configured as a linear near shore dike section. The proposed dike will be located at the approximate -1.0 foot contour, with the lakeside toe at the approximate -3.0 NAVD88 contour.

The dike will be constructed to an elevation of +4.0 NAVD88 with a 5-foot crown width. The dike will be constructed of a graded 1500# top size stone, underlain with a geotextile fabric to minimize settlement. Moderate flotation dredging is anticipated for access to the site for construction equipment and material barges. Flotation excavation along the dike alignment will be limited to an 80-foot bottom width channel not to exceed elevation -8.0 NAVD88. Barge access to the site is available via the GIWW through Chef Pass. It is currently estimated that 492,000 tons of stone and 210,000 square yards of separator geotextile will be required to complete this construction effort. Surveys and borings are currently being analyzed to determine the stability of the proposed dike section, and adequacy of anticipated settlement. Results of this analysis could result in the requirement for stone stability berms, increasing the anticipated cost of this construction feature.

7.3 Swamp Restoration/ Nourishment Component:

Swamp restoration is proposed in areas that were historically cypress-tupelo swamps and are currently shallow water. Swamp restoration consists of pumping dredged material from study area borrow areas, as noted for each feature, to a maximum elevation of +4.5 feet within containment dikes. Swamp restoration areas would be planted with cypress. The construction of swamp restoration features is similar to marsh restoration features as described above. Swamp restoration features would have a dewatered and settled target elevation of approximately 2 ft. to support cypress habitat.

Swamp nourishment is proposed for areas that are currently at marsh elevation, and consists of placing a layer of dredged material to nourish the area, raise elevation to approximately +2ft, and encourage the recruitment of cypress-tupelo community species. The

depth of the layer of dredged material will be determined on a site-by-site basis to adjust for varying topography.

7.3.1 Proposed Feature CC 1

Feature CC 1 is a swamp restoration feature located south of the MRGO and within the Central Wetlands in St. Bernard Parish, LA **(Figure 13)**. The project area is immediately adjacent to the 40 Arpent levee and Bayou Dupre/Violet Diversion channel.

The project will consist of restoring approximately 1,020 acres of open water to an elevation conducive to swamp creation/restoration, along with the nourishment of approximately 953 acres of adjacent wetlands, through dedicated dredging of material to be borrowed from Lake Borgne via hydraulic dredge. Approximately 6 million cubic yards (mcy) of borrow will be required for this swamp restoration and nourishment feature. The material will be transported directly to the swamp restoration and nourishment site via pipeline. Access for the dredge pipeline from Lake Borgne will be via Dupre Cut/Martello Channel, the MRGO channel and south bank disposal area, and Bayou Dupre.

The dredge material will be placed to a maximum slurry elevation of +4.5', and dredge effluent waters will be returned to either adjacent marshes for nourishment, and/or Bayou Dupre. Approximately 27,200' of earthen retention dike will be constructed from adjacent borrow and 2' of freeboard will be maintained at all times during pumping operations. The earthen dikes shall also be constructed to an approximate 5' crown width, slopes no steeper than 1V on 3H, and with a minimum 40' interior berm to be maintained between the inside toe of the earthen dikes and the top of cut of the adjacent borrow pits. In addition to the earthen dike, it is estimated that three

Three closures, totaling approximately 700' in length, will be required along the west bank of Bayou Dupre in order to retain the dredge slurry. The closures would consist of vinyl sheet pile, between 25' to 30' in length, along with timber piles spaced 6' to 8' on center.

As surveys were not available for this phase of the study, in order to estimate the amount of cubic yards of borrow required, it was assumed that the existing elevation within the swamp restoration site is an approximate average elevation of -1.0' and that the adjacent marsh is an approximate average elevation of +1.5'.

Ingress and egress to the site would be via the GIWW, Chef Pass, Lake Borgne, the MRGO, and Bayou Dupre, as well as Federal, State and local highways.

7.3.2 Proposed Feature CC 2

Feature CC 2 is a swamp restoration feature located south of the MRGO and within the Central Wetlands in St. Bernard Parish, LA **(Figure 14)**. The project area is immediately adjacent to Feature CC 1, the back dike canal adjacent to the MRGO south bank disposal area, and Bayou Dupre/Violet Diversion channel.

The project will consist of restoring approximately 250 acres of open water to an elevation conducive to swamp creation/restoration, along with the nourishment of approximately 250 acres of adjacent wetlands, through dedicated dredging of material to be borrowed from Lake Borgne via hydraulic dredge. Approximately 1.7 mcy of borrow will be required for this swamp restoration and nourishment feature. The material will be transported directly to the swamp restoration and nourishment site via pipeline. Access for the dredge pipeline from Lake Borgne will be via Dupre Cut/Martello Channel, the MRGO channel, a 300' access corridor across the south bank disposal area, and a 300 access corridor leading from the back dike canal to Feature CC 2.

The dredge material will be placed to a maximum slurry elevation of +4.5', and dredge effluent waters will be returned to either adjacent marshes for nourishment, and/or Bayou Dupre. Approximately 11,450' of earthen retention dike will be constructed from adjacent borrow and 2' of freeboard will be maintained at all times during pumping operations. The earthen dikes shall also be constructed to an approximate 5' crown width, slopes no steeper than 1V on 3H, and with a minimum 40' interior berm to be maintained between the inside toe of the earthen dikes and the top of cut of the adjacent borrow pits. In order to assist in the development of the swamp restoration site, approximately 5900' of interior earthen weirs will be constructed from adjacent borrow. The earthen weirs will be constructed to an elevation of +3.5 to +4.0', to an approximate minimum 5' crown width, side slopes no steeper than 1V on 3H, and with a minimum 40' interior berm to be maintained between the inside toe of the weirs and the top of cut of the adjacent borrow pits.

As surveys were not available for this phase of the study, in order to estimate the amount of cubic yards of borrow required, it was assumed that the existing elevation within the swamp restoration site is an approximate average elevation of -0.5' and that the adjacent marsh is an approximate average elevation of +1.5'.

Ingress and egress to the site would be via the GIWW, Chef Pass, Lake Borgne, the MRGO, the back dike canal, and Bayou Dupre, as well as Federal, State and local highways.

7.3.3 Proposed Feature CC 3

Feature CC 3 is a swamp restoration feature located south of the MRGO and within the Central Wetlands in St. Bernard Parish, LA (**Figure 15**). The project area is immediately adjacent to the 40 Arpent levee and Paris Road.

The project will consist of restoring approximately 370 acres of open water to an elevation conducive to swamp creation/restoration, along with the nourishment of approximately 790 acres of adjacent wetlands, through dedicated dredging of material to be borrowed from Lake Borgne via hydraulic dredge. Approximately 3.7 mcy of borrow will be required for this swamp restoration and nourishment feature. The material will be transported directly to the swamp restoration and nourishment site via pipeline. Access for the dredge pipeline from Lake Borgne will be via a 300' access corridor across the MRGO north bank, the MRGO channel, and

a 300 access corridor leading from the MRGO and crossing the south bank disposal area, the back dike canal and Feature CM1.

The dredge material will be placed to a maximum slurry elevation of +4.5', and dredge effluent waters will be returned to either adjacent marshes for nourishment, and/or Bayou Dupre. Approximately 24,150' of earthen retention dikes and 5,100' of closures will be constructed. At this time, as surveys and borings are currently not available, it is being assumed that the closures will be earthen and constructed from adjacent borrow, with a 2' of freeboard to be maintained at all times during pumping operations. The earthen dikes and closures will also be constructed to an approximate 5' crown width, slopes no steeper than 1V on 3H, and with a minimum 40' interior berm to be maintained between the inside toe of the earthen dikes and the top of cut of the adjacent borrow pits.

As surveys were not available for this phase of the study, in order to estimate the amount of cubic yards of borrow required, it was assumed that the existing elevation within the swamp restoration site is an approximate average elevation of -3.0' and that the adjacent marsh is an approximate average elevation of +1.5'.

Ingress and egress to the site would be via the GIWW, Chef Pass, Lake Borgne, the MRGO, the back dike canal, and Bayou Dupre, as well as Federal, State and local highways.

7.3.4 Proposed Feature CC 4

Feature CC 4 is a swamp restoration feature located south of the GIWW/MRGO (Reach 1) and within the Central Wetlands in Orleans and St. Bernard Parishes, LA (**Figure 16**). The project area is located between the IHNC and Paris Road, and immediately adjacent to and north of the 40 Arpent levee.

The project will consist of restoring four (4) areas of open water, totaling approximately 1465 acres in size, to an elevation conducive to swamp creation/restoration through dedicated dredging of material to be borrowed from Lake Borgne via hydraulic dredge. Approximately 10.4 mcy of borrow will be required for this swamp restoration feature. The material will be transported directly to the four (4) swamp restoration sites via pipeline. Access for the dredge pipeline from the GIWW/MRGO will be via 3- 300' access corridors extending across the MRGO south bank disposal area, as well as Feature CM 2.

The dredge material will be placed to a maximum slurry elevation of +4.5', and dredge effluent waters will be returned to Bayou Bienvenue and/or Feature CM 2 which is adjacent to Sites 2, 3 and 4 of Feature CC 4. Approximately 54, 100' of retention features would be required. At this time, as borings are currently not available, it is being assumed that the closures will be earthen and constructed from adjacent borrow, with a 2' of freeboard to be maintained at all times during pumping operations. However, it is possible that geotechnical investigations could warrant alternative types of retention features such as sheet pile. This assessment will be completed prior to completion of the final feasibility report. The earthen dikes and closures will be constructed to an approximate 5' crown width, slopes no steeper than 1V on 3H, and with a

minimum 40' interior berm to be maintained between the inside toe of the earthen dikes and the top of cut of the adjacent borrow pits.

As surveys were not available for this phase of the study, in order to estimate the amount of cubic yards of borrow required, it was assumed that the existing elevations within the swamp restoration sites could range from -1.0' to -3.0' and that the adjacent marsh is an approximate average elevation of +1.5'.

Ingress and egress to the site would be via the GIWW/MRGO, Chef Pass, Lake Borgne, and Bayou Bienvenue, as well as Federal, State and local highways.

7.3.5 Proposed Feature CC 5

Feature CC 5 is a swamp restoration feature located south of the MRGO and within the Central Wetlands in St. Bernard Parish, LA (**Figure 17**). The project area is immediately adjacent to and east of the Bayou Dupre/Violet Diversion channel and the 40 Arpent levee.

The project will consist of restoring approximately 1120 acres of open water to an elevation conducive to swamp creation/restoration, along with the nourishment of approximately 1645 acres of adjacent wetlands, through dedicated dredging of material to be borrowed from Lake Borgne via hydraulic dredge. Approximately 7.8 mcy of borrow will be required for this swamp restoration and nourishment feature. The material will be transported directly to the swamp restoration and nourishment site via pipeline. Access for the dredge pipeline from Lake Borgne will be via Dupre Cut/Martello Channel, the MRGO channel and south bank disposal area, as well as Bayou Dupre and the Tennessee Gas pipeline canal that crosses through the northern half Feature CC 5.

The dredge material will be placed to a maximum slurry elevation of +4.5', and dredge effluent waters will be returned to either adjacent marshes for nourishment, Bayou Dupre, and/or the Tennessee Gas pipeline canal. Approximately 37,700' of earthen retention dike will be constructed from adjacent borrow and 2' of freeboard will be maintained at all times during pumping operations. The earthen dikes shall also be constructed to an approximate 5' crown width, slopes no steeper than 1V on 3H, and with a minimum 40' interior berm to be maintained between the inside toe of the earthen dikes and the top of cut of the adjacent borrow pits.

As surveys were not available for this phase of the study, in order to estimate the amount of cubic yards of borrow required, it was assumed that the existing elevation within the swamp restoration site is an approximate average elevation of -0.5' and that the adjacent marsh is an approximate average elevation of +1.5'.

Ingress and egress to the site would be via the GIWW, Chef Pass, Lake Borgne, the MRGO, and Bayou Dupre, as well as Federal, State and local highways.

7.3.6 Proposed Feature CC 6

Feature CC 6 is a swamp restoration feature located south of the MRGO and within the Central Wetlands in St. Bernard Parish, LA (**Figure 18**). The project area is immediately adjacent to the back canal behind the MRGO south bank disposal area, and Bayou Dupre/Violet Diversion channel.

The project will consist of restoring approximately 1028 acres of open water to an elevation conducive to swamp creation/restoration, along with the nourishment of approximately 1,540 acres of adjacent wetlands, through dedicated dredging of material to be borrowed from Lake Borgne via hydraulic dredge. Approximately 5.2 mcy of borrow will be required for this swamp restoration and nourishment feature. The material will be transported directly to the swamp restoration and nourishment site via pipeline. Access for the dredge pipeline from Lake Borgne will be via Dupre Cut/Martello Channel, the MRGO channel and south bank disposal area, Bayou Dupre, the Tennessee Gas pipeline canal that crosses through the southern half Feature CC 6, and the back dike canal.

The dredge material will be placed to a maximum slurry elevation of +4.5', and dredge effluent waters will be returned to either adjacent marshes for nourishment, and/or Bayou Dupre. Approximately 31,600' of earthen retention dike will be constructed from adjacent borrow and 2' of freeboard will be maintained at all times during pumping operations. The earthen dikes shall also be constructed to an approximate 5' crown width, slopes no steeper than 1V on 3H, and with a minimum 40' interior berm to be maintained between the inside toe of the earthen dikes and the top of cut of the adjacent borrow pits. In addition to the earthen dikes, it is estimated that three (3) closures, totaling approximately 1000' in length, will be required in order to retain the dredge slurry. The closures would be earthen, constructed from adjacent borrow, and would be breached upon completions of the project.

As surveys were not available for this phase of the study, in order to estimate the amount of cubic yards of borrow required, it was assumed that the existing elevation within the swamp restoration site is an approximate average elevation of -1.0' and that the adjacent marsh is an approximate average elevation of +1.5'.

Ingress and egress to the site would be via the GIWW, Chef Pass, Lake Borgne, the MRGO, and Bayou Dupre, as well as Federal, State and local highways.

7.4 Marsh Restoration/Nourishment Component:

A hydraulic dredge would be used to discharge slurry into shallow water areas and degraded marsh areas. Material would be obtained from study area borrow sites as noted for each feature. Slurry would be discharged to an elevation conducive to the development of wetlands habitat following dewatering and compaction. It is anticipated that the final result of this dredged material placement would be a combination of wetlands, mud flat, and shallow water habitat within the placement site. Following compaction and dewatering, the area would

be planted with marsh vegetation appropriate for the site. Material would be allowed to overflow over existing emergent marsh vegetation within the proposed restoration area.

Retention dikes, deflection dikes, and/or closures may be used to contain material as noted in the plan view for each feature. Dikes will be from adjacent borrow with a 2' freeboard (+6.0') and consist of a minimum 5' crown width and slopes no steeper than 1 on 3 and min 40' interior berm. All retention dikes for marsh creation and nourishment features will include an opening with a minimum width of 100 feet to accommodate the escape of any protected species that may be present within the marsh creation site. Interior low-level earthen weirs also may be constructed within the disposal area to facilitate the deposition of sediments in a manner that would enhance wetlands development. Borrow material for dike/closure/weir construction would be taken from within the disposal area. Earthen dikes/closures would be allowed to degrade naturally. If earthen dikes/closures do not sufficiently degrade to provide fisheries and tidal ingress/egress following appropriate settlement of dredged material placed within the disposal area, earthen dikes/closures would be mechanically breached and/or degraded as necessary. The planting plan to be utilized for creation and nourishment activities has identified those species native to the region which are best adapted to the salinity fluctuations. *Juncus* and *Spartina* species currently found in the fresh, intermediate, and brackish marshes of the project area are the most likely candidates for planting.

Marsh nourishment is proposed for areas of degraded marsh, and consists of the placement of a thin layer of dredged material slurry that would be allowed to overflow over existing emergent marsh vegetation within the proposed disposal area, but would not be allowed to exceed a height of about 1 – 1.5-foot above the existing marsh elevation to facilitate the recruitment and consolidation of marsh vegetation after dewatering. Unlike marsh restoration features, no plantings are associated with marsh nourishment features. Dredged material would be obtained from study area borrow sites as noted for each feature. The elevation of marsh restoration areas varies from +1 to 1.5 ft, as noted in the plan view for each feature. Material would be allowed to overflow over existing emergent marsh vegetation and into waterbodies within the project boundaries; some shallowing of these features is anticipated. Retention dikes, deflection dikes, earthen weirs and/or closures would be used to contain material as noted in the plan view for each feature. Borrow material for dike/closure/weir construction would be taken from within the project area. Dikes/closures would be allowed to degrade naturally and would be breached and/or degraded within 3 years following construction to provide fisheries access if they do not sufficiently degrade following settlement of dredged material.

7.4.1 Proposed Feature BM 1

Feature BM 1 calls for marsh nourishment within the Biloxi Marshes immediately adjacent to the east shoreline of Lake Borgne (**Figure 19**).

The project will consist of nourishing approximately 8,000 acres of marsh. At the same time, approximately 295 acres of adjacent waters will be shallowed during this marsh creation feature which will be accomplished through dedicated dredging of material to be borrowed from Lake Borgne via hydraulic dredge. Approximately 9.7 mcy of borrow will be required for this

marsh nourishment feature. The material will be transported directly to the site via pipeline and placed within the marsh nourishment site. Access to the marsh nourishment site will be via Lake Borgne and excavation for access to the site will not be required.

The dredge material will be placed to a maximum slurry elevation of approximate +3' to +3.5' in order for the initial fill placed over the existing marsh not to exceed 1.25' (after dewatering) and to allow for the fill to consolidate to approximately 1' prior to completion of the work. An earthen weir, approximately 94,800' in length, will be constructed from adjacent borrow and essentially parallel the Lake Borgne shoreline. A minimum of 2' of freeboard will be maintained at all times during pumping operations. The earthen weir will also be constructed to a minimum 5' crown width, slopes no steeper than 1V on 3H, and with a minimum 40' interior berm to be maintained between the inside toe of the weir and the top of cut of the adjacent borrow pit.

As surveys were not available for this phase of the study, in order to estimate the amount of cubic yards of borrow required, it was assumed that the existing elevation of the marsh within the marsh nourishment site is between +1' and +1.5'.

Ingress and egress to the site would be via access corridors depicted in the plan view, as well as the GIWW and Lake Borgne.

7.4.2 Proposed Feature CM 1

Feature CM 1 is a marsh nourishment feature located south of the MRGO and within the Central Wetlands in St. Bernard Parish, LA (**Figure 20**). The project area is immediately adjacent to the back canal, behind the MRGO south bank disposal area, Bayou Bienvenue and Paris Road.

The project will consist of nourishing four (4) wetland areas, totaling approximately 1,240 acres in size. These four (4) areas consist of approximately 870 acres of existing marsh and approximately 370 acres of adjacent shallow water areas which will be nourished through dedicated dredging of material to be borrowed via hydraulic dredge from the adjacent GIWW/MRGO channel (Reach 1), between miles 66 and 60, as well as the Michoud Canal project which begins at approximate GIWW/MRGO mile 60 and extends east to the Michoud Canal slip. Borrow will be restricted to the currently authorized and NEPA cleared dimensions for these channels. Additional borrow may be removed from Lake Borgne. Approximately 1.5 mcy of borrow will be required for this marsh nourishment feature. The material will be transported directly to the four (4) marsh nourishment sites via pipeline. Disposal will be unconfined with effluent allowed to run over adjacent wetlands. Access for the dredge pipeline from Lake Borgne will be via a 300' access corridor across the MRGO north bank, the MRGO channel, and two (2) – 300' access corridors leading from the MRGO and crossing the south bank disposal area and the adjacent back dike canal.

The dredge material will be placed unconfined with fill not to exceed 1.5' above adjacent marsh and to a maximum elevation of between +2.5' and 3.0'. Dredge effluent waters will be

allowed to run over adjacent marsh for marsh nourishment, as well as adjacent water bodies. Approximately 35,200' of earthen retention dikes, which also includes approximately 10 closures totaling approximately 12,100', will be constructed. Upon completion of the project, the closures will be removed. At this time, as surveys and borings are currently not available, it is being assumed that all dikes and closures for this feature will be earthen and constructed from adjacent borrow, with a 2' of freeboard to be maintained at all times during pumping operations. The earthen dikes and closures will also be constructed to an approximate 5' crown width, slopes no steeper than 1V on 3H, and with a minimum 40' interior berm to be maintained between the inside toe of the earthen dikes and the top of cut of the adjacent borrow pits.

As surveys were not available for this phase of the study, in order to estimate the amount of cubic yards of borrow required, it was assumed that the existing marsh elevation ranges between approximate elevation of +0.5' and 1.0', and that between 1' and 1.5' of fill will initially be placed over existing marsh for nourishment.

Ingress and egress to the site would be via the GIWW, Chef Pass, Lake Borgne, the MRGO, the back dike canal, and Bayou Bienvenue, as well as Federal, State and local highways.

7.4.3 Proposed Feature CM 2

Feature CM 2 is a marsh creation and nourishment feature located south of the GIWW/MRGO (Reach 1) and within the Central Wetlands in St. Bernard Parish, LA (**Figure 21**). The project area is immediately adjacent to Bayou Bienvenue, Paris Road, and Feature CC 4.

The project will consist of creating marsh over approximately 795 acres, along with the nourishment of an additional 190 acres of adjacent wetlands, through dedicated dredging of material to be borrowed from Lake Borgne via hydraulic dredge. Approximately 4.7 mcy of borrow will be required for this marsh nourishment feature. The material would be obtained via hydraulic dredge and transported directly to the marsh creation and restoration site via pipeline. Disposal will be semi-confined with effluent allowed to run over adjacent wetlands within adjacent Feature CC 4, scheduled to be constructed prior to this project feature. Access for the dredge pipeline from Lake Borgne will be via two (2) access corridors crossing the GIWW/MRGO south bank disposal area and Bayou Bienvenue.

The dredge material will be placed to a maximum slurry elevation of +4', and dredge effluent waters will be returned to either Bayou Bienvenue via spill box weirs and/or allowed to flow into adjacent Feature CC 4. Approximately 22,700' of earthen retention dikes would be constructed. As Feature CC 4 requires retention dikes along the northern end of its swamp creation sites that will be constructed prior to this feature, it was assumed that those same dikes would be able to serve as a retention barrier for the southern boundary of Feature CM 2. At this time, as surveys and borings are currently not available, it is being assumed that all dikes for this feature will be earthen and constructed from adjacent borrow. With regards to the perimeter retention dikes, a minimum 2' of freeboard will be maintained at all times during pumping operations. The earthen dikes will also be constructed to an approximate 5' crown width, slopes

no steeper than 1V on 3H, and with a minimum 40' interior berm to be maintained between the inside toe of the earthen dikes and the top of cut of the adjacent borrow pits.

As surveys were not available for this phase of the study, in order to estimate the amount of cubic yards of fill required, it was assumed that the existing elevation within the marsh creation site is an approximate average elevation of -0.5' and that and that the adjacent marsh is an approximate average elevation of +1.5'.

Ingress and egress to the site would be via the GIWW/MRGO, Bayou Bienvenue, the designated access corridors, as well as Federal, State and local highways.

7.4.4 Proposed Feature CM 3

Feature CM 3 is a marsh creation and nourishment feature located south of the MRGO and within the Central Wetlands in St. Bernard Parish, LA (**Figure 14**). The project area is immediately south of the back dike canal, located behind the MRGO south bank disposal area, and adjacent to and upstream of the Bayou Dupre/Violet Diversion channel. The feature is also adjacent to project Feature CC 2.

The project will consist of creating approximately 300 acres of marsh, along with the nourishment of approximately 215 acres of adjacent wetlands, through dedicated dredging of material to be borrowed from Lake Borgne via hydraulic dredge. Approximately 1.6 mcy of borrow will be required for this marsh creation and nourishment feature. The material will be transported directly to the marsh creation and nourishment sites via pipeline. Disposal will be semi-confined with effluent allowed to run over adjacent wetlands. Access for the dredge pipeline from Lake Borgne will be via Bayou Dupre Cut/Martello channel, the MRGO channel, and via a 300' access corridor leading from the MRGO and crossing the south bank disposal area, and the adjacent back dike canal.

The dredge material will be placed semi-confined to a maximum slurry elevation of +4', and dredge effluent waters will be allowed to run over adjacent marsh for marsh nourishment, as well as adjacent water bodies. At this time, as surveys and borings are currently not available, it is being assumed that all dikes, weirs and closures for this feature will be earthen and constructed from adjacent borrow, with a 2' of freeboard to be maintained at all times during pumping operations. Approximately 37,100' of earthen retention dikes, which also includes approximately 11 earthen closures totaling approximately 5,300', will be constructed. In order to assist in the development of the marsh creation and nourishment sites, approximately 6,850' of interior earthen weirs will also be constructed. The earthen dikes, weirs, and closures will also be constructed to an approximate 5' crown width, slopes no steeper than 1V on 3H, and with a minimum 40' interior berm to be maintained between the inside toe of the earthen dikes, weirs, and closures and the top of cut of the adjacent borrow pits. The earthen weirs will be constructed to an approximate elevation of +3.0'. Upon completion of the project, the closures along Bayou Dupre/Violet Canal will be removed.

As surveys were not available for this phase of the study, in order to estimate the

amount of cubic yards of borrow required, it was assumed that the existing elevation within the marsh creation sites was approximately -0.5', and the elevation of the adjacent marsh was approximately +1.5', and that between 1' and 1.5' of fill will initially be placed over existing marsh for nourishment.

Ingress and egress to the site would be via the GIWW, Chef Pass, Lake Borgne, the MRGO, the back dike canal, and Bayou Dupre, as well as Federal, State and local highways.

7.4.5 Proposed Feature CM 4

Feature CM 1 is a marsh creation and nourishment feature located south of the MRGO and within the Central Wetlands in St. Bernard Parish, LA (**Figure 22**). The project area is immediately adjacent to the back canal behind the MRGO south bank disposal area, the Bayou Dupre/Violet Diversion channel, and Feature CC 6.

The project will consist of creating and nourishing a total of approximately 226 acres of marsh through dedicated dredging of material to be borrowed from Lake Borgne via hydraulic dredge. Of this 226 acres, approx 97.5 acres is open water at approximate elevation -1.5' that will be restored to marsh, and approximately 128.5 acres of adjacent wetlands that will be re-nourished with 11.5' of effluent allowed to overflow into the marsh for nourishment. Approximately 600,000 cy of borrow will be required for this marsh creation and nourishment feature. The material will be transported directly to the marsh creation and nourishment sites via pipeline. Disposal will be unconfined with effluent allowed to run over adjacent wetlands. Access for the dredge pipeline from Lake Borgne will be via Dupre Cut/Martello Channel, the MRGO channel, Bayou Dupre, and the back dike canal.

The dredge material will be placed unconfined to a maximum slurry elevation of +4'. Dredge effluent waters will be allowed to run over adjacent marsh for marsh nourishment. Approximately 26,560' of earthen perimeter dikes, which also includes approximately six (6) earthen closures totaling approximately 2,470', will be constructed in order to prevent material from entering adjacent natural and man-made waterways. Upon completion of the project, the closures will be removed. At this time, as surveys and borings are currently not available, it is being assumed that all dikes and closures for this feature will be earthen and constructed from adjacent borrow, with a 2' of freeboard to be maintained at all times during pumping operations. The earthen dikes and closures will also be constructed to an approximate 5' crown width, slopes no steeper than 1V on 3H, and with a minimum 40' interior berm to be maintained between the inside toe of the earthen dikes and the top of cut of the adjacent borrow pits.

As surveys were not available for this phase of the study, in order to estimate the amount of cubic yards of borrow required, it was assumed that the approximate existing elevation of the proposed marsh creation sites is -1.5' and that the average existing marsh elevation ranges between approximate elevation of +1' and +1.5'.

Ingress and egress to the site would be via the GIWW, Chef Pass, Lake Borgne, the MRGO, Bayou Dupre, the back dike canal, as well as Federal, State and local highways.

7.4.6 Proposed Feature CM 5

Feature CM 5 is a marsh creation and nourishment feature located south of the GIWW/MRGO (Reach 1) and within the Central Wetlands in St. Bernard Parish, LA (**Figure 23**). The project area is immediately adjacent to Bayou Bienvenue, Paris Road, and Feature CM 2.

The project will consist of creating approximately 245 acres of marsh, along with the nourishment of an additional 70 acres of adjacent wetlands, through dedicated dredging of material to be borrowed from Lake Borgne via hydraulic dredge. Approximately 1 mcy of borrow will be required for this swamp restoration feature. Access for dredge pipeline shall be via a 300' access corridor, leading from the GIWW/MRGO (Reach 1) and crossing the south bank disposal area, to the marsh restoration site. Access from Lake Borgne could also be via Bayou Bienvenue.

The dredge material will be transported to the proposed restoration site and placed to a maximum slurry elevation of +4', and dredge effluent waters will be returned to Bayou Bienvenue via spill box weirs. Approximately 16,100' of earthen retention dikes would be constructed. At this time, as surveys and borings are currently not available, it is being assumed that all dikes for this feature will be earthen and constructed from adjacent borrow. With regards to the perimeter retention dikes, a minimum 2' of freeboard will be maintained at all times during pumping operations. The earthen dikes will also be constructed to an approximate 5' crown width, slopes no steeper than 1V on 3H, and with a minimum 40' interior berm to be maintained between the inside toe of the earthen dikes and the top of cut of the adjacent borrow pits.

As surveys were not available for this phase of the study, in order to estimate the amount of cubic yards of fill required, it was assumed that the existing elevation within the marsh creation site is an approximate average elevation of -0.5' and that and that the adjacent marsh is an approximate average elevation of +1.5'.

Ingress and egress to the site would be via Chef Pass, the GIWW/MRGO, the designated access corridor crossing the GIWW/MRGO south bank disposal site, Bayou Bienvenue, as well as Federal, State and local highways.

7.4.7 Proposed Feature EM 1

Feature EM 1 is a marsh creation and nourishment feature located in the New Orleans East along the south shore of Lake Ponchartrain and bounded by Chef Menteur Highway, Highway 11, Lake Ponchartrain and Chef Pass (**Figure 24**).

The project will consist of converting approximately 1175 acres of open water to marsh

habitat, along with the nourishment of approximately 2830 acres of adjacent wetlands, through dedicated dredging of material to be borrowed from Lake Borgne via hydraulic dredge. Approximately 8 mcy of borrow will be required for this marsh creation and nourishment feature. The material may be transported directly to the site via pipeline, or may be placed within barges that would then be transported to the south shore adjacent to the site. The barges would then be pumped out and the material placed within marsh creation and nourishment areas. Access to the marsh creation and nourishment site will be via the Chef Pass, leading to the south shore of Lake Ponchartrain.

The dredge material will be placed to a maximum slurry elevation of +4.0', and dredge effluent will be returned to canal and bayou, immediately adjacent to and west and south of the marsh creation and nourishment site, via spill box weirs. Approximately 47,000' of earthen retention dikes will be constructed from adjacent borrow and 2' of freeboard will be maintained at all times during pumping operations. The earthen dikes shall also be constructed to an approximate 5' crown width, slopes no steeper than 1V on 3H, and with a minimum 40' interior berm to be maintained between the inside toe of the earthen dikes and the top of cut of the adjacent borrow pits. In addition, approximately 77,000' of interior earthen weirs will be constructed in order to assist in maximizing development of the marsh creation sites. The weirs will be constructed from adjacent borrow and will be constructed to an elevation of +3.0 to 3.5'. The weirs will be constructed to an approximate 5' crown width, slopes no steeper than 1V on 3H, and with a minimum 40' interior berm to be maintained between the inside toe of the weirs and the top of cut of the adjacent borrow pits. In addition to the earthen dikes and weirs, it is estimated that three (3) closures, totaling approximately 4350' in length, will be required in order to retain the dredge slurry. The closures would consist of vinyl sheet pile, sheets averaging approximately 30' in length, along with timber piles spaced approximately 6' on center.

As surveys were not available for this phase of the study, in order to estimate the amount of cubic yards of borrow required, it was assumed that the existing elevation within the marsh creation site is an average elevation of -0.5' and that the adjacent marsh is an approximate average elevation of +1.5'. In addition, it was estimated that possibly one (1) mile of floatation channel access dredging may be required, and if indeed required, the access channel will be backfilled upon completion of the contract in order to restore the lake as close as possible to its pre-construction conditions.

Ingress and egress to the site would be via Chef Pass, Lake Ponchartrain, Lake Borgne and the GIWW, as well as Federal, State and local highways.

7.4.8 Proposed Feature EM 2

Feature EM 2 calls for marsh nourishment of Hog Island, located west of Hwy 90, and bounded by the Pearl River – East and West Mouth, Little Lake and the Rigolets (**Figure 25**).

The project will consist of nourishing approximately 800 acres of marsh. At the same time, approximately 295 acres of adjacent waters will be shallowed during this marsh creation

feature which will be accomplished through dedicated dredging of material to be borrowed from Lake Borgne via hydraulic dredge. Approximately 1.3 mcy yards of borrow will be required for this marsh nourishment feature. The material will be transported directly to the site via pipeline and placed within the marsh nourishment site. Access to the marsh nourishment site will be via the Rigolets, and both the East and West Mouth of the Pearl River.

The dredge material will be placed to a maximum slurry elevation of approximate +3' to +3.5' in order for the initial fill placed over the existing marsh not to exceed 1.25' (after dewatering) and to allow for the fill to consolidate to approximately 1' prior to completion of the work. Dredge effluent waters will be returned to adjacent waterways via spill box weirs that will be installed in the retention dike system. Approximately 37,150' of earthen retention dikes will be constructed from adjacent borrow (either from within the marsh nourishment site or adjacent waterways) and 2' of freeboard will be maintained at all times during pumping operations. The earthen dikes will also be constructed to an approximate minimum 5' crown width, slopes no steeper than 1V on 3H, and with a minimum 40' interior berm to be maintained between the inside toe of the dikes and the top of cut of the adjacent borrow pits if borrow is obtained from within the site.

As surveys were not available for this phase of the study, in order to estimate the amount of cubic yards of borrow required, it was assumed that the existing elevation of the marsh within the marsh nourishment site is between +1' and +1.5'.

Ingress and egress to the site would be via access corridors depicted in the plan view, the GIWW, the Rigolets, West and East Mouth of Pearl River, Lake Borgne, as well as Federal, State and local highways.

7.4.9 Proposed Feature EM 3

Feature EM 3 is a marsh creation and nourishment feature, located in the New Orleans East along the north shore of Lake Ponchartrain and west of Hwy 90 (**Figure 26**).

The project will consist of converting approximately 861 acres of open water to marsh habitat, along with the nourishment of approximately 180 acres of adjacent wetlands, through dedicated dredging of material to be borrowed from Lake Borgne via hydraulic dredge. Approximately 3.7 mcy of borrow will be required for this marsh creation and nourishment feature. The material may be transported directly to the site via pipeline, or may be placed within barges that would then be transported to the north shore adjacent to the site. The barges would then be pumped out and the material placed within marsh creation and nourishment areas.

Access to the marsh creation and nourishment site will be via the Rigolets, leading to the north shore of Lake Ponchartrain, thence via a 300' access corridor leading from the lake shoreline to the marsh creation site.

The dredge material will be placed to a maximum slurry elevation of +4.0', and dredge effluent will be returned to Salt Bayou via spill box weirs. Approximately 22,300' of earthen

retention dikes will be constructed from adjacent borrow and 2' of freeboard will be maintained at all times during pumping operations. The earthen dikes shall also be constructed to an approximate minimum 5' crown width, slopes no steeper than 1V on 3H, and with a minimum 40' interior berm to be maintained between the inside toe of the earthen dikes and the top of cut of the adjacent borrow pits. In addition, approximately 70,500' of interior earthen weirs will be constructed in order to assist in maximizing development of the marsh creation sites. The weirs will be constructed from adjacent borrow and will be constructed to an elevation of +3.0 to 3.5'. The weirs will be constructed to an approximate minimum 5' crown width, slopes no steeper than 1V on 3H, and with a minimum 40' interior berm to be maintained between the inside toe of the weirs and the top of cut of the adjacent borrow pits.

As surveys were not available for this phase of the study, in order to estimate the amount of cubic yards of borrow required, it was assumed that the existing elevation within the marsh creation site is an average elevation of -0.5' and that the adjacent marsh is an approximate average elevation of +1.5'.

Ingress and egress to the site would be via access corridors depicted in the plan view, the GIWW, Lake Borgne and the Rigolets, as well as Federal, State and local highways.

7.4.10 Proposed Feature EM 4

Feature EM 4 is a marsh creation and nourishment feature, located in the New Orleans East along the north shore of Lake Ponchartrain and immediately east of Hwy 90 (**Figure 27**).

The project will consist of converting approximately 2625 acres of open water to marsh habitat, along with the nourishment of approximately 1455 acres of adjacent wetlands, through dedicated dredging of material to be borrowed from Lake Borgne via hydraulic dredge. Approximately 9.2 mcy of borrow will be required for this marsh creation and nourishment feature. The material may be transported directly to the site via pipeline, or may be placed within barges that would then be transported to the north shore adjacent to the site. The barges would then be pumped out and the material placed within marsh creation and nourishment areas. Access to the marsh creation and nourishment site will be via the Rigolets, leading to the north shore of Lake Ponchartrain, thence via a 300' access corridor leading from the lake shoreline to the marsh creation site.

The dredge material will be placed to a maximum slurry elevation of +4.0', and dredge effluent will be returned to adjacent waterways, including the Rigolets, via spill box weirs. Approximately 75,200' of earthen retention dikes will be constructed from adjacent borrow and 2' of freeboard will be maintained at all times during pumping operations. The earthen dikes shall also be constructed to an approximate minimum 5' crown width, slopes no steeper than 1V on 3H, and with a minimum 40' interior berm to be maintained between the inside toe of the earthen dikes and the top of cut of the adjacent borrow pits. In addition, approximately 60,000' of interior earthen weirs will be constructed in order to assist in maximizing development of the marsh creation sites. The weirs will be constructed from adjacent borrow

and will be constructed to an elevation of +3.0 to 3.5'. The weirs will be constructed to an approximate minimum 5' crown width, slopes no steeper than 1V on 3H, and with a minimum 40' interior berm to be maintained between the inside toe of the weirs and the top of cut of the adjacent borrow pits.

As surveys were not available for this phase of the study, in order to estimate the amount of cubic yards of borrow required, it was assumed that the existing elevation within the marsh creation site is an average elevation of -0.5' and that the adjacent marsh is an approximate average elevation of +1.5'.

Ingress and egress to the site would be via access corridors depicted in the plan view, the GIWW, Lake Borgne and the Rigolets, as well as Federal, State and local highways.

7.4.11 Proposed Feature LM 1

Feature LM 1 is a marsh creation and nourishment feature located just inside the IHNC surge barrier, at the confluence of the MRGO and the GIWW, and within Orleans and St. Bernard Parishes, LA (**Figure 28**).

The project will consist of creating approximately 3,240 acres of marsh, along with the nourishment of approximately 777 acres of adjacent existing wetlands, through dedicated dredging of material to be borrowed from Lake Borgne via hydraulic dredge. Approximately 14.3 mcy of borrow will be required for this marsh creation and nourishment feature. The material would be obtained via hydraulic dredge and transported directly to the marsh creation and nourishment sites via pipeline. Disposal within the marsh creation sites will be semi-confined with effluent allowed to run over adjacent wetlands. Access for the dredge pipeline from Lake Borgne will be via Bayou Bienvenue and through the new Bienvenue floodgate, currently under construction.

The dredge material will be placed semi-confined within the marsh creation sites to a maximum slurry elevation of +4', and dredge effluent waters will be allowed to run over adjacent marsh for marsh nourishment, as well as adjacent water bodies. At this time, as surveys and borings are currently not available, it is being assumed that all dikes and weirs for this feature will be earthen and constructed from adjacent borrow. Approximately 105,700' of perimeter earthen retention dikes will be required and 2' of freeboard shall be maintained at all times during pumping operations. In order to assist in the development of the marsh creation sites, approximately 92.700' of interior earthen weirs will also be constructed around the marsh creation sites. The earthen retention dikes and weirs will be constructed to an approximate 5' crown width, slopes no steeper than 1V on 3H, and with a minimum 40' interior berm to be maintained between the inside toe of the retention dikes and earthen weirs and the top of cut of the adjacent borrow pits. The interior earthen weirs will be constructed to an approximate elevation of +3.0'. In addition to the dikes and weirs, seven (7) closures, totaling approximately 6450' in length, will also be required in order to prevent effluent sedimentation from entering the GIWW and Bayou Bienvenue during pumping operations. Four (4) closures, for a total of

approximately 5,400', would consist of vinyl sheet pile, between 25' to 30' in length, along with timber piles spaced 6' to 8' on center. The remaining three (3) closures, totaling approximately 1,050'in length, would be constructed of earthen materials. Upon completion of the project, the closures will be removed.

As surveys were not available for this phase of the study, in order to estimate the amount of cubic yards of fill required, it was assumed that the existing elevation within the marsh creation site is an approximate average elevation of -0.5' and that and that the adjacent marsh is an approximate average elevation of +1.5'.

Ingress and egress to the site would be via the GIWW/MRGO, Chef Pass, Lake Borgne, and Bayou Bienvenue, as well as Federal, State and local highways.

7.4.12 Proposed Feature LM 2

Feature LM 2 is a marsh creation and nourishment feature located north of the MRGO and within St. Bernard Parish, LA (**Figure 29**). The project area is located between the MRGO and Proctor Point, and adjacent to both the north and south lobes of Lake Borgne.

The project will consist of creating approximately 422 acres of marsh immediately adjacent to and south of Proctor Point, along with the nourishment of an approximately 2,523 acres of existing wetlands, through dedicated dredging of material to be borrowed from Lake Borgne via hydraulic dredge. Approximately 5.1 mcy of borrow will be required for this marsh creation and nourishment feature. The material would be obtained via hydraulic dredge and transported directly to the marsh creation and nourishment sites via pipeline. Disposal within the marsh creation sites located south of Proctor Point will be semi-confined with effluent allowed to run over adjacent wetlands. Material placed within the marsh nourishment sites will be unconfined with effluent waters allowed to run over adjacent wetlands. Access for the dredge pipeline from Lake Borgne will be via the access corridors depicted on the plan map for this feature. Excavation for flotation access will not be required. Based upon preliminary lake bottom classification surveys, approximately 3 acres of hard bottom surface falls within the northern-most access corridor leading from the borrow sites in Lake Borgne Site No 4. As excavation for flotation access will not be performed, marsh buggy access will simply be required within this 3 acres area in order to access the marsh creation sites.

The dredge material will be placed semi-confined within the marsh creation sites to a maximum slurry elevation of +4', and dredge effluent waters will be allowed to run over adjacent marsh for marsh nourishment, as well as adjacent water bodies. In order to assist in the development of the marsh creation sites, approximately 50,600' of interior earthen weirs will also be constructed around the marsh creation sites. The earthen weirs will be constructed to an approximate 5' crown width, slopes no steeper than 1V on 3H, and with a minimum 40' interior berm to be maintained between the inside toe of the earthen weirs and the top of cut of the adjacent borrow pits. The interior earthen weirs will be constructed to an approximate elevation of +3.0'. At this time, as surveys and borings are currently not available, it is being assumed that all weirs for this feature will be earthen and constructed from adjacent borrow. In addition to the

weirs, a closure, approximately 180' in length, will also be required in order to prevent effluent sedimentation from entering Lake Borgne via a natural bayou during pumping operations. The closure would consist of vinyl sheet pile, between 25' to 30' in length, along with timber piles spaced 6' to 8' on center. Upon completion of the project, the closure will be removed.

As surveys were not available for this phase of the study, in order to estimate the amount of cubic yards of fill required, it was assumed that the existing elevation within the marsh creation site is an approximate average elevation of -0.5' and that and that the adjacent marsh is an approximate average elevation of +1.5'. Ingress and egress to the site would be via the GIWW/MRGO, Chef Pass, and Lake Borgne, as well as Federal, State and local highways.

7.4.13 Proposed Feature LM 3

Feature LM 3 is a marsh creation and nourishment feature located along the south shore of the southern lobe of Lake Borgne, and bounded by the MRGO, Lena Lagoon and Bayou St. Malo, and located St. Bernard Parishes, LA (**Figure 30**).

The project will consist of creating approximately 911 acres of marsh, along with the nourishment of approximately 950 acres of adjacent existing wetlands, through dedicated dredging of material to be borrowed from Lake Borgne via hydraulic dredge. Approximately 6.3 mcy of borrow will be required for this marsh creation and nourishment feature. The material would be obtained via hydraulic dredge and transported directly to the marsh creation and nourishment sites via pipeline. Disposal within the marsh creation sites will be semi-confined with effluent allowed to run over adjacent wetlands.

The dredge material will be placed semi-confined within the marsh creation sites to a maximum slurry elevation of +4', and dredge effluent waters will be allowed to run over adjacent marsh for marsh nourishment, as well as adjacent water bodies. At this time, as surveys and borings are currently not available, it is being assumed that all dikes and weirs for this feature will be earthen and constructed from adjacent borrow. Approximately 47,200' of perimeter earthen retention dikes will be required and 2' of freeboard shall be maintained at all times during pumping operations. In order to assist in the development of the marsh creation sites, approximately 38,700' of interior earthen weirs will also be constructed around the marsh creation sites. The earthen retention dikes and weirs will be constructed to an approximate 5' crown width, slopes no steeper than 1V on 3H, and with a minimum 40' interior berm to be maintained between the inside toe of the retention dikes and earthen weirs and the top of cut of the adjacent borrow pits. The interior earthen weirs will be constructed to an approximate elevation of +3.0'.

As surveys were not available for this phase of the study, in order to estimate the amount of cubic yards of fill required, it was assumed that the existing elevation within the marsh creation site is an approximate average elevation of -0.5' and that and that the adjacent marsh is an approximate average elevation of +1.5'.

Ingress and egress to the site would be via the GIWW/MRGO, Chef Pass, and Lake

Borgne, as well as Federal, State and local highways.

7.4.14 Proposed Feature LM 4

Feature LM 4 is a marsh creation and nourishment feature located just inside the IHNC surge barrier, at the confluence of the MRGO and the GIWW, and within Orleans and St. Bernard Parishes, LA (**Figure 31**).

The project will consist of creating approximately 289 acres of marsh, along with the nourishment of approximately 95 acres of adjacent existing wetlands, through dedicated dredging of material to be borrowed from Lake Borgne via hydraulic dredge. Approximately 1.2 mcy of borrow will be required for this marsh creation and nourishment feature. The material would be obtained via hydraulic dredge and transported directly to the marsh creation and nourishment sites via pipeline and/or barges. Disposal within the marsh creation sites will be semi-confined with effluent allowed to run over adjacent wetlands. Access for the dredge pipeline from Lake Borgne will be via Bayou Bienvenue and through the new Bienvenue floodgate, currently under construction.

The dredge material will be placed semi-confined within the marsh creation sites to a maximum slurry elevation of +4', and dredge effluent waters will be allowed to run over adjacent marsh for marsh nourishment, as well as adjacent water bodies. At this time, as surveys and borings are currently not available, it is being assumed that all dikes and weirs for this feature will be earthen and constructed from adjacent borrow. Approximately 17,200' of perimeter earthen retention dikes will be required and 2' of freeboard shall be maintained at all times during pumping operations. In order to assist in the development of the marsh creation sites, approximately 13,100' of interior earthen weirs will also be constructed around the marsh creation sites. The earthen retention dikes and weirs will be constructed to an approximate 5' crown width, slopes no steeper than 1V on 3H, and with a minimum 40' interior berm to be maintained between the inside toe of the retention dikes and earthen weirs and the top of cut of the adjacent borrow pits. The interior earthen weirs will be constructed to an approximate elevation of +3.0'. In addition to the dikes and weirs, three (3) closures, totaling approximately 2500' in length, will also be required in order to prevent effluent sedimentation from entering the GIWW and Bayou Bienvenue during pumping operations. Approximately 1,700' of closures would consist of vinyl sheet pile, between 25' to 30' in length, along with timber piles spaced 6' to 8' on center. The remaining 800' of closures, which would be required across both ends of the pipeline canal that passes through the project feature area, would be earthen. Upon completion of the project, the closures will be removed.

As surveys were not available for this phase of the study, in order to estimate the amount of cubic yards of fill required, it was assumed that the existing elevation within the marsh creation site is an approximate average elevation of -0.5' and that and that the adjacent marsh is an approximate average elevation of +1.5'.

Ingress and egress to the site would be via the GIWW/MRGO, Chef Pass, Lake

Borgne, and Bayou Bienvenue, as well as Federal, State and local highways.

7.4.15 Proposed Feature TM 1

Feature TM 1 is a marsh creation and nourishment feature located south of the MRGO and within St. Bernard Parish, LA (**Figure 32**). The project area is located in the vicinity of Yscloskey, LA and south of LA 46 and between Bayou Terre Aux Boeufs and the Tennessee Gas twin pipeline canals.

The project will consist of creating approximately 760 acres of marsh within two (2) proposed marsh creation sites, along with the nourishment of an additional 223 acres of existing wetlands, through dedicated dredging of material to be borrowed from Lake Borgne via hydraulic dredge. Approximately 3.7 mcy of borrow will be required for this marsh creation and nourishment feature. Access for dredge pipeline from Lake Borgne shall be via the bayou leading to Antonio's Lagoon, thence crossing the MRGO channel and leading to a 200' access corridor across the MRGO south bank disposal site immediately adjacent to and upstream of the Tennessee Gas twin pipeline canal, and thence via a 450' access corridor (which includes the twin pipeline canal) leading to the marsh restoration site.

The dredge material will be placed semi-confined to a maximum slurry elevation of +4', and dredge effluent waters will be allowed to run over adjacent marsh for marsh nourishment, as well as adjacent water bodies. At this time, as surveys and borings are currently not available, it is being assumed that all dikes and weirs for this feature will be earthen and constructed from adjacent borrow, with a 2' of freeboard to be maintained at all times during pumping operations. Approximately 20,350' of perimeter earthen retention dikes will be required. In order to assist in the development of the marsh creation and nourishment sites, approximately 38,250' of earthen weirs will also be constructed. The earthen dikes and weirs will be constructed to an approximate 5' crown width, slopes no steeper than 1V on 3H, and with a minimum 40' interior berm to be maintained between the inside toe of the earthen dikes, weirs, and closures and the top of cut of the adjacent borrow pits. The earthen weirs will be constructed to an approximate elevation of +3.0'. In addition to the earthen perimeter retention dikes and weirs, 4 closures, totaling approximately 1,200' in length, will also be required. The closures would consist of vinyl sheet pile, between 25' to 30' in length, along with timber piles spaced 6' to 8' on center. Upon completion of the project, the closures will be removed.

As surveys were not available for this phase of the study, in order to estimate the amount of cubic yards of fill required, it was assumed that the existing elevation within the marsh creation site is an approximate average elevation of -0.5' and that and that the adjacent marsh is an approximate average elevation of +1.5'.

Ingress and egress to the site would be via the GIWW/MRGO, Chef Pass, Lake Borgne, the designated access corridor crossing the MRGO south bank disposal site, the Tennessee Gas pipeline canal, Bayou Terre Aux Boeufs, as well as Federal, State and local highways.

7.4.16 Proposed Feature TM 2

Feature TM 2 is a marsh creation and nourishment feature located south of the MRGO and within St. Bernard Parish, LA (**Figure 33**). The project area is located in the vicinity of Alluvial City, LA, south of Bayou La Loutre, and between Lake Ameda and the Tennessee Gas twin pipeline canals.

The project will consist of creating approximately 770 acres of marsh, along with the nourishment of an approximately 3,400 acres of existing wetlands, through dedicated dredging of material to be borrowed from Lake Borgne via hydraulic dredge. Approximately 8.8 mcy of borrow will be required for this marsh creation and nourishment feature. Access for dredge pipeline from Lake Borgne shall be via the Bayou Yscloskey and Bayou La Loutre leading to the marsh restoration site.

The dredge material will be placed semi-confined to a maximum slurry elevation of +4', and dredge effluent waters will be allowed to run over adjacent marsh for marsh nourishment, as well as adjacent water bodies. At this time, as surveys and borings are currently not available, it is being assumed that all dikes and weirs for this feature will be earthen and constructed from adjacent borrow, with a 2' of freeboard to be maintained at all times during pumping operations. Approximately 146,000' of perimeter earthen retention dikes will be required. In order to assist in the development of the marsh creation site, approximately 25,500' of interior earthen weirs will also be constructed around the marsh creation site. The earthen dikes and weirs will be constructed to an approximate 5' crown width, slopes no steeper than 1V on 3H, and with a minimum 40' interior berm to be maintained between the inside toe of the earthen dikes, weirs, and closures and the top of cut of the adjacent borrow pits. The interior earthen weirs will be constructed to an approximate elevation of +3.0'.

As surveys were not available for this phase of the study, in order to estimate the amount of cubic yards of fill required, it was assumed that the existing elevation within the marsh creation site is an approximate average elevation of -0.5' and that and that the adjacent marsh is an approximate average elevation of +1.5'.

Ingress and egress to the site would be via the GIWW/MRGO, Chef Pass, Lake Borgne, Bayous Yscloskey and Bayou La Loutre, as well as Federal, State and local highways.

7.4.17 Proposed Feature TM 7

Feature TM 7 is a marsh creation and nourishment feature located south of the MRGO and within St. Bernard Parish, LA (**Figure 34**). The project area is located in the vicinity of Delacroix Island and bounded by Feature TM 1 on the north, Feature TM 8 on the south, Bayou Terre Aux Boeufs on the west, and the Tennessee Gas twin pipeline canals on the east.

The project will consist of creating approximately 2,255 acres of marsh within seven (7) proposed marsh creation sites through dedicated dredging of material to be borrowed from Lake Borgne via hydraulic dredge. In addition, approximately 2,144 acres of adjacent wetlands would be nourished with as much as 1' of fill through effluent overflow. A maximum of 3,338 acres could be nourished via effluent waters. Approximately 12.4 mcy of borrow will be required for this marsh creation and marsh nourishment feature. Access for dredge pipeline from Lake Borgne shall be via the bayou leading to Antonio's Lagoon, thence crossing the MRGO channel and leading to a 200' access corridor across the MRGO south bank disposal site immediately adjacent to and upstream of the Tennessee Gas twin pipeline canal, and thence for approximately 3 miles via a 450' access corridor (which includes the twin pipeline canal) leading to the marsh restoration site.

The dredge material will be placed semi-confined to the marsh creation sites to a maximum slurry elevation of +4', and dredge effluent waters will be allowed to run over adjacent marsh for marsh nourishment, as well as adjacent water bodies. At this time, as surveys and borings are currently not available, it is being assumed that all dikes and weirs for this feature will be earthen and constructed from adjacent borrow, with a 2' of freeboard to be maintained at all times during pumping operations. Approximately 105,000' of perimeter earthen retention dikes, weirs and closures will be required. The earthen dikes, weirs and closures will be constructed to an approximate 5' crown width, slopes no steeper than 1V on 3H, and with a minimum 40' interior berm to be maintained between the inside toe of the earthen dikes, weirs, and closures and the top of cut of the adjacent borrow pits. The earthen dikes and closures will be constructed to an approximate elevation of +6.0' and the weirs to an approximate elevation of +3' to +3.5'. In addition to the earthen perimeter retention dikes, weirs and closures, four (4) closures, consisting of vinyl sheet pile between 25' to 30' in length, along with timber piles spaced 6' to 8' on center, would be constructed. Upon completion of the project, the closures will be removed.

As surveys were not available for this phase of the study, in order to estimate the amount of cubic yards of fill required, it was assumed that the existing elevation within the marsh creation site is an approximate average elevation of -0.5' and that and that the adjacent marsh is an approximate average elevation of +1.5'.

Ingress and egress to the site would be via the GIWW/MRGO, Chef Pass, Lake Borgne, the designated access corridor crossing the MRGO south bank disposal site, the Tennessee Gas pipeline canal, Bayou Terre Aux Boeufs, as well as Federal, State and local highways.

7.4.18 Proposed Feature TM 8

Feature TM 8 is a marsh creation feature located south of the MRGO and within St. Bernard Parish, LA (**Figure 35**). The project area is located in the vicinity of Delacroix Island and northeast of Bayou Terre Aux Boeufs, and west of the Tennessee Gas twin pipeline canals.

The project will consist of creating approximately 1511 acres of marsh within five (5)

proposed marsh creation sites, through dedicated dredging of material to be borrowed from Lake Borgne via hydraulic dredge. Approximately 10.1 mcy of borrow will be required for this marsh creation feature. Access for dredge pipeline from Lake Borgne shall be via the bayou leading to Antonio's Lagoon, thence crossing the MRGO channel and leading to a 200' access corridor across the MRGO south bank disposal site immediately adjacent to and upstream of the Tennessee Gas twin pipeline canal, and thence for approximately 5 miles via a 450' access corridor (which includes the twin pipeline canal) leading to a natural bayou that leads to the marsh restoration site.

The dredge material will be placed semi-confined to a maximum slurry elevation of +4', and dredge effluent waters will be allowed to run over adjacent marsh for marsh nourishment, as well as adjacent water bodies. At this time, as surveys and borings are currently not available, it is being assumed that all dikes and weirs for this feature will be earthen and constructed from adjacent borrow, with a 2' of freeboard to be maintained at all times during pumping operations. Approximately 67,200' of perimeter earthen retention dikes will be required. In order to assist in the development of the marsh creation and nourishment sites, approximately 11,600' of earthen weirs will also be constructed. The earthen dikes and weirs will be constructed to an approximate 5' crown width, slopes no steeper than 1V on 3H, and with a minimum 40' interior berm to be maintained between the inside toe of the earthen dikes, weirs, and closures and the top of cut of the adjacent borrow pits. The earthen weirs will be constructed to an approximate elevation of +3.0'. In addition to the earthen perimeter retention dikes and weirs, six (6) closures, totaling approximately 6,200' in length, will also be required. The closures would consist of vinyl sheet pile, between 25' to 30' in length, along with timber piles spaced 6' to 8' on center. Upon completion of the project, the closures will be removed.

As surveys were not available for this phase of the study, in order to estimate the amount of cubic yards of fill required, it was assumed that the existing elevation within the marsh creation site is an approximate average elevation of -0.5' and that and that the adjacent marsh is an approximate average elevation of +1.5'.

Ingress and egress to the site would be via the GIWW/MRGO, Chef Pass, Lake Borgne, the designated access corridor crossing the MRGO south bank disposal site, the Tennessee Gas pipeline canal, Bayou Terre Aux Boeufs, as well as Federal, State and local highways.

7.4.19 Proposed Feature HM 1

Feature HM 1 is a marsh creation and nourishment feature located in Hopedale, LA and bounded by Bayou La Loutre, Highway 624, Bayou Yscloskey, and the MRGO (**Figure 36**).

The project will consist of converting approximately 757 acres of open water to marsh habitat, along with the nourishment of approximately 973 acres of adjacent wetlands, through dedicated dredging of material to be borrowed from Lake Borgne via hydraulic dredge. Approximately 4.1 million gross cubic yards of borrow will be required for this marsh creation and nourishment feature. The material will be transported directly to the marsh creation and

nourishment site via pipeline. Access for the dredge pipeline from Lake Borgne will be via Doulluts Canal, across the MRGO, and thence via a 200' access corridor across the former MRGO south bank disposal site to the marsh creation and nourishment site.

The dredge material will be placed to a maximum slurry elevation of +4.0', and dredge effluent will be returned via spill box weirs to the adjacent back dike canal and Portman Lagoon which both run north of and adjacent to the marsh creation and nourishment site. Approximately 54,500' of earthen retention dike will be constructed from adjacent borrow and 2' of freeboard will be maintained at all times during pumping operations. The earthen dikes shall also be constructed to an approximate 5' crown width, slopes no steeper than 1V on 3H, and with a minimum 40' interior berm to be maintained between the inside toe of the earthen dikes and the top of cut of the adjacent borrow pits. In addition, an interior earthen weir, approximately 17,300' in length, will be constructed in order to assist in maximizing development of the marsh creation site. The weir will be constructed from adjacent borrow and will be constructed to an elevation of +3.0 to 3.5'. The weirs will be constructed to an approximate 5' crown width, slopes no steeper than 1V on 3H, and with a minimum 40' interior berm to be maintained between the inside toe of the weir and the top of cut of the adjacent borrow pits.

As surveys were not available for this phase of the study, in order to estimate the amount of cubic yards of borrow required, it was assumed that the existing elevation within the marsh creation site is an approximate average elevation of -0.5' and that the adjacent marsh is an approximate average elevation of +1.5'.

Ingress and egress to the site would be via the GIWW, Chef Pass, Lake Borgne, and the MRGO, as well as Federal, State and local highways.

7.5 MRGO Shoreline Restoration Component:

This feature includes three distinct reaches of north bank reestablishment between approximate miles 58.5 to 56.0, miles 48.0 to 44.5, and miles 39.5 to 37.5. These alternatives will narrow the open water top width of the MRGO by reestablishing a new north shore bank line via wall construction. These three reaches combine for a proposed 480 acres of marsh creation behind a combination vinyl sheet pile/timber pile wall. The wall will be constructed along approximately a -6.0 NAVD88 contour, and will serve not only as future shoreline protection, but also as a retention device for dredged material placement. In light of the retention requirements for marsh creation, the ultimate retention structure must be built to a minimum +4.0 NAVD88 elevation to allow for marsh platform overbuild and subsequent dewatering and settlement to a suitable target marsh elevation. Dredged material will be obtained by cutterhead dredging of the proposed borrow sites, and will be transported directly to the marsh creation and nourishment site via pipeline. Several alternatives were investigated for construction of these potential retention structures.

a. Rock Dike Retention. A standard rock foreshore dike was considered. Poor soil conditions prohibited the use of rock dike containment, which would required a

theoretical 10-foot height along the proposed alignment. Anticipated continued settlement and failure concerns, in addition to the extensive quantities of rock required, eliminated this potential alternative.

b. Concrete Wall Retention. Concrete wall construction has been successfully completed for shoreline wavewash protection within the New Orleans District. The proposed wall called for 80-foot long x 18" grooved concrete piles at 20-foot spacing to provide structural strength. Installation of 6" thick x 20' wide x 6' tall concrete panels would complete the structure; being slid into the grooves between the piles for retention of dredged material. Two panels would be installed per section, resulting in complete coverage from +4.0 to -8.0 NAVD88. A crushed stone scour protection blanket was proposed on the channel side of the wall to prevent undermining. Preliminary geotechnical analysis indicated potential stability concerns upon placement of the marsh creation backfill, eliminating this alternative from consideration.

c. Vinyl Sheet pile/Timber Pile Retention. The tentatively selected plan calls for a combination timber pile/vinyl sheet pile wall section. The tentative design requires 70-foot class B treated timber piles driven at 4-foot spacing along the proposed wall alignment. Each pile will be battered within the marsh creation sites at a 30 degree angle with an additional similar pile. The timber piles will support a vinyl sheet pile wall, consisting of SG 950 vinyl sheet pile driven from +4.0 NAVD88 to -38.0 NAVD88. The wall will be completed with a double row of 4" x 6" timber wales, a 2" wide timber cap and associated hardware. Minimal strength geotextile separator fabric will drape the interior of the vinyl wall prior to marsh creation to maximize material retention.

7.5.1 Proposed Feature MRGO-5

Element MRGO-5 will be constructed along the north bank of the MRGO channel between approximate channel miles 40.0 and 37.3 (**Figure 37**). It will consist of 14,485 linear feet of vinyl sheet pile wall, to be backfilled with earthen material to create approximately 188 acres of new marsh. Based on historic available surveys it is anticipated that the existing elevation within the marsh creation site is an average elevation of -4.0'. It was assumed that the adjacent marsh is an approximate average elevation of +1.5'. Borrow for the marsh fill is anticipated to come from approximately 5 miles offshore in Lake Borgne, with pipeline access via Doullut's Canal to the MRGO channel. Additional investigation is currently ongoing to evaluate the use of the adjacent MRGO channel as an alternative borrow source. Approximately 3 mcy of borrow material will be required to construct the proposed marsh platform. Prior to hydraulically dredged material placement, 22,250 linear feet of backside retention dikes will be constructed along the existing marsh platform. In addition, approximately 2,050 linear feet of earthen weirs will be required across open waters areas. These earthen retention features will be constructed to elevation +5.0 NAVD88 with a crown width of 5-feet, slopes no steeper than 1V on 3H, and with a minimum 40' interior berm to be maintained between the inside toe of the earthen dikes and the top of cut of the adjacent borrow pits. The dredge material will be placed to a maximum slurry elevation of +4.0'. Strategically placed overflow weirs will be located to allow dredge slurry to overflow and nourish additional existing marsh. Minimal flotation

excavation may be required in the western half of the project reach to assure adequate access to the project site. All material excavated for flotation access will be cast to the north of the wall alignment and used in the marsh creation effort.

7.5.2 Proposed Feature MRGO-7

Element MRGO-7 will be constructed along the north bank of the MRGO channel between approximate channel miles 58.5 and 55.6 non-continuous (**Figure 38**), located immediately east of the IHNC Surge Barrier. It will consist of 9,700 linear feet of vinyl sheet pile wall, to be backfilled with earthen material to create approximately 91 acres of new marsh. Based on historic available surveys it is anticipated that the existing elevation within the marsh creation site is an average elevation of -4.0'. It was assumed that the adjacent marsh is an approximate average elevation of +1.5'. Borrow for the marsh fill is anticipated to come from approximately 4 miles offshore in Lake Borgne, with pipeline access via Bayou Bienvenue. Borrow within the lake will be limited to a maximum of 15' below the water surface. Additional investigation is currently ongoing to evaluate the use of the adjacent MRGO channel as an alternative borrow source. Approximately 1.65 mcy of borrow material will be required to construct the proposed marsh platform. Prior to hydraulically dredged material placement, 7,100 linear feet of backside retention dikes will be constructed along the existing marsh platform. In addition, approximately 3,000 linear feet of earthen weirs will be required across open waters areas. These earthen retention features will be constructed to elevation +5.0 NAVD88 with a crown width of 5-feet, slopes no steeper than 1V on 3H, and with a minimum 40' interior berm to be maintained between the inside toe of the earthen dikes and the top of cut of the adjacent borrow pits. The dredge material will be placed to a maximum slurry elevation of +4.0'. Strategically placed overflow weirs will be located to allow dredge slurry to overflow and nourish additional existing marsh. No flotation excavation is anticipated to access and construct this feature.

7.5.3 Proposed Feature MRGO-8

Element MRGO-8 will be constructed along the north bank of the MRGO channel between approximate channel miles 48.3 and 44.4 non-continuous, (**Figure 39**). It will consist of 20,640 linear feet of vinyl sheet pile wall, to be backfilled with earthen material to create approximately 200 acres of new marsh. Based on historic available surveys it is anticipated that the existing elevation within the marsh creation site is an average elevation of -4.0'. It was assumed that the adjacent marsh is an approximate average elevation of +1.5'. Borrow for the marsh fill is anticipated to come from within 2 miles offshore in Lake Borgne, with pipeline access via an existing access canal West of Shell Beach to the MRGO channel. Borrow within the lake will be limited to a maximum of 15' below the water surface. Additional investigation is currently ongoing to evaluate the use of the adjacent MRGO channel as an alternative borrow source. Approximately 3.6 mcy of borrow material will be required to construct the proposed marsh platform. Prior to hydraulically dredged material placement, 29,000 linear feet of backside retention dikes will be constructed along the existing marsh platform. In addition, approximately 2,800 linear feet of earthen weirs will be required across open waters areas. These earthen retention features will be constructed to elevation +5.0 NAVD88 with a crown width of 5-feet, slopes no steeper than 1V on 3H, and with a minimum 40' interior berm to be maintained

between the inside toe of the earthen dikes and the top of cut of the adjacent borrow pits. The dredge material will be placed to a maximum slurry elevation of +4.0'. Strategically placed overflow weirs will be located to allow dredge slurry to overflow and nourish additional existing marsh. No flotation excavation is anticipated to access and construct this feature. An additional reach of element MRGO-8 consists of rock foreshore construction and will be discussed below in the "Shoreline Protection" write-up below.

7.6 MRGO Shoreline Protection Component:

In addition to the bankline restoration features above, additional reaches of the north bank of the MRGO are included in this restoration plan to be protected along their existing alignment with newly constructed stone foreshore dikes. These dikes are proposed landward of the -4.0 NAVD88 contour to minimize stone quantities and afford protection against continued bankline recession and erosion. With the de-authorization of the MRGO channel, vessel driven waves resulting from deep draft navigation are no longer a concern. Preliminary hydraulic analysis was performed to provide minimal foreshore criteria such as stone size, dike crown width and height. To protect against the smaller tidal and wind-driven waves, a standard near-shore trapezoidal stone dike with a 4-foot crown to elevation +4.0 NAVD88 is sufficient for bankline protection. Prior to the discontinuation of deep draft navigation and the stone closure of the MRGO, all foreshore work on the navigation channel was constructed using 2200# top size stone gradation to protect against vessel driven waves. All MRGO shoreline protection features inshore of the existing stone channel closure in the proximity of Bayou la Loutre at channel mile will now be constructed using the following stone proposed stone gradation:

Stone (Weight in Pounds)	Percent Finer by Weight
650-260	100
280-130	50
130-40	15

Three (3) reaches of new foreshore dike protection are proposed as follows:

7.6.1 Proposed Feature MRGO-1

Element MRGO-1 will be constructed along the north bank of the MRGO channel between approximate channel miles 56.6 and 57.4 (**Figure 40**). This stone protection feature is embedded within the limits of the non-continuous shoreline restoration Element MRGO-7 discussed above. It will consist of approximately 3.850 linear feet of rock foreshore dike, constructed immediately nearshore of the existing marsh platform within these limits. The trapezoidal stone dike section will be underlain with a geotextile separator fabric. The requirement for flotation excavation to access the site with rock and equipment barges is anticipated. Allowances for flotation dredging will be limited to an access channel located 50-feet off the centerline of the proposed structure, not to exceed 80' in width or elevation -8.0 NAVD88. Material excavated for flotation will be stockpiled channelward of the rock structure and backfilled upon completion of the construction effort. Preliminary analysis indicates that

approximately 40,000 tons of stone and 16,000 square yards of geotextile fabric will be required to complete construction of this element.

7.6.2 Proposed Feature MRGO-6

Element MRGO-6 will be constructed along the north bank of the MRGO channel between approximate channel miles 36.0 and 34.2, non-continuous (**Figure 41**). This stone protection feature is immediately east of the existing stone channel closure of the MRGO, and ties into an existing foreshore dike which ends immediately downstream of that structure. Element MRG)-6 will consist of approximately 8,132 linear feet of rock foreshore dike, constructed immediately nearshore of the existing marsh platform within these limits. This proposed foreshore extension is broken into two reaches separated by natural water access channels. The lengths of these two reaches are approximately 3,820 feet and 4,312 feet respectively. The trapezoidal stone dike section will be underlain with a geotextile separator fabric. Minimal requirements for flotation excavation to access the site with rock and equipment barges are anticipated. Allowances for flotation dredging will be limited to an access channel located 50-feet off the centerline of the proposed structure, not to exceed 80' in width or elevation -8.0 NAVD88. Material excavated for flotation, where necessary, will be stockpiled channelward of the rock structure and backfilled upon completion of the construction effort. Preliminary analysis indicates that approximately 83,000 tons of stone and 36,000 square yards of geotextile fabric will be required to complete construction of this element. This element will be constructed using a top size of 2200# stone since it's outside the protection of the MRGO closure. Standard requirements for this gradation of stone are as follows:

Stone (Weight in Pounds)	Percent Finer by Weight
2200-900	100
930-440	50
460-130	15

7.7 MRGO Shoreline Repairs Component:

7.7.1 Proposed Feature MRGO-2,3,&4

Several existing stone foreshore features exist along the north shore of the MRGO channel, all constructed to minimize damage to existing marsh and to retain existing shoreline materials from sloughing into the MRGO channel. Although the majority of these existing features were repaired after Hurricane Katrina, it is prudent to consider the long term maintenance requirements of all existing and proposed ecosystem features and those features that provide protection thereto. Protection to existing MRGO north bank shoreline protection features are not warranted at the time of this document preparation, but repairs to these elements will be considered in the preparation of a project O&M manual. Repairs to these structures will consist of capping the existing structure with additional stone, and/or repairing isolated failures, areas of settlement, and breaches. Specific features meeting this description are tabulated in the chart below:

Feature Name	Description	Location
MRGO-2*	North Shore Foreshore	MRGO Miles 44.4 to 39.9(Non-Continuous)
MRGO-3*	North Shore Foreshore	MRGO Miles 56.0 to 51.0(Non-Continuous)
MRGO-4*	North Shore Foreshore	MRGO Miles 36.6 to 37.1 and MRGO Miles 33.9 to 32.9

*See **Figures 42, 43, & 44** for maps of these features.

7.8 Access Corridors Component:

Access corridors for construction equipment and dredge pipeline are depicted in the plan view for each feature. Access corridors would be a maximum of approximately 150 feet in width and would cross over wetlands and shallow water as necessary. Access corridors for some features may occur across existing levees and different methods will be utilized to best prevent compromise of the levee while allowing access. The level of protection provided by these levees would be maintained throughout construction, and any damage to levee vegetation would be repaired upon removal of the construction equipment. The construction, or designation, of staging areas may be necessary for construction equipment. Staging areas will be determined on a site-by-site basis to minimize impacts to existing wetlands.

7.9 Weir Component:

Interior low-level earthen weirs may be constructed within the disposal area to facilitate the deposition of sediments in a manner that would enhance wetlands development. Borrow material for weir construction would be taken from within the disposal area. Earthen dikes/closures would be allowed to degrade naturally. If earthen dikes/closures do not sufficiently degrade to provide fisheries and tidal ingress/egress following appropriate settlement of dredged material placed within the disposal area, earthen dikes/closures would be mechanically breached and/or degraded as necessary.

7.10 Canal Closures:

As identified on the feature footprints, an earthen plug would be constructed in the canal utilizing sediments from the canal. The earthen plug would serve to prevent the flow of sediment laden water from the dredging activity to flow outside of the designated area of impact.

7.11 Staging Areas:

Staging areas would be a maximum of about 350 feet by 350 feet in size. If necessary, materials such as gravel, sand, dirt, shell, or some combination of materials would be placed over existing wetlands or shallow water to construct staging areas. Staging areas for restoration measures would be located within access corridors. Staging areas for diversion construction would be located within the identified 2000-ft corridor identified for structure and canal.

7.12 Flotation Access Corridors Component:

Flotation access channels would be excavated, as needed, in shallow water areas to allow construction equipment to access the project features. If necessary, flotation access channels would be excavated by a mechanical dredge, as is depicted in **Figure 45**. It is estimated that access channels will average approximately -2 feet. Flotation access channel material would be used in dike/closure construction or refurbishment, to backfill flotation access channels, or would be placed adjacent to and behind the dikes and closures in shallow water to a maximum initial elevation conducive to wetlands development following consolidation of the material. Flotation access channel material used to backfill the flotation access channels following completion of disposal work would be temporarily stockpiled on water bottom adjacent to the flotation access channel.

If existing canals are used for access, they may be dredged to facilitate flotation of pipeline and other necessary equipment from the dredging reach as designated in the plan feature to pipeline discharge sites within the designated staging areas. Dredged material removed from existing canals would be placed on adjacent existing levees and/or into shallow water on either side of canals. Canal dredged material placed in shallow water areas would be placed to a height conducive for wetlands development.

7.13 Borrow Component and Implementation Schedule:

Table 3: MRGO Ecosystem Restoration -				REV: 17 Nov 11
Cycle	New Feature Label	Cubic Yards Required	Borrow Depth (12' MAX BELOW MUDLINE-UNLESS OTHERWISE SPECIFIED)	Top of Cut Acres with Side Slope adjustment For 12' Max Borrow
	LM 1*	**14,300,000**	17.0	1075
	LM 4*	**1,200,000**	12.0	132
	LM 2*	**5,100,000**	6.5	984
1	**TOTALS**	**20,600,000**	**TOTALS**	**2,191**
	CC4 SITE 1**	**2,600,000**		0
	BR 1**	**400,000**		0
	CM 2	**4,700,000**	12.0	501
	BS1			
2	**BS2**			

	TOTALS	**7,700,000**	**TOTALS**	**501**
3	**ES1** **ES2** **ES3**			
	TM 1	**3,700,000**	12.0	396
	TM 2	**8,800,000**	12.0	930
	HM 1	**4,100,000**	12.0	438
	M 5	**3,000,000**	12.0	322
	M 8	**3,600,000**	12.0	385
4	**TOTALS**	**23,200,000**	**TOTALS**	**2,471**
	EM 1	**8,000,000**	12.0	846
	M 7	**1,650,000**	12.0	180
5	**TOTALS**	**9,650,000**	**TOTALS**	**1,026**
	BM 1	**9,700,000**	12.0	1024
	LM 3	**6,300,000**	12.0	669
	TM 7	**12,400,000**	12.0	1306
	TM 8	**10,100,000**	12.0	1066
6	**TOTALS**	**38,500,000**	**TOTALS**	**4,065**
	CM 1* **	**1,500,000**		0
	CM 3* **	**1,600,000**	12.0	174
	CM 4* **	**600,000**	12.0	68
	CM 5* **	**1,000,000**		0
7	**TOTALS**	**4,700,000**	**TOTALS**	**242**
	EM 2	**1,300,000**	12.0	142
	EM 3	**3,700,000**	12.0	396
	EM 4	**9,200,000**	12.0	972
8	**TOTALS**	**14,200,000**	**TOTALS**	**1,510**
	CC 1	**6,000,000**	12.0	637
	CC 2	**1,700,000**	12.0	185
	CC 3	**3,700,000**	12.0	396
	CC4 SITE 2	**4,900,000**	12.0	522
9	**CC4 SITE 3**	**2,200,000**	12.0	238

	CC4 SITE 4	**700,000**	12.0	78
	TOTALS	**19,200,000**	**TOTALS**	**2,056**
	CC 5	**7,800,000**	12.0	825
	CC 6	**5,200,000**	12.0	553
10	**TOTALS**	**13,000,000**	**TOTALS**	**1,378**
	Total CYS Borrow Required For Project	**150,750,000**		15,439

* Borrow depths for these features vary so that 2 years of monitoring can determine how water quality parameters (i.e. DO) are impacted

**USE OF MISSISSIPPI RIVER BORROW SITE BETWEEN MILES 85R AND 83R WILL PROVIDE APPROX 3,920,000 CYS FOR DREDGING TO -70'.

**FEATURES CC 4, Site 1, and BR 1 WOULD REQUIRE AN ESTIMATED 2,900,000 and 425,000 CY, FOR A TOTAL OF APPROX 3,325,000 CY.

***Borrow for Features CM1 and 5 to come from Reach 1 of the MRGO/GIWW, and Michoud Canal, if necessary. It is estimated that the GIWW/MRGO Reach 1 could provide approx 2.6 million CY of the estimated 2.5 million CY required for these marsh creation features. Additional yardage, if required, could come from Michoud Canal or other sources such as Lake Borgne and/or the Mississippi River.

During the analysis of alternatives extensive energy was placed in reviewing the sources of the approximately 150,750,000 cubic yards of dredged material (**Table 3**) that would be required for swamp and marsh restoration features. The ridge restoration feature requires approximately 425,000 cubic yards of silty sand material to facilitate stacking.

Lake Borgne water bottoms are the closest source of borrow material for the restoration features, and therefore the least costly and most viable source. However, the lake bottom is designated as critical habitat for the endangered Gulf Sturgeon. A discussion of impacts can be found in section 9 of this document.

7.13.1 Potential Borrow Sources:

Potential borrow sources for swamp and marsh restoration features include the Mississippi River, the Inner Harbor Navigation Channel (IHNC) / Gulf Intracoastal Waterway (GIWW), the former MRGO, Lake Pontchartrain, Lake Lery, Lake Borgne, Breton Sound, and

offshore sources including the former MRGO ocean dredged material disposal site (ODMDS). Barges could be used to bring material from other locations in the region; however, the cost of bringing material by barge is generally twice as much as pumping material via pipeline from a nearby source. Other sources of material from outside of the study area were not considered practicable options due to the costs associated with obtaining, transporting, and stockpiling the needed volume of material.

Dredging the MRGO to obtain borrow material for wetland restoration is a potentially unacceptable alternative. However, congressional and public preference for filling in the channel and restoring the area to historic conditions is documented in the Scoping Report for this study and numerous other public documents:

- The Final Environmental Impact Statement (EIS) for the Mississippi River-Gulf Outlet (MRGO), Louisiana, and Lake Borgne – Wetland Creation and Shoreline Protection Project, a USACE document, states that "use of the MRGO channel as a borrow source was considered to be contrary to the Congressional intent, as described in House Report No. 109-359, that funds provided in P.L. 109-148 for authorized operation and maintenance activities along the MRGO not be used to conduct any dredging of the MRGO channel."
- Louisiana House Concurrent Resolution 34 (2005) to "suspend any current appropriations or authorizations for expenditure of funds to dredge the Mississippi River Gulf Outlet, to direct the United States Army Corps of Engineers not to engage in any dredging activities on the Mississippi River Gulf Outlet, and to begin the necessary process to return the waterway to wetlands marsh status as close as possible to what it was prior to establishment of the canal."
- "MRGO Must Go A Guide for the Army Corps Congressionally-Directed Closure of the Mississippi River Gulf Outlet" (Endorsed by LSU, Coalition to Restore Coastal Louisiana, Lake Pontchartrain Basin Foundation, Environmental Defense Fund, Gulf Restoration Network, National Wildlife Federation, Louisiana Wildlife Federation, American Rivers, and St. Bernard Parish).

Because Lake Borgne (the closest available borrow source for most features) is critical habitat for Gulf sturgeon, all viable alternatives must be investigated to avoid and minimize potential impacts to critical habitat to the extent practicable.

Analyses were conducted for using the MRGO as a potential borrow source between the closures at Bayou Bienvenue (IHNC Surge Barrier) and Bayou La Loutre. Assuming dredging to -40' by 500' with a 1' over-depth, approximately 15.5 million cubic yards of material would be available for use in restoration projects. The practicability and acceptability of the use of the MRGO must also be considered. "An alternative is practicable if it is available and capable of being done after taking into consideration cost, existing technology, and logistics *in light of overall project purposes*" (40 CFR 230.10 emphasis added). The purpose of the study is to restore areas affected by the MRGO. The area that was dredged to create the channel is the most directly affected area. Dredging the channel would not restore the area to a more natural

condition: it would alter conditions further. Therefore, dredging the channel would be contrary to the study purpose and is not a practicable alternative.

Degrading the MRGO spoil banks south of the Chalmette Loop Levee to marsh elevation was considered as a restoration feature that would also provide material. This alternative was rejected by the majority of the PDT, as it was perceived to be inconsistent with the goal of the study to restore natural features that would reduce storm surge.

7.13.2 Viable Borrow Sources:

7.13.2.1 Mississippi River:

The Mississippi River is a preferred source of material. The Mississippi River was the natural source of nourishing sediment for the study area prior to the construction of levees. The silty sand in the river is easier to stack than more organic material. Material from the river is "new" sediment in the system: it is carried downstream from outside of the study area. Given the need for sediment within the study area, it seems illogical that the majority of the sediment in the river is allowed to be lost off the continental shelf.

However, the cost per unit associated with moving sediments from the river to restoration areas is significantly higher than other sources (**Table 4**). All things being equal, using river sediment for a restoration area with an average pumping distance of 20,000 feet (3.8 miles) would cost approximately 25 to 30 percent more than using material from Lake Borgne. However, all of the proposed marsh and swamp restoration features are significantly farther away from point bar deposits of river sediment than the nearest borrow source. Dredging costs are positively correlated to distance: the cost of transporting material via pipeline for an average distance of 50,000 feet is about twice as much for an average distance of 20,000 feet. Because dredging at depths greater than 70 feet necessitates costly modifications to dredging equipment, it is not feasible to dredge the nearest location on the river. Other factors influencing the feasibility of using Mississippi River sediment include considerations for laying pipe across levees and land, rather than water, and potential impacts to navigation.

Table 4: Unit Cost of Dredging and Transporting via Pipeline

Average Pumping Distance	Source: Lake Borgne	Source: Mississippi River
20,000 lf	$4.50	$5.75
30,000 lf	$5.80	$6.75
40,000 lf	$7.25	$10.00
50,000 lf	$9.75	$10.25
60,000 lf	$11.00	$15.00

Notes: Very rough comparison of costs based on recent projects. Estimates for 5 million cubic yards of material. Assumes the same project from different source with all other factors being equal.

It is possible to load dredged river sediment onto barges and transport it to a restoration site. However, this process costs at least twice as much as dredging and distributing via pipeline. Mississippi River sediment was determined to be feasible for construction of the proposed ridge restoration feature at Bayou La Loutre (BR1), although it was not the most cost-effective sediment source. Dredged material from between Miles 83 and 85 of the river would be transported approximately 52 miles via barge to this site. **Figure 46** shows the path that must be taken for barging river sediments to this project feature. The relatively limited scope of this proposed restoration feature (425,000 cubic yards of material) and the benefits of using silty sand material from a freshwater source (more stackable, can immediately support woody vegetation) contribute to the feasibility of the river as a sediment source for this feature.

7.13.2.2 Lake Lery:

Lake Lery was determined to be a viable borrow source for features TM7 and TM8. However, a number of other restoration plans currently under development are considering the use of Lake Lery. Because of the uncertainty associated with the use of Lake Lery as a borrow site in the future, Lake Borgne is considered to be the source of borrow materials for these features for the purposes of evaluating potential impacts. If it is practicable to use Lake Lery as a borrow source for the implementation of these features, it would reduce the total amount of dredged material required from critical habitat by approximately 18.1 million cubic yards.

7.13.2.3 GIWW/ Michoud Canal:

Measure CM2 would utilize sediment from the adjacent GIWW channel between miles 66 and 60. The channel would be dredged to its authorized depth to provide material for this restoration feature. This feature would also utilize sediment from the Michoud Canal. The material needed to construct this feature would exhaust the supply from these sources for use elsewhere in the near-term.

7.13.2.4 MRGO ODMDS:

This site is not a practicable site for marsh and swamp restoration features, because it contains highly saline sediments and is located over 30 miles away from the nearest restoration sites and 50 to 70 miles from other features.

7.13.2.5 Borrow from Lake Borgne, Gulf Sturgeon Critical Habitat:

Lake Borgne water bottoms were determined to be the most cost-effective and feasible borrow source for construction of the remaining restoration features requiring sediment. In order to reduce impacts to critical habitat, hard bottom areas would be avoided because it is considered preferred habitat for the Gulf sturgeon. Although hard bottom areas would provide better material for restoration features and the duration of the potential impacts of turbidity could be reduced if sediments with a greater sand component were utilized, it was ultimately determined that impacts to Gulf sturgeon would be minimized by avoiding prime habitat locations. Lake Pontchartrain is the closest site for a few marsh creation features. However, the portion of Lake

Pontchartrain in the study area is also designated critical habitat for Gulf sturgeon. Due to the sandy composition of Lake Pontchartrain bottoms in the vicinity, these areas are considered prime habitat, and were removed from consideration. **Figure 47** and **Figure 48** reflect the USGS and NOAA sand/hard bottom survey findings that helped determine the areas in Lake Pontchartrain and Lake Borgne that needed to be avoided. The brown and yellow areas in Lake Pontchartrain represent sandy substrates. In Lake Borgne, the red areas are more reflective high backscatter areas (likely hard bottom/shell), while the blue areas are the low backscatter (uniform areas of likely very fine sand/silt). The results from the side scan sonar surveys in Lake Borgne were back checked in the field by Corps ERDC lab personnel using ponar grabs.

The proposed borrow plan is detailed in **Figure 49**. As the borrow plan depicts, borrow sites would be located a minimum of 3,000 ft (914 m) from the Lake Borgne shoreline to minimize potential impacts to hydraulic conditions (e.g., wave climate), as well as to avoid existing oyster leases to the maximum extent practicable. Borrow material would be excavated with a hydraulic dredge and transported via pipeline to wetland creation and nourishment sites.

Designated borrow areas are estimated larger than needed for each feature to ensure that adequate material is available in the event that environmental or cultural resources are discovered during construction that require avoidance. Borrow areas would be designed to minimize hypoxic (lack of dissolved oxygen) formation. Borrow sites would be excavated to relatively shallow depths of approximately 10 ft plus 2 ft of allowable over depth (3-4 m below existing depth), and would gradually transition from adjacent water bottoms to project depth. Proposed borrow sites would be located a minimum of approximately 3,000 ft (914 m) from shorelines and tidal passes that may potentially provide organic material (allochthonous) inputs that could contribute to hypoxic conditions. In addition, sedimentation rates within the project area are relatively low without the presence of predominant organic layers. Moreover, circulation within Lake Borgne is not restricted by physical barriers, and storm fronts generating considerable wave energy commonly occur. Proposed borrow site dimensions, combined with observed characteristics of the project area are therefore not expected to favor the formation of hypoxic conditions. The dredge pipeline would be floated over lake bottoms to minimize potential adverse impacts to the benthos, including oysters. In some areas, nearshore floatation/access channels may be required for equipment access. Floatation/access channels would be constructed, as needed, with a bucket or clamshell dredge. Flotation/access channel material would be used in dike/closure construction or refurbishment, to backfill flotation/access channels, or would be placed adjacent to and behind the dikes and closures in shallow water to a maximum initial elevation conducive to wetlands development following consolidation of the material.

The potential impacts of dredging in Lake Borgne to Gulf sturgeon are anticipated to be short-term temporary effects on marine water quality and benthic organisms within the borrow areas. The benthic community is anticipated to recover quickly from these impacts. Because Lake Borgne is impacted by storm and tidal events that result in similar temporary increases in turbidity and the species found in this area are used to fluctuations in abiotic factors, it is expected that the turbidity caused by the dredging operations would not have a significant effect on habitat quality within Lake Borgne. Approximately 150.7 million cubic yards of material is

proposed to be borrowed from critical Gulf sturgeon habitat, impacting 15,439 acres (2.5%) of Lake Borgne. Where it was determined feasible, alternative sites that are not critical habitat are proposed. The distance from other sites is the limiting factor, as transporting material by barge involves double handling and costs significantly more than transporting material via pipeline. Areas of high habitat value were identified in Lake Borgne and Lake Pontchartrain, and were removed from consideration to avoid adverse impacts.

7.14 Freshwater Diversion Component:

A FWDV would be studied further. Once this analysis is complete all necessary environmental clearances would be obtained for this feature

8.0 THREATENED AND ENDANGERED SPECIES

There are 10 animal species, under the jurisdiction of the U.S. Fish and Wildlife Service (USFWS) and/or the National Marine Fisheries Service (NMFS), presently classified as threatened or endangered within the project area (**Table 5**). The USFWS and NMFS share jurisdictional responsibility for sea turtles and the gulf sturgeon.

Table 5. Threatened (T) and Endangered (E) Species potentially in Orleans and St. Bernard Parishes

Common Name	Scientific name	Federal Status	State Status
Gulf Sturgeon	*Acipenser oxyrinchus desotoi*	T; Critical Habitat	T
Pallid Sturgeon	*Scaphirynchus albus*	E	
Shovelnose Sturgeon	*Scaphirynchus platorynchus*	T; SOA	
Green sea turtle	*Chelonia mydas*	T	T
Hawksbill sea turtle	*Eretmochelys imbricata*	E	E
Kemp's ridley sea turtle	*Lepidochelys kempii*	E	E
Leatherback sea turtle	*Dermochelys coriacea*	E	E
Loggerhead sea turtle	*Caretta caretta*	T	T
Piping plover	*Charadrius melodus*	T; Critical Habitat	T
West Indian manatee	*Trichechus manatus*	E	E
Source: United States Fish and Wildlife Service (USFWS; July 2011). (P = protected; T = Threatened; E = Endangered)			

8.1 Gulf Sturgeon (*Acipenser oxyrinchus desotoi*)

8.1.1 Description of Species

The Gulf sturgeon, *Acipenser oxyrinchus desotoi* (Vladykov, 1955), is a separate subspecies of the Atlantic sturgeon, *Acipenser oxyrinchus oxyrinchus*. Gulf sturgeon differ from their Atlantic counterparts in relative head length, pectoral fin lengths, dorsal scute shape, as well as spleen length and position. In 1996, Ong et al. presented genetic evidence that Atlantic and Gulf sturgeon are different species using direct sequence analysis of the mitochondrial DNA control region. Gulf sturgeon are anadromous fish (migrating seasonally between fresh and saltwater) that range primarily from the Suwannee River in Florida to the Mississippi River in Louisiana (Morrow et al, 1996). Their distribution is limited to the Gulf of Mexico by the emergence of peninsular Florida, which led to the development of the separate species. This speciation is maintained by the thermal barrier of the Gulf Stream around south Florida (Huff, 1975). Similarly, the Mississippi River also appears to limit their movements in the Gulf of Mexico to east of the Mississippi River though historically they have been known to occupy these waters.

Gulf sturgeon are light brown to dark brown in color with a pale underside (USFWS & Gulf States Marine Fisheries Commission, 1995). They have elongate, fusiform bodies covered by naked skin imbedded with bony plates or scutes. These scutes are strongly developed into 5 longitudinal rows with 7-13 dorsal scutes, 24-35 lateral scutes behind the dorsal fin in pairs, and 2 ventral rows of scutes (USFWS & GSMFC, 1995). The scutes are sharp in young adults, but wear down and become blunt with age. The skin between the scutes may develop ossifications (USFWS, 1980). The length of Gulf sturgeon scutes are shorter than their width, giving them a squarish appearance. In contrast, Atlantic sturgeon scutes are ovular (Huff, 1975). The skeleton is primarily cartilaginous and the chondrocranium (skull) grows throughout life (USFWS, 1980). The head is elongate with the snout longer than the postorbital distance in individuals up to 95 cm, but shorter than postorbital distance in older specimens (USFWS & GSMFC, 1995). The relative head length of the Gulf sturgeon, 30.9 to 33.6 percent of the fork length, is longer than the relative head length of the Atlantic sturgeon, 26.5 to 27.6 percent of the fork length (Huff, 1975).

The snout is greatly extended and bladelike with four fleshy barbels growing in front of the mouth. The mouth is protractile on the lower surface of the head (USFWS & GSMFC, 1995) and lacks teeth (USFWS, 1980). Gulf sturgeon have no operculum protecting their four gills and have only one accessory opercular gill. The number of gill rakers of adults varies between 17 and 27, with an average of 21.6 (USFWS, 1980). The enlarged, ossified first ray of the pectoral fin shows growth rings (annuli), which are used to determine the age of the fish (Huff, 1975). The dorsal fin is located posterior to the ventral fin. The upper lobe of the caudal fin is longer than the lower lobe (USFWS & GSMFC, 1995).

The largest recorded Gulf sturgeon was caught at Cow Horn Reef near the mouth of the Mississippi in September 1936. Its reported mass was 228.2 kg with a length of 274 cm (Reynolds, 1993). The average adult Gulf sturgeon ranges in size from 120-225 cm in length with an average weight between 35-320 lbs. Size is dependent on the individual's gender, age, and spawning condition (USFWS, 1980; Huff, 1975). Females live longer than males and continue to grow with age, consequently they are larger and weigh more than males (Huff, 1975). Females reach sexual maturity between 8 and 17 years of age while males reach sexual

maturity between the ages of 7 to 21 (Huff, 1975). Gulf sturgeon are long lived, having the possibility of reaching at least 42 years old (Huff, 1975).

8.1.2 Distribution and Abundance

Gulf sturgeon show a high fidelity for their natal rivers. In 1997, Wirgin et al. identified five genetically-based stocks: (1) Lake Pontchartrain and Pearl River; (2) Pascagoula River; (3) Escambia and Yellow Rivers; (4) Choctawhatchee River; and (5) Apalachicola, Ochlockonee, and Suwannee rivers. However, recent investigations using additional variable markers have since shown a genetic distribution for Gulf sturgeon on a river by river basis. Straying between rivers does occur, but actual gene flow between rivers appears to be low. Gulf sturgeon may share marine habitats and even lower river habitats with neighboring populations, but the number of fish found sharing the spawning grounds of adjacent rivers remains low. Mitochondrial genetic analysis of populations sampled showed that Gulf sturgeon return to natal river areas for feeding as well as spawning (Stabile et al., 1996). Wooley et al. (1985) suggested that sturgeon may be behaviorally or genetically imprinted on the water from their home rivers. In genetic studies using microsatellite markers, Dugo et al. (2004) found that their work supported patterns of stock structure and further resolved drainage level differentiation introduced by Stabile et al. (1996). Resolution in their study provided positive differentiation between the Pearl and Pascagoula populations, while reinforcing regional groupings suggested by mtDNA in previous studies. Recovery is expected to vary among systems prompting the need for site-specific recovery plans (Morrow et al. 1998)

Distribution of Gulf sturgeon in Louisiana extends from the Mississippi River east to the Pearl River. The majority of these sturgeon have their origins in the Pearl River system, where the largest population occurs. However, Gulf sturgeon have historically inhabited many of the larger tributaries east of the Mississippi River, including some upstream of the Ross Barnett Dam on the Pearl River (Morrow et al., 1996).

Below abundance has been described for each of the following Louisiana waterways. Most of these areas are not routinely sampled by the FWS or the LDWF. Catch data is in the form of scientific reports and/or incidental catch reports from commercial/recreational fishermen have been used to describe the relative abundance for Gulf sturgeon within these waterways.

8.1.2.1 Offshore

From 2001 to 2004 LDWF netted and radio/sonic tagged Gulf sturgeon in the Pearl River system in an effort to determine their over-wintering habitats by tracking these fish as they exited the rivers. These tracking studies showed that once Gulf sturgeon leave the Pearl River System they travel east along the Mississippi coast feeding around barrier islands such as Horne, Ship, Cat and Petit Boise Islands. As of 2004, there were 50 active sonic tags on Gulf sturgeon from Louisiana. In January of 2004, a remote sensing station on the northern-most tip of Chandeleur Island, LA picked up the sonic impulses of three different sturgeon as they passed within a half mile of the island.

In 2004, shrimpers working near Bay St. Louis, Mississippi, caught a Gulf sturgeon previously tagged by LDWF in the Bogue Chitto River that measured 20 inches long. D.K. Bradshaw reported three tag returns from Gulf sturgeon that were incidentally caught by shrimpers working in Mississippi Sound during the fall of 1985. Bradshaw originally collected these Gulf sturgeon from rkm 32 on the Pearl River earlier in 1985 (Parauka, 2000). In January of 1994, a fisherman recaptured a Gulf sturgeon, previously tagged in the Bogue Chitto River by LDWF, in Oak River Bay, St. Bernard Parish, LA.

8.1.2.2 Mississippi River

As a result of the channelization of the Mississippi River through its extensive lock and levee system, any spawning habitat that may have existed in the Mississippi River for Gulf sturgeon has since been severely degraded. There is no evidence indicating a reproducing population in this river and no verified captures of Gulf sturgeon have occurred in the Mississippi River. The movements of foraging sturgeon along the coast may occasionally place them in the vicinity of the mouth of the Mississippi. At present, they are not believed to utilize the MR, therefore no critical habitat has been designated in this area for Gulf sturgeon.

In 2002, a Gulf sturgeon previously tagged by LDWF in the Bogue Chitto River was caught in Tiger Pass at the mouth of the Mississippi River in a shrimp trawl. A sturgeon was caught by a commercial fisherman in the auxiliary outflow channel at the Old River Control Complex (ORCC) between rkm 500.3 of the Mississippi River and rkm 16.09 of the Red River on March 28, 1994. It was caught in a 1.2 m hoop net and weighed 28.8 kg with a length of 151.2 cm. Photographic examination of this sturgeon by several agencies resulted in the conclusion that this fish was not a Gulf sturgeon, but instead most likely a Lake sturgeon (G. Constant, personal communication). A Gulf sturgeon with a mass of 228.2 kg and a length of 274 cm was caught at Cow Horn Reef near the mouth of the Mississippi in September 1936 (Reynolds, 1993). A photograph of a Gulf sturgeon caught in Louisiana waters near mouth of the Mississippi was shown in *Fishes and Fishing in Louisiana* (1965).

8.1.2.3 Lake Pontchartrain Basin

Of the many distributaries that tie into the Lake Pontchartrain Basin only a few of the rivers still support a population of Gulf sturgeon. Channel modifications and impoundments have resulted in significant losses of summer habitat within this basin. The Pools Bluff sill on the Pearl River (rkm 78.3) and the Bogue Chitto sill on the Bogue Chitto River (rkm 6.4, from its confluence with the West Pearl River) were constructed in 1956 and are barriers to upstream fish migration during low-water conditions (Morrow et al., 1998). Davis et al. (1970) reported Gulf sturgeon within the Bogue Chitto, Pearl, Tangipahoa, Tchefuncte, and Tickfaw Rivers. Efforts have been made to better understand the habitat requirements of this species within these Louisiana waters. Below, the Lake Pontchartrain basin has been divided into functional elements and a summary of the latest information on Gulf sturgeon for these areas has been included.

8.1.2.3.1 ***Lake Maurepas, Lake Pontchartrain, Lake Catherine, The Rigolets, Lake Borgne, and Mississippi Sound***

In 2003, critical habitat Unit 8 was designated for the Gulf sturgeon within this area and includes the eastern half of Lake Pontchartrain, the Rigolets, Lake Catherine, Little Lake and Lake Borgne (**Figure 50**). Unit 8 includes approximately 1377 square miles (Miles ^{2}) of critical habitat with 277 miles ^{2} in Lake Borgne, 3 in Little Lake miles ^{2}, 295 in Lake Pontchartrain miles ^{2}, 10 in Lake St. Catherine miles ^{2}, 5 in the Rigolets miles ^{2}, 725 in Mississippi Sound miles ^{2}, and 62 along the MS near shore Gulf miles ^{2}. Prior to the listing of the species, Davis et al. (1970) reported the collection of Gulf sturgeon from Lake Pontchartrain during a LDWF anadromous fish survey from 1966 to 1969. From 1988 to 1999, LDWF, through various means and studies, captured and recorded at least 60 Gulf sturgeon throughout Lake Pontchartrain, Lake Catherine, the Rigolets and Lake Borgne. A LDWF trammel net study conducted by Inland Fisheries Division in the spring of 2001 resulted in the capture of three young of the year juvenile sturgeon at the intersection of the East Pearl River and Little Lake. In 2002, LDWF Seafood Division reported the capture of a Gulf sturgeon in one of their gill nets while sampling in a cove west of Alligator Point, Lake Borgne.

From September 2000 to October of 2001, Rogillio et al., conducted a study to document the status, movement and habitat use of Gulf sturgeon within the Lake Pontchartrain Basin. Rogillio et al. (2001) estimated the population size by use of directed trammel netting at the same sites sampled by Davis et al. 1970. The presence of sturgeon in this study were only documented in the Tchefuncte, Bogue Chitto, and Pearl Rivers. Sonic tags were placed on 25 adult Gulf sturgeon from within the Pearl River. Tracking demonstrated winter use of habitats near the Mississippi Gulf Islands. Incidental capture of a study animal near the Breton Island, Louisiana, indicates some us of barrier island sites within Louisiana. In this study Rogillio et al. indicated that one year of data collection was not adequate to determine population trends. In 2007, Rogillio et al., expanded their initial effort by conducting a three year mark and recapture study within the Pearl River Drainage. Between July 2000 and October 2003, Five hundred and three subadult and adult Gulf sturgeon were captured (or recaptured) in the Bogue Chitto and Pearl Rivers. In March and April, the majority of tagged fish began to move from offshore waters to the Rigolets Pass at the mouth of the Pearl River. Telemerty of Adult Gulf sturgeon in this study were consistent with known Gulf sturgeon movement patters in Mississippi, Alabama, and Florida (Rogillio et al., 2007)(see movements and migration section for more details).

By-catch of Gulf sturgeon has been reported by several recreational and commercial fishermen within these waters. A total of 177 Gulf sturgeon measuring up to 220 cm in length and weighing from 1 to 69 kg in these lakes and in the Rigolets from October 1991 to September 1992 (Rogillio, 1993). Reynolds (1993) reported that sturgeon measuring up to 220.0 cm in length and weighing up to 117.3 kg were incidentally caught by shrimp trawlers, netters and recreational anglers from 1889 to 1993 in Lake Pontchartrain. A Gulf sturgeon, weighing 175.9 kg, was caught in Lake Borgne in a shrimp trawl in 1978 (Sportsmen of Slidell, 2000).

8.1.2.3.2 ***Pearl River and Bogue Chitto River***

The Pearl and Bogue Chitto Rivers are two of the few rivers within the state of Louisiana that are believed to still support a spawning population, though a spawning location has not yet been identified. Originating above Jackson, MS and flowing into the Rigolets and Lake Borgne, the Pearl River drains approximately 22,690 km^2 in central Mississippi. The Bogue Chitto River originates 25.8 rkm northwest of McComb, Mississippi and runs southeasterly for 102.4 rkm through Louisiana to the navigation sill.

Barriers to fish migration occur on the Pearl River at the Ross Barnet Dam, river kilometer (rkm) 486, and at the Pools Bluff Sill, rkm 78.3 (Morrow et al. 1998). In 1956 the USACE completed the Pearl River Navigation Project which was designed to aid commercial barge navigation westward to Bogalusa, LA. Three locks and three low water sills were added to the river/canal system to maintain water levels for barge traffic (**Figure 51**). The sills were placed on the Pearl River at Pools Bluff north of lock 3, on the Bogue Chitto River south of lock 3, and on Talisheek Creek between locks 1 and 2. The low water sills on the Pearl River obstruct up to 407.7 rkm of potential sturgeon spawning and summer habitat between Ross Barnett and Pools Bluff during critical spring migration. Only the last 16.1 rkm below the Bogue Chitto sill contributes to spawning and summer habitat on this river. Possible habitat loss due to the sill is 91 percent. Morrow et al. (1998) found that the Bogue Chitto sill is a barrier to sturgeon passage during low water levels up to 292 days a year.

In 2003, critical habitat Unit 1 was designated for the Pearl and Bogue Chitto River systems. Approximately 393 river miles of the Pearl River are designated and 101 river miles of the Bogue Chitto River are designated. The Pearl River critical habitat extends from its mouth to the Ross Barnett Dam near Jackson, MS (**Figure 51**). Critical habitat in the Bogue Chitto River extends from its confluence with the Pearl River up to Hwy 570 near Summit, MS.

Many research efforts have been conducted over the past 15 years, in an effort to better understand habitat associations within this river system. Given the limited distribution of the Gulf sturgeon population within the state of Louisiana, the viability of the population within this drainage is very important. Catch rates for these rivers remain the highest within the state of Louisiana.

A commercial fisherman caught a Gulf sturgeon, weighing 90.9 kg, in the Bogue Chitto River in St. Tammany Parish in October, 1989 (H. Rogillio, personal communication). From 1992 to 1996, Morrow et al. (1998), sampled for 256,930 net-meter-hours from the Pools Bluff and Bogue Chitto sills. The Pearl River between Pools Bluff sill and Ross Barnett Dam was sampled for 131,530 net-meter-hours in 1995 and 1996. In all, 257 Gulf sturgeon were captured in four reaches of the Pearl River system. No Gulf sturgeon were netted upstream from these sills by Morrow et al. (2001), but a commercial fishermen did capture a Gulf sturgeon near Monticello Mississippi, in April of 1996. . In 1993, LDWF captured three Gulf sturgeon below

the sill with weights between 2.9 to 4.5 kg (H. Rogillio, personal communication). . Ninety three were caught in the 2002 season and seventy four sturgeon were caught in the 2001 season, all below the sill. Fifty nine Gulf sturgeon were caught on the Bogue Chitto below the sill in the 2003 netting season by LDWF

Pearl River Gulf sturgeon populations appear to have recovered substantially from levels reported in the mid 1990s with noticeable improvements in the population's size distribution characteristics. The population in the mid 1990s was estimated at approximately 300 fish, with only about 3 percent of the population adults. High annual mortality rates of 34 percent were estimated for the 1995-1996 season. Morrow et al. (1999) suggested that the Pearl River Gulf sturgeon population would be self-sustaining if the number of adults was at least 100, recruitment was satisfactory, and annual mortality was less than 15 percent. Data collected during 2000 and 2001 by Rogillio et al 2001, suggests that the population is at lease self-sustaining and may even be recovering based on these criteria. In 2004, the Pearl River population contained 100+ adults and recruitment was satisfactory with numerous juveniles captured. The total annual mortality rate for the population was estimated at 7 percent and the population appeared to be self sustaining. Five Gulf sturgeon have been collected between Pools Bluff sill and Ross Barnett Dam since 1970 indicating some upstream migration over Pools Bluff sill.

8.1.2.3.3 ***MRGO***

The MRGO is a man-made navigational channel that originates from the inner harbor navigation canal in eastern New Orleans, Louisiana, and cuts southeasterly through the marsh into the Breton Sound. Presently, no critical habitat has been established for this channel.

In 1990, LDWF's Seafood Division captured a Gulf sturgeon previously tagged in the Bogue Chitto River, weighing 6.5 lbs and measuring 32 inches, in a trammel net set in Lena's Lagoon off the MRGO. In January 2005, the USACE- Engineering Research and Development Center (ERDC) biologists tracked a sturgeon in the MRGO near the Breton Sound Marina as it moved from the channel into marshes adjacent to the channel. This fish had been tagged in the Bogue Chitto in August of the same year and had a fork length of 33.25 inches and weighed 6.7 lb at the time of capture. A commercial fisherman reported catching a Gulf sturgeon in the fall of 1983 in Violet Canal that was 6 ft long (D. Walther, personal communication). Violet Canal connects the wetlands to the west of the MRGO to the MRGO. A commercial fisherman reported taking a Gulf sturgeon 7 ft long and 170 lbs. in weight in his trawl in Bayou Bienvenue in 1974 (D. Walther, personal communication). Though Bayou Bienvenue once connected Lake Borgne and the MRGO, the construction of the IHNC-Lake Borgne Surge Barrier has reduced access to this area. The project consists of a bypass barge gate and a flood control sector gate at the GIWW, a vertical lift gate at Bayou Bienvenue, a braced concrete barrier wall across the MRGO and the Golden Triangle Marsh, and floodwalls on the north and south ends that tie into the risk reduction system in Orleans Parish and St. Bernard Parish, respectively.

Amidst concerns expressed by the USFWS regarding potential impacts of dredging and disposal operations associated with the O&M of the MRGO shipping channel, a 3-year study

began to evaluate the potential occurrence of Gulf sturgeon in the MRGO. A joint tagging effort between ERDC and the LDWF began in the summer of 2004. The inland portion of MRGO was surveyed using mobile sonic monitoring. Approximately 100 soundings were made monthly in the MRGO and a total approaching 2,400 soundings were made during the period of this study. Only one Gulf sturgeon was located in the MRGO on 19 January 2005 near marker 96 (29° 50' 669" N, 089° 37' 643" W). This juvenile fish was captured and tagged on 19 August 2004 in the East Pearl River near the National Aeronautics and Space Administration's (NASA) John C. Stennis Space Center (Kirk, 2008)

On June 5, 2008, the MRGO was deauthorized and a channel closure structure was authorized to be constructed south of Bayou la Loutre. In late July 2009 the final load of rock was placed completing the closure structure. The ERDC and LDWF sampling effort in 2004 showed that Gulf sturgeon usage of the channel was probably a rare event; the construction of this closure has further reduced access to the MRGO channel and therefore further reduced the likelihood of encountering this species within this remnant channel.

8.1.2.3.4 *Tchefuncte/Bogue Falaya River*

The Tchefuncte River originates 16.1 km southeast of Kentwood, LA and flows 98.5 rkm south to Lake Pontchartrain. At present no man-made barriers or structures occur on this river. No critical habitat has been established for this river.

Davis et al. (1970) reported the collection of Gulf sturgeon from the Tchefuncte River during a LDWF anadromous fish survey from 1966 to 1969. Between February and March 1991 commercial gill-netters reported catching 15 Gulf sturgeon weighing from 1-18 kg in the mouth of the Techefuncte River (H. Rogillio, personal communication). In March of 1996, a fisherman caught a 6 kg Gulf sturgeon on a trot line in the river. The catch was reported by a local taxidermist and LDWF was able to retrieve the fish and obtain its measurements. Researchers collected three Gulf sturgeon, 60.9 to 91.4 cm in length, in May 1998 in the Techefuncte River below the confluence of the Bogue Falaya River (Parauka, 2000).

8.1.2.3.5 *Tangipahoa River*

The headwaters of the Tangipahoa River are 13.9 km northwest of McComb, Mississippi, flowing 179 rkm south to Lake Pontchartrain. At present no man-made barriers or structures occur on this river. No critical habitat has been established for this river.

Davis et al. (1970) reported the collection of Gulf sturgeon from the Tangipahoa River during a LDWF anadromous fish survey from 1966 to 1969. No recent captures of Gulf sturgeon have been reported for this river.

8.1.2.3.6 *Tickfaw River*

The Tickfaw River originates 15 km southwest of McComb, Mississippi and flows 150.8 km south to Lake Maurepas. At present, no man-made barriers or structures occur on this river. No critical habitat has been established for this river.

In 1970, Davis et al. reported the collection of Gulf sturgeon from the Tickfaw River during a LDWF anadromous fish survey from 1966 to 1969. In May of 2001, the USFWS caught 3 Gulf sturgeon in gill nets with weights of 1.4, 8.6 and 17.7 kg near the confluence of the Natalbany and Tickfaw rivers.

8.1.2.3.7 *Amite River*

The Amite River and its tributaries drain approximately 2,200 square miles in southeastern Louisiana and southwestern Mississippi. The 274 km long Amite River originates in southwestern Mississippi and flows generally southward draining into Lake Maurepas. Only the lower 71 km of the river is navigable. No critical habitat has been established for this river.

Davis et al. (1970) reported the capture of a sturgeon by a commercial fisherman from the Amite River. Identification of this fish was confirmed by fisheries biologists with the Louisiana Wildlife (sic) and Fisheries Commission participating in an anadromous fish survey from 1966 to 1969. Recent sampling efforts in this river by the LDWF have produced only one capture of a Gulf sturgeon, (0.8 m, 2.7 kg), in August of 2003. This capture was 77 km from the western critical habitat boundary.

8.1.2.4 Incidental captures

The LDWF (1979) reported that an Atlantic sturgeon was caught by a Mr. Hugh Mhire in an otter trawl while shrimping in the Gulf of Mexico off the mouth of the Mermentau River, Cameron Parish, LA. This specimen was probably a Gulf sturgeon (Paruka, 2000). In 1990 a commercial fisherman reported trawling up a Gulf sturgeon three miles out from Last Island (Raccoon Island), Terrebonne Parish, LA (D. Walther, personal communication).

No documented Gulf sturgeon captures or sightings have occurred in the following waterways: Baptiste Collette Bayou, Bayou Bonfuca, Bayou Dupre, Bayou Lacombe, Bayou La Loutre, Bayou Manchac, Bayou St. Malo, Bayou Yscloskey, the Blood River, the GIWW, Michoud Canal, the Mississippi River, the Natalbany River, Pass Manchac, the Pontchatoula River, South Pass, Southwest Pass, nor any rivers west of the Mississippi River.

8.1.2.5 Movements and Migration

Gulf sturgeon live in the estuaries and coastal shelf regions of the Gulf of Mexico during the cooler months from October to March. In March and early April, adult sturgeon start their migration into the freshwater rivers in search of spawning habitat. Non-ripe adults, juveniles and subadults also participate in this yearly migration, but usually lag behind the spawning adults, moving into the rivers anywhere from days to months later. Sexually mature, ripe males and females enter the rivers when the surface water temperatures reach 62-70° F (Carr, Tatman, &

Chapman, 1996). Fox et al. (2002), in their studies of Gulf sturgeon in the Choctawhatchee Bay, found that male sturgeon enter the river earlier than female sturgeon and move greater distances upstream. Males were also found to remain at the spawning grounds longer than females. Ripe specimens of both sexes entered the Choctawhatchee River earlier and moved significantly further upstream than non-ripe fish. After spawning, both males and females return to the lower river reaches and join their non-spawning counterparts in summer holding areas where they reside until the fall migration. After hatching, age-0 fish remain in riverine habitats through January, moving into the estuaries in February as age-1 fish (Sulak et al., 1998).

Telemetry of adult Gulf sturgeon in Louisiana has provided dates of ingress and egress into critical habitat areas 1 and 8. (**Diagram 1; Figures 52**). These movement dates are consistent with known Gulf sturgeon movement patterns in Mississippi, Alabama, and Florida (Rogillio et al, 2007).

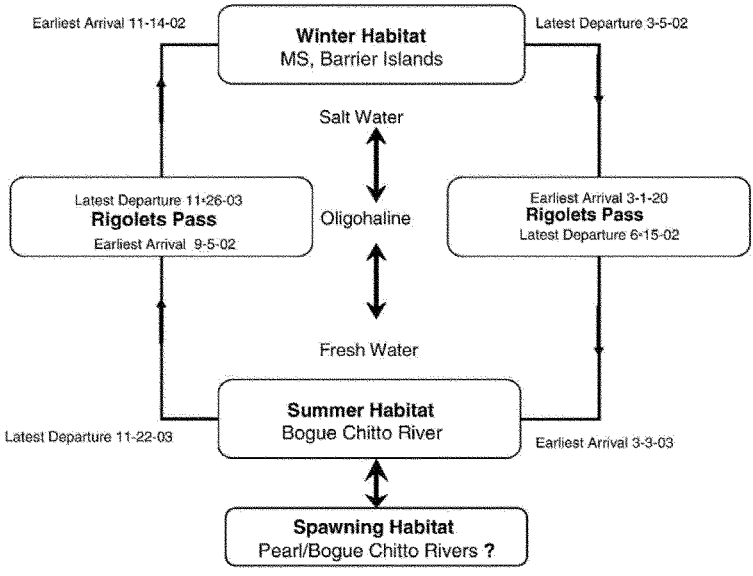


Diagram 1: Gulf sturgeon ingress and egress into the Pearl River Drainage (Rogillio et al, 2007).

It is believed that river temperatures may drive the return of sturgeon to the Gulf of Mexico in the fall. When river temperatures approximate the fall temperatures of the Gulf of Mexico (usually in late October or early November), and surface temperatures drop between 62-72° F, sturgeon leave the rivers for their winter marine habitats (Chapman, 2001; Foster & Clugston, 1997). Sulak et al. (1999) reported that adult Gulf sturgeon in the Suwannee River spend up to several weeks of pre-migratory staging (late November to early December) in the lower river and

adjacent estuary. While it has been suggested that this kind of holding pattern prior to the sturgeon's movement between fresh and saline environments may be necessary due to osmoregulatory functions (Murphy & Skaines, 1994), some rivers, like the Pearl River, report sturgeon moving through the river/bay interface rapidly, requiring little if any time for acclimatization. In 2001, Rogillio et al, documented a pearl river sturgeon which remained in the Rigolets, a brackish water area, for only two days before moving into more saline waters. Altinok et al. (1998) determined that, by age one, Gulf sturgeon have developed an active mechanism for osmoregulation and ion balance in euryhaline environments. Though, it appears to not be necessary this early in life, since most Gulf sturgeon stay in their natal river for the first 2 to 3 years of their life (NMFS, website). Odenkirk, (1989) suggested that osmoregulatory adjustment might occur in brackish waters for a period of 8 to 12 hours before movement into marine habitat.

Stabile et al. (1996) presented genetic evidence supporting the high fidelity of Gulf sturgeon to natal rivers regardless of reproductive state. However, populations do show some emigration of low numbers of individuals within genetic stocks (Zehfuss, Hightower, & Pollack, 1999). Even so, straying to other river systems accounts for less than one percent of the population at any given time (Wirgin et al., 1997). Straying from natal rivers has been documented for both sub-adult and adult sturgeon. However, the reproductive state of adult fish at the time of their discovery in a non-natal river system is unknown. It is possible that straying may take place during years of gonadal recrudescence and that no spawning actually occurs, or that these fish are merely stopping temporarily on the way back to their natal rivers. Shared habitat between the Pearl and Pascagoula Rivers occurs for the most part in the lower river reaches of the Pascagoula in know estuarine holding areas. Many of these fish move on and are found later in the season in the Pearl River. The numbers of Pearl River sturgeon found in the known spawning grounds of the upper Pascagoula River have historically been low and low genetic transference among rivers is supported thus far in current studies. Dugo et al. (2004) in genetic studies using microsatellite markers found that their work supported patterns of stock structure and further supported drainage level differentiation introduced by Stabile, et al 1996. Resolution in their study provided positive differentiation between the Pearl and Pascagoula units, while reinforcing regional groupings suggested by mitochondrial DNA analysis.

8.1.3 Food Habits

Gulf sturgeon generally consume soft-bodied foods, avoiding armored or spiny organisms. Organisms that are encrusted or have hardened tubes, such as polychaetes and corophiid amphipods, are not preferred food types (Mason et al., 1993). The diet of juvenile sturgeon 1 to 2 kg includes brackish-water amphipods, chironomid larvae, certapogonid larvae, aquatic insects, and small bivalves. Prey consumed by juvenile sturgeon in the rivers that are also eaten by adults in the estuaries include arthropods, annelids, and mollusks. Macroinvertebrates, such as dipteran larvae, amphipods, isopods, small grass shrimps, and annelids are key prey species of 1-10 kg Gulf sturgeon feeding in the mouth of the river. Subadults 10-19 kg, have diets that include mud or ghost shrimp. Adult Gulf sturgeon in the estuaries and coastal areas mainly consume amphipods, polychaetes, lancelets, gastropods, isopods, brachiopods and shrimp (Mason et al., 1993; and Carr et al., 1996). Gulf sturgeon have

been found to feed primarily on species such as brachiopods, lancelets, haustorid amphipods and the callianassid *L. louisianensis*, all species associated with sandy, polyhaline habitats. This habitat is absent from Lake Borgne. Mason and Clugston (1993) however, report prey to include brackish water amphipods such as *Cerapus* sp. And *Corophium tuberculatum*, chironomid and ceratopogonid fly larvae, mysid shrimp, polychaetes and tubificid oliochaetes. These species are most closely associated with muddy, mesohaline habitats habitats similar to the Lake Borgne borrow areas. Bony fish are seldom consumed. Detritus, both inorganic and organic, is consumed incidentally by Gulf sturgeon of all sizes as they feed on various prey (Mason et al., 1993). Non-spawning sturgeon appear to feed longer in the estuaries and bays prior to moving into the rivers than spawning adults (Fox et al., 2000).

Stomach contents of sturgeon caught returning to the Gulf of Mexico in the fall compared to stomach contents of sturgeon caught entering the rivers in the spring supports evidence that sturgeon over 5 kg do not feed during their summer residency in fresh water (Mason et al., 1993). Gulf sturgeon arriving in the rivers from the estuaries and coastal shelf regions have ingested estuarine and marine species. During periods of migratory staging when sturgeon occupy the lower river region, fresh and brackish water species may also be consumed (Wooley et al., 1985). In the fall, however, even though suitable prey are available in the river, sturgeon stomachs are empty, their spiral valves containing only a greenish mucus (Mason et al., 1993). If Gulf sturgeon over 5 lbs fed in the rivers, the holding areas where they congregate during the summer would quickly become devoid of prey species thereby necessitating the abandonment of these holding areas and dispersal throughout the system in search of a food source. This type of movement has not been observed. Sturgeon typically do not move more than 0.6 km from their holding areas during the summer months (Foster et al., 1997; Hightower et al., 2001). Furthermore, in comparison to marine environments, freshwater sturgeon habitats typically offer meager invertebrate prey abundance and biomass (Magnin, 1963). Foraging in riverine habitats is therefore energetically expensive and of low adaptive value to sturgeons that have adopted anadromy (Sulak et al., 2002; Sulak et al., 1999). Fall and spring mass comparisons additionally show that most Gulf sturgeon mass is accumulated in the nearshore continental shelf and shipping channels during their winter marine residency (Collins et al., 2000). Sub-adults in a capture/recapture study in the Apalachicola River lost 4 to 15 percent of their body mass during summer residency in the river (Wooley et al., 1985). Carr et al., (1996) observed that Suwannee sturgeon gained an average of 20 percent of their body weight while in the Gulf of Mexico and lost 12 percent of their body weight while in riverine habitats.

8.1.4 Habitat Association

Gulf sturgeon congregate in specific areas within the rivers during the summer and seldom move from these areas by more than about 0.6 km (Foster et al. 1997 and Hightower et al., 2001). These holding areas are characterized by short mid-depth (3-4 m) reaches of the river immediately below deep turbulent holes (>5 m), and immediately above long sand shoals (2-3 m depth) (Sulak et al., 1999). Foster et. al (1997) identified the typical features of a congregation area in the Suwannee River as: "A deep river bend (usually a depression about 1-2 m deeper than the main channel) and a shallow sandy section." These mid-depth holes are thought to provide an energetic refuge against strong laminar downriver currents, enabling sturgeon to hold position

in eddy zones with a minimum of swimming (Sulak et al., 1999). The river reaches occupied by sturgeon during the summer vary in length from 4-8 km and are anywhere from 40-200 km upriver. Sturgeon move between the deep and the shallow areas of the river during the summer, but do not move out of their holding areas until fall, when water temperatures drop (Chapman, 2001). In the Suwannee River, surface dissolved oxygen levels ranged between 4 to 8.5 ppm during the summer months and did not seem to influence sturgeon behavior (Foster et al., 1997).

In a laboratory study done by Chan et al. (1997), juvenile Gulf sturgeon exhibited a preference for stream flow velocity depending upon whether they were traveling in a group or individually. Groups of sturgeon selected high flow velocities, greater than 12 cm/s while individual sturgeon avoided these high flow velocities preferring to stay in areas with 8-10 cm/s flows. The variance in preferred swimming speeds between groups and individuals seen in juvenile Gulf sturgeon has also been observed among other species of schooling fish such as the golden shiner (*Notemigonus crysoleucas*). Chan et al., (1997) also observed the substrate preferences of Gulf sturgeon during their study. Individual sturgeon in high flows preferred cobbled substrates while individuals in low flow velocities showed no preference for substrate. Groups showed no substrate preference in high flow velocities and showed only a moderate preference for sand in low flow velocities (Chan et al., 1997). Cobble substrates and holes deeper than the channel bottom are believed to provide energetic refuges from high stream flow velocities for juvenile Gulf sturgeon, (Chan et al., 1997; Sulak et al., 1998).

When traveling in groups, sturgeon rarely contact each other during their routine activities. Separation between individuals is maintained within the group through horizontal stratification along the water bottom. No vertical stacking within groups has been observed (Chan et al., 1997).

The frequency of spawning varies between the sexes. Male sturgeon have the capacity to spawn every year while females appear to have a recovery or regressing phase of one to two years between spawning events (Huff et al., 2000, Fox et al., 2000). The reason for this is likely due to the massive energy requirements females need to produce the 275,000-475,000 eggs the average female generates (Chapman et al., 1993). Meeting this energy requirement is problematic considering the amount of time spent by sturgeon in freshwater environments and the scarcity of their desired prey species in these environments. Given these energy requirements, and upon examination of existing tracking data, Fox et al., (2000), hypothesized that some sturgeon remain in marine or estuarine waters for a year or more where they undergo gonadal recrudescence before returning to freshwater to spawn.

Gulf sturgeon spawn for about three weeks, when the water temperatures are 17-22°C. Temperature is critical for the survival of Gulf sturgeon eggs and larvae. A temperature of 25° C is the upper limit for sturgeon larvae survival (Chapman et al., 1995). Eggs collected late in the spawning season at higher temperatures than this were not viable. Rapid, unpredictable variations in water conditions, such as temperature, conductivity, hardness (Ca^{++} ion content), pH, and dissolved oxygen are potentially deleterious to developing Gulf sturgeon embryos. Moreover, a predicable range in Ca^{++} ion concentration may be essential to gamete success (Carr et al., 1985). In laboratory studies, juvenile shortnose sturgeon, *A. brevirostrum*, from 11 to 330

days old began to encounter mortality when held at dissolved oxygen (DO) concentrations below 3.5 mg/l (Jenkins et al., 1995).

Spawning occurs over clean gravel beds and limestone substrates. Sturgeon eggs are adhesive, typically sinking to the bottom and sticking to the substrate almost immediately after extrusion (Sulak et al., 1998). Because they are so adhesive, a bottom free of small grain particles and debris that could encapsulate and smother the eggs is essential to egg survival. Spawning over hard substrates with coarse surfaces may also be advantageous to young sturgeon. Sturgeon researchers have observed developing larvae occupying the interstitial spaces between rocks and cobble. This behavior may be a result of young sturgeon seeking an energetic refuge from bottom currents and a place to hide from predators. Eggs and larvae are preyed upon by a variety of species including catfish, blackbanded darters, and large aquatic insect larvae (Sulak et al., 1998).

Riverbed topography, determining where gravel accumulates, where strong currents prevail, and where eddy fields develop, plays a fundamental role in determining sturgeon spawning sites (Sulak et al., 1999). Flow is an important feature of sturgeon spawning habitat. LaHaye et al., (1992) observed that spawning lake sturgeon, *A. fulvescens*, selected areas of mixed medium-coarse gravel substrate below boulders that produced current breaks (eddies). Diminished or reversed currents in these eddy fields may facilitate position-holding among spawning partners over spawning substrates, and egg retention in local eddies. These flow types would enhance fertilization success, reduce the number of eggs lost to otherwise prevailing strong downstream currents, and promote the rapid sinking and adhesion of eggs onto gravel substrates (Sulak et al., 1999). Due to their need for suitable substrates to spawn upon, and taking into account the river velocities in which they spawn, Gulf sturgeon are not believed to be true broadcast spawners. Unless sturgeon eggs are released directly over suitable hard substrate, enabling immediate adhesion, they are highly vulnerable to mortality. As demonstrated with *A. brevirostrum* (Richmond et al., 1995), Gulf sturgeon are similarly thought to be lithophilic spawners, utilizing very small, highly circumscribed gravel/cobble spawning reefs.

In some riverine systems lunar phase has been important in predicting spawning events. In the Suwannee River the new moon coincides with high water at the mouth of the river, such that the tides negate the out flowing river currents, facilitating upstream migration to spawning sites (Sulak et al., 1998). The onset of spawning appears to depend on a water temperature threshold of 17°C, and to be closely coordinated with the new moon phase (Sulak et al., 1999). Spawning in the Suwannee occurs within 10 days after the new moon. In contrast, other rivers like the Choctawhatchee have found little evidence coupling spawning with lunar cycles (Fox et al., 2000) thereby demonstrating the individuality of each river's population.

Fall spawning has not been observed in any of the rivers; however, the size range of some juveniles captured in the Suwannee does not adhere to spring spawned size classes, thus suggesting that a fall spawn may occur. On several occasions, a small number of gravid females carrying fully mature black ova (2.4-2.5 mm diameter) and running ripe males with motile sperm have been captured in the Suwannee River in the fall (Sulak et al., 1998).

Gulf sturgeon spawn 215 km upstream in the Suwannee River, Florida in a relatively small area, approximately 9,375 m^2 (Sulak et al., 1998). Additional spawning sites at rkm 209 and 220 have also been discovered. All three of these sites have substrates composed of exposed bedrock covered by gravel and small cobble. A spawning site identified in the upper Choctawhatchee River, Alabama, is 110 km upstream with steep limestone banks and a hard bottom substrate overlaid with gravel (Fox et al., 2000). One of the spawning sites in the Pascagoula River, Mississippi is at rkm 250 and is characterized by a gravel substrate. Spawning sites have not been identified in any of Louisiana's rivers to date and the low-water sills on the Bogue Chitto River and the East Pearl River do inhibit sturgeon from reaching part of their historic range and suitable spawning grounds. However, numerous juvenile fish have been caught in the lower Pearl River indicating that at least some suitable spawning sites do exist below these structures. In the Apalachicola River, Florida, the movement of Gulf sturgeon past Jim Wooddruff Dam is similarly prevented. Even so, spawning below the dam appears to be occurring with a larval Gulf sturgeon collected 3.3 km below the dam in 1977.

Early larvae are benthic, negatively phototactic, strongly thigmotactic, and largely sedentary. They find refuge from predators and bottom flows in gravel substrates, making their collection difficult. Young of the year appear to disperse widely, using extensive portions of the river as nursery habitat. Suwannee juveniles less than 3 months of age have been captured from 33-207 km from the river's mouth. Juveniles are typically found on sandbars and sand shoals over rippled bottom and in shallow, relatively open, unstructured areas. This dispersion may be an adaptation to maximize scarce food resources. Juvenile sturgeon avoid areas of vegetated substrate where structure may impede feeding, orientation and maneuvering (Randall et al., 1999).

Young of the year, do not emigrate to the estuaries with the subadult and adult sturgeon but remain in riverine habitats through January and arrive in estuaries in February as age one fish (Carr et al., 1996). Juveniles one to six years of age are not believed to migrate offshore with the larger, older adults, but instead over-winter in close proximity to the river mouth, in the estuaries or in nearshore reaches. In late spring and early summer juveniles re-disperse upriver (Sulak et al., 1998).

Limited data exists regarding the Gulf sturgeon wintering habitat. Though Rogillio et al., (2007) monitored Gulf sturgeon movement from the pearl river into the Mississippi Sound between November and March, marine habitat data (i.e. depth, substrate type, water, temperature, and food availability), was not collected and would have greatly strengthened this study.

Since marine habitat data has not been correlated to Gulf sturgeon concentrations within this area, a review of other estuaries is necessary to make some correlations on the Gulf sturgeon requirements for productive wintering habitat. Harris et al. (2005) compared the distribution of Gulf sturgeon to benthic invertebrate prey resources and physiochemical variables in the Suwannee River Estuary in Florida. Telemetry equipment was used to monitor Gulf sturgeon within the Suwannee River Estuary to determine their habitat preferences. They found that in both the fall and spring, there was a significant relationship between the number of Gulf sturgeon

relocations and the abundance and mass of their major prey resources – brachiopods, amphipods, and brittle stars. The frequency of relocations of sturgeon was greatest within cluster 1, relative to the area within each prey abundance cluster. Cluster 1 included core sites with medium to high abundances of all three prey types and had the greatest abundance of brachiopods. They determined that relative to brachiopod abundance, the frequency of relocations of Gulf sturgeon was highest in cluster 1, which contained the highest overall abundance of brachiopods. In addition, the frequency of relocations of sturgeon on a unit area basis was lowest in cluster 4, which lacked brachiopods. Thus, Gulf sturgeon appear to be associated with areas of high density of brachiopods.

Harris et al. (2005) also concluded that relocations were distributed according to physiochemical features such as sediment type, salinity, DO, and water depth. They found that the frequency of relocations were comparatively highest in sites composed of 76.4-80.1% sand. Salinity was significantly greater at relocation positions in the fall than in the spring (29.2 ppt and 23.3 ppt respectively). Dissolved oxygen near the bottom did not vary significantly (6.0 to 9.8 mg/L) at relocation sites. An interesting finding of the study was the variation in habitat usage between the fall and the spring. Harris et al. (2005) found that relocations of Gulf sturgeon during the fall season was with areas farther away from any mouth of the Suwannee River (hence the higher salinities at these relocation sites) and over sediments composed mostly of sand and small shell. In contrast, the spring 2002 relocations were in shallow areas closer to one of the mouths of the Suwannee River, often over sediments composed of sand and very fine sand in the proximity of oyster bars.

8.1.5 Status and Cause of Decline

The Gulf sturgeon was Federally listed as threatened throughout its range on September 30, 1991 and is also listed as a threatened species in Louisiana. Initial declines for sturgeon populations worldwide were primarily due to three factors: overharvest, barriers to migration, and riverine habitat loss. For many species in North America these three influences to recruitment and survival occurred simultaneously during the early 1900s (Auer, 2004).

Historically, Gulf sturgeon have supported both commercial and recreational fisheries throughout most of their range from the Mississippi River east to Tampa Bay (U.S. Commission of Fish and Fisheries, 1902, cited in Wooley and Crateau, 1985). Large-scale exploitation of Gulf sturgeon began around 1860, when it was discovered that smoked sturgeon could be substituted for smoked halibut and that Gulf sturgeon eggs could be made into high-quality caviar (Smith, 1990). Sturgeon have been harvested with gillnets, pound nets, otter trawls, harpoons, trammel nets, weirs, stake row nets, and seines (Huff, 1975; Smith, 1985; Van Den Avyle, 1984; Smith & Clugston, 1997).

Gulf sturgeon populations have declined due to fisheries over-exploitation (Barkuloo, 1988), spawning habitat loss via dam construction, and deterioration of water quality in their natal rivers (Morrow et al., 1996). Sturgeon are particularly vulnerable to gill net fisheries and are also found in the bycatch of shrimp trawls. Turtle excluder devices (TEDs) are thought to reduce sturgeon bycatch, though, to date no studies have been conducted to specifically evaluate

this possibility. Even though sturgeon fishing regulations are in place, poaching of Gulf sturgeon still occurs (Collins et al., 2000). Restrictions applied to the sturgeon fisheries have not resulted in the restoration of population size. This may be due to the reduction of suitable spawning habitat. Poss (1998) notes that dredging operations reduce the deeper holes and hard substrate sturgeon require for spawning. Dams and low water sills prevent the movement of spawning adults to traditional spawning grounds. Low dissolved oxygen levels from eutrophication also contribute to spawning habitat degradation. Adults and subadults are not greatly affected by changes in salinity, dissolved oxygen, or high temperatures, however, eggs and larval stages of the sturgeon have low tolerance ranges for these criteria (Collins et al., 2000). Another reason recovery has been slow could be because sturgeon have unique life history strategies when compared to other fish species. Most Acipenseriformes reach sexual maturity at a great age, often 15 to 20 years, recruitment to a spawning population is therefore slow, and once reproductive age is reached spawning occurs often intermittently. These life history traits, coupled with low abundance resulting from the historic over harvest, barriers to migration, and habitat loss, have resulted in finding only small, remnant populations or stocks in many regions during assessment efforts (Auer, 2004).

8.2 Pallid Sturgeon (*Scaphirynchus albus*) and Shovelnose Sturgeon (*Scaphirynchus platorynchus*)

8.2.1 Description of Species

The pallid sturgeon is a bottom oriented, large river obligate inhabiting the Missouri and Mississippi Rivers from Montana to Louisiana and the Atchafalaya River. The pallid sturgeon is adapted to the predevelopment habitat conditions that historically existed in these large rivers. Those conditions can generally be described as large, free-flowing, warm water, turbid habitats with a diverse assemblage of physical attributes that were in a constant state of change. Floodplains, backwaters, chutes, sloughs, islands, sandbars and main channel waters formed the large-river ecosystem that provided macrohabitat requirements for all life stages of pallid sturgeon and other large river fish. Within this range, pallid sturgeon tend to select main channel habitats in the Mississippi River and main channel areas with islands or sand bars in the upper Missouri River (USFWS 2009).

The pallid sturgeon has a robust body tapering posteriorly into a long and narrow caudal peduncle. The snout is broad, flat and spatulate in shape. Viewed dorsally, the pallid sturgeon's rostrum is more elongated than that of other species of Scaphirhynchus. The inner barbels are situated slightly anterior to the outer barbels and are heavily fimbriated. The pallid sturgeon's mouth is transverse with four papillose lobes on the continuous lower lip. The branchiostegal connection is narrow and the posterior edge of the branchiostegal membranes is sub horizontal (Mayden and Kuhajda 1996). The pectoral fins are large and rounded. Most specimens, especially adults, lack retrose spins on the tip of the snout, parietal spines and pre orbital typical of Alabama sturgeon (*Scaphirhynchus suttkusi*) and shovelnose sturgeon. The frontl spines are always absent. The squamation on the ventral surface is weak and reduced (Mayden and Kuhajda 1996, 1997). Similar to other shovelnose sturgeons, the spiracle is absent in *S. albus*. The anterior edge of the clavicle keel is smooth. The flattened caudal peduncle is entirely

covered with scutes and the upper lobe of the caudal fin has a distinct filament, but absent in large individuals. The post anal plates range in number from 7-8. There are 9 post dorsal plates. Both these counts overlap meristically with Alabama sturgeon and shovelnose sturgeon. The average size of adult pallid sturgeon is 8-15 kg with a historic maximum size of 40 kg being noted in the literature (Vecsei and Peterson, 2004).

The coloration of pallid sturgeon is lighter than other species of Scaphirhynchus, with the entire fish having an overall grayish-white appearance (trautman 1981; Robison and Buchanan 1984). The principal rows of scutes are slightly darker than the surrounding body. The transition from the pale dorsum coloration to the white ventrum is subtle compared to other shovelnose sturgeon (Vecsei and Peterson, 2004).

The shovelnose sturgeon has an elongated, tapering body. The caudal peduncle is narrow and long. The upper lobe of the caudal fin extends into a long filament. The body is more flattened in cross-section than Acipenser or Huso. The rostrum is wide, flat and shovel shaped. Bemis et al (1997) show allometric lengtheninig of the rostrum of shovelnose sturgeon. The two sets of barbels are extensively fimbriated with inner barbells being more than half of the length of the outer barbels (Robison & Buchanan 1984). The lower lips have four papillose lobes. The eyes are tiny and spiracles are absent. The 5 rows of scutes remain prominent throughout the individual's life. All scutes have a prominent retrose hood appendage. The narrow, elongated caudal peduncle is entirely covered with scutes and plates. The filament of the upper lobe of the heterocercal tail is present only in small, immature individuals. Adult shovelnose sturgeon are usually 1.5-4kg. Carlander (1969) reported a maximum weight of 4.5 kg with most individuals weighing less than 2.5 kg. However, Keenlyne (1997) reported individuals of over 7 kg in the upper Missouri River. Keenlyne (1997) suggests that the larger shovelnose sturgeon of the upper Missouri represent a different strain or "stock" from those lower downstream (Vecsei and Peterson, 2004).

Shovelnose sturgeon coloration is consistent throughout this species' range. The dorsum is dark brown, becoming progressively lighter on the lateroventral surface. The principal rows of scutes are slightly darker than the surrounding body. The ventral surface of the head and body is white or cream colored. The fins are pigmented and similar in color to the body region of origin (Vecsei and Peterson, 2004).

Pallid sturgeon are similar in appearance to the more common and darker shovelnose sturgeon prompting a Similarity of Appearance rule passed in 2010 (75 FR 53598-53606). Pflieger (1975) reported the principal features distinguishing pallid sturgeon from shovelnose sturgeon as the paucity of dermal ossifications on the belly, 24 or more anal fin rays, and 37 or more dorsal fin rays. Forbes and Richardson (1905) noted that pallid sturgeon contain 20 to 22 ribs while the shovelnose sturgeon has only 10 to 11 ribs. The air bladder was also noted as being relatively smaller in the pallid sturgeon. Those authors recorded differences between the pallid and shovelnose sturgeon in the number of ventral radials, relative depth of lateral scutes, orbital space size, proportional lengths of inner and outer barbels, mouth width, proportion of head width to head length, and proportion of head length to body length (USFWS, 2010).

While these morphological differences are commonly used to distinguish pallid sturgeon from shovelnose sturgeon (Bailey and Cross 1954, Keenlyne et al. 1994) visual differences can sometimes be difficult to note because of geographic variation, allometric growth, and hybridization between shovelnose and pallid sturgeon. Genetic testing can be another tool to further identify individuals though this technology needs further development. Since the pallid sturgeon was listed in 1990, however, geneticists and ichthyologists have worked to refine testing procedures and develop the materials to definitively distinguish and identify these two fish species. More information is needed on the evolutionary dynamics of intermediate forms between pallid and shovelnose sturgeon to understand the role and effects of hybridization on the status of pallid sturgeon (USFWS, 2010).

8.2.2 Distribution and Abundance

Historically the Missouri and Mississippi River were characterized by a shifting braided channel with abundant sandbars and accumulations of large woody debris. The shifting channel contained a wide variety of hydraulic environments that provided diverse habitat for many benthic fish species. In the 1800's, training into a fast, deep, and single-thread channel to support navigation was begun. Wing dikes concentrated flow, and revetments and levees kept the channels in place and disconnected it from the flood plains. Reservoir regulation substantially changed the annual hydrograph, sediment load, and temperature regime of the Missouri and Mississippi Rivers. As in other large flood-plain rivers, agricultural pesticides, nutrient runoff, and increasing discharge of domestic and industrial effluents affect the aquatic biota and the ecological health of the Missouri River Basin. Proliferation of introduced and non-indigenous species has further threatened to diminish the ecological integrity of the river ecosystem. Together these changes in flow, channel morphology, water quality, and biota have been implicated as causative agents in the dramatic declines in native river fishes and their resource base in general, and with the decline of pallid sturgeon in particular (USGS, 2007).

The pallid sturgeon is endemic to the turbid waters of the Missouri River and the Lower Mississippi River (USGS, 2007). Although pallid sturgeon captures in the middle and lower reaches of the Mississippi River continue to increase with fishing effort, habitat use, population levels and trends, and movement patterns within this portion of the species range remain unknown. Extensive sampling in the lower Mississippi River is currently being undertaken by the USACE-ERDC so that a better understanding of population size, population density, habitat preference, extent of range in lower Mississippi River, and impacts from entrainment on the population can be quantified. Captures of pallid sturgeon in the Mississippi River have been associated with islands, sand bars, gravel bars, and dikes, in both the main channel and in secondary channels (USFWS 2007).

On April 4, 2008, one week prior to the 2008 opening of the Bonnet Carré Spillway (BCS), personnel of the LDWF captured at least one pallid sturgeon in willow trees along the flooded bank of the river adjacent the Spillway structure. Although no diagnostic measurements were taken of the sturgeon, experts who have reviewed the photographic evidence have all concluded that the fish was a pallid sturgeon. This capture represented a very rare capture of a pallid sturgeon from the flooded riverbank of the river. Prior to this capture, pallid sturgeon

were generally believed to inhabit only the main river channel and side slopes, not overbank areas during high-water events. It is not known if pallid sturgeon might also be found in grassy or revetted areas. The USACE responded to this capture by initiating and rescue and recovery effort for sturgeon entrained through the BCS during the flood of 2008. The ERDC team in conjunction with the Louisiana Division of Wildlife and Fisheries (LDWF) captured 41 shovelnose sturgeon and 14 pallid sturgeon in the outfall of the BCS during this recovery effort. To date the use of the flooded river batture by sturgeon has received little study. Following this flood event, the USACE initiated a study aimed at filling in data gaps that exist regarding sturgeon distribution and abundance in the lower Mississippi River. Dr. Jack Killgore, who is in charge of this sampling effort, believes that pallid sturgeon could be found over nearly any flooded habitat, if enough sampling effort was expended, but they are more likely to be found in open water than in flooded willows. Currently this study is ongoing, with ERDC continually increasing their understanding of the habitat preferences and population size of sturgeon within this reach of river. Upon the conclusion of ERDC's study a Population Viability Assessment (PVA) will be completed for the pallid sturgeon. This PVA will allow for better management of the species within Louisiana, as well as a better understanding of what new risks the species faces in the Lower Mississippi River.

Genetic and morphological data have been used to differentiate pallid sturgeon into three groupings, an upper Missouri River group and two less differentiated groups in the lower Missouri/middle Mississippi and Atchafalaya River (USFWS 2007). This data suggest that the genetic structuring within the pallid sturgeon's range represents two distinct groups at the extremes of the species range with a middle intermediate group representing the lower Missouri and middle Mississippi Rivers. This pattern is suggestive of a pattern of isolation by distance, with gene flow more likely to occur between adjacent groups than among geographically distant groups, and thus, genetic differences increase with geographical distance.

The shovelnose sturgeon historically was more common and widespread than the pallid sturgeon. Before anthropogenic disturbances, distribution of the species included the Mississippi, Missouri, Ohio, and Rio Grande Rivers and their tributaries. Similar to the pallid sturgeon, the shovelnose sturgeon is declining and has been extirpated or is at risk of extirpation from considerable parts of its range. Of the 24 states that comprise the historical range of the shovelnose sturgeon, five list the species as extirpated, and eight list the species as either imperiled or vulnerable. The World Conservation Union listed the species as "vulnerable". The "vulnerable" assessment reflects a past reduction in species range of 30 percent, and anticipates a further 30 percent reduction in population within the next 10 years, or three generations (USGS, 2007). Current USACE sturgeon sampling efforts in the Lower Mississippi River initiated in 2008, have been collecting shovelnose sturgeon distribution and abundance data. Over the course of this study the shovelnose sturgeon has been found to be more abundant than the pallid sturgeon. Early ERDC estimates on population size and abundance have been included in **Appendix A** of this document. The persistence and resiliency of the shovelnose sturgeon in comparison to the pallid sturgeon may be partly because of its earlier maturity, lower trophic status, and adaptability to a broader range of environmental conditions. The shovelnose sturgeon matures earlier and attains a smaller maximum size than the pallid sturgeon. The smaller shovelnose sturgeon primarily subsists on invertebrates, whereas the larger pallid sturgeon becomes

piscivorous relatively early in life. Pallid sturgeon, also are highly adapted to large, turbid, riverine environments, and are believed to not use tributaries or clear-water riverine habitats that are frequented by shovelnose sturgeon (USGS, 2007).

8.2.3 Movements and Migration

Pallid sturgeon exhibit seasonal variation in movement patterns based upon temperature and discharge. The timing of pallid sturgeon movements and migration in the Lower Mississippi River may differ from that of other rivers (i.e. the Missouri River) and other portions of the Mississippi River. Migrations and movement in the Atchafalaya River was associated with water temperatures between 140 and 21 0 Celsius *(C)* and spring and early summer season. Movement patterns also vary between spawning versus non-spawning years. Pallid sturgeon have been reported as having an average home range of 48.8 mi (78 km) in the Yellowstone and upper Missouri Rivers while only having a home range of 21.2 mi (34 km) in the middle Mississippi River. It has been speculated that because habitat in the Mississippi River is relatively uniform, large movements and home ranges may not be as beneficial in the Mississippi River as in the Yellowstone and Upper Missouri Rivers area, because study fish are not likely to encounter new habitats and thus have a smaller home range. (USFWS, 2010)

As large river fish, pallid sturgeon are capable of moving long distances in search of favorable habitat or during spawning runs. Sheehan et al. (1998) noted one study fish moving along a 60.3 mi (97 km) stretch of river. Bramblett (1996) noted a maximum home range as large as 198.6 mi (319 km), with pallid sturgeon moving up to 13 mi/day (21 km/day) and shovelnose sturgeon moving up to 9 mi/day (15 km/day). Schramm and Dunn (2008) documented one fish in the Atchafalaya River moving 96 mi. Dean (2007) reported the capture of a pallid sturgeon in the Atchafalaya River that was produced at the Blind Pony State Fish Hatchery in Missouri and released in 1997. Hoover et al. (2007) hypothesized that long-range movements during the spring may not just be associated with spawning but could also be associated with feeding. (USFWS, 2010)

Although shovelnose sturgeon are capable of migrating long distances telemetry data suggests they are predominately a sedentary species. Shovelnose sturgeon in the Mississippi and Missouri Rivers typically exhibit limited movement. Fish movements were reduced during the winter, moving on average less than a total of 2km. However, migrations upstream by shovelnose sturgeon are made for the purposes of spawning. Seasonal migrations in the Missouri River have been extensive, with total movements cited to be in excess of 480 km from the tagging site (Wison and Mckinley, 2004).

Erickson (1992) found pallid sturgeon movement greater during the night while Bramblett (1996) observed greater movements during the day. The primary habitat difference suspected in those findings was turbidity. Erickson (1992) had sec chi readings as high as 157 in. (400 cm) while Bramblett (1996) averaged 8 in (20 cm) and rarely exceeded 39 in (100 cm). Bramblett (1996) modeled the information from his study and found that predictive depth of pallid sturgeon was greater during the hours following sunrise and suggested that pallid sturgeon may be photophobic. (USFWS, 2010)

Hoover, et al. (2005) examined swimming performance of juvenile pallid sturgeon (maximum size 6.3 inches) at different velocities to determine possible entrainment by dredges. Minimum escape speeds for pallid sturgeon ranged from 1.6 to 1.7 feet per second (fps) and burst speeds were determined to range from 1.7 to 2.95 fps. Because they frequently failed to exhibit rheotaxis or orientation to the direction of flow (greater than 25 percent were non-swimmers); their ability to avoid entrainment based on swimming performance was determined to be relatively low. Hoover, et al (2011) examined swimming performance of adult shovelnose sturgeon in rectilinear and boundary layer flow. Mean critical swim speed in rectilinear flow was documented as 102 cm s^{-1} and boundary layer flow was documented as 160 cm s^{-1}. Swim speeds were reduced in rectilinear flow because shovelnose sturgeon were unable to seek velocity refugia by skimming above the ground. (USFWS, 2010)

Adams (1999) also studied swim performance in juvenile pallid sturgeon. It was found that maximum sustained swimming speed was 0.328 fps and 0.82 fps for their two groups of fish. The fish were found to transition to burst swimming speeds at 1.31 fps and 1.9 fps, respectively. White and efford (2002) examined swimming behavior and performance of shovelnose sturgeon ranging from 25.2 to 31.5 inches in length to aid in the design of a fish passage on the Yellowstone River. The ability of shovelnose sturgeon to navigate the length of the test flume was best (60 to 90 percent) over a smooth bottom followed by coarse sand, gravel and then cobble, but the small sample size and large variability precluded this from being a definitive conclusion. The greatest success at negotiating the flume was determined to occur between the range of 2 and 4 fps; however success at greater velocities, 6 fps, did occur. Failure to exhibit rheotaxis was also observed at velocities below 1.6 fps. Conversely, Adams et al. (1997) found all adult shovelnose to be positively rheotatic. Pallid sturgeon are believed to avoid areas that have no water velocity (Constant et al 1997) though Erickson (1992) observed individuals in low water velocities between .001 *mls* to 0.3 *mls* (DeLonay and Little 2002, cited in Quist 2004, Erickson 1992 cited in USFWS 2007, Backes et al., 1992, Constant et al. 1997). It's important to note that swim studies are often performed on hatchery fish or fish kept in tanks with low water velocity. (USFWS, 2010)

8.2.4 Food Habits

Carlson et al. (1985) determined composition of food categories, by volume and frequency of occurrence, in the diet of shovelnose sturgeon (n=234), pallid sturgeon (n=9), and hybrids (n=9). Although benthic macro invertebrates characteristic of river habitats are important dietary components (Modde and Schmulbach 1977, Carlson et ai. 1985), the occurrence of lake and terrestrial invertebrates in sturgeon stomachs suggest that drifting invertebrates may also be important forage organisms (Modde and Schmulbach 1977, Constant et al. 1997). Aquatic invertebrates (principally the immature stages of insects) compose most of the diet of shovelnose sturgeon, while adult pallid sturgeon and purported hybrids consume a greater proportion of fishes (mostly cyprinids) (Hoover et al., 2007). Grohs et al (2009) reported that pallid sturgeon in the Missouri River downstream of Fort Randall Dam, had high percent occurrences' of Diptera, Emphemeroptera and fish and that percent composition of fishes increased with pallid sturgeon body size. It was noted that between ages four and five in their study, pallid sturgeon shifted from predominately invertebrates to fishes. Other researchers also

reported a higher incidence of fishes in the diet of adult pallid sturgeon than in the diet of shovelnose sturgeon (Cross 1967, Held 1969). Most piscivorous Missouri River species eat large quantities of aquatic insect larvae in early life and even as adults (Modde and Schmulbach 1977). (USFWS 2010)

8.2.5 Habitat Association

Pallid and shovelnose sturgeon are generally found to utilize the similar habitat types in the lower Mississippi River. The USACE-ERDC has an on-going study aimed at identifying some of the habitats utilized by the pallid and shovelnose sturgeon species in the lower Mississippi River. Forbes and Richardson (1905), Schmulbach et al. (1975), Kallemeyn (1983), and Gilbraith et al. (1988) describe pallid sturgeon as being a fish well-adapted to life on the bottom in swift water of large, turbid, free-flowing rivers. Mayden and Kuhajda (1997) describe the natural habitats to which pallid sturgeon are adapted as: braided channels, irregular flow patterns, flooding of terrestrial habitats, extensive microhabitat diversity and turbid waters. The historic floodplain habitat of the Missouri and Mississippi Rivers provided important functions for the native large-river fish. Floodplains were the major sources of organic matter, sediments, and woody debris for the main stem rivers when flood flows crested their banks. The transition zone between the vegetated floodplain and the main channel included habitats with varied depths described as chutes, sloughs, or side channels. The chutes or sloughs between the islands and shore were shallower and had less current than the main channel. These areas provided valuable diversity to the fish habitat, and probably served as nursery and feeding areas for many aquatic species (Funk and Rovinson 1974). The still waters in this transition zone allow organic matter accumulations; important to macroinvertebrate production. Both shovelnose and pallid sturgeon have a high incidence of aquatic invertebrates in their diet (Carlson et al. 1985; Gardner and Stewart 1987). Flood flows connected those important habitats and allowed fish from the main channel to utilize those habitat areas and to exploit available food sources. (USFWS, 2010)

8.2.6 Status and Cause of Decline

The pallid sturgeon was listed as endangered throughout its range on October 9, 1990. The reasons for listing were habitat modification, apparent lack of natural reproduction, commercial harvest, and hybridization in parts of its range. To date Critical Habitat has not been proposed nor designated for this species.

Pallid sturgeon are Federally listed as endangered and have been described as one of the rarest fish in North America. The pallid sturgeon was listed due to the apparent lack of recruitment for over 15 years, and the habitat threats existing at the time of listing. Destruction and alteration of habitats by human modification of the river system is believed to be the primary cause of decline in reproduction, growth, and survival of the pallid sturgeon. The curtailment of range and habitat destruction/modification were primarily attributed to the construction and operation of dams on the upper Missouri River and modification of riverine habitat by channelization of the lower main stem Missouri River and Mississippi Rivers. Dams substantially fragmented pallid sturgeon range in the upper Missouri River. However, free-flowing riverine conditions currently exist throughout the lower 2,000 mi (3218 km) (60%) of

the pallid sturgeon's historical range (USFWS 2009). Until this past decade, they were considered a rare occurrence in the Lower Mississippi. New information from recent collection efforts indicates that the Mississippi River currently supports substantial numbers of wild fish. Since 1997, more than 200 pallid have been collected at more than 60 locations in the Mississippi River between the confluence of the Missouri River and New Orleans, LA (Bettoli, 2006). When listed, there were only 28 recognized records of pallid sturgeon from the Mississippi River, with no recognized records from the Atchafalaya River. (USFWS 2010)

Aquatic habitats in the Mississippi River have been modified though the construction of flood control levees and channel modification through time, and some changes resulting from those modifications have likely been detrimental to pallid sturgeon (USFWS 2007). Although the river flows unobstructed for about 2,000 river miles (RM) from Gavins Point Dam in the middle Missouri River to the Gulf of Mexico, tributary impoundments, bendway cutoffs, and dike and levee construction have each changed localized patterns of channel erosion and deposition in the Mississippi River; collectively they resulted in a degradation trend throughout the system. Effects of these changes on pallid sturgeon are unknown, because there is no historical data for comparison. In 1981, the USACE established the Lower Mississippi River Environmental Program, with a goal of protecting fisheries and other natural resources in the lower Mississippi River (USFWS 2007). Input from the Lower Mississippi River Environmental Program resulted in experimentations with dike placement and notches as measures to protect secondary channels and maintain shallow water and fisheries habitats.

The Pallid Sturgeon Lower Basin Recovery Workgroup has identified information gaps essential to the consultation and recovery processes in the Lower Mississippi River Basin. These include: relative abundance of pallid sturgeon, demographics, feeding habits, habitat use, hybridization ratios, presence of fish diseases in the wild, population anomalies, and reliable separation and identification of pallid sturgeon, shovelnose sturgeon, and hybrids. While recent publications have contributed to filling some of these data gaps (e.g., Killgore et al., 2007) incomplete knowledge of those areas remains. Therefore, the sturgeons' response and the effect to encountering the diversion flows (e.g., avoidance, actively sought) is unknown, which can affect the number of sturgeon believed to be "taken" by a structure's operation. It is not known if the number of sturgeon that risk entrainment within a diversion structure are; only those located near the structure during its opening (no increase in sturgeon entrained because of active avoidance); are sturgeon that actively swam into the structure seeking velocity refuge from main-channel flows and/or seeking food sources on the batture and/or in a perceived secondary channel (i.e., spillway); or are entrained during down-river migration passively (i.e., no avoidance) or actively (i.e., failed to resist entrainment) or a combination of any of the above. (USFWS 2009). There are no known topographic or hydrographic features that would appear to attract the sturgeon to the vicinity of the proposed medium diversion at Violet, LA.

The USFWS, determined it necessary to treat shovelnose sturgeon (*Scaphirhynchus platorynchus*) as threatened due to similarity of appearance (September 1, 2010) to the endangered pallid sturgeon (*Scaphirhynchus albus*) under the similarity of appearance provisions of the Endangered Species Act of 1973, as amended. The shovelnose sturgeon and the endangered pallid sturgeon are difficult to differentiate in the wild and inhabit overlapping

portions of the Missouri and Mississippi River basins. Commercial harvest of shovelnose sturgeon has resulted in the documented take of pallid sturgeon where the two species coexist and is a threat to the pallid sturgeon (75 FR 53598-53606).

Other factors which threaten the species include: poaching (Commercial take of any species of sturgeon was prohibited by Mississippi and Louisiana during the early 1990s to avoid incidental take of pallid sturgeon.), predation, disease, contaminants, tug boat propeller entrainment, and hybridization. The cumulative impacts to the species currently are not quantifiable. Further study is needed to document to what extent these factors are impacting the species.

8.3 West Indian Manatee (*Trichechus manatus*)

8.3.1 Description of Species

The West Indian manatee is a large gray or brown aquatic mammal. Adults average approximately 10 feet in length and weigh up to 2,200 pounds. They have no hind limbs, and their forelimbs are modified as flippers. Manatee tails are flattened horizontally and rounded. Their body is covered with sparse hairs and their muzzles with stiff whiskers (USFWS 2001). The nostrils, located on the upper snout, open and close by means of muscular valves as the animal surfaces and dives (Husar 1977, Hartman 1979).

Observations of mating herds indicate that females mate with a number of males during their 2- to 4-week estrus period, and then they go through a pregnancy estimated to last 12 to 14 months (O'Shea *et al.* 1992). Births occur during all months of the year with a slight drop during winter months. Manatee cows usually bear a single calf, but 1.5 percent of births are twins. Calves reach sexual maturity at 3 to 6 years of age. Mature females may give birth every 2 to 5 years (USFWS 2001).

8.3.2 Distribution and Abundance

Range encompasses rivers, estuaries, and coastal areas of subtropical and tropical areas of northern South America, West Indies/Caribbean region (but apparently never very abundant in the Greater Antilles, except perhaps Cuba), Gulf of Mexico (now mainly western and southwestern portions), and southeastern North America (mainly Florida). (Nature Serve accessed 7-13-2011)

Present range limits are similar to those known historically, but the distribution is fragmented due to areas of local extirpation. Area of occupancy and abundance are apparently greatly reduced in Central and South America compared to the historical situation. Small numbers exist in the Greater Antilles but the species has not been documented in the Lesser Antilles south of the Virgin Islands since the 1700s. Sightings are rare in the Bahamas. Manatees remain relatively abundant in Belize (compared to elsewhere in Central America) and in Guyana, and they are still reasonably abundant in some areas of Mexico and on both coasts of Florida. In Puerto Rico, manatees are most often observed in coastal areas from San Juan

eastward to the east coast, (and including Vieques Island) and then south and west, past Jobos Bay, to the west coast, and about as far to the northwest as Rincon; they are concentrated in several areas, including Ceiba, Vieques Island, Jobos Bay, and Boquerón Bay, and are less abundant along the north coast, between Rincón and Dorado. Manatees are very rare (transient) in the U.S. Virgin Islands. (Nature Serve accessed 7-13-2011)

U.S. populations occur primarily in Florida, where they are effectively isolated from other populations by the cooler waters of the northern Gulf of Mexico and the deeper waters of the Straits of Florida. In the southeastern United States, manatees are more or less restricted to the vicinity of warm-water sites in peninsular Florida during the winter, although a few may remain year-round in Cumberland Sound, southeastern Georgia, where factory warm-water outfalls allow survival of colder winter months. Occasional manatees occur in summer from Texas to North Carolina. Those in Texas may be wanderers from Mexican population, but DNA analysis of an individual captured linked it to the Florida population. Manatees range along most of the Gulf coast of Florida but infrequently occur north of the Suwannee River and between the Chassahowitzka River and Tampa Bay. They inhabit the Atlantic coast of Florida from the Georgia coast to Biscayne Bay and the Florida Keys, including the St. Johns River, the Indian River lagoon system, and various other waterways. In Florida, the most used wintering areas are at Crystal River, Homosassa River, Tampa Bay, Ft. Myers, Port Everglades, Riviera Beach, near Titusville, and Blue Spring. (Nature Serve accessed 7-13-2011)

8.3.3 Movements and Migration

During winter months, the United States' 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. Power plant and paper mill outfalls created most of the artificial warm water refuges utilized by manatees. During summer months, they migrate as far north as coastal Virginia on the east coast and the Louisiana coast in the Gulf of Mexico.

During summer months, manatees disperse from winter aggregation areas, and are commonly found almost anywhere in Florida where water depths and access channels are greater than 3.3 to 6.6 feet (O'Shea 1988). In the warmer months, manatees usually occur alone or in pairs, although interacting groups of 5 to 10 animals are not unusual (USFWS 2001). A few individuals have been known to stray as far north as the northern Georgia coast and as far west as the coastal waters of Louisiana.

8.3.4 Food Habits

Manatees are herbivores that feed opportunistically on a wide variety of marine, estuarine, and freshwater plants, including submerged, floating, and emergent vegetation. Common forage plants include and are not limited to: cord grass, alga, turtle grass, shoal grass, manatee grass, eel grass, and other plant types. Manatees will consume any aquatic vegetation (i.e., submerged, floating, and emergent) available to them and sometimes even shoreline vegetation. Although primarily herbivorous, they will occasionally feed on fish. Manatees may spend about 5 hours a day feeding, and may consume 4 to 9 percent of their body weight per day.

Calves initially suckle and may start feeding on plants when a few months of age. Weaning generally takes place within a year of birth. Manatees also require sources of freshwater, obtained from both natural and anthropogenic sources (ECOS accessed 7-13-2011).

8.3.5 Habitat Association

Manatees inhabit both salt and freshwater of sufficient depth (5 feet to usually less than 20 feet) throughout their range. Shallow grassbeds with ready access to deep channels are preferred feeding areas in coastal and riverine habitats (USFWS 2001). They may also be encountered in canals, rivers, estuarine habitats, saltwater bays, and have been observed as much as 3.7 miles off the Florida Gulf Coast. Between October and April, Florida manatees concentrate in areas of warmer water. Severe cold fronts have been known to kill manatees when the animals did not have access to warm water refuges. During warmer months they appear to choose areas based on an adequate food supply, water depth, and proximity to fresh water. Manatees may not need fresh water, but they are frequently observed drinking water from hoses, sewage outfalls, and culverts.

8.3.6 Status and Cause of Decline

The West Indian manatee was listed as endangered throughout its range for both the Florida and Antillean subspecies on June 2, 1970 and received Federal protection with the passage of the ESA in 1973. Critical Habitat was designated in 1976, 1994, 1998, 2002, and 2003 for the Florida subspecies. The West Indian manatee is also protected under the Marine Mammal Protection Act (MMPA) of 1972. The MMPA establishes a national policy for the maintenance of health and stability of marine ecosystems and for obtaining and maintaining optimum sustainable populations of marine mammals. It includes a moratorium on the taking of marine mammals. The recovery planning under the ESA includes conservation planning under the MMPA (USFWS 2001).

In the early 1980s, scientists tried to develop procedures for estimating the overall manatee population in the southeastern United States. The best estimate throughout the State of Florida was 1,200 manatees (USFWS 2001). In the early 1990s, the State of Florida initiated a statewide aerial survey in potential winter habitats during periods of severe cold weather (Ackerman 1995), and the highest count of 3,276 manatees was recorded in January 2001. Manatees were reported in Lake Pontchartrain prior to the landfall of Hurricane Katrina, however, there were no reports of manatee mortality following the hurricane.

The most significant problem faced by manatees in Florida is death or injury from boat strikes (USFWS 2001). Minimum flows and levels for warm water refuges need to be established to ensure their long-term availability for manatees. Their survival will depend on maintaining the ecosystems and habitat sufficient to support a viable manatee population (USFWS 2001). The focus of recovery is on implementing, monitoring, and addressing the effectiveness of conservation measures to reduce or remove threats that will lead to a healthy and self-sustaining population (USFWS 2001).

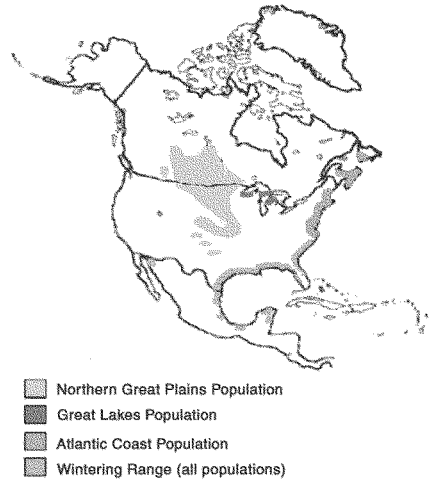
8.4 Piping Plover (*Charadrius melodus*)

8.4.1 Description of Species

The piping plover, (*Charadrius melodus),* is a small shorebird approximately 7 inches in length with a wingspan of approximately 15 inches and an average weight of 1.5 to 2 ounces. It is sand-colored on the back with white undersides. The piping plover is distinguished from similar species by its bright orange legs. During the breeding season, the plover has a single black band across its breast and forehead, which are absent during the winter.

The piping plover is named for its melodic mating call. It is a small, pale-colored North American shorebird. The bird's light sand-colored plumage blends in with sandy beaches and shorelines. There are three populations of piping plovers in the United States. The most endangered is the Great Lakes breeding population, which encompasses only 32 breeding pairs. The Northern Great Plains and Atlantic Coast populations are classified as threatened and include 1398 and 1372 breeding pairs respectively. All piping plovers winter along the southeast and Gulf coasts and are classified as threatened in their wintering habitat (USFWS, 2000)

8.4.2 Distribution and Abundance



The breeding range of the piping plover ranges for the northern Great Plains region encompasses southern Alberta, northern Saskatchewan, southern Manitoba, northwestern and (formerly) southwestern Ontario, south to eastern Montana, the Dakotas, southeastern Colorado, Iowa, Minnesota, and Nebraska with sporadic nesting occurs in Oklahoma. Breeding birds are widely distributed in small populations throughout this range. The species once ranged throughout much of the Great Lakes region, but now is now only found in northern Michigan. On the Atlantic coast the species can be found from Newfoundland, southeastern Quebec, and New Brunswick south to North Carolina. 82 percent of nesting pairs for the Atlantic coast are found in Massachusetts, New York, New Jersey, and Virginia (Nature Serve accessed 7-13-2011).

The complete non-breeding winter distribution is not known. Birds have been reported wintering from North Carolina south to Florida, the Gulf coast states, Mexico, and the Caribbean. About 5 percent of the total North American breeding population and 14 percent of the entire Atlantic coast breeding population winters from North Carolina through Florida. Plovers wintering on the Atlantic coast occurred most frequently in Georgia and least frequently in Florida. Approximately 35 percent of the species total breeding population winters along the

gulf coast from Florida to Texas and represents 56 percent of the Great Lakes/Great Plains population. Also there are reports of small numbers of plovers wintering in the Bahamas and Greater Antilles, and eastern Mexico (Nature Serve accessed 7-13-2011).

8.4.3 Movements and Migration

All populations could potentially occur within the proposed action areas since it falls within the wintering range of the species. They arrive from their northern breeding grounds as early as late July and may be present for 8 to 10 months of the year. Inland breeders appear to migrate nonstop to the Gulf of Mexico or Atlantic Coast. Great Lakes and Northern Plains birds are rare at seemingly appropriate inland stopover places: Great Salt Plains National Wildlife Refuge, OK, and Cheyenne Bottoms National Wildlife Refuge, KS (Haig, 1986). Both sping and fall migration routes of Atlantic Coast breeders are believed to occur primarily within a narrow zone along the Atlantic Coast (USFWS, 2010b). Existing stopover records suggest that migration routes are predominantly south/southeast in the fall. In fall, birds depart Massachusetts breeding sites by late August (Haig, 2004). Manitoba and North Dakota nests hatch in late July or early August and stay into September. Generally, females go first, then unpaired males, males with fledglings, followed by unaccompanied juveniles. Peak return to Texas beaches is in August and September, although small numbers may arrive as late as November. Adults may arrive before juveniles as early captures in Texas were of adult birds (sex unknown) and juveniles were not recorded until early November; however, since sample size was small further research is needed.

8.4.4 Food Habits

The piping plover eats various small invertebrates, though relatively little information is available on breeding and winter diet. Food sources identified consists of worms, fly larvae, beetles, crustaceans, mollusks, and other invertebrates. The chicks learn to feed themselves and eat smaller versions of adult food items. Piping plovers feed more leisurely than other sandpipers, alternately running and pausing to search for prey. Open shoreline areas are preferred, and vegetated beaches are avoided. In New Jersey, intertidal polychaetes were the main prey of plovers foraging at night. In the Magdalen Islands, Quebec, Staphylinidae, Curculionidae, and Diptera were the organisms most commonly found in fecal droppings (Nature Serve Accessed 7-13-2011).

Behavioral observation of piping plovers on the wintering grounds suggests that they spend the majority of their time foraging. Feeding activities may occur during all hours of the day and night, and at all stages in the tidal cycle. Wintering plovers primarily feed on invertebrates such as polychaete marine worms, various crustaceans, fly larvae, beetles, and occasionally biyalye mollusks. They peck these invertebrates on top of the soil or just beneath the surface. Plovers forage on moist substrate features such as intertidal portions of ocean beaches, washover areas, mudflats, sand flats, algal flats, shoals, wrack lines, sparse vegetation, shorelines of coastal ponds, lagoons, ephemeral pools and adjacent to salt marshes. Studies from the coastal breeding range have shown that the relative importance of various feeding habitat types may vary by site (USFWS, 2010b). Cohen et al. (2006) documented more abundant prey

items and biomass on sound island and sound beaches than the ocean beach. On the wintering grounds, Ecological Associates, Inc. (2009) observed that during piping plover surveys at St. Lucie Inlet, Martin County, Florida, intertidal mudflats and/or shallow subtidal grass flats appear to have greater value as foraging habitat than the unvegetated intertidal areas of a flood shoal (USFWS, 2010b).

8.4.5 Habitat Association

The piping plover is a shorebird that inhabits open beaches, alkali flats, and sandflats of North America. It breeds primarily along the Atlantic coast from North Carolina to southern Canada, along rivers and wetlands of the northern Great Plains from Nebraska to the southern prairie provinces, and along portions of the western Great Lakes. In winter, most individuals are found on coastal beaches and sand flats from the Carolinas to Yucatan; some scatter through the Bahamas and West Indies. (Haig, 1992)

This plover is divided into two subspecies based on geographic distribution and presence or absence of complete neck bands, although there is little support for this designation (Haig and Oring 1988a). Numerous breeding studies have been conducted across the species range, yet habitat requirements and limiting factors remain poorly known. Conservation efforts are well organized in breeding areas across North America, whereas little has been attempted in winter areas.

Ideal wintering habitat for the piping plover on the Gulf of Mexico coast would contain large sand flats or sand-mud flats adjacent to a tidal pass or tidal inlet (Haig 1985, Nicholls 1989). A thin layer of mud covering the sand seems to attract plovers, due to possible food or refuge association (Nicholls 1989). Nicholls observed that barrier beaches with over wash areas or sections of old marshes also attract plovers. A gulf-facing beach having a very low gradient, thus an increased intertidal zone, offers an almost equally attractive area (Haig 1985). Also piping plovers will inhabit spoil islands on the Gulf Intercoastal Waterway on both Atlantic and Gulf Coasts. Birds are frequently associated with bays, lagoons and inlets. Winter 2001 census observations were in the following habitat type: mudflats (36.3%), sandy beaches (33.2%), sand/salt flats (23.1%) algal mats (2.8%), oyster reefs (1.0%) and gravel shores (0.1%; Haig 2004). Foraging habitat in winter is fairly consistent among numerous Gulf and Atlantic coast sites. On Dauphin Island, AL: protected mudflats or sandflats exposed at low tide; at Texas sites: primarily bayshore sand and algal flats. Comparison among 36 Atlantic winter sites (222 birds observed once each) and 75 Gulf sites (1,508 birds observed once each) indicates foraging activity most often associated with mudflats (25.6% of observations), sandflats (25.1%), and sandy mudflats (31.8%; Haige, 2004).

8.4.6 Status and Cause of Decline

The USFWS determined the piping plover to be endangered and threatened on December 11, 1985. Endangered status was determined for the plover in the watershed of the Great Lakes (Illinois, Indiana, Michigan, Minnesota, New York, Ohio, Pennsylvania, Wisconsin, and Ontario). It was determined to be threatened in the remainder of its range: northern Great Plains

(Iowa, northwestern Minnesota, Montana, Nebraska, North Dakota, South Dakota, Alberta, Manitoba, and Saskatchewan); Atlantic coast (Quebec, Newfoundland, Maritime Provinces, and states from Maine to Florida); Gulf coast (Florida to Mexico); Bahamas; and West Indies.

In July of 2001, the USFWS designated specific areas in the United States as Critical Habitat for wintering piping plovers (Federal Register / Vol. 66, No. 132, 10 July 2001). Piping plover Critical Habitat is defined by the USFWS as "those elements essential for the primary biological needs of foraging, sheltering, roosting, and the physical features necessary for maintaining the natural processes that support those habitat components. These primary elements are found only in coastal areas with intertidal beaches or flats that are associated with dunes systems and flats above annual high tide." The USFWS also indicated that constituent elements are found in geologically dynamic coastal areas that contain intertidal beaches and flats (between annual low tide and annual high tide), and associated dune systems and flats above annual high tide. Important primary constituent elements of intertidal flats include sand and/or mud flats with no or very sparsely emergent vegetation. Adjacent unvegetated or sparsely vegetated sand, mud, or algal flats above high tide are also important, especially for roosting plovers. The USFWS designated a total of 1,798 miles (165,211 acres) of shoreline along the Gulf of Mexico and Atlantic coasts as wintering Critical Habitat. Critical Habitat in Louisiana encompasses 24,950 acres along 342.5 miles of shoreline, which is most of the coast of Louisiana including the island of Grand Isle. The Critical Habitat designation within Louisiana includes:

- **Unit LA-1**: Texas/Louisiana border to Cheniere au Tigre. 2,650 ha (6,548 ac) in Cameron andVermilion Parishes
- **Unit LA-2**: Atchafalaya River Delta. 921 ha (2,276 ac) in St. Mary Parish, LA
- **Unit LA-3**: Point Au Fer Island. 195 ha (482 ac) in Terrebonne Parish.
- **Unit LA-4**: Isles Dernieres. 795 ha (1,964 ac) in Terrebonne Parish
- **Unit LA-5**: Timbalier Island to East Grand Terre Island. 2,321 ha (5,735 ac) in Terrebonne, Lafourche, Jefferson, and Plaquemines Parishes.
- **Unit LA-6**: Mississippi River Delta. 105 ha (259 ac) in Plaquemines Parish, LA.
- **Unit LA-7**: Breton Islands and Chandeleur Island Chain. 3,116 ha (7,700 ac) in Plaquemines and St. Bernard Parishes, LA

The closest piping plover Critical Habitat to the proposed action area is unit LA-7 (**Figure 53**).

Unit LA-7: The Breton Island and the Chandeleur Island Chain, 3,116 ha (7,700 ac), were designated in Plaquemines and St. Bernard Parishes, LA. This unit includes Breton, Grand Gosier, and Curlew Islands and the Chandeleur Island chain. Those islands are part of the Breton National Wildlife Refuge or are state owned. The entire islands where primary constituent elements occur to MLLW are included in this unit. Due to recent storm events that resulted in extensive land loss along this barrier island chain, most of the designated Critical Habitat on the Chandeleur Island chain is now unavailable to the piping plover, therefore it is no longer providing the entire 3,116 ha of Critical Habitat.

Hunting in the early 1900s resulted in a drastic reduction of the piping plover population. Ongoing destruction of historical nesting sites further reduced plover populations (USFWS 1988). The primary causes for decline of this species are listed as habitat loss/degradation and human disturbance. Loss of breeding habitat has resulted from recreation and commercial development of sandy beaches on the Great Lakes, Atlantic Coast, and Gulf of Mexico. Where breeding does occur on coastal beaches, inland lakes, and river sites, reproductive success has been reduced by disturbance from humans and pets. Additional habitat has been lost due to construction and operation of reservoirs and river channelization.

Dune stabilization projects that result in steep beach slopes, narrower beach widths, or increased vegetation to the water's edge, reduce piping plover habitat (Haig 1985). In at least one instance, stabilization of the backside of the dune on Padre Island, Texas, resulted in the destruction of essential sand flat habitat (USFWS ESIS). Additionally, increased urbanization has led to an increase in predation on the piping plover population (USFWS 1988). Recreational activities in localized areas along the gulf coast have been correlated with a decrease in piping plover use of those areas (Nicholls 1989).

Habitat loss is a problem on both breeding and wintering grounds. It occurs when nesting beaches or basins become unsuitable or unavailable to piping plovers through natural causes such as drought, vegetation encroachment, tides and floods, as well as through activities such as beach visitation, housing developments, cattle ranching and water management. Natural factors will undoubtedly continue to be an unpredictable challenge for piping plover recovery in the future, and habitat loss due to human activity will increase with demands for more resources, recreation and living space, as the human population continues to grow (National Recovery Plan).

The barrier islands in Louisiana are the remains of an abandoned Mississippi River Delta; and their degradation is the result of the natural deltaic processes. Barrier islands act as a buffer to reduce the effects of ocean waves and currents on associated estuaries and wetlands. Louisiana's barrier islands are eroding at a rate of up to 65 feet per year: according to recent USGS estimates, several will disappear by the end of the century (LACPR 2008). With the rapid loss of this habitat occurring along the Louisiana coast restoration efforts are of the highest priority given the large population of piping plovers that winter along the Louisiana coast. With large tracks of Critical Habitat disappearing piping plovers will be forced to nest in other regions. If barrier islands become unavailable they will be forced to move to mainland beaches where there is increased likelihood for human disturbance and predation. If nothing is done to restore this habitat the piping plover will face difficulty returning to a stable population size.

8.5 Green Sea Turtle (*Chelonia mydas*)

8.5.1 Description of Species

The green sea turtle is one of the largest marine turtles with adult weights averaging between 250 to 450 pounds (Dundee 1989). The green sea turtle has a brown carapace, often

with radiating mottled or wavy dark markings or large dark brown blotches. It has 4 costal plates on each side of its carapace. The first costal does not contact the nuchal. It has one pair of prefrontal plates between the eyes. The limbs are flattened flippers. Young are black to dark brown above, mainly white below, with a middorsal keel and two plastral keels, 4-6 cm at hatching. Adults have a carapace length of usually 90-122 cm (to 153 cm), and a mass of 113-295+ kg) (Conant and Collins 1991). The green sea turtle differs from the hawksbill sea turtle in having one rather than two pairs of prefrontals and carapace scutes that do not overlap. It differs from the loggerhead and the Kemp's ridley in having the first costal not in contact with the nuchal (Nature Serve Accessed 7-13-2011).

This species can live upwards of 50 years and usually reaches sexual maturity between ages 20-50 years. During the yearling stages, the species lives in and around offshore areas and its diet is primarily carnivorous (NOAA-1). During their first year of life, green sea turtles are primarily carnivorous, feeding mainly on invertebrates. Green turtles are the only sea turtles that eat large amounts of plants, feeding in shallow water areas with abundant seagrasses or algae (Fritts et al. 1983; Spotila 2004). Green sea turtles will also feed on invertebrates and carrion (Dundee and Rossman 1989).

Reproductive females lay 1-8 clutches per season, averaging about 90-140 eggs, at about two-week intervals usually every 2-5 years. Nesting occurs from March to October in the Caribbean-Gulf of Mexico region, with its peak occurring in May and June. Green sea turtles nest in Florida between May and September. Eggs hatch usually in 1.5 to 3 months. Eggs and hatchlings typically incur high mortality from various terrestrial and aquatic predators, including both vertebrates and invertebrates (e.g., crabs). Many nests are destroyed by tidal inundation and erosion. In Costa Rica, annual survivorship of adult females was calculated as 0.61; in other areas it varies from 0.40-0.86. Humans are the most important predators on adults. Females mature probably at an average age of 27 years in Florida, but growth rates and hence age of maturity may vary greatly (from perhaps fewer than 20 years to 40+ years) throughout the range (slower growth in Australia, Hawaii, and Galapagos than in Florida and West Indies region). (Nature Serve Accessed 7-13-2011)

8.5.2 Distribution and Abundance

Distribution is pantropical in the Atlantic, Pacific, and Indian oceans. In some areas this species occurs in higher temperate latitudes due to drifting in ocean currents in conjunction with above-normal sea temperatures or as a normal life history event; young turtles regularly range as far north as New England. Major nesting activity occurs on Ascension Island, Aves Island, in Costa Rica (24,000 females nests each year at Tortuguero), and in Surinam (Nature Serve Accessed 7-13-2011). Although green sea turtles are found worldwide in oceans and gulfs with water temperatures greater than 68°F (20°C), their distribution can be correlated to grassbed distribution, location of nesting beaches, and associated ocean currents (Hirth 1971; Perrine 2003; Spotila 2004). Long migrations are often made between feeding and nesting grounds (Carr and Hirth 1962). Within Louisiana waters, these turtles probably occur all along the coast and may nest on the Chandeleur Islands (Dundee and Rossman 1989).

In U.S. Atlantic waters, green sea turtles occur around the U.S. Virgin Islands and Puerto Rico, where small numbers nest on islas Mona, Vieques, and Culebra, and St. Thomas, St. John, St. Croix islands. A juvenile population exists in eastern portion of Puerto Rican Bank, and from Texas to Massachusetts. Relatively small numbers nest in Florida, particularly in Brevard, Indian River, St. Lucie, Martin, Palm Beach, and Broward counties. Most nest from Volusia County to Dade County, with rare recent nesting on the Gulf Coast in Santa Rosa County. Important feeding areas in Florida include the Indian River, Florida Bay, Homossassa Bay, Crystal River, and Cedar Key. On rare events, the species has also been known to nest in Georgia, North Carolina, and Texas (nature serve accessed 7-13-2011).

8.5.3 Movements and Migration

Green sea turtles migrate from nesting areas to feeding grounds, which are sometimes several thousand miles away. Most turtles migrate along the coasts, but some populations are known to migrate across the ocean from nesting area to feeding grounds. The major nesting beaches are always found in places where the seawater temperature is greater than 77°F (25°C). As a species that migrates long distances, these turtles face special problems associated with differing attitudes toward conservation in different countries. Green turtles are the only sea turtles known to come ashore for purposes other than nesting. Both immature and adult green sea turtles are known to bask (Perrine 2003).

In the southeastern United States, green sea turtles are found around the U.S. Virgin Islands, Puerto Rico, and the continental U.S. from Texas to Massachusetts. Important feeding grounds in Florida include Indian River Lagoon, the Florida Keys, Florida Bay, Homosassa, Crystal River and Cedar Key. The primary nesting sites in U.S. Atlantic water are along the east coast of Florida, with additional sites in the U.S. Virgin Islands and Puerto Rico.

In the eastern North Pacific, green sea turtles have been sighted from Baja California to southern Alaska. In the central Pacific, green sea turtles can be found at most tropical islands. In U.S. Hawaiian waters, green sea turtles are found around most of the islands in the Hawaiian Archipelago. The primary nesting site is at French Frigate Shoals (NOAA-2). Neonates of green sea turtles have been known to migrate far from natal beaches to foraging areas and return to natal beach to breed/nest up to 40+ years later. (nature serve 7-13-2011)

In the western Atlantic, several major nesting assemblages have been identified and studied (Peters, 1954; Carr and Ogren, 1960; Parsons, 1962; Pritchard, 1969; Carr *et al.*, 1978). In the continental United States, green turtle nesting occurs on the Atlantic coast of Florida (Ehrhart, 1979). Occasional nesting has been documented along the Gulf coast of Florida, at Southwest Florida beaches, as well as the beaches on the Florida Panhandle (Meylan *et al., 1995*). Most documented green turtle nesting activity occurs on Florida index beaches, which were established to standardize data collection methods and effort on key nesting beaches. The pattern of green turtle nesting shows biennial peaks in abundance, with a generally positive trend during the six years of regular monitoring since establishment of the index beaches in 1989. This is perhaps due to increased protective legislation that has been established throughout the Caribbean (Meylan *et al.*, 1995).

8.5.4 Food Habits

While nesting activity is obviously important in identifying population trends and distribution, the majority portion of a green turtle's life is spent on the foraging grounds. Green turtles are herbivores, and appear to prefer marine grasses and algae in shallow bays, lagoons and reefs (Rebel, 1974). Some of the principal feeding pastures in the Gulf of Mexico include inshore south Texas waters, the upper west coast of Florida and the northwestern coast of the Yucatan Peninsula. Additional important foraging areas in the western Atlantic include the Indian River Lagoon System in Florida, Florida Bay, the Culebra archipelago and other Puerto Rico coastal waters, the south coast of Cuba, the Mosquito coast of Nicaragua, the Caribbean coast of Panama, and scattered areas along Colombia and Brazil (Hirth, 1971). The preferred food sources in these areas are *Cymodocea, Thalassia, Zostera, Sagittaria, and Vallisneria* (Babcock, 1937; Underwood, 1951; Carr, 1952; 1954). The typical diet includes"seagrass," macroalgae and other marine vegetation, and various invertebrates such as mollusks, sponges, crustaceans, and jellyfish. (natureserve 7-13-2011)

8.5.5 Habitat Association

Feeding occurs in shallow, low-energy waters with abundant submerged vegetation, and also in convergence zones in the open ocean. Migrations may traverse open seas. Adults are tropical in distribution, whereas juveniles range into temperate waters (e.g., see Morreale and Standora, no date). Hatchlings often float in masses of marine macroalgae (e.g., *Sargassum*) in convergence zones. Coral reefs and rocky outcrops near feeding pastures often are used as resting areas. Inactive individuals may rest on the bottom in winter in the northern Gulf of California. Basking on beaches has been documented in some areas (e.g., Hawaii) (natureserve 7-13-2011).

Nesting occurs on beaches, usually on islands but also on the mainland. Sand may be coarse to fine, and has little organic content. Physical characteristics vary greatly in the different nesting regions. Most nesting occurs on high energy beaches with deep sand. At least in some regions, individuals generally nest at same beach in successive nestings, though individuals sometimes change to a different nesting beach within a single nesting season. Beach development and illumination has made many beaches unsuitable for successful nesting. (natureserve 7-13-2011)

8.5.6 Status and Cause of Decline

The green sea turtle was listed as threatened in U.S. waters, except for the Florida breeding population which is listed as endangered, on July 28, 1978. Due to the inability to distinguish between these populations away from the nesting beach, green turtles are considered endangered wherever they occur in U.S. waters. In 1998, Critical Habitat for this species was designated in and around the Culebra Islands, which are situated off the eastern coast of Puerto Rico (NMFS 1998).

Green turtles were traditionally highly prized for their flesh, fat, eggs, and shell. Fisheries in the United States and throughout the Caribbean are largely to blame for the decline of the species. Green turtles were once abundant enough in the shallow bays and lagoons of the Gulf to support a commercial fishery, which landed over one million pounds of green turtles in 1890 (Doughty, 1984). Historically, green sea turtles were fished off the Louisiana coast, especially the Chandeleur Islands (Rebel 1974; http://www.wlf.state.la.us/apps/netgear/index.asp?cn=lawlf&pid=703). Doughty (1984) reported the decline in the turtle fishery throughout the Gulf of Mexico by 1902. Currently, green turtles are uncommon in offshore waters of the northern Gulf, but abundant in some inshore embayments. Shaver (1994) live-captured a number of green turtles in channels entering into Laguna Madre, in south Texas. She noted the abundance of green turtle strandings in Laguna Madre inshore waters and opined that the turtles may establish residency in the inshore foraging habitats as juveniles. Algae along the jetties at entrances to the inshore waters of south Texas was thought to be important to green turtles associated with a radio-telemetry project (Renaud *et al.*, 1995). Transmitter-equipped turtles remained near jetties for most of the tracking period. This project was restricted to late summer months, and therefore may reflect seasonal influences. Coyne (1994) observed increased movements of green turtles during warm water months.

In the Southeast United States, major nest protection efforts and beach habitat protection are underway for most of the significant nesting areas, and significant progress has been made in reducing mortality from commercial fisheries in U.S. waters with the enforcement of Turtle Exclusionary Device (TED) regulations. Many coastal counties and communities in Florida have developed lighting ordinances to reduce hatchling disorientations. Important U.S. nesting beaches have been and continue to be acquired for long-term protection. The FWS and NMFS have been funding research on the fibropapilloma disease for several years to expand our knowledge of the disease with the goal of developing an approach for remedying the problem. Due to the long range migratory movements of sea turtles between nesting beaches and foraging areas, long-term international cooperation is absolutely essential for recovery and stability of nesting populations (USFWS North Florida Fact Sheet).

Additional threats, specifically in the U.S., include the erosion of the coastline and the barrier islands, which results in the loss of suitable habitat for this species (LDWF-2). Fishing and dredging operations, specifically hopper-type dredges, have also adversely impacted this species throughout the years. Also, commercial harvest, habitat degradation, coastal development, disease, and predation have all contributed to the decline of the species.

8.6 Hawksbill Sea Turtle (*Eretmochelys imbricata*)

8.6.1 Description of Species

The hawksbill is a sea turtle in which the large scutes of the brown carapace overlap, except in very young and very old individuals. The carapace has middorsal keel and some individuals exhibit a "tortoiseshell" pattern with radiating streaks. There are 4 costal plates on each side of carapace with two pairs of prefrontals between the eyes, and the limbs are flattened flippers with 2 claws on each flipper. The snout is pointed and beaklike. The young are all

black or dark brown except for light brown raised ridges, shell edges, and areas on the neck and flippers. The adults carapace length usually ranges from 76 to 89 cm (to 90+ cm), with a mass of 43 to 75 kg (to 127 kg). (natureserve 7-13-2011)

This species differs from the green turtle in having two rather than one pair of prefrontals and having overlapping scutes on the carapace (they may overlap in very young green turtles). It differs from the loggerhead and ridleys in having only four rather than 5 or more costals on each side of the carapace, and in having the first costal not in contact with the nuchal. (natureserve 7-13-2011)

8.6.2 Distribution and Abundance

Hawksbill sea turtles are found in pantropical and warm-temperate regions, rarely venturing into the higher latitudes of Atlantic, Pacific, and Indian oceans. Nesting occurs on beaches generally between 25 degrees latitude north and south, including tropical waters in the Gulf Coast of Mexico, West Indies, Bahamas, and the Americas. Nesting in U.S. waters occurs on the Virgin Islands, Puerto Rico (including Isla Vieques, Isla Mona, and the Culebra group) and infrequently on the Atlantic coast of central and southern Florida, and in the southeastern Hawaiian chain. (natureserve 7-13-2011)

In the West Indies, most nesting occurs between May and November with the peak occurring between May and June. Individual adult females lay 3-6 clutches with 50-200+ eggs per clutch during the night at intervals averaging 14-18.5 days. Adult females nest at intervals of usually 2 or more years (mean as low as 1.84 years in Malaysia, 5-7 years in the Solomon Islands). Eggs hatch in about 2 months. Eggs and hatchlings incur high mortality from various predators. Humans are the most important predators on adults. Age of sexual maturity is between 20 and 40 years (ranges from 20+ years in the Caribbean to at least 30-35 years in the Indo-Pacific to 31-38 years in Australia). Historically, nesting concentrations likely were larger than they currently are in most areas; now nesting generally is distributed at low densities in the Caribbean (small nesting concentrations may occur on Antigua). Up to 100 per night may nest on some islands in northern Australia. Nesting aggregations also occur in Oman, Yucatan, and the Sychelles, and these may be typical of pre-exploitation nesting densities. (natureserve 7-13-2011)

8.6.3 Movements and Migration

Adults may migrate hundreds or thousands of kilometers between nesting beaches and marine feeding areas. In the Caribbean region, 19 adults traveled distances of 110 to 1,936 kilometers and 9 immatures traveled a distances of 46 to 900 kilometers. Recapture of immatures suggest a long-term residency in their developmental habitats. Adult females that nested in Barbados traveled 200 to 435 kilometers (straight-line distance) over 7 to18 days to foraging areas in Dominica, Grenada, Trinidad, and Venezuela. A female tagged on a nesting beach at Buck Island Reef National Monument near St. Croix, U.S. Virgin Islands, was recovered at Miskito Cays, Nicaragua. A feeding population at Isla Mona (Puerto Rico) included individuals from nesting populations throughout the Caribbean region. (natureserve 7-13-2011)

MtDNA data from the Caribbean region indicate that a natal homing mechanism predominates and that nesting populations should be considered separate stocks; foraging populations evidently are composed of cohorts from multiple regional nesting colonies (natureserve 7-13-2011).

Foraging home range sizes of individuals in the West Indies were 1.96-49.5 square kilometers and were positively correlated with average water depth (natureserve 7-13-2011).

8.6.4 Food Habits

Hawksbills feed primarily on a wide variety of sponges, but also consume bryozoans, coelenterates, and mollusks (NMFS BO, 1998). This species generally has been regarded as a generalist, but recent research indicates specialization on demosponges in Florida and the Caribbean. Their Diet has been shown to consist of invertebrates (crabs, sea urchins, shellfish, jellyfish, etc.) fish, and plant material. Foraging microhabitats include the bottom and reef faces, close to shore (natureserve 7-13-2011).

8.6.5 Habitat Association

The hawksbill sea turtle is relatively uncommon in the waters of the continental United States, preferring coral reefs, such as those found in the Caribbean and Central America (NMFS BO, 1998). Natureserve describes the species habitat associations as follows. This species uses a wide range of tropical and subtropical habitats, including shallow coastal waters with rocky bottoms, coral reefs, beds of sea grass or algae, mangrove-bordered bays and estuaries, and submerged mud flats. Hatchlings and small juveniles associate with masses of floating sea plants (sargassum rafts) in the open ocean. Nesting occurs on undisturbed, deep-sand, insular or mainland beaches, from high energy ocean beaches to tiny pocket beaches several meters wide contained in crevices of cliff walls. A typical site would be a low-energy sand beach with woody vegetation, such as sea grape or saltshrub, near the water line. Successive nestings are usually in the same general area.

8.6.6 Status and Cause of Decline

The hawksbill sea turtle was listed endangered throughout its range on June 2, 1970. Multiple factors have contributed to the decline of the species including commercial harvest, habitat degradation, coastal development, disease, and predation. Protecting a species that has such a large range can be difficult. Since hawksbills migrate long distances and co-mingle extensively on foraging areas, and since there are 36 geopolitical units in the Caribbean, implementing effective conservation measures in the Caribbean is complex and will require long-term cooperation between Caribbean nations for recovery efforts to succeed. The most important hawksbill nesting beaches in the Caribbean occur along the Yucatán Peninsula of Mexico. Several Yucatán beaches account for 25 to 30 percent of all hawksbill nesting in the Caribbean. Since 1985, the Fish and Wildlife Service has provided annual funding for surveying and protecting nests at three key beaches along the Yucatán Peninsula. Continued efforts are

needed to protect nesting beaches; minimize the threat from illegal exploitation through intensified law enforcement efforts to curb the incidence of poaching and harassment; maintain the ban on international trade in hawksbill products; and ensure long-term protection of important foraging habitats by designating them as marine sanctuaries or as State, territorial, or Commonwealth aquatic preserves or sanctuaries. (USFWS Fact Sheet)

8.7 Kemp's Ridley Sea Turtle (*Lepidochelys kempii*)

8.7.1 Description of Species

The Kemp's ridley sea turtle is the smallest of the sea turtles (Dundee 1989). The Kemp's ridley sea turtle has an almost circular carapace, is olive green (adults) or gray (young) above and yellow below. It has 5 costals on each side of carapace with the first one touching the nuchal. There are usually 4 enlarged scutes on bridge, with a single pore at the posterior edge of each scute. Usually there is an interanal scute at the posterior tip of the plastron. The beak is somewhat parrotlike. The young have 3 tuberculate dorsal ridges and four plastral ridges. The limbs are flattened flippers. Adult carapace length usually reaches 58-70 cm (to 75 cm) in length and they reach a mass of 36-45 kg (to 50 kg). Juveniles are typically 3.8-4.4 cm in lenth at hatching (Conant and Collins 1991).

This species differs from the loggerhead in size (smaller), lack of a reddish-brown dorsum, presence of an interanal scute, and presence of pored scutes on the bridge. It differs from the hawksbill and green turtles in having the first costal in contact with the nuchal. It differs from the Pacific ridley in having usually five costals on each side of the carapace rather than usually six or more (natureserve 7-13-2011).

8.7.2 Distribution and Abundance

The Kemp's ridley has the most limited distribution of any sea turtles except the Australian flatback (Perrine 2003). For the most part, breeding is confined to a limited stretch of beach on the Gulf coast of Mexico. The known range of this species includes the Gulf of Mexico and the Atlantic Ocean. The current range for Kemp's ridley in the United States includes marine habitat of the following coastal states: Georgia, Florida, Alabama, Mississippi, Louisiana, and Texas.

Natureserve described the Kemp's ridley sea turtle's distribution as follows: Adults are essentially restricted to the Gulf of Mexico. Immatures inhabit the Gulf and also the U.S. Atlantic coast north to Long Island Sound, New England, and Nova Scotia. Occasional individuals can reach Bermuda, the Azores, and European waters. Important foraging areas include Campeche Bay, Mexico, and Louisiana coastal waters. Cold-stunned juveniles frequently appear in late fall/early winter on beaches on northern Long Island, New York. Live ridleys occur in Chesapeake Bay mainly from May through November.

There is a single major nesting beach, at Rancho Nuevo, Tamaulipas, Mexico; 60 percent of nesting occurs along a 40-kilometer stretch of beach there (NMFS and USFWS 2007). In

2006, eggs were deposited in several hundred nests near Tampico, Mexico, and in about 100 nests in Texas (NMFS and USFWS 2007). Sporadic nesting has occurred as far north as North Carolina and south to Colombia (Palmatier 1993).

During nesting, Individual adult females lay usually 3 clutches averaging about 95 to 100 eggs at intervals of 10 to 28 days, during daylight from April to July. Females nest at intervals of 1 to 4 years. Large numbers of females may nest simultaneously on one beach. The eggs hatch in 45 to58 days (NMFS and USFWS 2007). Predation on eggs (especially by coyote), hatchlings, and nesting adults sometimes has resulted in high mortality rates. Human predation on eggs and nesting adults formerly was an important mortality source. Currently, drowning of adults in commercial fishing gear is a more important mortality source. Egg survivorship (to hatching) was 0.59 in one study (see Iverson 1991). Available information indicates that females begin nesting at an estimated age of 10-17 years (NMFS and USFWS, 2007). As is true of all sea turtles, this species has temperature-dependent sex determination. (natureserve 7-13-2011).

8.7.2 Movements and Migration

Most individuals move north or south from the major nesting beach at Rancho Nuevo and then settle in resident feeding areas for several months or more in various coastal locations in the Gulf of Mexico (NMFS and USFWS, 2007). During the months of May to October, this species can be found in and around the shore line of Louisiana with adults occupying areas around the mouth of Mississippi during the spring and summertime. As winter approaches, adults and juveniles generally head to warmer waters offshore. The Kemp's Ridley sea turtle's habitat is comprised of warm bays, coastal waters, sea grass beds, and sandy beaches utilized for nesting (LDWF-4). This species has been observed within the Sabine and Calcasieu Lakes as well as in Lake Borgne and areas around St. Bernard Parish (Dundee 1989). Similar to other sea turtles, threats to this species include the harvest of eggs and nesting adults, incidental trapping in fishing nets, and loss of suitable habitat. It has been suggested that sea turtles may burrow into the estuarine mud along the Gulf coast during the winter, essentially when water temperatures are too low for normal activity, but no dormant sea turtles have been reported in coastal Louisiana.

8.7.3 Food Habits

The species is carnivorous and usually feeds upon crabs, clams, and snails that inhabit the shallow coastal waters (Dundee 1989). Adults are primarily benthic feeders that specialize on crabs. Juveniles feed on sargassum, mollusks often associated with sargassum, and fish and shrimp probably discarded by anglers (Shaver 1991). Recorded stomach contents also include sea urchins and sea stars. (natureserve 7-13-2011)

8.7.4 Habitat Association

Inshore areas of the Gulf of Mexico appear to be important habitat for Kemp's ridleys, as they tend to concentrate around the mouths of major rivers (Frazier 1980). Members of this genus are characteristically found in waters of low salinity and high turbidity and organic content, where shrimp are abundant (Zwinenberg 1977; Hughes 1972 as cited in Frazier 1980;). Kemp's ridleys have been collected in Louisiana from Lake Borgne, Barataria and Terrebonne Bays, and near Calcasieu Pass (Dundee and Rossman 1989). Occurrence of these sea turtles in bays and estuaries along the Louisiana coast would not be unexpected, as many of their primary food items occur there. Stomach analyses of specimens collected in shrimp trawls off Louisiana revealed crabs, gastropods, and clams (Dobie et al. 1961). Although Kemp's ridleys are considered primarily carnivorous benthic feeders (Ernst and Barbour 1972), jellyfish as well as by-catch from shrimp trawlers have been reported as part of their diet (Landry 1986).

Research being conducted by Texas A&M University at Galveston has resulted in the intentional live-capture of 516 sea turtles from 1991-1997. Green turtles comprise over 95% of all sea turtle captures recorded by Texas A&M researchers from South Padre/Laguna Madre studies. Conversely, the Kemp's ridley dominates (92.2%) captures from more turbid, blue-crab laden waters of the upper Texas and Louisiana coasts. Capture statistics readily justify Sabine and Calcasieu Passes being considered "index habitat" for the Kemp's ridley (Landrey *et al.*, 1997).

Seasonal abundance of sea turtles utilizing nearshore waters of the northwest Gulf of Mexico varies with species and location. Kemp's ridleys are transient users of the coastal zone who venture toward tidal passes and into bays during May-August when food sources and other environmental factors are favorable. The May-August period has yielded over 80% of the sea turtle captures (N=516) recorded by Texas A&M researchers, over 75% of which were Kemp's ridleys (Landry *et al.*, 1997).

Habitat of adults primarily includes shallow coastal and estuarine waters, often over sandy or muddy bottoms where crabs are numerous. Most adults stay in the Gulf of Mexico, and they are rare along the Atlantic coast of the northeastern United States. Apparently most activity is benthic. Post-hatchlings spend 1-4 years as surface pelagic drifters in weedlines of offshore currents in the Gulf of Mexico and Atlantic Ocean, then shift to benthic coastal habitats of various types, especially where crabs and other invertebrates are numerous (NMFS and USFWS 2007). Nesting occurs on well-defined elevated dune areas, especially on beaches backed up by large swamps or bodies of open water having seasonal, narrow ocean connections. (natureserve 7-13-2011)

8.7.5 Status and Cause of Decline

Of the seven extant species of sea turtles of the world, the Kemp's ridley has declined to the lowest population level. The Kemp's ridley sea turtle was listed as endangered throughout its range on December 2, 1970. Commercial harvest, habitat degradation, coastal development, disease, and predation have all contributed to the decline of the species.

Kemp's ridleys nest in daytime aggregations known as arribadas, primarily at Rancho Nuevo, a stretch of beach in Mexico. Most of the population of adult females nest in this single locality (Pritchard, 1969). When nesting aggregations at Rancho Nuevo were discovered in 1947, adult female populations were estimated to be in excess of 40,000 individuals (Hildebrand, 1963). By the early 1970s, the world population estimate of mature female Kemp's ridleys had been reduced to 2,500-5,000 individuals. The population declined further through the mid-1980s. Recent observations of increased nesting, suggest that the decline in the ridley population has stopped, and there is cautious optimism that the population is now increasing.

The recent nesting increase can be attributed to full protection of nesting females and their nests in Mexico, and the requirement to use TEDs in shrimp trawls both in the United States and Mexico. In 1966, conservation efforts for the Kemp's ridley were initiated on the beach near Rancho Nuevo in Tamaulipas, Mexico. This locale is the only place in the world where large nesting aggregations of this sea turtle were and are known to occur. From 1966 to 1987, conservation efforts focused on the area of Rancho Nuevo with one turtle protection camp. In 1978, the U.S. joined with Mexico at Rancho Nuevo in a bi-national effort to prevent the extinction of the Kemp's ridley. In 1988, this bi-national program expanded to the south and another camp was added. In 1989, a third camp was established when the program was expanded to the north of Rancho Nuevo. By 1997, a total of seven camps had been established along the Tamaulipas and Veracruz coasts to allow for increased nest protection efforts. (USFWS North Florida Fact Sheet)

The Mexico government also prohibits harvesting and is working to increase the population through more intensive law enforcement, by fencing nest areas to diminish natural predation, and by relocating all nests into corrals to prevent poaching and predation. While relocation of nests into corrals is currently a necessary management measure, this relocation and concentration of eggs into a "safe" area is of concern since it makes the eggs more susceptible to reduced viability due to movement-induced mortality, disease vectors, catastrophic events like hurricanes, and marine predators once the predators learn where to concentrate their efforts. (USFWS North Florida Fact Sheet)

In recent years, unprecedented numbers of Kemp's ridley carcasses have been reported from Texas and Louisiana beaches during periods of high levels of shrimping effort. NMFS established a team of population biologists, sea turtle scientists, and managers, known as the Expert Working Group (EWG) to conduct a status assessment of sea turtle populations. Analyses conducted by the group have indicated that the Kemp's ridley population is in the early stages of recovery; however, strandings in some years have increased at rates higher than the rate of increase in the Kemp's ridley population (EWG, June 1996). While many of the stranded turtles observed in recent years in Texas and Louisiana are believed to have been incidentally taken in the shrimp fishery, other sources of mortality exist in these waters. These stranding events illustrate the vulnerability of Kemp's ridley and loggerhead turtles to the impacts of human activities in nearshore Gulf of Mexico waters. (NMFS BO, 1998)

The EWG developed a population model to evaluate trends in the Kemp's ridley population through the application of empirical data and life history parameter estimates chosen

by the EWG. Model results identified three trends in benthic immature Kemp's ridleys. Benthic immatures are those turtles that are not yet reproductively mature but have recruited to feed in the nearshore benthic environment, where they are available to nearshore mortality sources that often result in strandings. Benthic immature ridleys are estimated to be 2-9 years of age and 20-60 cm in length. Increased production of hatchlings from the nesting beach beginning in 1966 resulted in an increase in benthic ridleys that leveled off in the late 1970s. A second period of increase followed by leveling occurred between 1978 and 1989 as hatchling production was further enhanced by the cooperative program between the USFWS and Mexico's Instituto Nacional de Pesca (INP) to increase the nest protection and relocation program in 1978. A third period of steady increase, which has not leveled off to date, has occurred since 1990 and appears to be due to the greatly increased hatchling production and an apparent increase in survival rates of immature turtles beginning in 1990 due, in part, to the introduction of TEDs. Adult ridley numbers have now grown from a low of approximately 1,050 adults producing 702 nests in 1985, to greater than 3,000 adults producing 1940 nests in 1995 and about 3,425 nests in 1998. (NMFS BO, 1998)

The EWG was unable to estimate the total population size and current mortality rates for the Kemp's ridley population. However, they listed a number of preliminary conclusions. They indicated that the Kemp's ridley population appears to be in the early stage of exponential expansion. Over the period 1987 to 1995, the rate of increase in the annual number of nests accelerated in a trend that would continue with enhanced hatchling production and the use of TEDs. Nesting data indicated that the number of adults declined from a population that produced 6,000 nests in 1966 to a population that produced 924 nests in 1978 and a low of 702 nests in 1985. This trajectory of adult abundance tracks trends in nest abundance from an estimate of 9,600 in 1966 to 1,050 in 1985. The EWG estimated that in 1995 there were 3,000 adult ridleys. The increased recruitment of new adults is illustrated in the proportion of neophyte, or first time nesters, which has increased from 6% to 28% from 1981 to 1989 and from 23% to 41% from 1990 to 1994. The EWG's population model projected that Kemp's ridleys could reach the intermediate recovery goal identified in the Recovery Plan, of 10,000 nesters by the year 2020 if the assumptions of age to sexual maturity and age specific survivorship rates plugged into their model are correct. They determined that the data they reviewed suggested that adult Kemp's ridley turtles were restricted somewhat to the Gulf of Mexico in shallow near shore waters, and benthic immature turtles of 20-60 cm straight line carapace length are found in nearshore coastal waters including estuaries of the Gulf of Mexico and the Atlantic. (NMFS BO, 1998)

The EWG identified an average Kemp's ridley population growth rate of 13% per year between 1991 and 1995. Total nest numbers have continued to increase. However, the 1996 and 1997 nest numbers reflected a slower rate of growth, while the increase in the 1998 nesting level has been much higher. The population growth rate does not appear as steady as originally forecasted by the EWG, but annual fluctuations, due in part to irregular internesting periods, are normal for other sea turtle populations. (NMFS BO, 1998)

The area surveyed for ridley nests in Mexico was expanded in 1990 due to destruction of the primary nesting beach by Hurricane Gilbert. The EWG assumed that the increased nesting

observed particularly since 1990 was a true increase, rather than the result of expanded beach coverage. Because systematic surveys of the adjacent beaches were not conducted prior to 1990, there is no way to determine what proportion of the nesting increase documented since that time is due to the increased survey effort rather than an expanding ridley nesting range. As noted by the EWG, trends in Kemp's ridley nesting even on the Rancho Nuevo beaches alone suggest that recovery of this population has begun but continued caution is necessary to ensure recovery and to meet the goals identified in the Kemp's ridley Recovery Plan. (NMFS BO, 1998)

8.8 Leatherback Sea Turtle (*Dermochylys coriacea*)

8.8.1 Description of Species

The leatherback sea turtle is the largest living sea turtle and reptile with adults ranging in length from 4 ½ to 5 ½ feet and weighing between 650 to 2,000 pounds (Dundee 1989). The leatherback is unique in that is lacks a hard, bony shell and instead has a leathery thick connective tissue that sits upon dermal bones (NOAA-4). Carapace has seven prominent longitudinal ridges, the plastron has five ridges, and there are no scutes on skin-covered carapace and plastron. The carapace is blackish or dark bluish, often with irregular whitish or pink blotches. The young are black and white and covered with numerous small beady scales (later shed). The carapace is about 6-7.5 cm at hatching (Conant and Collins 1991).

The leatherback sea turtle is unique because no other sea turtle lacks scutes on the shell or has prominent dorsal longitudinal ridges. This species also lacks chewing plates, which a wide variety of sea turtles use to crush hard-shelled prey. Leatherback turtles are omnivorous but feed primarily on jellyfish and other cnidarians, and have been associated with large schools of cabbage head jellyfish *(Stomolophus meleagris)*. Fritts et al. (1983) reported that these turtles also ingest plastic, apparently mistaking it for food. The leatherback instead has hard cusps in addition to a sharp edged jaw, which it uses to eat soft-bodied prey such as jellyfish. The esophagus of the leatherback contains numerous backwards pointing spines that trap jellylike prey and prevent it from escaping (NOAA-4).

Nesting females lay up to 10+ (average 5 in Virgin Islands, 5-7 in Puerto Rico) clutches of 50-170 eggs (typically 70-90 normal eggs in the Atlantic, usually fewer than 60 in the eastern Pacific) at intervals of about 1-2 week. Most individuals nest at intervals of every 2-3 years. The species nests at night between March-August in Western Hemisphere. Eggs hatch in 8-10 weeks. Reportedly sexually mature in 6-10 years, or possibly less, or perhaps 20-50 years; females in the Atlantic mature at a carapace length of 137-145 cm, Pacific females mature at slightly smaller size. A skeletochronological analysis concluded that for conservation management purposes, 9 years is a likely minimum age for maturity based on the youngest adult in the sample. Limited data indicate a post-maturation longevity of up to about two decades. (Natureserve,)

8.8.2 Distribution and Abundance

Leatherbacks are widely distributed throughout the oceans of the world, and are found throughout waters of the Atlantic, Pacific, Caribbean, and the Gulf of Mexico (Ernst and Barbour, 1972). Leatherbacks are predominantly distributed pelagically, feeding primarily on jellyfish such as *Stomolophus, Chryaora*, and *Aurelia* (Rebel, 1974). The leatherback migrates to barrier islands and coastal beaches to nest (LDWF-5). Nesting occurs from February through July at sites located from Georgia to the U.S. Virgin Islands. Nesting leatherbacks occur along beaches in Florida, Nicaragua, and islands in the West Indies; however, no nesting has been reported in Louisiana (Gunter 1981, Dundee and Rossman 1989). In Louisiana, leatherbacks are believed to occur offshore in deep waters; however, they have been collected from or sighted in Cameron Parish, Atchafalaya Bay, Timbalier Bay, and Chandeleur Sound (Dundee and Rossman 1989). Leatherbacks are believed to come into shallow waters if there is an abundance of jellyfish nearshore. Leary (1957) reported a large group of up to 100 leatherbacks just offshore of Port Aransas, Texas associated with a dense aggregation of *Stomolophus*.

8.8.3 Movements and Migration

Leatherback sea turtles move hundreds to thousands of kilometers between nesting beaches and distant marine waters. Transequatorial migrations have also been documented. Their pattern of epibiont colonization in the Caribbean suggests that gravid turtles do not arrive from temperate latitudes until just prior to nesting, and that they go directly to a preferred nesting beach. Nesters apparently arrive asynchronously. Individual females may nest on multiple islands within a region. Caribbean nesters have been shown to move north along the Atlantic coast after nesting. A leatherback tagged in Chesapeake Bay in late May 1985 was captured off southern Cuba in late July 1986. Also, leatherbacks from nesting areas in Suriname and Costa Rica were found in the summer off of Nova Scotia. In 1996 a migration corridor that extending from the Pacific coast of Costa Rica through the vicinity of the Galapagos Islands was documented for this species. A nesting female tagged in Suriname was captured off Ghana, West Africa, less than 1 year later. (natureserve 7-13-2011)

8.8.4 Food Habits

The principal food of the leatherback is jellyfish, though other invertebrates, fishes, and seaweed are sometimes eaten. Pelagic foraging is believed to focus on jellyfish in the deep scattering layer. (natureserve 7-13-2011)

8.8.5 Habitat Association

The leatherback sea turtle is typically found in the marine environment of the open ocean, often near the edge of continental shelf. They have also been found seas, gulfs, bays, and estuaries. The species is mainly pelagic, seldomly approaching land except for nesting. Concentrates in summer is in waters mostly 20-40 m deep near Cape Canaveral, Florida. This species dives almost continuously, to depths of up to at least several thousand meters. Leatherbacks may linger at the surface at midday, but spend most of their time submerged (natureserve 7-13-2011).

Nesting habitat is typically on sloping sandy beaches backed by vegetation, often near deep water and rough seas. The largest colonies use continental, rather than insular, beaches (CSTC 1990). The absence of a fringing reef appears to be an importantant factor for selecting nesting sites. During nesting the females deposit eggs in moist sand and may sometimes change to different nesting beachs during a single year (natureserve 7-13-2011).

8.8.6 Status and Cause of Decline

The Leatherback sea turtle was listed as endangered throughout its range on June 2, 1970. Commercial harvest, habitat degradation, coastal development, disease, and predation have all contributed to the decline of the species. Eggs and hatchlings incur high rates of mortality from predation with humans being significant egg predators. Adults often die from drowning in commercial fishing nets and from eating floating debris, especially plastic (natureserve 7-13-2011).

The status of the leatherback population is the most difficult to assess since major nesting beaches occur over broad areas within tropical waters outside the United States. The primary leatherback nesting beaches occur in French Guiana and Suriname in the western Atlantic and in Mexico in the eastern Pacific. Although increased observer effort on some nesting beaches has resulted in increased reports of leatherback nesting, declines in nest abundance have been reported from the beaches of greatest nesting densities. At Mexiquillo, Michoacan, Mexico, Sarti *et al.* (1996) reported an average annual decline in leatherback nesting of about 23 percent between 1984 and 1996. The total number of females nesting on the Pacific coast of Mexico during the 1995-1996 season was estimated at fewer than 1,000. The major western Atlantic nesting area for leatherbacks is located in the Suriname-French Guiana trans-boundary region. Chevalier and Girondot (1998) report that combined nesting in the two countries has been declining since 1992. Some nesting occurs on Florida's east coast, although nests are likely under reported because surveys are not conducted during the entire period that leatherbacks may nest. In the eastern Caribbean, nesting occurs primarily in the Dominican Republic, the Virgin Islands, and on islands near Puerto Rico. Sandy Point, on the western edge of St. Croix, Virgin Islands, has been designated by the U.S. Fish and Wildlife Service (USFWS) as Critical Habitat for nesting leatherback turtles, and NMFS has designated the adjacent waters surrounding St. Croix, up to and inclusive of the 100 fathom curve, as Critical Habitat for leatherbacks. Anecdotal information suggests nesting has declined at Caribbean beaches over the last several decades (NMFS and USFWS, 1995).

It is imperative that hatchling production be maximized for the remaining leatherback nesting that occurs along the extensive Pacific coasts of Mexico, Costa Rica, and other Central American countries. Due to the long range migratory movements of sea turtles between nesting beaches and foraging areas, long-term international cooperation is absolutely essential for recovery and stability of nesting populations. Since the 1998-99 nesting season, the Fish and Wildlife Service has provided funding annually to assist recovery efforts for the leatherback in Mexico and Costa Rica, including support for nesting surveys and nest protection. In the Southeast United States and U.S. Caribbean, major nest protection efforts and beach habitat protection are underway for most of the significant nesting areas. In addition, research is

underway to develop technologies to minimize leatherback mortality associated with the longline fishery. Many coastal counties and communities have developed lighting ordinances to reduce hatchling disorientations. Important U.S. nesting beaches have been and continue to be acquired for long-term protection. (USFWS north Florida fact sheet for the leatherback)

Threats to this species include predation of juveniles by humans and other mammals, commercial exploitation of its oil for cosmetics, incidental capture in fishing nets, and the loss of nesting grounds with the erosion of the barrier islands and coastline (Dundee 1989 & NOAA-4).

8.9 Loggerhead Sea Turtle (*Caretta caretta*)

8.9.1 Description of Species

The loggerhead sea turtle is also one the larger marine turtles with average adult lengths ranging from 3 to 7 feet and weighing approximately 300 to 1,100 pounds (Dundee 1989). Loggerheads sea turtles are reddish-brown with relatively large heads. They have 5 or more costals (pleurals) on each side of the carapace with the first costal always touching the nuchal. They have three or four large poreless scutes on bridge between shells. The middorsal keel becomes inconspicuous in large individuals. They have limbs which are flattened flippers and the tail of adult male (extends past tips of back-stretched hind flippers) is much longer than that of adult female (barely reaches rear edge of carapace). The young are brown or reddish-brown dorsally and have three dorsal keels and two plastral keels. The adult carapace length usually ranges between 70 and 125 cm (to 122+ cm). The typical mass of adults is between 70 and 180 kg (to 227+ kg). The hatchling shell length is 4 to 5 cm and the hatchling mass is about 20 g (natureserve).

The loggerhead differs from ridleys in size (larger, ridley maximum shell length is 75 cm), coloration (reddish-brown dorsal coloration olive-green or gray in ridleys), and in the 3 poreless scutes on the bridge (usually 4 pored scutes in ridley). The loggerhead differs from hawksbill and green turtles by having the first costal in contact with the nuchal. Also, the head is relatively larger than that of other sea turtles (natureserve).

This species usually reaches sexual maturity around age 35 and mating in the southeastern U.S. can occur between late March and early June. Females lay 1-9 clutches (mostly 2-6) of about 45-200 eggs (average 120) at intervals of about 2 weeks. Nesting typically occurs every 2-3 years. Nesting occurs mainly at night and often at high tide. In the U.S., loggerheads nest in late April to early September with the peak occurring in June. Eggs hatch in about 7 to 11 weeks (generally 8-9 weeks in the southeastern U.S.). Sex of hatchlings is affected by incubation temperature, with warmer temperatures resulting in a preponderance of females and cooler temperatures producing mainly or only males. Hatchlings emerge from their nests a few days after hatching, typically during darkness. The sex ratio of hatchlings and immatures in Atlantic coastal waters of U.S. is strongly biased toward females. Females are sexually mature at an average age of about 15-30 years in the southeastern U.S. Females are reproductively active over a period of about 30 years (CSTC 1990). Nesting density can reach nearly 450 nests/km in some areas of Florida. Of every thousand hatchlings, only a few are believed to survive to

adulthood; this is characteristic even of stable populations. (natureserve 7-13-2011)

8.9.1 Distribution and Abundance

Loggerheads are distributed circumglobally, inhabiting continental shelves, bays, estuaries, and lagoons in temperate, subtropical, and tropical waters. In the Atlantic, the loggerhead sea turtle's range extends from Newfoundland to as far south as Argentina. During the summer, nesting occurs in the lower latitudes. The primary Atlantic nesting sites are along the east coast of Florida, with additional sites in Georgia, and the Carolinas; some nesting also occurs on the Gulf Coast of Florida. In the eastern Pacific, loggerheads are reported as far north as Alaska, and as far south as Chile. Occasional sightings are also reported from the coast of Washington, but most records are of juveniles off the coast of California. Southern Japan is the only known breeding area in the north Pacific. Loggerheads probably range all along the Louisiana coast; however, Dundee and Rossman (1989) reported specimens only from Chandeleur Sound, Barataria Bay, and Cameron Parish. The loggerhead sea turtle has continued to decline in Louisiana; though loggerheads are capable of living in a variety of environments, such as in brackish waters of coastal lagoons and river mouths. (USFWS 1990). The population decline of loggerheads can be attributed to egg and nestling predation by mammals and birds (Dundee and Rossman 1989).

8.9.2 Movements and Migration

Nesting on the Gulf Coast occurs between the months of April and August, with 90 percent of the nesting effort occurring on the south-central Gulf Coast of Florida (Hildebrand 1981). Although loggerheads have been documented as nesting on the Chandeleurs in 1962 and Grand Isle in the 1930s, it is doubtful whether this species currently successfully nests on the Louisiana coast (Hildebrand 1981, Dundee and Rossman 1989).

The loggerhead migrates between nesting beaches and marine waters. At least some temperate zone nesters migrate to tropical waters after the nesting season. Females that nest on east coast of Florida migrate to the Gulf of Mexico and West Indies for non-nesting periods. Some individuals in the southeastern U.S. move north in spring and south as fall approaches others remain in Florida waters year-round. Hatchlings from the southeastern U.S. apparently enter drift lines and ride currents to Europe and the Azores and back. MtDNA data confirm that juveniles occurring in pelagic habitats of the eastern Atlantic (Azores, Madeira) are derived from nesting populations in the southeastern United States and adjacent Yucatan Peninsula in Mexico. MtDNA data indicate that stranded individuals along foraging habitat in the northeastern United States from Massachusetts to Virginia originated from three demographically independent nesting areas: northeast Florida/North Carolina, southern Florida, and Quintana Roo (Mexico). MtDNA data indicate that young occurring along the coast of Baja California derive from nesting areas in Japan and Australia; evidently trans-Pacific migrations occur, encompassing several years. (natureserve 7-13-2011).

8.9.3 Food Habits

The loggerhead's diet includes marine invertebrates such as mollusks, shrimp, crabs, sponges, jellyfish, squid, sea urchins, and basket stars. It has been suggested that these turtles may also feed on discarded by-catch from shrimp trawling. Adult loggerheads feed in waters less than 50 meters deep, while the primary foraging areas for juveniles appears to be in estuaries and bays. Horseshoe crabs are preferred prey in Chesapeake Bay. Spider crabs and rock crabs were important prey at Long Island, New York. Adults forage primarily on the bottom, but will also take jellyfish from surface. Young feed on prey (e.g., gastropods, fragments of crustaceans and sargassum) concentrated at the surface. (natureserve 7-13-2011)

8.9.4 Habitat Association

The habitat for loggerheads consists of three different zones throughout their lifetime: terrestrial zone, oceanic zone, and near shore or neritic zone (NOAA-5). The lifecycle of the loggerhead, from hatchling to adult, begins when hatchlings leave the ocean beach nesting site and migrate towards waters consisting of seaweed and sea grass cover. Adults occupy various habitats, from turbid bays to the clear waters of reefs. Subadults occur mainly in nearshore and estuarine waters. The juveniles head into the neritic zone during the ages of 7 to 12 and remain there maturing into adulthood (NOAA-5). Hatchlings move directly to sea after hatching, often float in masses of sea plants (Sargassum); may remain associated with sargassum rafts perhaps for 3-5 years. In Chesapeake Bay, occurs mainly in deeper channels, usually at river mouths or in the open bay (natureserve 7-13-2011). Coastal Areas not only provide an excellent food source for adults inhabiting the area, but they also allow for easy access to migratory routes (NOAA-5).

Nesting occurs usually on open sandy beaches above high-tide mark, seaward of well-developed dunes. Loggerheads primarily nest on high-energy beaches on barrier strands adjacent to continental land masses in warm temperate and subtropical regions. Steeply sloped beaches with gradually sloped offshore approaches are favored. Renesting generally occurs at the same beach or within a few km. Loggerheads generally return to the same area in subsequent years if habitat remains suitable. Individuals sometimes change to different nesting beach within a single nesting season; has changed to sites up to several hundred km away. Maximum hatching success and hatchling size occur when sand moisture level is about 25%. In Florida, nesting on urban beaches was strongly correlated with the presence of tall objects (trees, buildings), which apparently shield the beach from city lights. (natureserve 7-13-2011)

8.9.5 Status and Cause of Decline

The Loggerhead sea turtle was listed as endangered throughout its range on July 28, 1978. Commercial harvest, habitat degradation, coastal development, disease, and predation have all contributed to the decline of the species. Egg mortality may result from predation, beach erosion, invasion of clutches by plant roots, crushing by off-road vehicles, or flooding by sea water overwash or excessive rainfall. Among a wide array of animals that eat loggerhead eggs, raccoons are the most important predators on eggs in the southeastern U.S.; on some beaches they have been responsible for more than 90% of nest mortality (natureserve 7-13-2011). Cold stunning in estuaries (e.g., Long Island Sound) sometimes can result in significant

mortality.

The loggerhead is the most abundant species of sea turtle occurring in U.S. waters. The nearshore waters of the Gulf of Mexico are believed to provide important developmental habitat for juvenile loggerheads. Studies conducted on loggerheads stranded on the lower Texas coast (south of Matagorda Island) have indicated that stranded individuals were feeding in nearshore waters shortly before their death (Plotkin *et al.*, 1993).

In the Southeast United States, major nest protection efforts and beach habitat protection are underway for most of the significant nesting areas, and significant progress has been made in reducing mortality from commercial fisheries in U.S. waters with the enforcement of TED regulations. Many coastal counties and communities in Florida, Georgia, and South Carolina have developed lighting ordinances to reduce hatchling disorientations. Important U.S. nesting beaches have been and continue to be acquired for long-term protection. The migratory nature of loggerheads severely compromises these efforts once they move outside U.S. waters, however, since legal and illegal fisheries activities in some countries are causing high mortality on loggerhead sea turtle nesting populations of the western north Atlantic region. Due to the long range migratory movements of sea turtles between nesting beaches and foraging areas, long-term international cooperation is absolutely essential for recovery and stability of nesting populations (USFWS North Florida Fact Sheet).

9.0 ANTICIPATE EFFECTS OF THE PROPOSED ACTION

9.1 Gulf Sturgeon (*Acipenser oxyrinchus desotoi*)

The USFWS and NMFS designated Critical Habitat for the Gulf sturgeon on April 18, 2003 (68 FR 13370). Critical Habitat determinations focus on those physical and biological features (Primary Constituent Elements (PCE)) that are essential to the conservation of the species (50 CFR 424.12) The PCEs are those habitat components that support feeding, resting, sheltering, reproduction, migration, and physical features necessary for maintaining the natural processes that support those habitat components. The following are the PCEs identified as essential for the conservation of the Gulf sturgeon and CEMVN's analysis on how the MRGO, ecosystem restoration project, in conjunction with all past, present, and reasonably foreseeable projects within the study area would affect these elements.

1. Abundant food items, such as detritus, aquatic insects, worms, and/or mollusks, within riverine habitats for larval and juvenile life stages; and abundant prey items, suc as amphipods, lancelets, polychaetes, gastropods, ghost shrimp, isopods, mollusks and/or crustaceans, within estuarine and marine habitats and substrates for subadult and adult life stages.

The proposed action would have no impact on prey species within riverine Critical Habitat Unit 1. Impacts to the prey items within Critical habitat Unit 8 would result from the implementation of the TSP during the construction of shoreline protection features, borrow material removal, flotation access channel construction, and stock piling of flotation access

material within Lake Borgne. The proposed action could result in a permanent change to the bathymetry of approximately 15,439 acres of Lake Borgne following the removal of borrow material. Approximately 150.7 mcy of material would be needed to construct the proposed action. The proposed borrow areas include approximately 301 mcy of material. This 2 to 1 designation ensures that an adequate amount of material is available given the uncertainties that still exist within the borrow areas. Since engineering and cultural surveys of the borrow areas have not been completed, avoidance areas within the borrow areas have not been designated. Though it is not anticipated that the proposed action would impact all of the designated area of lake bottom, until the necessary surveys are completed the borrow areas size is assumed at 15,439 acres. Gulf sturgeon are opportunistic feeders which prey on benthic organisms within an estuarine environment. The removal of borrow material will result in a temporary loss of benthic prey items within the project area. To determine the level of impacts to Gulf sturgeon prey items the existing benthic habitats of Lake Borgne were characterized.

In 2009, MVN tasked ERDC to characterize the benthic habitats within Lake Borgne. A copy of Dr. Gary Ray's report is attached in **Appendix B** of this BA. His analysis found that the physical environment within the southern lobes of Lake Borgne was remarkable uniform. Sediments in the borrow areas were poorly sorted sandy mud with a mean grain size in the range of very coarse silts. Total silts and clays (mud) accounted for more than 64% of the sediment with the remainder dominated by very fine sand (~30%). Sediments in the proposed access channel sites differed somewhat with the innermost (shoreward) stations dominated by organic peat and the outermost resembling those of the "borrow areas" (the term "borrow areas" refers to the borrow areas designated in the MRGO, Louisiana, and Lake Borgne Wetland Creation and Shoreline Protection Project; June 2009). Sediment organic content averaged less than 4% at all stations except those where peat was found and these had values as high as 43%. These high organic content levels were encountered in near shore sampling sites were peat was prevalent.

The benthic assemblage of the study area, as determined by Dr. Gary Ray, was dominated by polychaetes (62%), bivalves (14%) and amphipods (11%). The most abundant species, that polychaete *Mediomastus ambiseta* accounted for more than 28% of all animals collected. Other important polychaete species included *Parandalia Americana, Streblospio benedicti, Sigambra bassi, Glycinde solitaria, Nereis succinea, Pectinaria gouldii,* and *Capitella* sp. The most abundant bivalve mollusks were *Macoma mitchelli, Mulinia lateralis,* and *Mulinia pontchartrainesis.* The amphipods were dominated by *Ampelisca abdita, Ameroculodes* sp. *A,* and *Cerapus benthophilus.* Other numerically abundant species included the gastropod *Acetocina canaliculata,* two unidentified species of nemerteans, and the oligochaete *Tubificoides* sp. Together these eighteen species comprised nearly 94% of all fauna encountered. Nonmetric Dimensional Scaling (NMDS) performed by ERDC indicated that a high degree of similarity existed among the sampled sites. The highest degree of difference between stations existed when comparing North to South (further from shore) sites. This is to be expected given the high amount of peat found in the nearshore sites.

The benthic assemblage identified could reveal why few Gulf sturgeon have been found inhabiting Lake Borgne and instead are tracked traveling to the Mississippi Sound during the winter (i.e. Rogillio et al., 2007). Gulf sturgeon have been found to feed primarily on species

such as brachiopods, lancelets, haustorid amphipods and the callianassid *L. louisianensis*, all species associated with sandy, polyhaline habitats. This habitat is absent from Lake Borgne. Mason and Clugston (1993) however, report prey to include brackish water amphipods such as *Cerapus* sp. And *Corophium tuberculatum*, chironomid and ceratopogonid fly larvae, mysid shrimp, polychaetes and tubificid oliochaetes. These species are most closely associated with muddy, mesohaline habitats similar to the Lake Borgne borrow areas and therefore it is possible that foraging Gulf sturgeon within Lake Borgne could be disrupted. Fortunately, this habitat is also the single most common type present in the immediate area and large areas of Mississippi Sound (Ray, 2007).

The composition of the benthic community within an area can be directly correlated to the sediment composition. Most of the lake bottoms along the coast are characterized by organic clays and peat over clay and silty clay. The thickness of the organic layers is highly variable but generally less than 10 feet (Louis D. Britsch, personal communication; May et al. 1984). To date boring surveys have not yet been completed for the proposed borrow pits. However, boring data obtained for the MRGO, Louisiana, and Lake Borgne Wetland Creation and Shoreline Protection Project; June 2009, identified in **Figures 54-57**, overlaps with portions of the proposed borrow areas. This boring data indicates that the sediment stratification within Lake Borgne is fairly uniform. Fat clay interspersed with small bands of lean clay, silty sand and pear are the predominant sediments occurring in the project area. Given the history of the alluvial deposits of the St. Bernard Delta, as discussed in May et al, 1984, it is believed that the sediment composition within the borrow pits would be consistent with this data. However once borings are completed for the borrow pits, if sediment composition does not conform to the before mentioned assumption of uniformity, then consultation with the resource agencies would be re-initiated to document impacts to sediment composition and the benthic assemblage.

Though a change to the sediment composition of Lake Borgne is not expected to occur, the removal of borrow material would result in the direct, indirect, temporary, and irretrievable[1] impacts to the benthic communities within Lake Borgne. The proposed action would use a cutterhead dredge to remove borrow material from the designated borrow areas (**Figures 49**). Material would be removed from the lake gradually over 10 implementation cycles. Table 3 on page 49 describes the impacts to Critical Habitat Unit 8 within Lake Borgne from the removal of borrow material. As the implementation plan reflects, impacts to the benthic communities in Lake Borgne have been minimized through the adherence to spacial restrictions on dredging operations within the lake. Dredging would be restricted to one lobe of Lake Borgne per cycle. By alternating dredging operations between the lobes of Lake Borgne, benthic communities impacted through direct disturbance (sediment removal) and indirect disturbance (turbidity) are allowed to recover and recolonize newly exposed sediments. Direct impacts to benthic organisms from the borrow pit footprint would result during the removal of borrow material. Given the anticipated sediment composition of the newly exposed sediments, these impacts would be temporary in nature. Since benthic recovery is not immediate, an irretrievable, but temporary, loss of foraging habitat during the recovery period is anticipated. Estimates of

[1] Irretrievable commitments are those that are lost for aperiod of time. In this case irretrievable loss lasts for the period of benthic recovery.

benthic recovery rates can range from several months to several years (Wilber and Clarke, 2007). Several environmental conditions which influence benthic recovery rates include sediment type, depth of overburden, and frequency and timing (Wilber and Clarke, 2007). Newell et al. (1998) characterized typical recovery times at 6-8 months for mud habitats and 2-3 years for sand and gravel substrata. A general benthic successional paradigm states that following initial decreases to benthic diversity, abundance, and biomass that immediately follow a disturbance, pioneering (Stage I) organisms, such as small, tube-dwelling polychaetes and small bivalves colonize the surficial sediments. These opportunistic taxa occur in relatively high abundnances and low diversity and over time are replaced by larger, longer-lived and deeper-burrowing (Stage II) species. The Stage III assemblage is comprised of a more diverse, but less abundant group of larger taxa such as maldanid polchaetes. Thus, the absence of deposit feeders and mid-depth burrowers is indicative of areas that are in a state of recovery. Reviews of dredging impacts on seagrass and unvegetated benthic habitats indicate that site specific factors influence impacts, thus limiting the extrapolation of results across geographical regions (Wilber and Clarke, 2007). Recovery of infaunal abundance, diversity and community composition in New Jersey occurred in one year, whereas the return of biomass to reference conditions took 1.5 to 2.5 years. In Florida, relatively rapid recovery (~1 year) was reported for borrow areas when measured in terms of total abundance and taxonomic diversity, however, recovery times of up to three years were needed to restore functional groups, such as deposit feeders and mid-depth burrowers (Wilber and Clarke, 2007). Based on characteristics of the existing benthic community it seems likely that Lake Borgne sites would recover in one to two years (Ray, 2007). Assuming that sufficient recovery of the benthic community has occurred within one year; the temporary and irretrievable loss of no more than 4,065 acres of critical habitat would result during the implementation of the proposed action. Critical habitat Unit 8 designated approximately 881,280 acres of estuarine habitat. Approximately 162,505 acres of this habitat is located within Lake Borgne. A maximum impact of 4,065 acres to benthic prey species per cycle would remove approximately 2.5 percent of the available foraging habitat located within Lake Borgne, or .5 percent of the available foraging habitat located in Critical Habitat Unit 8. As a new implementation cycle is being initiated the borrow areas disturbed in the previous cycle for that lobe would have recovered sufficiently to support foraging. Since Gulf sturgeon only occupy wintering habitat for half of the year, monitoring indicates they prefer to forage within the Mississippi Sound, and benthic impacts would be temporary in nature, MVN concludes the temporary loss of prey availability during the period of recovery is not likely to adversely affect the Gulf sturgeon or its critical habitat.

The major caveat to the temporary nature of benthic impacts and the estimate of benthic recovery is that current data suggests that low dissolved oxygen (DO) concentrations would not prevail and that bathymetric changes to Lake Borgne would not result in reduced current flow in the borrow areas. A discussion of water quality impacts to critical habitat can be found on page 110 of this section under the discussion of Critical Habitat PCE number 5.

Additional impacts to prey items within critical habitat unit 8 would result from the placement of stone associated with the 5 shoreline protection features. The TSP includes approximately 222,150 linear feet (382 acres) of shoreline protection measures that would permanently remove water bottoms from critical habitat, eliminating the benthic community and

use of this area as foraging habitat by Gulf sturgeon. However, the construction of the shoreline features would occur in waters typically less than 2 meters deep, which are not regularly frequented by Gulf sturgeon. Fox et al., (AFS Symposium 28:111-126, 2002) found in their investigations of the estuarine and nearshore marine habitats used by Gulf sturgeon in the Choctawhatchee Bay and nearshore Gulf of Mexico, that Gulf sturgeon were typically found in water depths of 2 – 4 meters over substrates high in sand (>80%). The depths along the majority of foreshore protection alignment in Lake Borgne are shallower than 1 meter in depth. Also, investigations of the Pearl River drainage sub-population of Gulf sturgeon has found that most Gulf sturgeon do not over winter within Lake Borgne and instead overwinter in the vicinity of the barrier islands of the Mississippi Sound (Rogillio et. al, 2001; Rogillio et. al, 2007).

Temporary impacts associated with the placement of the shoreline protection features would include the dredging of floatation access channels parallel to the shoreline protection features and access dredging from the lake into the floatation channels for shoreline protection feature construction, see **Figures 12 and 45**. Flotation/access channel material would be used in dike/closure construction or refurbishment, to backfill flotation/access channels, or would be placed adjacent to and behind the dikes and closures in shallow water to a maximum initial elevation conducive to wetlands development following consolidation of the material. Dredged material used to backfill the flotation/access channels would be temporarily stockpiled on the water bottoms adjacent to the flotation/access channels. Floatation channel excavation would temporarily disturb 603 acres of critical habitat, access channel excavation from the lake in to the floatation channels would temporarily disturb 45 acres of critical habitat and floatation/access channel dredged material stockpile would temporarily disturb 607 acres of critical habitat.

CEMVN's analysis indicates that the proposed action would have temporary and permanent impacts to the Gulf sturgeon and its critical habitat PCE number 1 within the project area. Existing sediment data for Lake Borgne indicates that the proposed removal of borrow material would not change the benthic community composition. Impacts to the prey species of Gulf sturgeon have been minimized in the following ways: A phased implementation plan would allow no more than 2.5 percent of lake bottom to be impacted during any given implementation cycle. Alteration of dredging between the lobes of the lake would allow benthic species to recover between implementation cycles. Hard bottom habitats within Lake Borgne would be avoided. Given the aforementioned minimization components in conjunction with the known foraging habits of Gulf sturgeon, the proposed action would not appreciably reduce the abundance of estuarine prey for juvenile and adult Gulf sturgeon. Therefore CEMVN has determined that implementation of the proposed action may affect, but is not likely to adversely affect the Gulf sturgeon. CEMVN has also determined that the proposed action would not adversely modify Critical Habitat Unit 8 PCE 1.

2) Riverine spawning sites with substrates suitable for egg deposition and development, such as limestone outcrops and cut limestone banks, bedrock, large gravel or cobble beds, marl, soapstone, or hard clay.

The proposed action has no components within a riverine system.

3) Riverine aggregation areas, also referred to as resting, holding and staging areas, used by adult, sub-adult, and/or juveniles, generally, but not always, located in holes below normal riverbend depths, believed necessary for minimizing energy expenditures during freshwater residency and possibly for osmoregulatory functions.

The proposed action has no components within a riverine system.

4) A flow regime (i.e., the magnitude, frequency, duration, seasonality, and rate-of-change of freshwater discharge over time) necessary for normal behavior, growth, and survival of all life stages in the riverine environment, including migration, breeding site selection, courtship, egg fertilization, resting, and staging; and necessary for maintaining spawning sites in suitable condition for egg attachment, egg sheltering, resting, and larvae staging.

The proposed action has no components within a riverine system.

5) Water quality, including temperature, salinity, pH, hardness, turbidity, oxygen content, and other chemical characteristics, necessary for normal behavior, growth, and viability of all life stages.

Water quality of the Gulf sturgeon's Critical Habitat within the Lake Pontchartrain Basin has entered a transitional phase. The completion of the MRGO closure in July 2009 has already begun to reduce salinity intrusion within Lake Pontchartrain and the surrounding marshes. Before the deauthorization and closure of the MRGO channel, saltwater intrusion through the MRGO navigation channel had been linked to degraded water quality and habitat conditions in the south eastern portion of Lake Pontchartain. Ray (2009) described how a portion of Lake Pontchartrain has been shown to experience repeated episodes of low oxygen concentrations as a result of the intrusion of salt water from the MRGO via the IHNC (Poirrier 1978, Junot et al. 1983, Pedalino 1999). Li et al. (2008) developed a model of the phenomenon and demonstrated that under northerly winds a wedge of saltwater entered the lake from the IHNC and spread through the deeper portions of the lake. Hypoxic or anoxic conditions can develop as the denser salt wedge becomes stagnant. Poirrier (1978) documented salinity stratification beginning in late spring and progressing through the summer months particularly in the deeper southern portion of the lake near the IHNC. Stratification was broken up as lake waters became mixed over winter months. Both Junot et al. (1983) and Pedalino (1999) have detected decreased abundance and diversity of benthos during such hypoxic and anoxic conditions.

Conversely, Lake Borgne has been shown to consistently have good water quality conditions. Lake Borgne is a well mixed estuary with a large hydrological connection to the Mississippi Sound. The tidal ingress and egress of water into the lake was modeled as part of the deepwater horizon oil spill response. Modeling indicated that good circulation and flushing of Lake Borgne occurs (**Figure 58**) (Dr. John McCorquodale, Personal Communication). Also, 3 years of monitoring within the Southwestern end of Lake Borgne showed that DO levels fluctuated between 4.47 mg/L and 13.57 mg/L.

The proposed action would remove approximately 150.7 mcy of dredged material from the bottom of Lake Borgne for the project's marsh creation components. The removal of the dredged material would permanently change the bathymetry of Lake Borgne. **Figure 59** shows the current bathymetry of Lake Borgne. Removal of borrow material would result in elevated levels of turbidity and the re-suspension of pollutants or other trapped sediments. A majority of the borrow locations would be in areas with bottom sediments composed of silt and clay soils. These types of soils are finer in size and require a longer time period to settle out of the water column after disturbance. Therefore, the duration and potential impact of turbidity from suspended sediments during construction of the restoration measures to water quality could be longer than if sediments with a greater sand component were utilized. The use of larger sandy sediments from project area was eliminated from consideration as a possible alternative since sandy substrates support the preferred benthic prey communities of the Gulf sturgeon. A hard bottom survey identified these prime foraging areas within Lake Borgne so that they could be avoided (**Figure 48**).

The enhanced suspension of fine-grained sediments from dredging can affect the water quality of the estuarine environment in several ways. Resuspension of organically rich sediments can cause increased biological oxygen demand and result in a sag in dissolved oxygen concentration. Also, turbidity reduces light penetration into the euphotic zone causing a reduced rate of photosynthetic production of oxygen (Schubel 1977). Though suspended sediment would be greatly increased during dredging operations; increases in suspended sediment would be restricted spatially and would not persist once dredging operations have ceased. Acute effects on estuarine organisms occur at high suspended sediment concentrations (>500 mg/l) (Schubel 1977). The oligohaline estuarine zone is composed of opportunistic species that respond rapidly to dynamic abiotic factors such as salinity, TSS (total suspended solids), and dissolved oxygen.

The implementation schedule has been developed so that the removal of material would be staggered over the course of ten years. Impacts to Lake Borgne sediments would be no more than 4,065 acres of the total area of Lake Borgne (162,505 acres) per year (approximately 2.5 percent of the total Lake area). This ensures that increased turbidity would only disturb a small portion of the lake during any given cycle. The borrow plan also limits dredging to one lobe of Lake Borgne per implementation cycle, therefore isolating the increased turbidity to one lobe of the lake. Lake Borgne is impacted by storm events, tidal events, and the operation of the Bonnet Carré spillway, all of which result in temporary events of increased turbidity in the area. The resident fauna populations are adapted to this dynamic environment and can rapidly recover by recruitment from adjacent coastal waters. The anticipated increase in turbidity from the dredging operations, would not increase turbidity levels as high as a have been seen during the operation of the Bonnet Carré Spillway. Turbidity increases from dredging would mimic the high turbidity events common to Lake Borgne.

Although turbidity impacts would be localized and temporary, concern over borrow pit water quality impacts is justified. A wealth of evidence suggests that improperly planned dredge pits can result in hypoxic/anoxic conditions. The development of these conditions has been linked to the inability of the water to be properly mixed and flushed within the pits, resulting in stagnation and stratification. Water quality impacts from borrow pits varies greatly due to

geographical location, pit design, and environmental parameters. In an effort to better understand what the likely changes to the water quality of Lake Borgne would be from the deepening of approximately 15,439 acres of critical habitat; MVN conducted a literature review and compiled data from local water quality monitoring from deep holes which occur within the project area. MVN believes that the development of hypoxic conditions within Lake Borgne would be contrary to the goals of an ecosystem restoration project such as this.

Hypoxic and anoxic conditions have been linked to the tendency for a borrow pit to accumulate organic material. This accumulation can be reduced by: 1) limiting the depth of the pit; 2) increasing the pits surface area; and 3) decreasing side-slopes that transition from the pit to adjacent water bottoms. A shallow and broad "pan-shaped" borrow pit would facilitate circulation with adjacent waters, thereby decreasing the likelihood that organic material would become entrained, as well as allow for periodic flushing of the pit during storm events. In contrast, narrow and deep pits would be less influenced by circulation in the overlying water column and would require greater energy for flushing of organic material. Shallower pits would require less energy to mix the water column and would facilitate the mixing with adjacent waters (FEIS for MRGO and Lake Borgne Wetland Creation and Shoreline Protection, USACE 2009).

The proposed borrow plan has been developed with an emphasis of mimicking a natural depression in the lake bottom. A gradual side slope of 1V:3H has been designed for the borrow pits. This gradual slope would facilitate tidal flushing. Borrow pits also have been consolidated together to increase their surface area which will facilitate tidal mixing of the water column. The depth of the dredge pits would be 10 to 12 feet below the existing mud line of Lake Borgne. Lake Borgne is currently 8 to 9 feet deep in the vicinity of the proposed borrow pits. The removal of borrow material could deepen approximately 15,439 acres of Lake Borgne to 18 to 21 feet deep; approximately 5 percent of the lakes total area (Lake Borgne is 162,505 acres). The proposed borrow depth was developed through an analysis of the existing water quality data which exists within the project area.

In 2007, the United States Geological Survey (USGS) was contracted to conduct water quality sampling within and in the vicinity of the now deauthorized MRGO navigation channel. To date, three years of sampling data have been collected within and around the deauthorized MRGO navigation channel. From 2008 to 2010, nine locations had monthly water quality monitoring of salinity, dissolved oxygen, and pH. The data from this monitoring has been included in **Appendix C**. Current trends in the data suggest that hypoxia does not form until approximately 25feet in depth for this area. A snapshot of the summer salinity and dissolved oxygen profiles for the site closest to Lake Borgne can be found in **Figure 60**. These samples were taken within the MRGO navigation channel directly adjacent to the southern lobe of Lake Borgne. Though the MRGO channel does experience hypoxia formation below the 25 foot depth; the USGS data indicates sufficient mixing does occur above this depth. Since Lake Borgne is more readily mixed than the MRGO channel, MVN believes that the proposed pit design, combined with the hydrological nature of Lake Borgne would ensure that sufficient mixing of the water column would result to prevent hypoxia formation within the borrow pits. To ensure that water quality is not sacrificed within Lake Borgne, MVN has included two years of water quality monitoring into the proposed action. Three test borrow pits would be

constructed in implementation cycle number 1. The first pit would be constructed to 15' deep below the water surface, the second pit would be constructed to the proposed depth of 20' deep below the water surface, and a third pit would be constructed to approximately 25' deep below the water surface. After the borrow pits are constructed, monthly water quality monitoring would be used to determine if hypoxia formation was occurring within the borrow pits. Once the two years of monitoring is complete, the remaining borrow pits would be adjusted to ensure that hypoxia formation would not result within the remaining borrow pits. The MVN would continue to coordinate with NMFS throughout the monitoring process to adjust the plans for the remaining borrow pits if needed. The MVN believes that the design of the borrow pits, coupled with the proposed water quality monitoring and agency coordination, would ensure that the proposed action would only temporarily impact the water quality of Lake Borgne. The water quality necessary for normal behavior, growth, and viability of all life stages of Gulf sturgeon would be maintained within the project area. Therefore, the MVN concludes that the proposed removal of borrow material from Lake Borgne may affect, but is not likely to adversely affect the Gulf sturgeon or adversely modify its Critical Habitat.

6) Sediment quality, including texture and other chemical characteristics, necessary for normal behavior, growth, and viability of all life stages.

The discussion for impacts to the Gulf sturgeons PCE number 1 includes a discussion for impacts to the sediment composition of Lake Borgne.

7) Safe and unobstructed migratory pathways necessary for passage within and between riverine, estuarine, and marine habitats (e.g., a river unobstructed by a permanent structure, or a dammed river that still allows for passage).

Recent investigations of the Pearl River drainage sub-population of Gulf sturgeon has found that most Gulf sturgeon do not over winter within Lake Borgne and instead overwinter in the vicinity of the barrier islands of the Mississippi Sound (Rogillio et. al, 2001; Rogillio et. al, 2007). The proposed action would have no impact on the migratory pathway between the Pearl River Drainage and the Mississippi Sound. However, it is anticipated that temporary impacts to access to portions of Lake Borgne would result from the implementation of the proposed action.

Impacts to Gulf sturgeon access would result from borrow material removal, flotation access channel construction, and the stock piling of flotation access material within Lake Borgne. Though the TSP includes approximately 222,150 linear feet (382 acres) of shoreline protection measures that would permanently remove water bottoms from critical habitat, the construction of the shoreline features would occur in waters typically less than 2 meters deep, which are not regularly frequented by Gulf sturgeon. Since the depths along the majority of the foreshore protection alignment in Lake Borgne are shallower than 1 meter in depth, Gulf sturgeon migratory pathways would not be impacted from the construction of shoreline protection features.

During dredging operations, noise, turbidity, and benthic organism recovery would limit Gulf sturgeon access to no more than 2.5 percent of Lake Borgne area. It is believed that the

increased turbidity and noise resulting from the operation of the cutterhead dredge would deter Gulf sturgeon from foraging within its vicinity. Hard bottom surveys completed for Lake Borgne have identified prime areas for Gulf sturgeon foraging. Temporary impacts from the implementation of the borrow plan would include reduced access to some of these foraging areas during borrow excavation. Once dredging operations have ceased, wintering Gulf sturgeon would again be able to access these hard bottom areas. However, if hypoxic conditions were to develop within the proposed borrow pits; foraging access to these areas would be permanently impacted. Since, MVN has designed the borrow pits to encourage flushing and reduce the likelihood of hypoxia formation, and has included an extensive monitoring effort to document hypoxia formation within the borrow pits, access impacts to Gulf sturgeon hard bottom foraging sites within Lake Borgne would be temporary in nature. Abundant foraging habitat exists within the project area, approximately 162,505 acres within Lake Borgne, for displaced Gulf sturgeon to utilize. Given the aforementioned borrow pit design coupled with water quality monitoring; the MVN believes that implementation of the MRGO ecosystem restoration and shoreline protection project may affect the Gulf sturgeon and would not adversely modify its critical habitat.

9.2 Pallid Sturgeon (*Scaphirynchus albus*) and Shovelnose Sturgeon (*Scaphirynchus platorynchus*)

The proposed freshwater diversion at Violet has been deferred for further study. Since Freshwater diversions have been documented to entrain pallid sturgeon within the lower Mississippi River. However, additional study is needed to get the proposed diversion to a feasibility level of design. Therefore, an effects determination for pallid and shovelnose sturgeon cannot be made at this time. To properly document the risk of entrainment, the impact analysis would need to include a calculation of the anticipated flow field data as was requested by the Lafayette office of the USFWS on August 27, 2010. Once the feasibility level of design for the proposed diversion has been completed, a risk assessment for pallid and shovelnose sturgeon entrainment will be completed. Consultation with the USFWS will be initiated at that time.

9.3 West Indian Manatee (*Trichechus manatus*)

West Indian manatees are rare along the coast of Louisiana. Sightings of the West Indian manatee in Louisiana have primarily occurred in Lakes Pontchartrain and Maurepas and associated coastal waters and streams (i.e., Amite, Blind, Tchefuncte, and Tickfaw Rivers), within the Mississippi River, and a few rare sightings along the Gulf coast during the summer months (i.e., June through September). However, there is no known resident population in the State. To avoid potential impacts to manatees during construction and restoration activities the following standard protective measures have been incorporated into the proposed action.

- All contract personnel associated with the project should be informed of the potential presence of manatees and the need to avoid collisions with manatees, which are protected under the Marine Mammal Protection Act of 1972 and the Endangered Species Act of 1973.
- All construction personnel are responsible for observing water-related activities for the presence of manatee(s).

- Temporary signs should be posted prior to and during all construction/dredging activities to remind personnel to be observant for manatees during active construction/dredging operations or within vessel movement zones (i.e., work area), and at least one sign should be placed where it is visible to the vessel operator.
- Siltation barriers, if used, should be made of material in which manatees could not become entangled, and should be properly secured and monitored.
- If a manatee is sighted within 100 yards of the active work zone, special operating conditions should be implemented, including: no operation of moving equipment within 50 feet of a manatee; all vessels shall operate at no wake/idle speeds within 100 yards of the work area; and siltation barriers, if used, should be re-secured and monitored. Once the manatee has left the 100-yard buffer zone around the work area on its own accord, special operating conditions are no longer necessary, but careful observations would be resumed.
- Any manatee sighting should be immediately reported to the U.S. Fish and Wildlife Service (337/291-3100) and the Louisiana Department of Wildlife and Fisheries, Natural Heritage Program (225/765-2821).

Also, to prevent entrapment of manatees within dredged material receiving areas that have dikes or other retention features that enclose an area of open water; the area would be inspected for the presence of manatee: 1) before complete closure of the confining features, and 2) again before material is discharged in to the receiving area. Any manatee that is sighted would be allowed to leave the area before work resumes.

Adherence to the before mentioned protection measures will help ensure that any manatee that wanders into the project area would not be adversely affected by the proposed action. Disturbance to manatees would only be temporary during project construction, and would result in temporary displacement. The manatees would be allowed to move to other areas suitable for foraging or resting purposes. The implementation schedule has been developed so that only small portions of Lake Borgne and the Biloxi marshes are disturbed during any given implementation cycle. Therefore, suitable habitat is available for the animals to relocate to. Since Louisiana has no resident population of West Indian manatee and the before mentioned protection measures would be adhered to, CEMVN concludes that the proposed MRGO ecosystem restoration project may affect, but is not likely to adversely affect the species.

9.4 Piping Plover (*Charadrius melodus*)

The Piping plover winters along the coast of Louisiana. They inhabit nonvegetated intertidal habitat found along headlands and barrier islands. This non-vegetated habitat utilized by the piping plover, would not be impacted by the proposed action. During construction activities if a piping plover was found to be utilizing an area that is being restored, the proposed restoration would displace that individual from the project area. Marsh restoration/nourishment projects help stabilize headland portions of the coastline. Ecosystem restoration projects such as this project help to reduce shoreline loss rates which indirectly helps stabilize piping plover wintering habitat. Since piping plover habitat does not exist within the project area, the MVN

concludes that the MRGO ecosystem restoration and shoreline protection project would have no effect on the piping plover species.

9.5 Green Sea Turtle (*Chelonia mydas*)

The use of a hydraulic cutterhead-type dredge has not been documented to regularly take sea turtles. Indirect impacts to the green sea turtle include the potential temporary removal of food sources by dredging operations, which may cause the green sea turtle to forage elsewhere in Lake Borgne until the area is re-colonized by prey species. The lack of extensive back barrier marsh and sea grass beds, and the low incidence of sightings in the proposed project areas, makes it unlikely that green sea turtles would be foraging in the project area. Therefore, after comparing the impacts of the proposed action to the habitat preferences of the green sea turtle, the MVN concludes that the MRGO ecosystem restoration and shoreline protection project is not likely to adversely affect the green sea turtle species.

9.6 Hawksbill Sea Turtle (*Eretmochelys imbricata*)

The likelihood of encountering a hawksbill sea turtle in waters of the United States is low. Hawksbill sea turtles typically nest on beaches in the Caribbean and Central America. Therefore, after comparing the impacts of the proposed action to the habitat preferences of the hawksbill sea turtle, the MVN concludes that the MRGO ecosystem restoration and shoreline protection project is not likely to adversely affect the hawksbill sea turtle species.

9.7 Kemp's Ridley Sea Turtle (*Lepidochelys kempii*)

Impacts to Kemp's Ridley sea turtle population would be similar to those detailed in the green sea turtle section. Indirect impacts to the green sea turtle include the potential temporary removal of food sources by dredging operations, which may cause the Kemp's Ridley sea turtle to forage elsewhere in Lake Borgne until the area is re-colonized by prey species. Coastal erosion and habitat loss is one limiting factor for the successful recovery of sea turtle populations in the Louisiana coastal zone. Marsh restoration/nourishment projects help stabilize headland portions of the coastline. Ecosystem restoration projects such as this project help to reduce shoreline loss rates which can indirectly help to stabilize sea turtle habitat. Therefore, after comparing the impacts of the proposed action to the habitat preferences of the Kemp's Ridley sea turtle, the MVN concludes that the MRGO ecosystem restoration and shoreline protection project is not likely to adversely affect the Kemp's Ridley sea turtle species.

9.8 Leatherback Sea Turtle (*Dermochylys coriacea*)

The likelihood of encountering a leatherback sea turtle in waters of the United States is low. Leatherback sea turtles typically are found in deep ocean waters and typically nest on beaches along Central America and Costa Rica. Therefore, after comparing the impacts of the proposed action to the habitat preferences of the leatherback sea turtle, the MVN concludes that the MRGO ecosystem restoration and shoreline protection project is not likely to adversely affect the leatherback sea turtle species.

9.9 Loggerhead Sea Turtle (*Caretta caretta*)

Impacts to the loggerhead sea turtle population would be similar to those detailed in the green sea turtle section. Habitat in Louisiana that is suitable for Loggerheads to nest on is typically associated with that of barrier islands. Coastal erosion and habitat loss are limiting factors for the successful recovery of sea turtle populations in the Louisiana coastal zone. Marsh restoration/nourishment projects help stabilize headland portions of the coastline. Ecosystem restoration projects such as this project help to reduce shoreline loss rates which can indirectly help to stabilize sea turtle habitat. Therefore, after comparing the impacts of the proposed action to the habitat preferences of the loggerhead sea turtle, the MVN concludes that the MRGO ecosystem restoration and shoreline protection project is not likely to adversely affect the loggerhead sea turtle species.

10.0 CONCLUSION

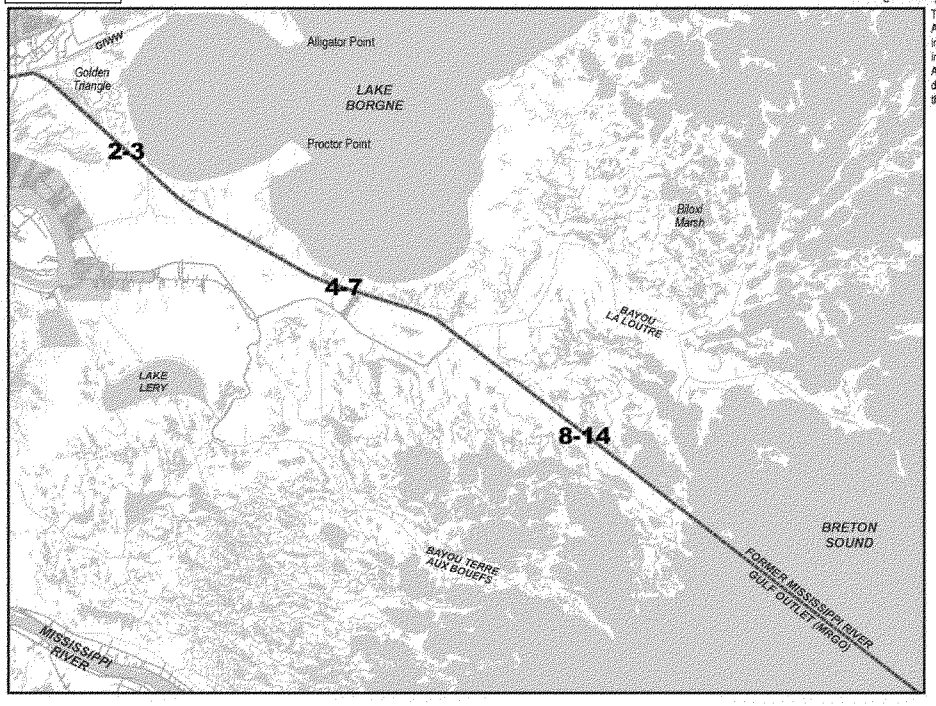
Based on currently available historical and catch data, a review of current literature and studies, and with the employment of avoidance measures recommended through guidelines set up during coordination with USFWS and NMFS, the CEMVN, believes that federally listed species of Gulf sturgeon, pallid sturgeon, shovelnose sturgeon, West Indian manatee, piping plover, and the five species of sea turtles including the green, Kemp's Ridley, loggerhead, hawksbill, and leatherback would not be adversely affected by the implementation of the proposed action. Based on the information provided in this document, the MVN requests concurrence with a not likely to adversely affect determination for the West Indian manatee, piping plover, and the green, Kemp's Ridley, leatherback, hawksbill, and loggerhead sea turtles. The MVN requests the initiation of formal consultation with the NMFS for impacts to the Gulf sturgeon and its Critical Habitat. Pallid and shovelnose sturgeon consultation is being deferred at this time. The USFWS and the NMFS would be notified immediately if any of the actions considered in this document are modified and require further consultation. If impacts to Gulf sturgeon and their critical habitat occur beyond what has been already considered, all operations would cease and the NMFS would be notified. Any modifications or conditions to the proposed action as a result of this concurrence would be implemented prior to commencement of activities.

FIGURES

Figure 1:

MISSISSIPPI RIVER GULF OUTLET (MRGO) ECOSYSTEM RESTORATION PLAN

Average Salinity 1959 to 1961 (in parts per thousand)



The US Fish and Wildlife Service and the Texas A&M Research Foundation measured salinity in three areas at nine sites (three sites per area) in the study area between 1959 and 1961. Average monthly salinities were averaged to determine the annual average salinity during this period.

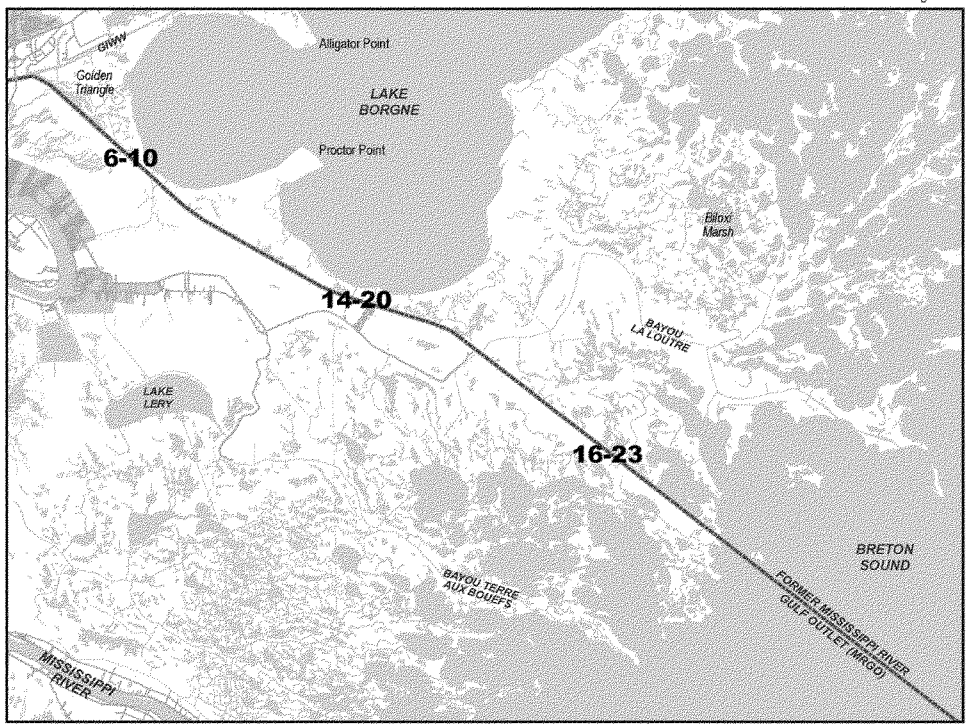
Source: El-Sayed, 1961.

SCALE 1:200,000
JULY 2010

Figure 2:

MISSISSIPPI RIVER GULF OUTLET (MRGO) ECOSYSTEM RESTORATION PLAN

Annual Average Salinity 1990 to 2008 (in parts per thousand)



This graphic shows average salinity in parts per thousand from data collected between 1990 and 2008. The ranges depicted in this map are outputs of the data collected from the UNO Mass Balance model. The UNO Mass Balance model is a mathematical tool that performs first-order approximations of mass transfer due to physical inputs like water level, flow, and salinity. This model was selected for use in this study because it has been demonstrated to accurately characterize salinity variability on monthly time scales in the Lake Pontchartrain/Lake Borgne regions (McCorquodale, et. al., 2008).

Source: University of New Orleans, 2010.

SCALE 1:200,000
JULY 2010

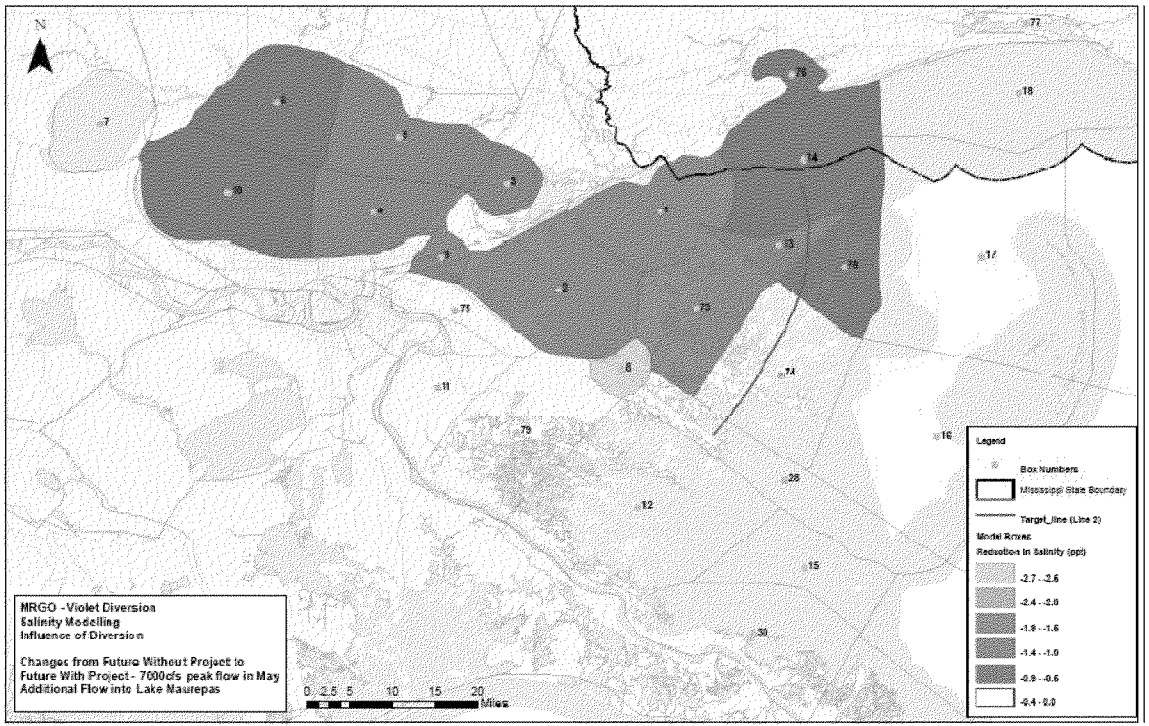
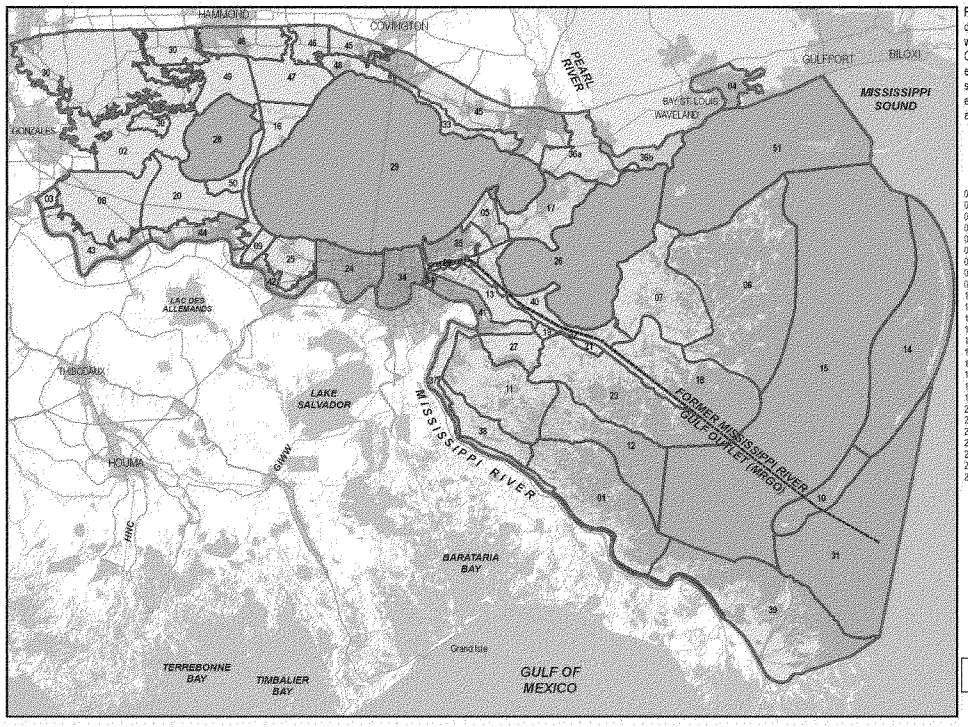


Figure 3: Area of influence of Violet diversion combined with proposed Convent/Blind River diversion structure

MISSISSIPPI RIVER GULF OUTLET (MRGO) ECOSYSTEM RESTORATION PLAN

Study Area Sub-Units



For planning purposes, the study area was divided into 52 subunits as depicted. Subunits were based on the subunits developed for the Coast 2050: Toward a Sustainable Louisiana effort. The larger study area was divided into subunits by grouping areas with similar ecosystem problems, restoration opportunities, and hydrologic conditions.

SUB-UNIT CODES

01	American Bay	27	Lake Lery
02	Amite River	28	Lake Maurepas
03	Ascension East	29	Lake Pontchartrain
04	Bay St. Louis	30	Livingston
05	Bayou Sauvage	31	MRGO Offshore
06	Biloxi Marshes Exterior	32	MRGO Spoil Bank
07	Biloxi Marshes Interior	33	Northshore Marshes
08	Blind River	34	Orleans Central
09	Bonnet Carré	35	Orleans East
10	Breton/Grand Gosier Is.	36a	Pearl River Mouth - LA
11	Caernarvon North	36b	Pearl River Mouth - MS
12	Caernarvon South	37	Plaquemines
13	Central Wetlands	38	River aux Chenes
14	Chandeleur Is.	39	River Delta
15	Chandeleur/Breton Sd.	40	South Lake Borgne
16	East Manchac LB.	41	St. Bernard
17	East Orleans LB.	42	St. Charles East
18	Eloi Bay	43	St. James East
19	Florissant	44	St. John TB East
20	Hope Canal	45	St. Tammany
21	Hopedale	46	Tangipahoa
22	IHNC/GIWW	47	Tangipahoa River Mouth
23	Jean Louis Robin	48	Tchefuncte River Mouth
24	Jefferson East	49	Tickfaw River Mouth
25	La Branche Wetlands	50	West Manchac LB.
26	Lake Borgne	51	Western Mississippi Sd.

Figure 4: Study Area Sub-Units

SCALE: 1:625,000
FEBRUARY 2010

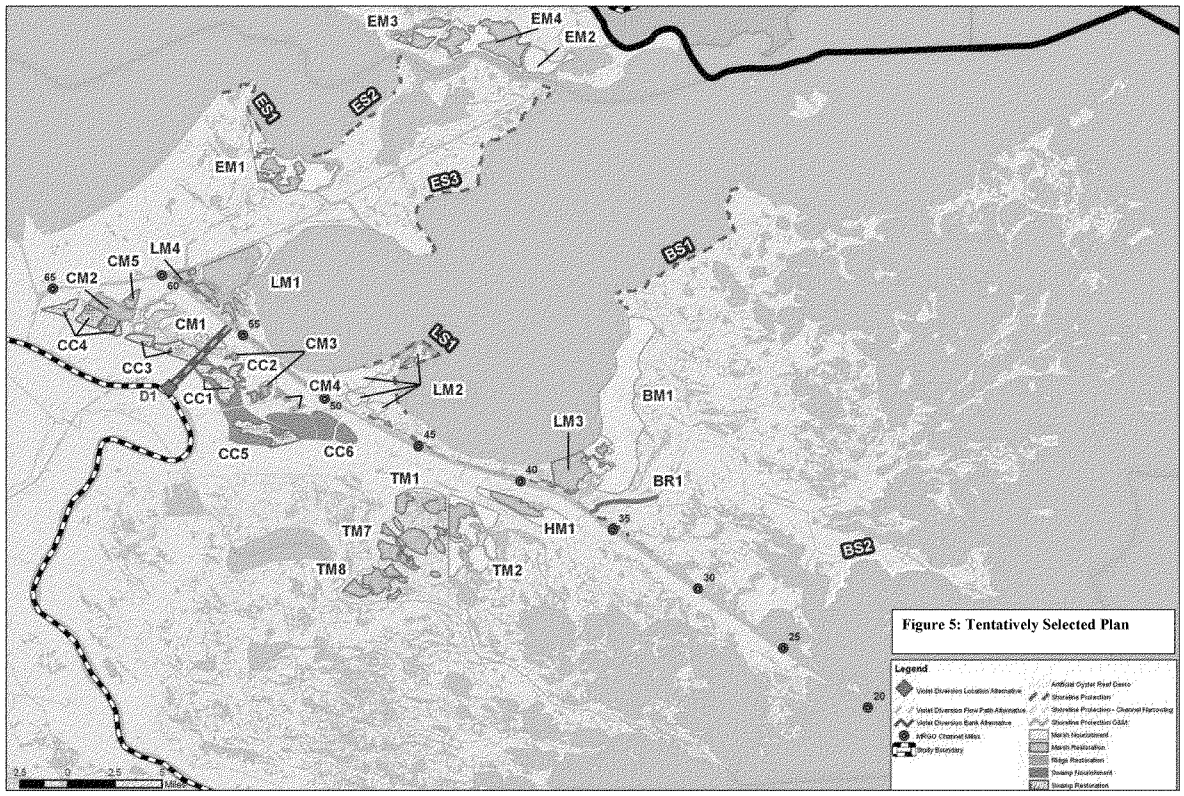
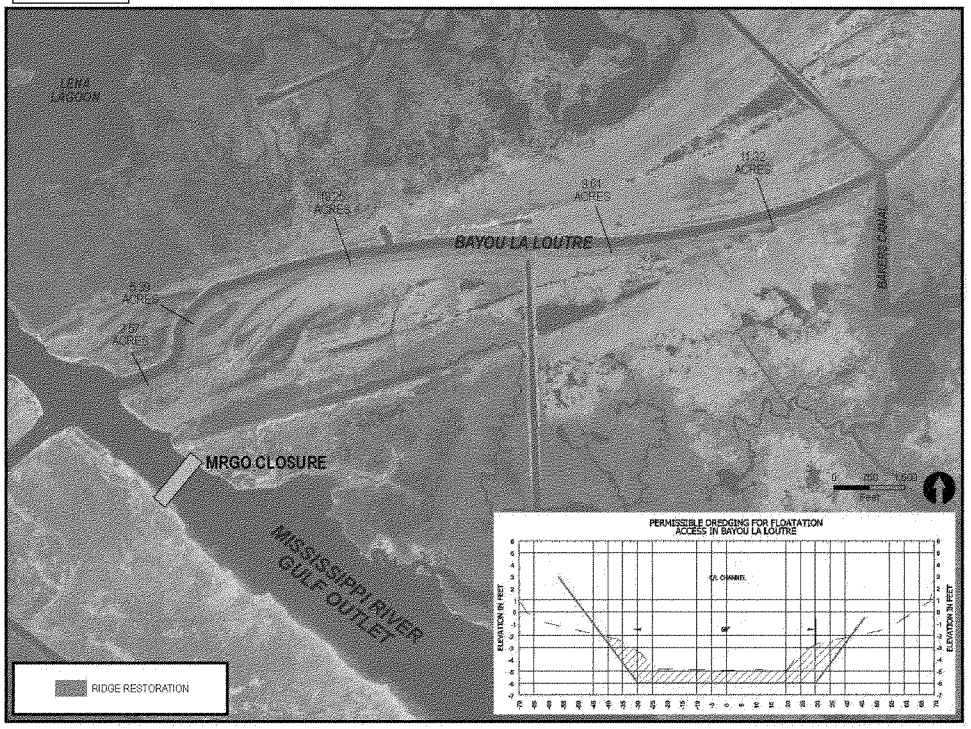
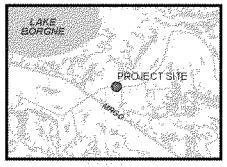

EM3
EM4
EM2
ES1
ES2
EM1
ES3
BS1
LM4
CM5
65
CM2
60
LM1
CM1
55
CC4
CM3
LS1
CC3
CC2
CM4
LM2
BM1
D1
CC1
50
LM3
45
CC5
CC6
TM1
40
BR1
TM7
HM1
35
BS2
TM8
TM2
30
25
20
Legend
Figure 5: Tentatively Selected Plan

Figure 6:

MISSISSIPPI RIVER GULF OUTLET (MRGO) ECOSYSTEM RESTORATION PLAN

Project Footprint Detail: BR1





Approximately 49 acres of ridge restoration.

Ridge features would be planted with woody vegetation.

Approximately 425,000 cubic yards of Mississippi River borrow material required.

PROJECT NOTES:

1. Ridge along southbank of Bayou La Loutre would be restored over a distance of approximately 17,500' beginning at the MRGO and proceeding downstream. The ridge would be built to an initial elevation of approx +6' NAVD88 (design elevation would be +6' NAVD88), with a crown width of 25' side slopes of 1v on 8h. While the base width of the ridge would vary, the average width would be approximately 120', assuming the natural ground elevation was +2'. A 50' access corridor along the backside would be made available for equipment necessary for hauling, moving, and shaping the ridge material.

2. Ridge would be constructed of silty sand with borrow material coming from the Mississippi River (between LMR 83R and LMR 85R). Borrow material would be hauled by barges to the IHNC, MRGO/GIWW, Chef Menteur Pass, Lake Borgne, Martello Channel and MRGO to Bayou La Loutre--an approximate one-way 52 mile transit. Approximately 425,000 cubic yards of silty sand would be required.

3. Access along Bayou La Loutre may require excavation. If excavation is required, the permissible excavation is defined by the theoretical section depicted to the left. Material excavated for floatation will be placed in the footprint of the proposed ridge restoration work. Access to Bayou La Loutre would be from Breton Sound, Lake Borgne, the MRGO or other navigable waterways; as well as state and local highways.

Figure 7:

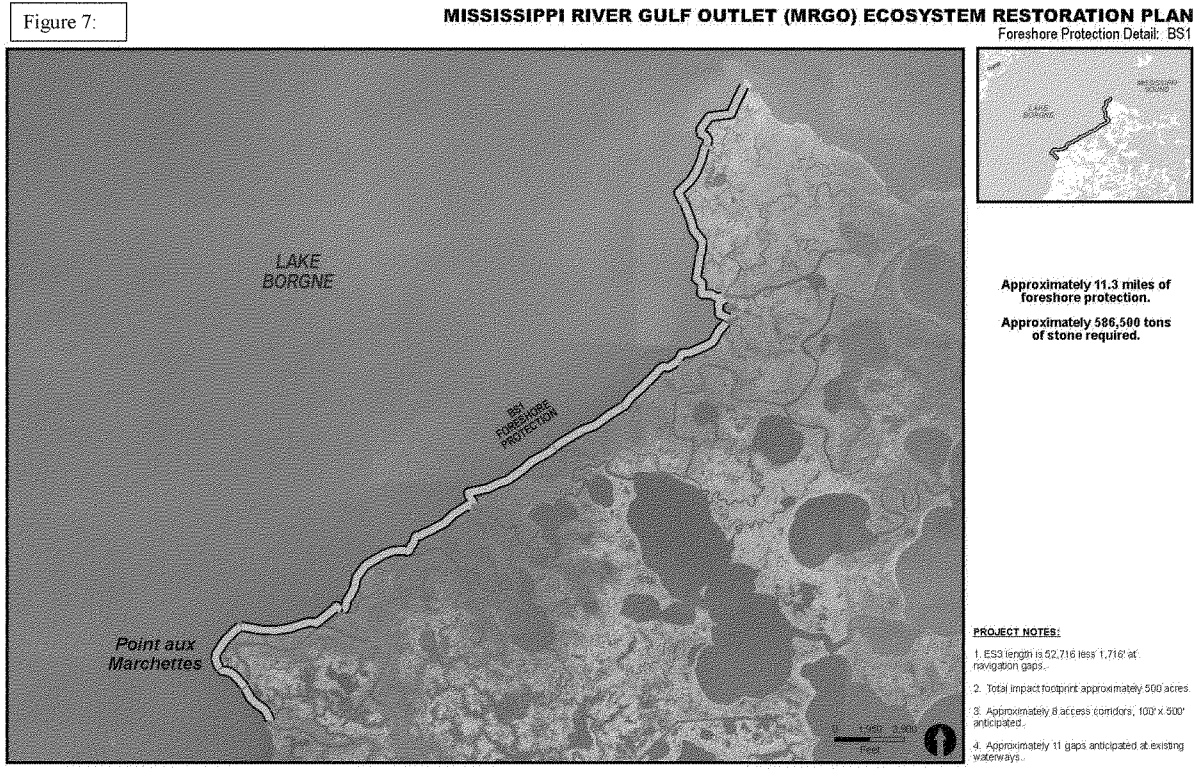
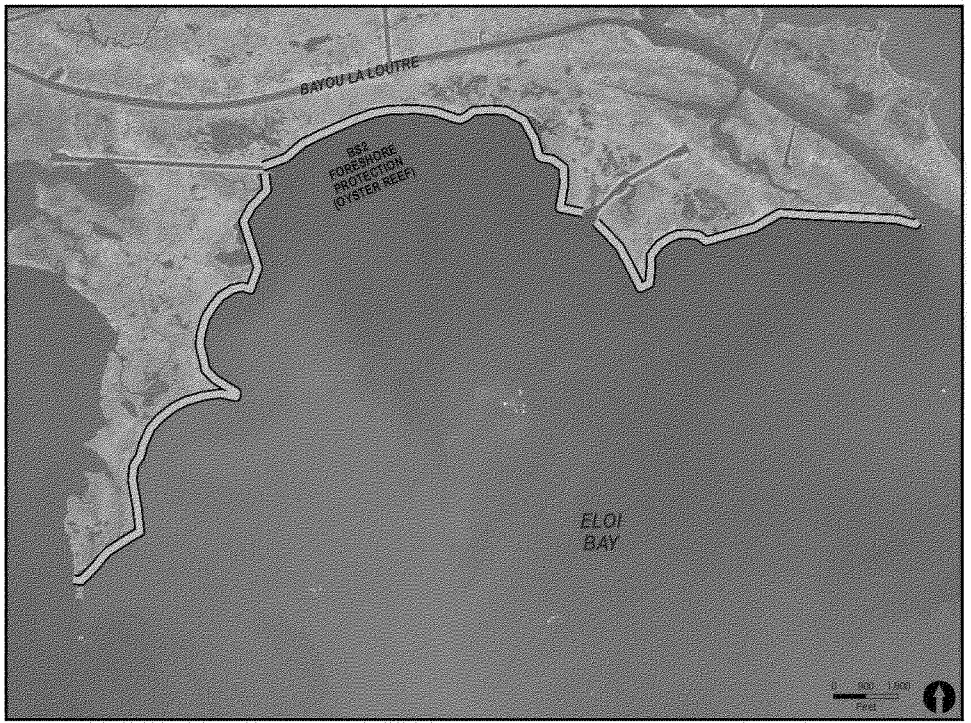
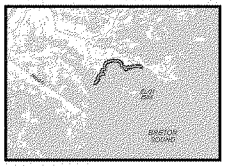

MISSISSIPPI RIVER GULF OUTLET (MRGO) ECOSYSTEM RESTORATION PLAN
Foreshore Protection Detail: BS1
LAKE BORGNE
BS1 FORESHORE PROTECTION
Point aux Marchettes
Approximately 11.3 miles of foreshore protection.
Approximately 586,500 tons of stone required.
PROJECT NOTES:
1. ES3 length is 62,716 less 1,716' at navigation gaps..
2. Total impact footprint approximately 500 acres.
3. Approximately 8 access corridors, 100' x 500' anticipated..
4. Approximately 11 gaps anticipated at existing waterways..

Figure 8:

MISSISSIPPI RIVER GULF OUTLET (MRGO) ECOSYSTEM RESTORATION PLAN

Foreshore Protection Detail: BS2





Subsurface shoreline protection feature.

Artificial oyster reef using crushed stone.

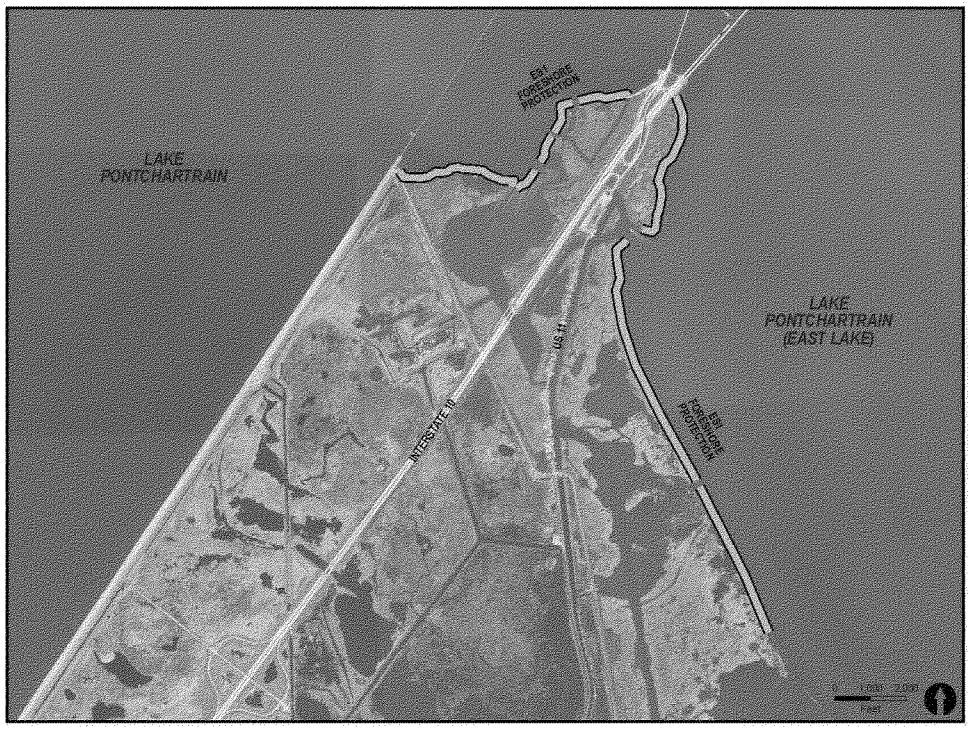
Feature is approximately 7.4 miles in length.

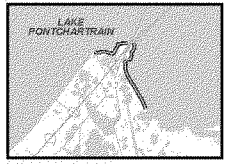
Total impact of footprint is approximately 272 acres.

Figure 9:

MISSISSIPPI RIVER GULF OUTLET (MRGO) ECOSYSTEM RESTORATION PLAN

Foreshore Protection Detail: ES1





Approximately 4.6 miles of shoreline protection.

Approximately 153,000 tons of stone required.

PROJECT NOTES:

1. ES1 length is 17,000', less a navigation gap of approximately 720'.

2. Additional 8,530' between bridges, less navigation gaps of approximately 750'.

3. Total impact footprint approximately 117 acres.

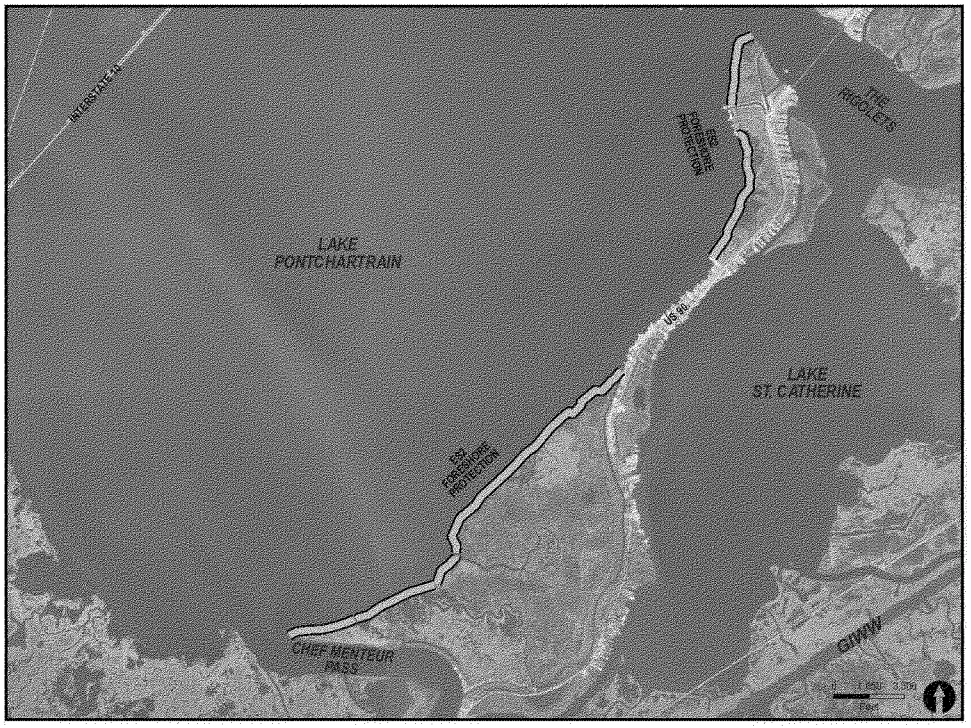
4. Approximately five access corridors, 100' x 500' anticipated.

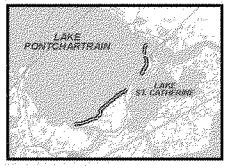
5. Approximately two gaps anticipated at existing waterways below I-10. Four additional gaps remain between railroad bridge and I-10 for access.

Figure 10:

MISSISSIPPI RIVER GULF OUTLET (MRGO) ECOSYSTEM RESTORATION PLAN

Foreshore Protection Detail: ES2





Approximately 6.0 miles of shoreline protection.

Approximately 195,000 tons of stone required.

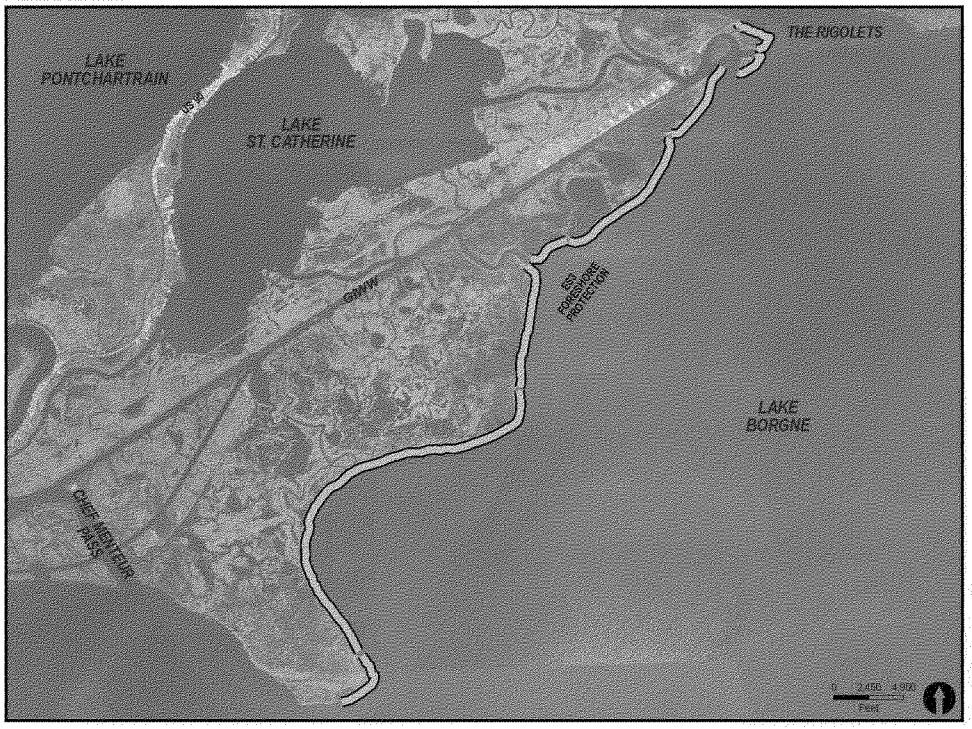
PROJECT NOTES:

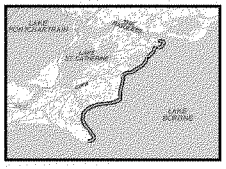
1. ES2 length is 31,600' non-continuous, less gaps.
2. Total impact footprint approximately 217 acres.
3. Approximately six access corridors, 100' x 500' anticipated.
4. Approximately seven gaps anticipated at existing waterways.

Figure 11:

MISSISSIPPI RIVER GULF OUTLET (MRGO) ECOSYSTEM RESTORATION PLAN

Foreshore Protection Detail: ES3





Approximately 13.3 miles of shoreline protection.

Approximately 633,000 tons of stone required.

PROJECT NOTES:

1. ES3 length is 73,428', less 3,100' at existing waterways.
2. Total impact footprint approximately 500 acres.
3. Approximately 11 access corridors, 100' x 500' anticipated.
4. Approximately 8 gaps anticipated at existing waterways.

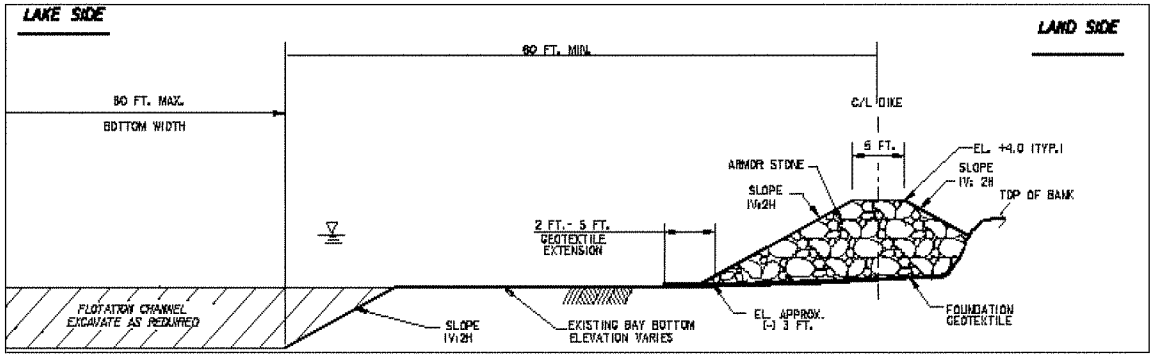
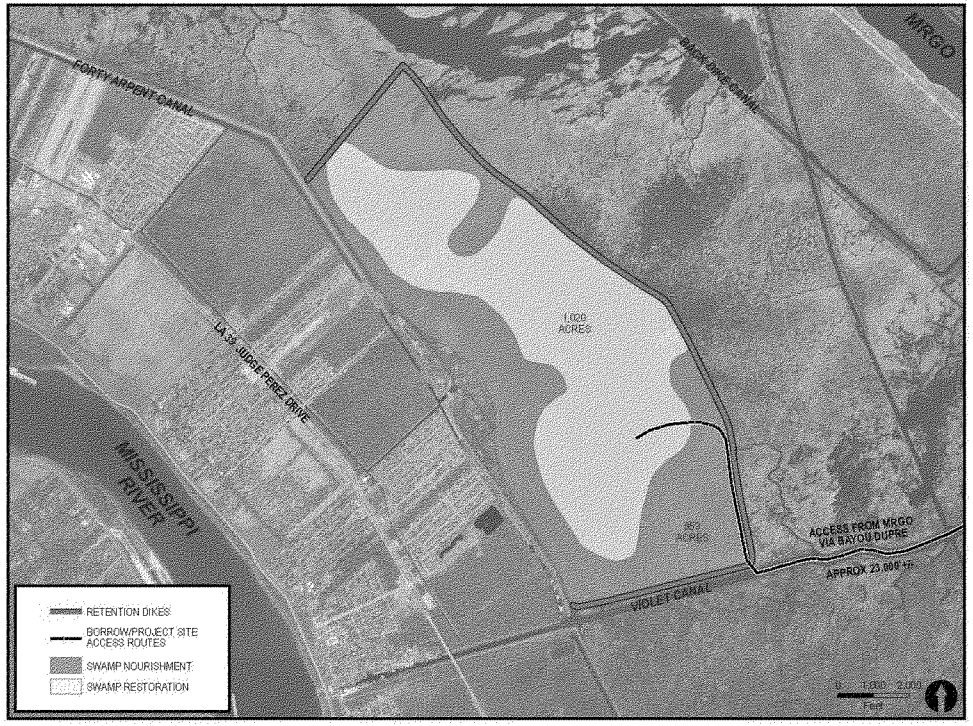


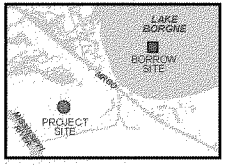
Figure 12: Theoretical sections of shore line protection measures

Figure 13:

MISSISSIPPI RIVER GULF OUTLET (MRGO) ECOSYSTEM RESTORATION PLAN

Project Footprint Detail: CC1





Approximately 1,020 acres of cypress restoration and 953 acres of nourishment.

Areas to be planted with cypress trees and protected from nutria.

Approximately 8.5 million cubic yards of borrow would be required.

1. Existing elevation within the swamp restoration site is an average of -1' and the adjacent marsh is approximately +1.5' (average). Approximately 1,020 acres of open water would be filled to an elevation conducive to swamp restoration. Approximately 953 acres of adjacent lands could be nourished with 1' of fill material allowed over adjacent lands.

2. Maximum slurry elevation would be +4.5' and effluent would be discharged upon adjacent wetlands for re-nourishment. Retention dikes and closures would be constructed from interior adjacent borrow with a 2' freeboard (+6.5') to be maintained, minimum 5' crown width, side slopes no steeper than 1v on 3h, and minimum 40' interior berm.

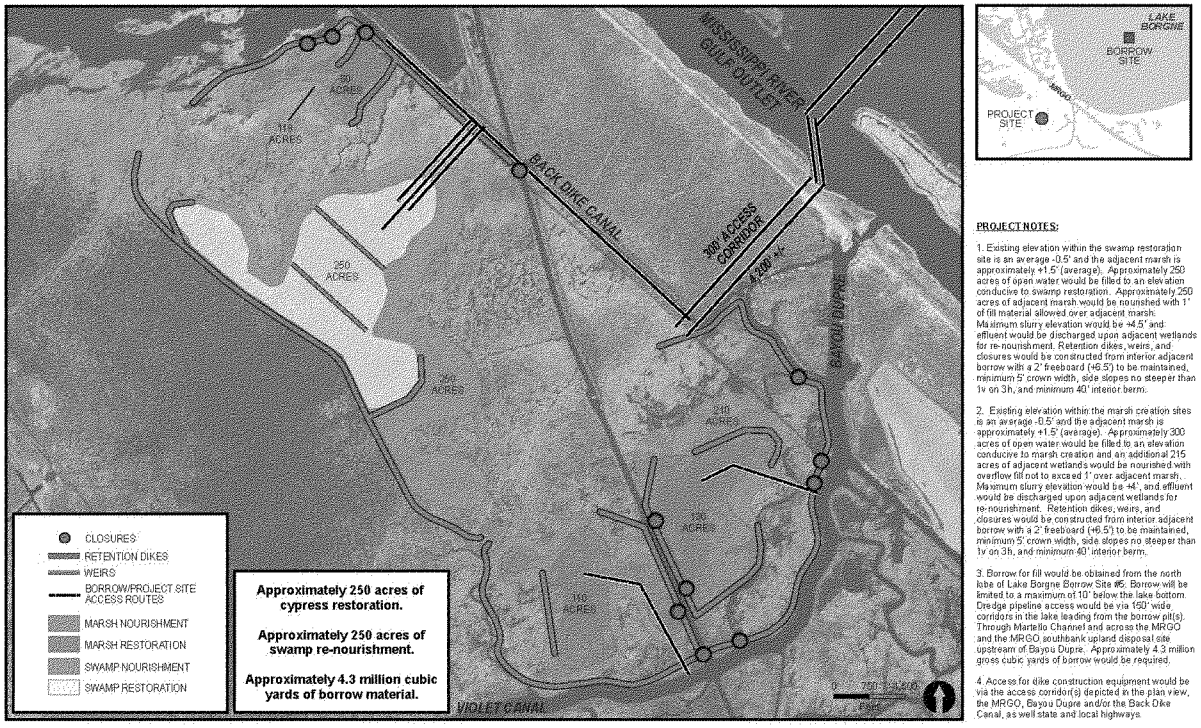
3. Borrow for fill would be obtained from the north lobe of Lake Borgne. Borrow will be limited to a maximum of 10' below the lake bottom. Dredge pipeline access would be via 150' wide corridors in the lake leading from the borrow pit(s) through Martello Channel and across the MRGO and the MRGO southbank upland disposal site upstream of Bayou Dupre. Approximately 8.5 million gross cubic yards of borrow would be required.

4. Access for dike construction equipment would be via the access corridor(s) depicted in the plan view, the MRGO, Bayou Dupre and/or the Back Dike Canal, as well state and local highways.

Figure 14:

MISSISSIPPI RIVER GULF OUTLET (MRGO) ECOSYSTEM RESTORATION PLAN

Project Footprint Detail: CC2 and CM3



PROJECT NOTES:

1. Existing elevation within the swamp restoration site is an average -0.5' and the adjacent marsh is approximately +1.5' (average). Approximately 250 acres of open water would be filled to an elevation conducive to swamp restoration. Approximately 250 acres of adjacent marsh would be nourished with 1' of fill material allowed over adjacent marsh. Maximum slurry elevation would be +4.5' and effluent would be discharged upon adjacent wetlands for re-nourishment. Retention dikes, weirs, and closures would be constructed from interior adjacent borrow with a 2' freeboard (+6.5') to be maintained, minimum 5' crown width, side slopes no steeper than 1v on 3h, and minimum 40' interior berm.

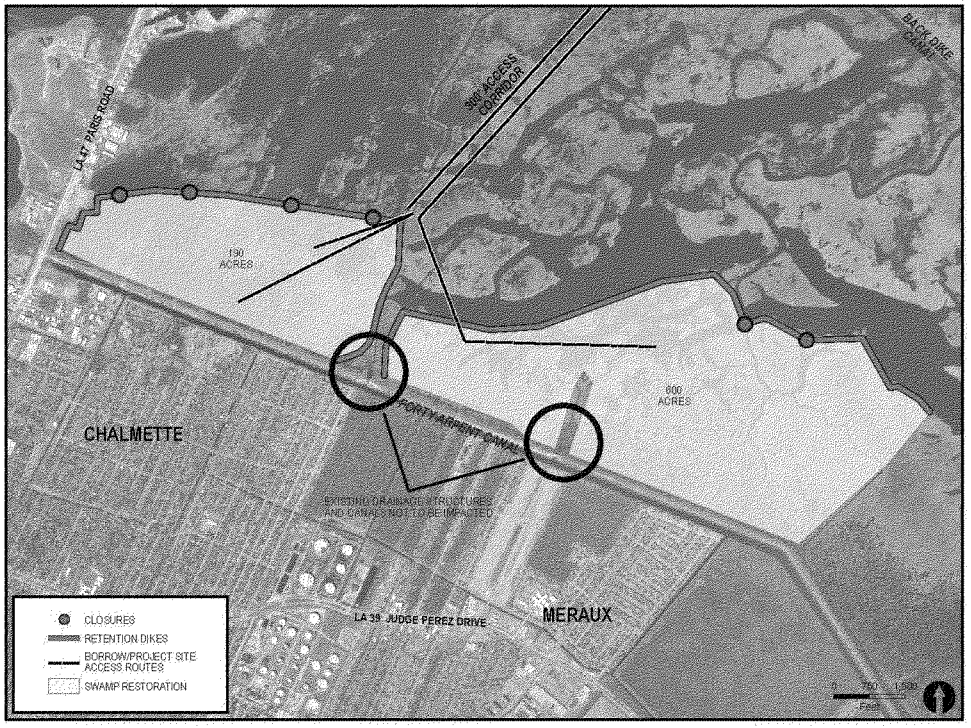
2. Existing elevation within the marsh creation sites is an average -0.5' and the adjacent marsh is approximately +1.5' (average). Approximately 300 acres of open water would be filled to an elevation conducive to marsh creation and an additional 215 acres of adjacent wetlands would be nourished with overflow fill not to exceed 1' over adjacent marsh. Maximum slurry elevation would be +4', and effluent would be discharged upon adjacent wetlands for re-nourishment. Retention dikes, weirs, and closures would be constructed from interior adjacent borrow with a 2' freeboard (+6.5') to be maintained, minimum 5' crown width, side slopes no steeper than 1v on 3h, and minimum 40' interior berm.

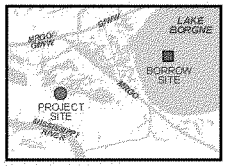
3. Borrow for fill would be obtained from the north lobe of Lake Borgne Borrow Site #5. Borrow will be limited to a maximum of 10' below the lake bottom. Dredge pipeline access would be via 150' wide corridors in the lake leading from the borrow pit(s). Through Martello Channel and across the MRGO and the MRGO southbank upland disposal site upstream of Bayou Dupre. Approximately 4.3 million gross cubic yards of borrow would be required.

4. Access for dike construction equipment would be via the access corridor(s) depicted in the plan view, the MRGO, Bayou Dupre and/or the Back Dike Canal, as well state and local highways.

Figure 15:

MISSISSIPPI RIVER GULF OUTLET (MRGO) ECOSYSTEM RESTORATION PLAN
Project Footprint Detail: CC3





Approximately 790 acres of swamp nourishment.

Area would be planted with cypress trees (to be protected from nutria).

Approximately 5.3 million cubic yards of borrow material required.

PROJECT NOTES:

1. Existing elevations within the swamp sites are approximately -3.0' as shown in the plan view. A total of approximately 370 acres of open water would be filled to an elevation conducive for swamp restoration, and approximately 790 adjacent acres would be re-nourished.

2. Maximum slurry elevation for swamp restoration would be +4.5' and effluent would be discharged over adjacent marshes for nourishment. Retention dikes and closures would be constructed from interior adjacent borrow with a 2' freeboard (+6.5') to be maintained, minimum 5'crown width, side slopes no steeper than 1v on 3h, and a minimum 40' interior berm.

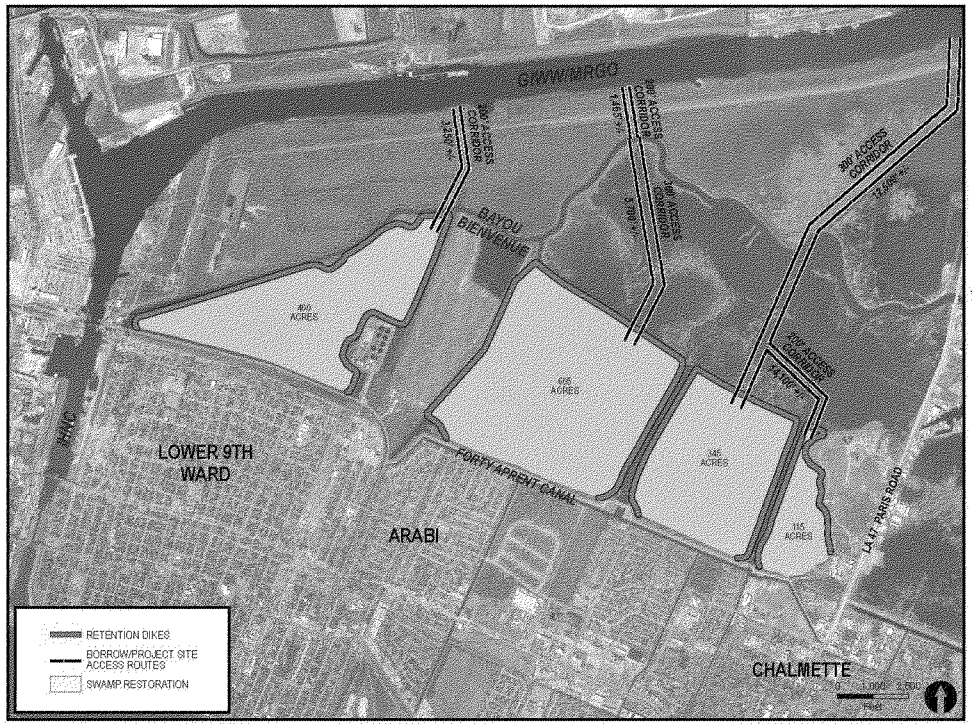
3. A total of approximately 5.3 million cubic yards would be required to re-nourish the two swamp sites. Borrow for fill would come from Lake Borgne north lobe (Site #5) and would be restricted to a maximum depth of 10' and approximately 640 acres of borrow would have to be cleared to allow for possible environmental, cultural, oyster and infrastructure impacts that could impact available borrow.

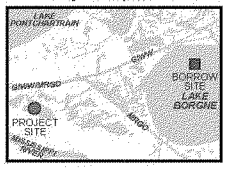
4. Access for dike construction equipment shall be via state and local highways.

Figure 16:

MISSISSIPPI RIVER GULF OUTLET (MRGO) ECOSYSTEM RESTORATION PLAN

Project Footprint Detail: CC4





Approximately 1,465 acres of cypress swamp restored.

The bankline of Bayou Bienvenue would be re-established.

Approximately 11.3 million cubic yards of borrow would be required.

Restoration areas woud be planted with cypress trees.

PROJECT NOTES:

1. Existing elevations within the swamp sites vary from -1.0' to -3.0'. A total of approximately 1,465 acres of open water would be restored to an elevation conducive for swamp restoration.

2. Maximum slurry elevation for swamp restoration will be +4.5', and effluent would be discharged through spill boxes north of the sites. Retention dikes and closures will be constructed from interior adjacent borrow, including adjacent where applicable, with a 2' freeboard (+6.5') to be maintained, min 5'crown width, side slopes no steeper than 1v on 3h, and min 40' interior berm.

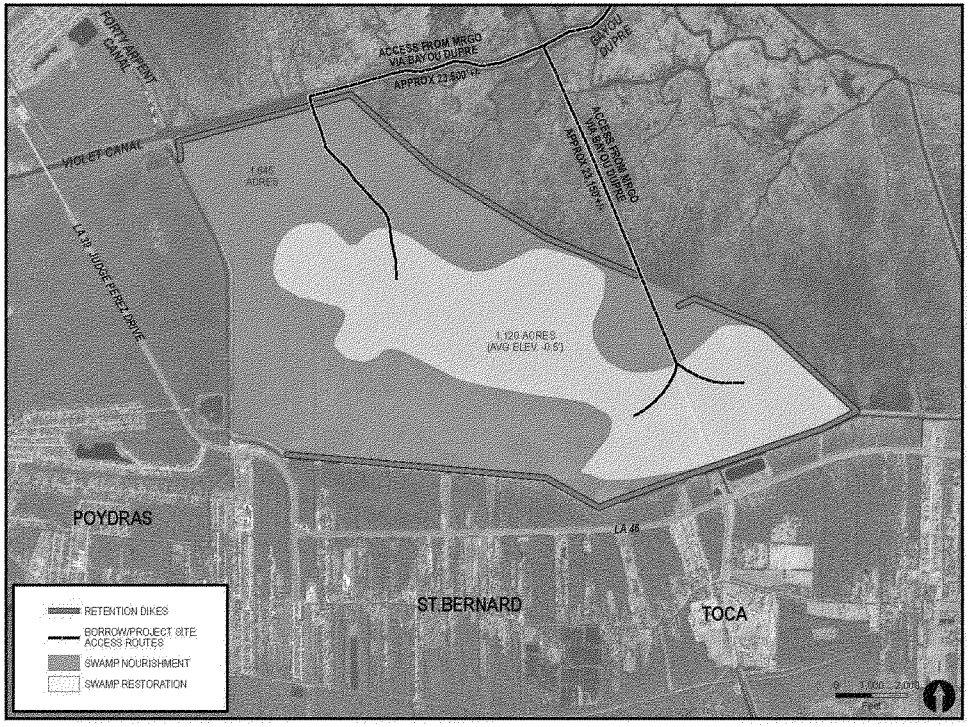
3. A total of approximately 11.3 million cubic yards would be required to restore the four swamp sites. Borrow would be obtained from Lake Borgne Borrow Site #6, adjacent to and south of Alligator Point and Chef Menteur Pass. Approximately 660 acres of borrow would be required, thus meaning 1,920 acres would need to be cleared and available to allow for contingencies. (i.e. cultural sites, fish impacts, unknown infrastructure to be avoided, etc.).

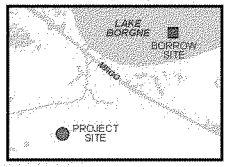
4. Access for dike construction equipment would be via the access corridor(s) depicted in the plan view, the MRGO/GIWW, Bayou Bienvenue, as well state and local highways.

Figure 17:

MISSISSIPPI RIVER GULF OUTLET (MRGO) ECOSYSTEM RESTORATION PLAN

Project Footprint Detail: CC5





Approximately 1,120 acres of swamp restoration and 1,645 acres nourishment.

Restored areas would be planted with cypress trees.

Approximately 9.3 million acres of borrow would be required.

PROJECT NOTES:

1. Existing elevation within the swamp restoration site is an average of -0.5' and the adjacent marsh averages approximately +1.5'. Approximately 1,120 acres would be filled to an elevation conducive to swamp restoration. Approximately 1,645 acres adjacent to the proposed swamp restoration site would be nourished with 0.5' to 1' of fill material allowed over adjacent swamp.

2. Maximum slurry elevation would be +4.5' and effluent would be discharged upon adjacent wetlands for re-nourishment. Retention dikes and closures would be constructed from interior adjacent borrow with a 2' freeboard (+6.5') to be maintained, minimum 5' crown width, side slopes no steeper than 1v on 3h, and minimum 40' interior berm.

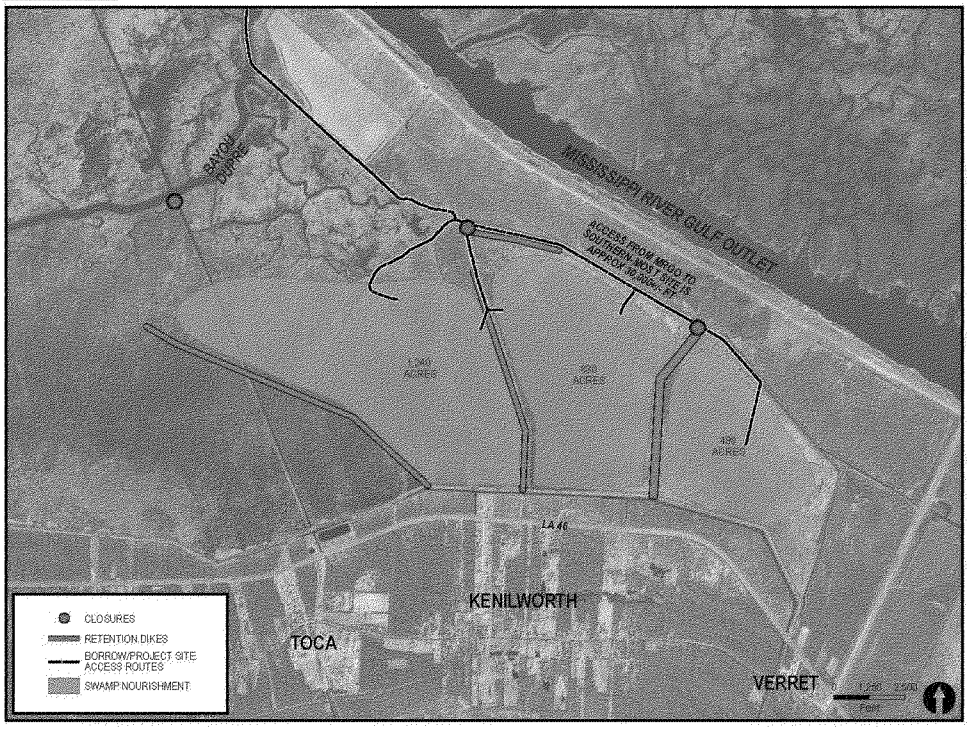
3. Borrow for fill would be obtained from the north lobe of Lake Borgne, Borrow Site #4. Dredge pipeline access would be via 150' wide corridors in the lake leading from the borrow pit(s) through Martello Channel and across the MRGO and the MRGO southbank upland disposal site upstream of Bayou Dupre. Approximately 9.3 million gross cubic yards of borrow would be required.

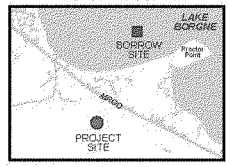
4. Access for dike construction equipment would be via the access corridor(s) depicted in the plan view, the MRGO, Bayou Dupre and/or the Back Dike Canal, as well state and local highways.

Figure 18:

MISSISSIPPI RIVER GULF OUTLET (MRGO) ECOSYSTEM RESTORATION PLAN

Project Footprint Detail: CC6





Approximately 2,658 acres of swamp nourishment.

Approximately 11.2 million cubic yards of borrow required.

PROJECT NOTES:

1. The existing elevation within the swamp nourishment sites is an average -1.0' and adjacent marsh is approximately +1.5' (average). Approximately 2,568 acres of marsh and open water would be nourished and filled to an elevation conducive to nourish the marsh/swamp. Of this 2,568 acres, approximately 40% (1,027 acres) is open water at approximately elevation -1.5' to be restored to swamp; and the remaining 60% (1,540 acres) would be nourished with 1.5' of fill allowed to overflow for nourishment.

2. Maximum slurry elevation would be +4.5' for swamp restoration, and effluent would be discharged upon adjacent wetlands for nourishment. Retention dikes and closures would be constructed from interior adjacent borrow with a 2' freeboard (+6.5') to be maintained, minimum 5' crown width, side slopes no steeper than 1v on 3h, and minimum 40' interior berm. Approximately 11.2 million cubic yards would be required for the swamp restoration project feature.

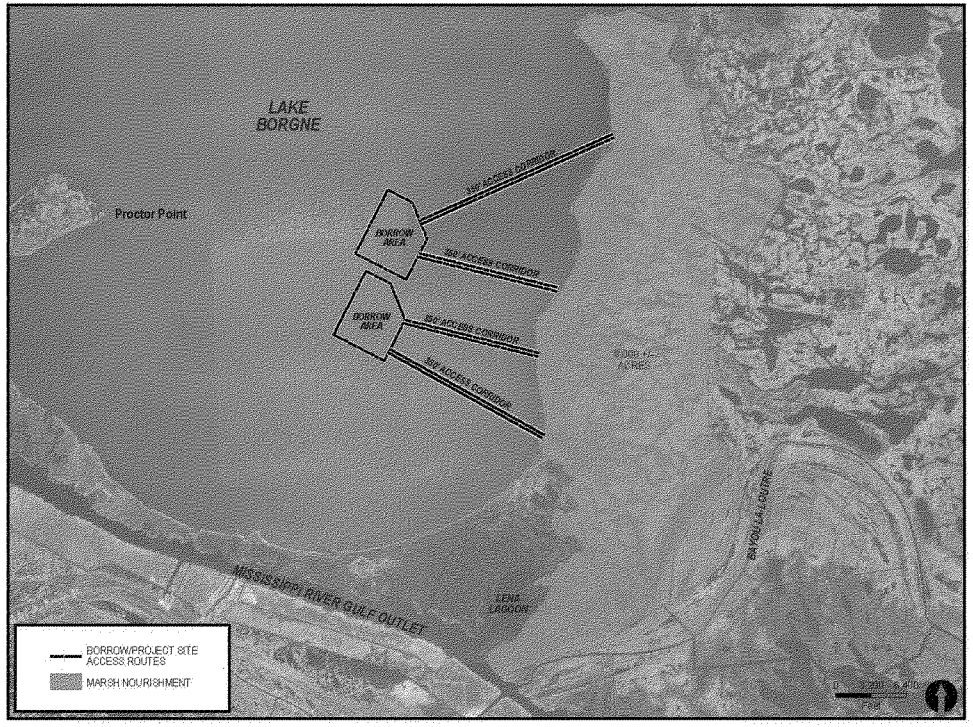
3. Borrow for fill will be obtained from the north lobe of Lake Borgne Borrow Site #4. Borrow will be limited to a maximum of 10' below the lake bottom. Dredge pipeline access will be via 350' wide corridors in the lake leading from the borrow pit(s), through Martello Channel, Bayou Dupre and the Back Dike Canal. Borrow in Lake Borgne would be restricted to 10 depth and approx 11.2 million gross cubic yards of borrow would be required. It is estimated that approximately 750 acres of borrow would be required, thus meaning 1,500 acres would need to be cleared and available to allow for contingencies (i.e. cultural sites, fish impacts, unknown infrastructure to be avoided, etc.).

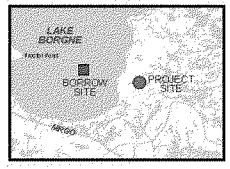
4. Access for dike construction equipment would be via the access corridor(s) depicted in the plan view, the MRGO, Bayou Dupre and/or the Back Dike Canal as well as state and local highways.

Figure 19:

MISSISSIPPI RIVER GULF OUTLET (MRGO) ECOSYSTEM RESTORATION PLAN

Project Footprint Detail: BM1





Approximately 8,000 acres of marsh nourishment.

Approximately 10.8 million cubic yards of borrow material required.

PROJECT NOTES:

1. Existing elevation within the marsh restoration site is assumed to be an average of -0.5' and the adjacent marsh is approximately +1.5' (average). Approximately 8,000 acres of marsh would be nourished.

2. Maximum slurry elevation would be +3.0', and effluent would be directed to the south, away from Lake Borgne. The discharged location would be a minimum 2,000' inside the bank of Lake Borgne. A deflection dike would be constructed from adjacent borrow and would run down the middle of the site, paralleling the bank of the lake.

3. Borrow would be obtained from Lake Borgne Borrow Site #2. It is estimated that approximately 10.8 million cubic yards of borrow would be required for this marsh restoration feature. This would require approximately 700 acres of borrow and approximately 1,400 acres would have to be cleared to account for pipelines, infrastructure, or other unknown cultural finds.

4. Access for dredge pipeline and dike construction equipment would be via access corridors depicted in the plan view and via the MRGO.

Figure 20:

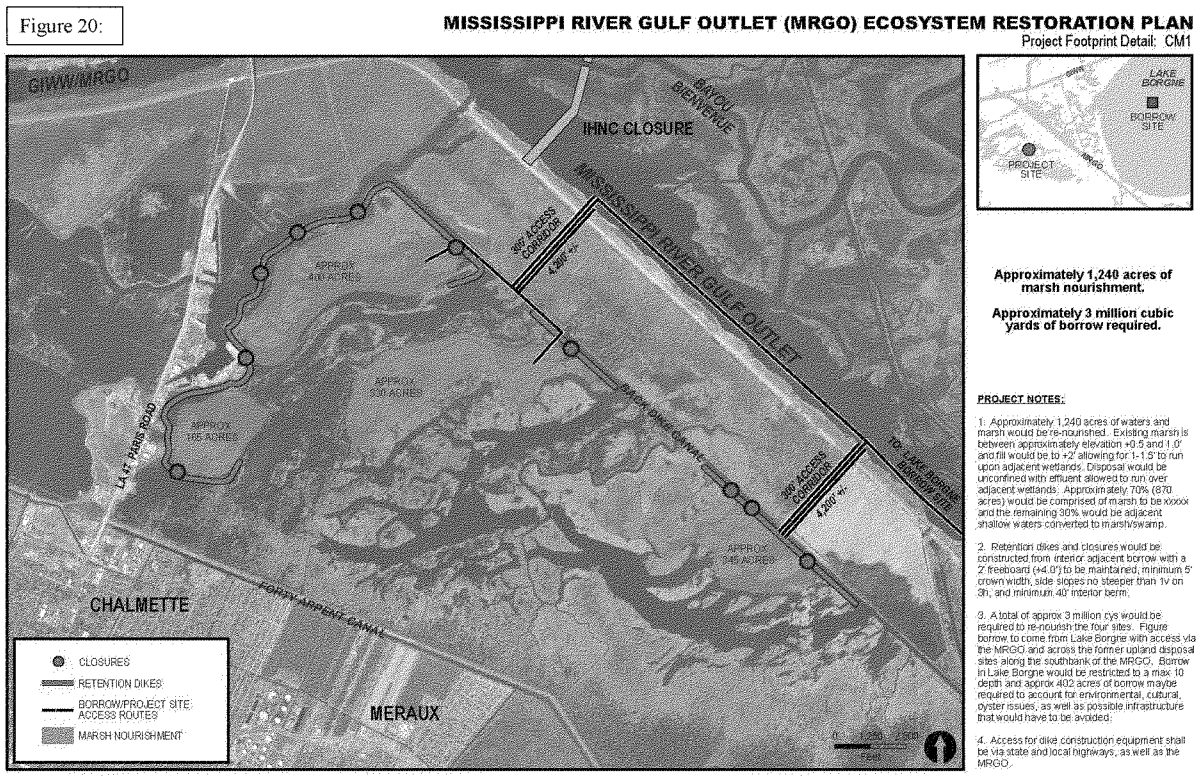
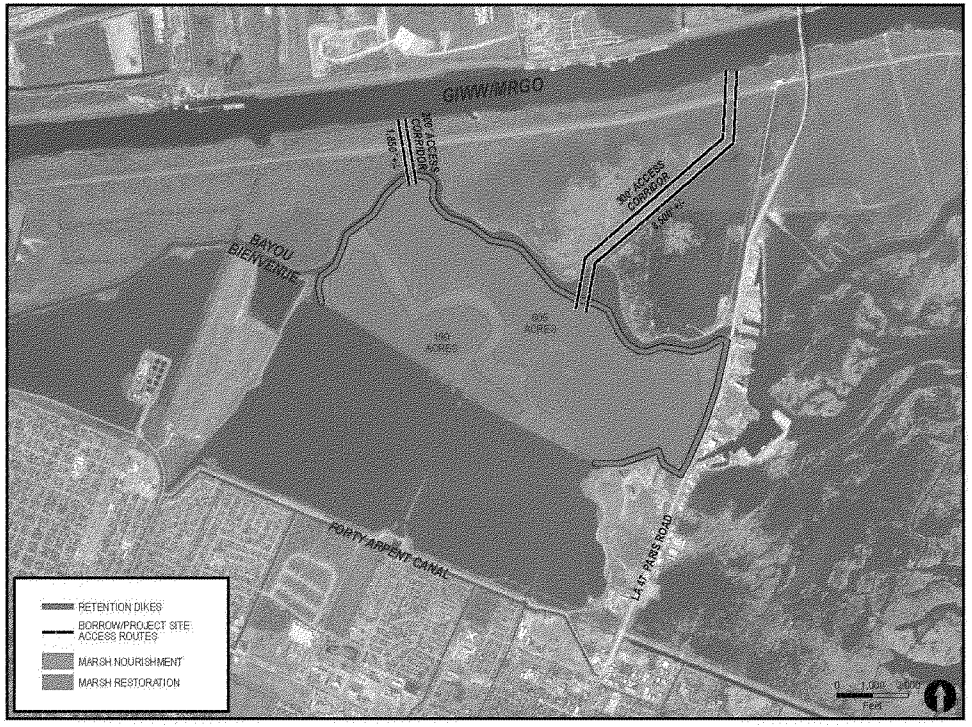
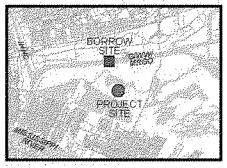

MISSISSIPPI RIVER GULF OUTLET (MRGO) ECOSYSTEM RESTORATION PLAN
Project Footprint Detail: CM1
GIWW/MRGO
BAYOU BIENVENUE
IHNC CLOSURE
MISSISSIPPI RIVER GULF OUTLET
300' ACCESS CORRIDOR
4,200' +/-
APPROX 410 ACRES
APPROX 530 ACRES
APPROX 165 ACRES
APPROX 745 ACRES
LA 47 PARK ROAD
BAYOU DUPRE CANAL
TO LAKE BORGNE BORROW SITE
FORTY ARPENT CANAL
CHALMETTE
MERAUX
CLOSURES
RETENTION DIKES
BORROW/PROJECT SITE ACCESS ROUTES
MARSH NOURISHMENT
LAKE BORGNE
BORROW SITE
PROJECT SITE
MRGO
Approximately 1,240 acres of marsh nourishment.
Approximately 3 million cubic yards of borrow required.
PROJECT NOTES:
1. Approximately 1,240 acres of waters and marsh would be re-nourished. Existing marsh is between approximately elevation +0.5 and 1.0' and fill would be to +2' allowing for 1-1.5' to run upon adjacent wetlands. Disposal would be unconfined with effluent allowed to run over adjacent wetlands. Approximately 70% (870 acres) would be comprised of marsh to be xxxxx and the remaining 30% would be adjacent shallow waters converted to marsh/swamp.
2. Retention dikes and closures would be constructed from interior adjacent borrow with a 2' freeboard (+4.0') to be maintained; minimum 5' crown width, side slopes no steeper than 1v on 3h; and minimum 40' interior berm.
3. A total of approx 3 million cys would be required to re-nourish the four sites. Figure borrow to come from Lake Borgne with access via the MRGO and across the former upland disposal sites along the southbank of the MRGO. Borrow in Lake Borgne would be restricted to a max 10 depth and approx 402 acres of borrow maybe required to account for environmental, cultural, oyster issues, as well as possible infrastructure that would have to be avoided.
4. Access for dike construction equipment shall be via state and local highways, as well as the MRGO.

Figure 21:

MISSISSIPPI RIVER GULF OUTLET (MRGO) ECOSYSTEM RESTORATION PLAN

Project Footprint Detail: CM2





Approximately 795 acres of marsh creation.

Approximately 2.6 million cubic yards of borrow required.

PROJECT NOTES:

1. Existing elevation within the marsh creation site is an average -0.5' and adjacent marsh is approximately +1.5' (average). Approximately 795 acres of open water would be filled to an elevation conducive to marsh creation.

2. Maximum slurry elevation would be +4.0' and effluent would be returned to Bayou Bienvenue via spill box weirs, or if possible, discharged immediately south of the proposed marsh creation site. Retention dikes would be from adjacent borrow with a 2' freeboard (+6.0') to be maintained, minimum 5' crown width and slopes no steeper than 1 on 3 and min 40' interior berm.

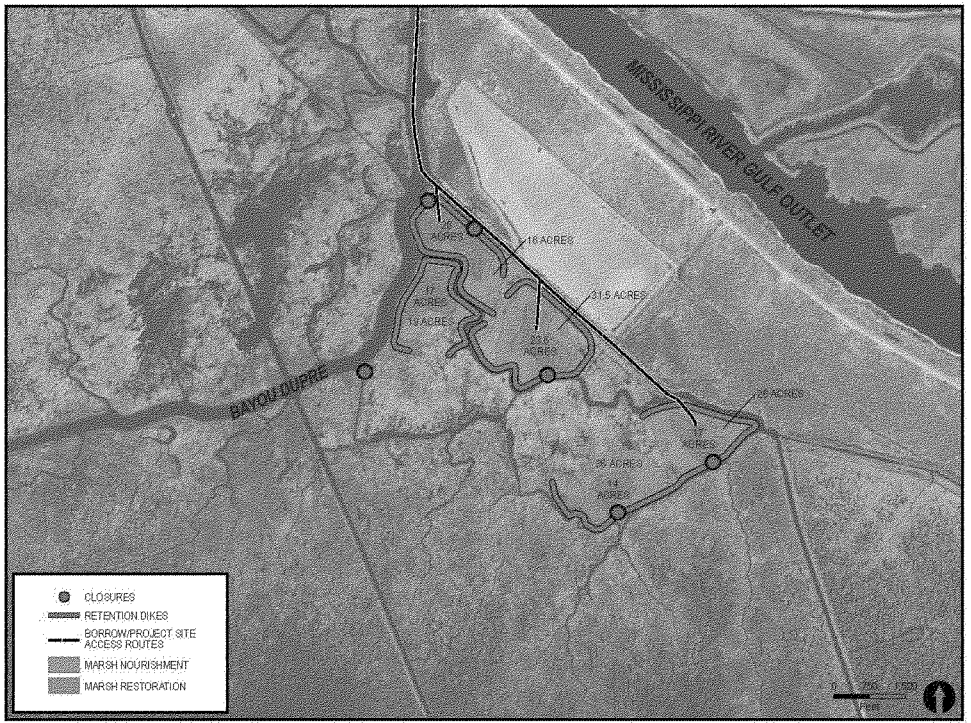
3. Borrow would be obtained from the adjacent GIWW/MRGO Channel (Reach 1) between miles 60 and 66. Borrow would be restricted to the currently authorized and NEPA-cleared dimensions for this reach (~40' mlg x 500', except at turning basin), 1 on 2 slopes and 2' over depth. It is estimated that this reach of the GIWW/MRGO could provide approx 2.6 million cubic yards of the estimated 3.3 million cubic yards of material required for this marsh creation feature. The remaining 700,000 cubic yards would come from another source. Other sources to be considered are Michaud Canal, Lake Borgne, and the Mississippi River.

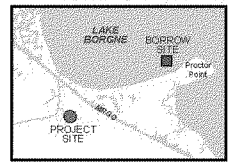
4. Access for dredge pipeline and dike construction equipment would be via access corridors depicted in the plan view and/or via Bayou Bienvenue, as well state and local highways.

Figure 22:

MISSISSIPPI RIVER GULF OUTLET (MRGO) ECOSYSTEM RESTORATION PLAN

Project Footprint Detail: CM4





Approximately 226 acres of marsh restoration.

Approximately 900,000 cubic yards of borrow material would be required.

PROJECT NOTES:

1. The existing elevation within the marsh creation sites is an average -1.5' and the adjacent marsh is approximately +1.5' (average). Approximately 226 acres of marsh would be created and nourished. Of this 226 acres, approximately 97.5 acres is open water at approximately elevation -1.5' to be restored to marsh, and the approximately 128.5 acres would be adjacent marsh that would be re-nourished with 1' of effluent allowed to overflow the marsh for nourishment. Maximum slurry elevation would be +4' for marsh creation, and effluent would be discharged upon adjacent wetlands for re-nourishment. Retention dikes and closures would be constructed from interior adjacent borrow with a 2' freeboard (+6') to be maintained, minimum 5' crown width, side slopes no steeper than 1v on 3h, and minimum 40' interior berm. Approximately 900,000 cubic yards would be required for this marsh creation project feature.

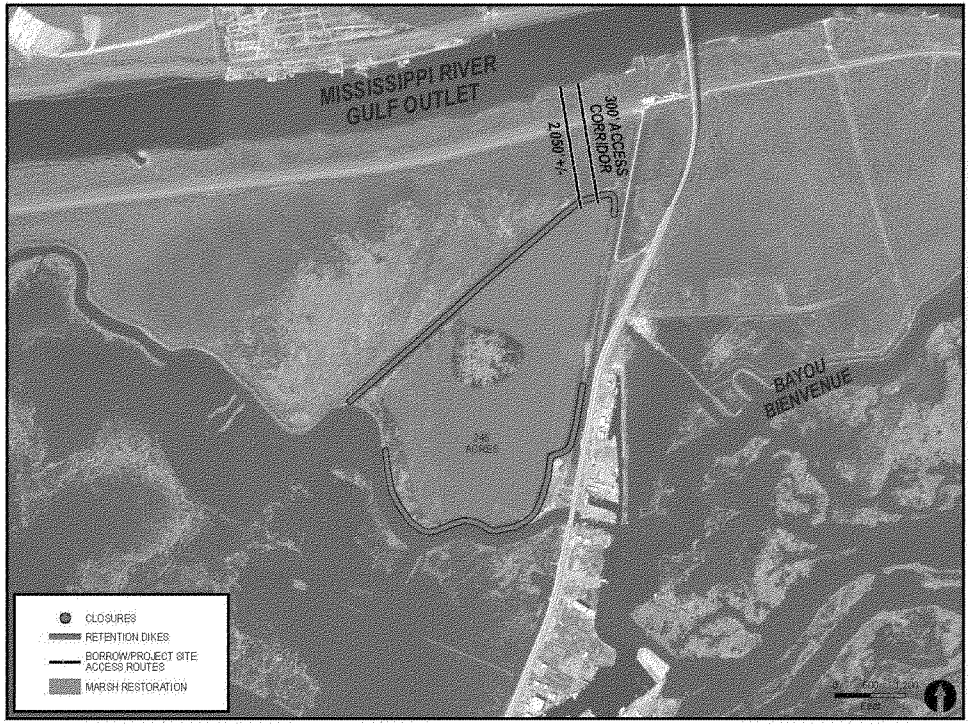
2. Borrow for fill would be obtained from the north lobe of Lake Borgne Borrow Site #4. Borrow would be limited to a maximum of 10' below the lake bottom. Dredge pipeline access would be via 350' wide corridors in the lake leading from the borrow pit(s), through Martello Channel, Bayou Dupre, and the Back Dike Canal. It is estimated that approximately 56 acres of borrow would be required and that approximately 112 acres would need to be cleared and available to allow for contingencies. (i.e.: cultural sites, fish impacts, unknown infrastructure to be avoided, etc.).

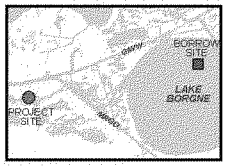
3. Access for dike construction equipment would be via the access corridor(s) depicted in the plan view, the MRGO, Bayou Dupre and/or the Back Dike Canal as well state and local highways.

Figure 23:

MISSISSIPPI RIVER GULF OUTLET (MRGO) ECOSYSTEM RESTORATION PLAN

Project Footprint Detail: CM5





Approximately 245 acres of proposed marsh creation.

Approximately 1.2 million cubic yards of borrow material would be required.

PROJECT NOTES:

1. Existing elevation within the marsh creation site is an average -0.5', and the adjacent marsh is approximately +1.5' (average). Approximately 245 acres of open water would be filled to an elevation conducive to marsh creation.

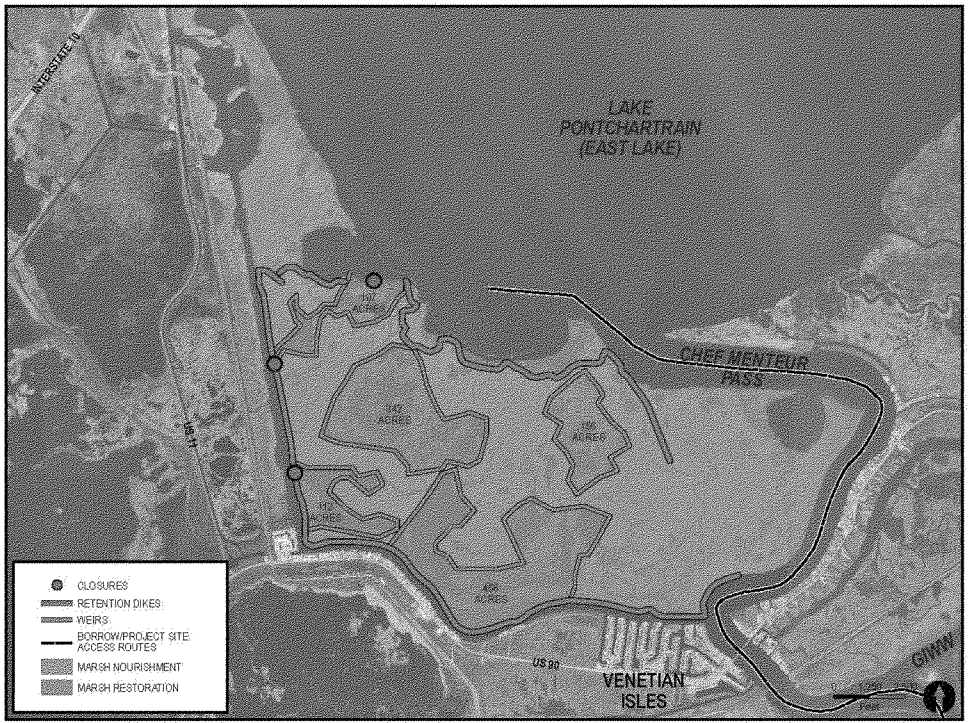
2. Maximum slurry elevation would be +4.0' and effluent would be returned to Bayou Bienvenue via spill box weirs. Retention dikes would be from interior adjacent borrow with a 2' freeboard (+6.0') to be maintained, minimum 5' crown width, side slopes no steeper than 1v on 3h, and minimum 40' interior berm.

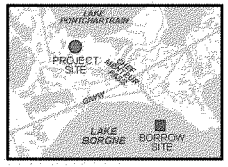
3. Borrow for fill would be obtained from Lake Borgne Borrow Site #6. It is estimated that approximately 1.2 million gross cubic yards of material would be required for this marsh creation feature. Approximately 76 acres of borrow would be required, with borrow in the lake restricted to a maximum depth of 10' below the lake bottom and thus approximately 152 acres of borrow would have to be cleared for this feature to allow for possible cultural, environmental and infrastructure that would have to be avoided.

4. Access for dredge pipeline and dike construction equipment would be via access corridor(s) depicted in the plan view and/or via Bayou Bienvenue, as well state and local highways.

Figure 24:

MISSISSIPPI RIVER GULF OUTLET (MRGO) ECOSYSTEM RESTORATION PLAN
Project Footprint Detail: EM1





Approximately 1,175 acres of proposed marsh creation.

Approximately 8.1 million cubic yards of borrow material would be required.

Approximately 2,830 acres of adjacent marsh to be nourished.

PROJECT NOTES:

1. Existing elevation within the marsh creation site is an average -0.5' and adjacent marsh is approximately +1.5' (average). Approximately 1,175 acres of open water would be filled to an elevation conducive to marsh creation.

2. Maximum slurry elevation would be +4.0', and effluent would be discharged immediately west and south within the proposed marsh creation site. Retention dikes would be from adjacent borrow with a 2' freeboard (+6.0') to be maintained, minimum 5' crown width and slopes no steeper than 1 on 3 and minimum 40' interior berm. Interior weirs would be from adjacent borrow to elevation +3.0', minimum 5' crown, and side slopes 1:3.

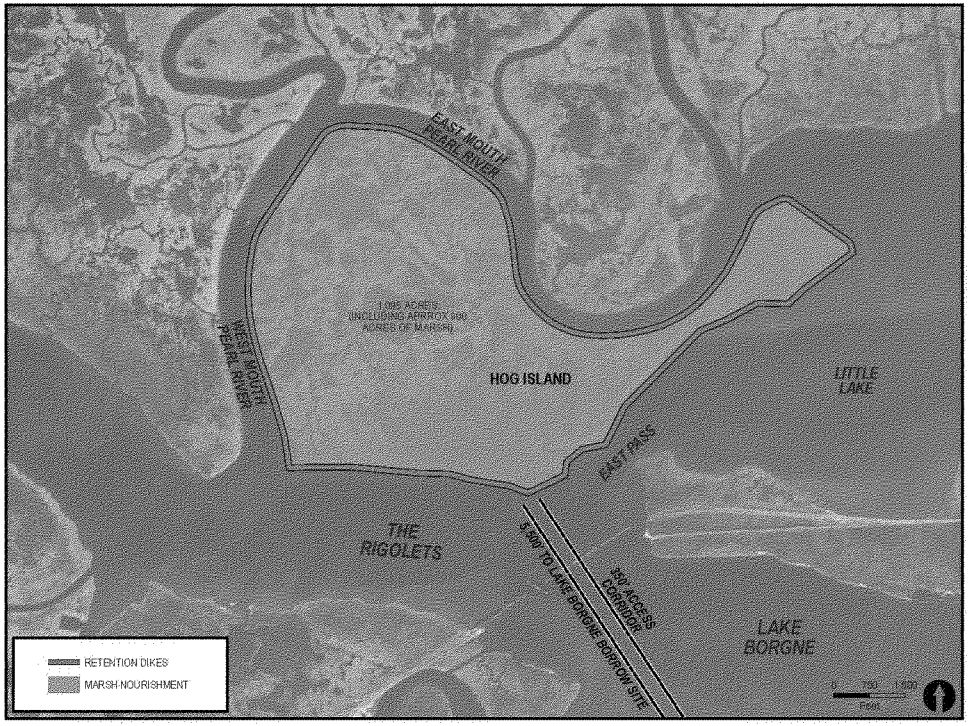
3. Borrow would be obtained from Lake Borgne Borrow Site #6. It is estimated that approximately 8.1 million cubic yards of material would be required for this marsh creation feature, and that approximately 502 acres would be required. Approximately 1,004 acres would have to be cleared in order to account for unknown pipelines, structures or other cultural finds.

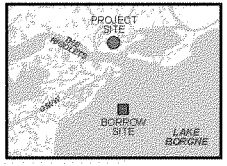
4. Access for dredge pipeline and dike construction equipment would be via Chef Menteur Pass, Lake Pontchartrain, as well as Lake Borgne and the GIWW.

Figure 25:

MISSISSIPPI RIVER GULF OUTLET (MRGO) ECOSYSTEM RESTORATION PLAN

Project Footprint Detail: EM2





Approximately 800 acres of marsh proposed for nourishment.

Approximately 2.2 million cubic yards of borrow would be required.

PROJECT NOTES:

1. Existing elevation within the marsh creation site is an average -0.5' and the adjacent marsh is approximately +1.5' (average). Approximately 600 acres of marsh to be nourished and an additional 295 acres of shallow waterbottoms would be impacted by effluent disposal.

2. Initial maximum fill over marsh would be approximately 1.25' in order to obtain a desired 1' after de-watering and consolidation. Effluent would be allowed to enter adjacent waterbodies within the project boundary and it is assumed they will be shallowed by 1-1.25' also. Perimeter retention dikes would be required and borrow would come either from within or outside and adjacent to project boundary. Maximum slurry elevation would be +3.5' to+4.0', and effluent would be returned to the adjacent bayou via spill box weirs. Retention dikes constructed would have a minimum 2' freeboard (+5.5 to +6.0'), minimum 5' crown width and slopes no steeper than 1v on 3h, and minimum 40' interior berm where interior borrow is obtained.

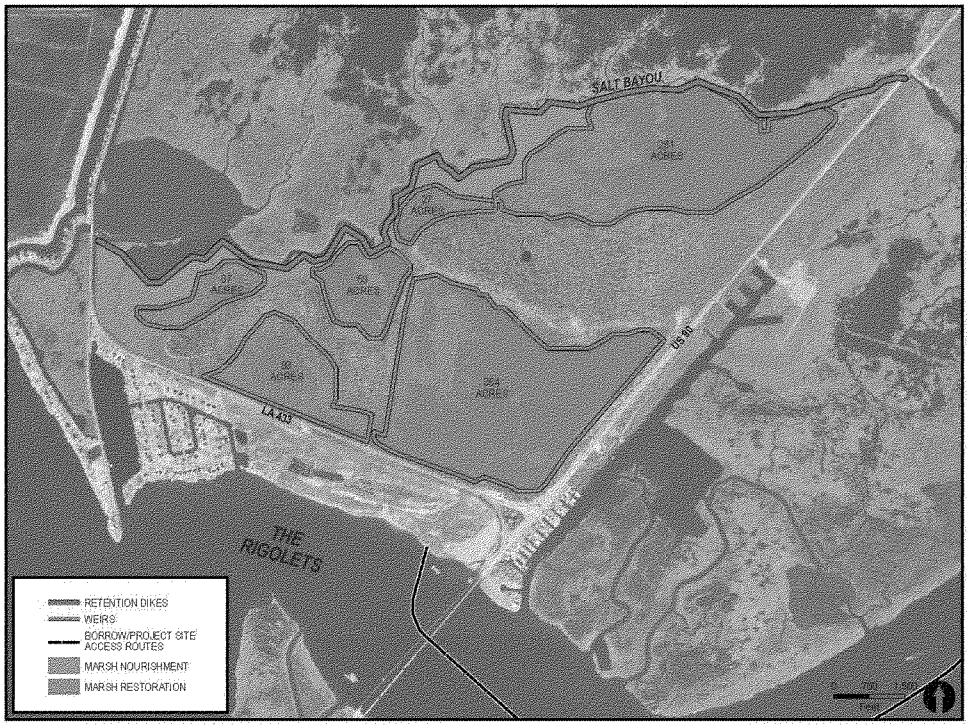
3. Borrow for marsh nourishment would be obtained from Lake Borgne. It is estimated that approximately 2.2 million cubic yards of Borrow Pit #6 would be required for this marsh nourishment feature.

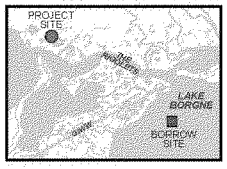
4. Access for dredge pipeline and dike construction equipment would be via access corridors depicted in the plan view and/or via the GIWW and Lake Borgne.

Figure 26:

MISSISSIPPI RIVER GULF OUTLET (MRGO) ECOSYSTEM RESTORATION PLAN

Project Footprint Detail: EM3





Approximately 861 acres of proposed marsh creation.

Approximately 180 acres of adjacent marsh to be nourished.

Approximately 3.4 million cubic yards of borrow would be required.

PROJECT NOTES:

1. Existing elevation within the marsh creation site is an average -0.5' and the adjacent marsh is approximately +1.5' (average). Approximately 861 acres of open water would be filled to an elevation conducive to marsh creation.

2. Maximum slurry elevation would be +4.0', and effluent would be returned to the bayou via spill box weirs. Retention dikes will be from adjacent borrow with a 2' freeboard (+6.0') to be maintained, minimum 5' crown width and slopes no steeper than 1 on 3 and minimum 40' interior berm.

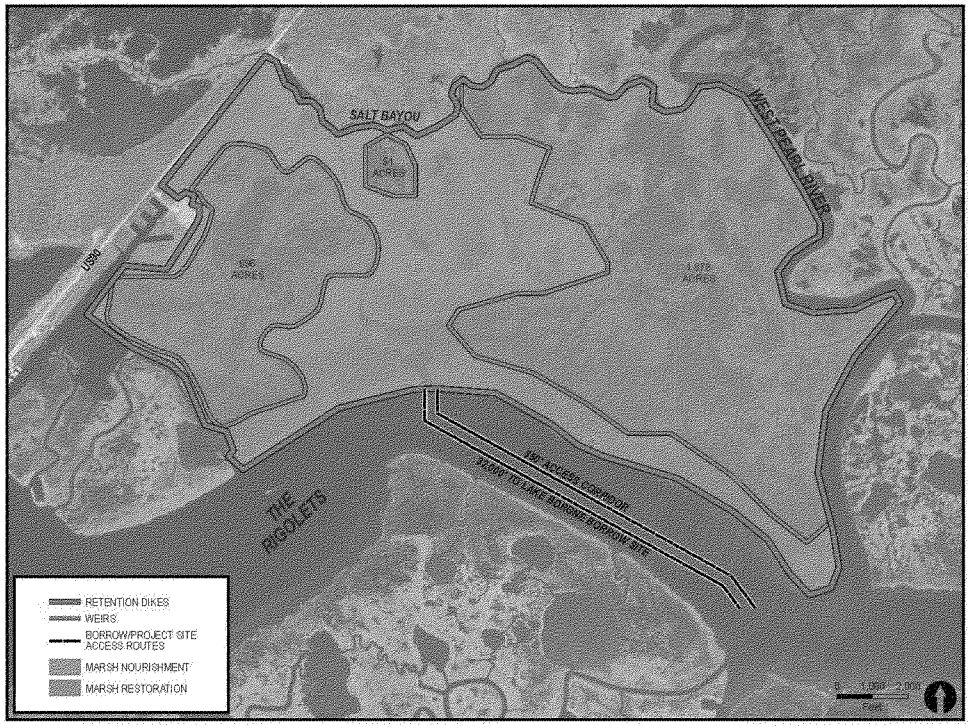
3. Borrow for fill would be obtained from the north lobe of Lake Borgne (Borrow Site #6). Borrow would be limited to a maximum of 10'-12' below the lake bottom. Dredge pipeline access would be via The Rigolets leading to the northshore of Lake Pontchartrain adjacent to the marsh creation site, thence via a 300' access corridor from the lake shoreline to the marsh creation site. Approximately 3.4 million gross cubic yards of borrow will be required.

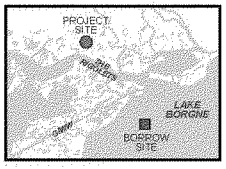
4. Access for dredge pipeline and dike construction equipment would be via access corridors depicted in the plan view and/or via the GIWW and Lake Borgne.

Figure 27:

MISSISSIPPI RIVER GULF OUTLET (MRGO) ECOSYSTEM RESTORATION PLAN

Project Footprint Detail: EM4





Approximately 2,625 acres of proposed marsh creation.

Approximately 1,455 acres of adjacent marsh to be nourished.

Approximately 11.5 million cubic yards of borrow would be required.

PROJECT NOTES:

1: Existing elevation within the marsh creation site is an average -0.5' and the adjacent marsh is approximately +1.5' (average). Approximately 2,625 acres of open water would be filled to an elevation conducive to marsh creation.

2: Maximum slurry elevation would be +4.0', and effluent would be returned to the bayou via spill box weirs. Retention dikes would be from adjacent borrow with a 2' freeboard (+6.0') to be maintained, minimum 5' crown width and slopes no steeper than 1 on 3 and minimum 40' interior berm.

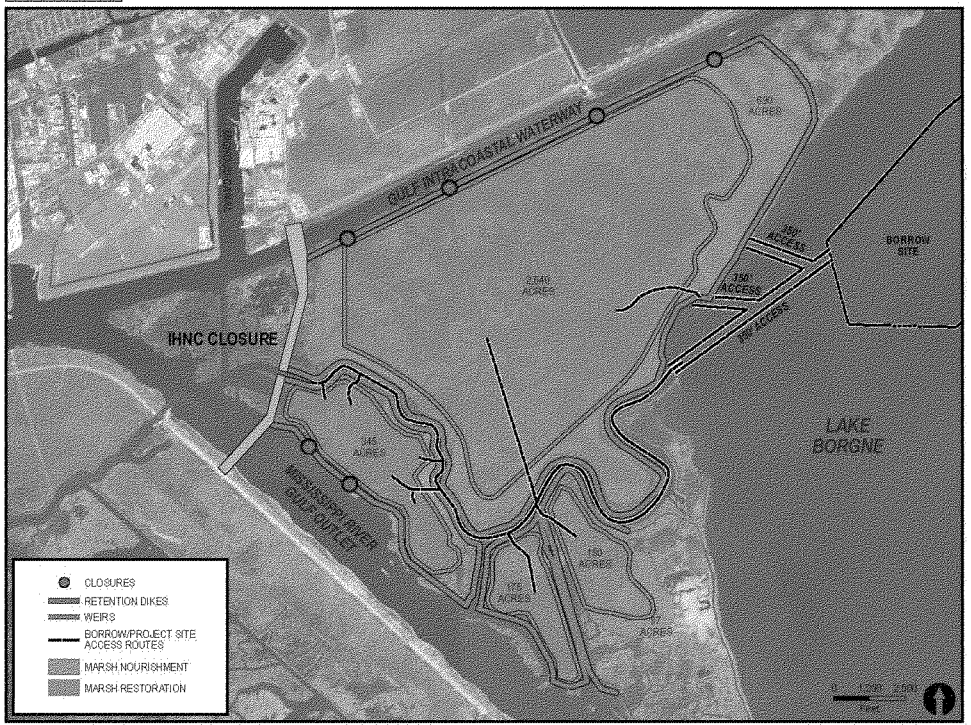
3: Borrow would be obtained from Lake Borgne. It is estimated that the Borrow Pit #9 would provide approximately 11.5 million cubic yards of the estimated material required for this marsh creation feature.

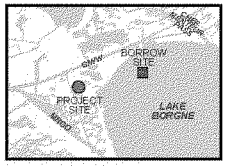
4: Access for dredge pipeline and dike construction equipment would be via access corridors depicted in the plan view, and/or via GIWW and Lake Borgne/Lake Pontchartrain.

Figure 28:

MISSISSIPPI RIVER GULF OUTLET (MRGO) ECOSYSTEM RESTORATION PLAN

Project Footprint Detail: LM1





Approximately 3,240 acres of proposed marsh creation and 777 acres of additional nourishment.

Approximately 13 million cubic yards of borrow would be required.

PROJECT NOTES:

1. Existing elevation within the marsh creation site is an average -0.5' and that adjacent marsh is approximately +1.5' (average). Approximately 3,240 acres of open water would be filled to an elevation conducive to marsh creation and nourishment, and approximately 777 acres of adjacent wetlands would be nourished.

2. Maximum slurry elevation would be +4.0' and effluent would be returned to Bayou Bienvenue via spill box weirs, the adjacent Pipeline Canal, the MRGO, or the GIWW. Retention dikes would be constructed from adjacent borrow with a minimum 2' freeboard (+6.0') to be maintained, minimum 9' crown width and slopes no steeper than 1 on 3 and minimum 40' interior berm. Closures would be constructed from either earthen borrow, and/or sheetpile or stone.

3. Borrow for the marsh creation/nourishment feature would be obtained from Lake Borgne Borrow Site #6. It is estimated that approximately 13 million cubic yards would be required for this marsh creation/nourishment feature, requiring approximately 825 acres. Thus, approximately 1,650 acres of borrow would have to be cleared for the marsh creation feature to account for possible cultural impacts, pipelines, wells, etc.

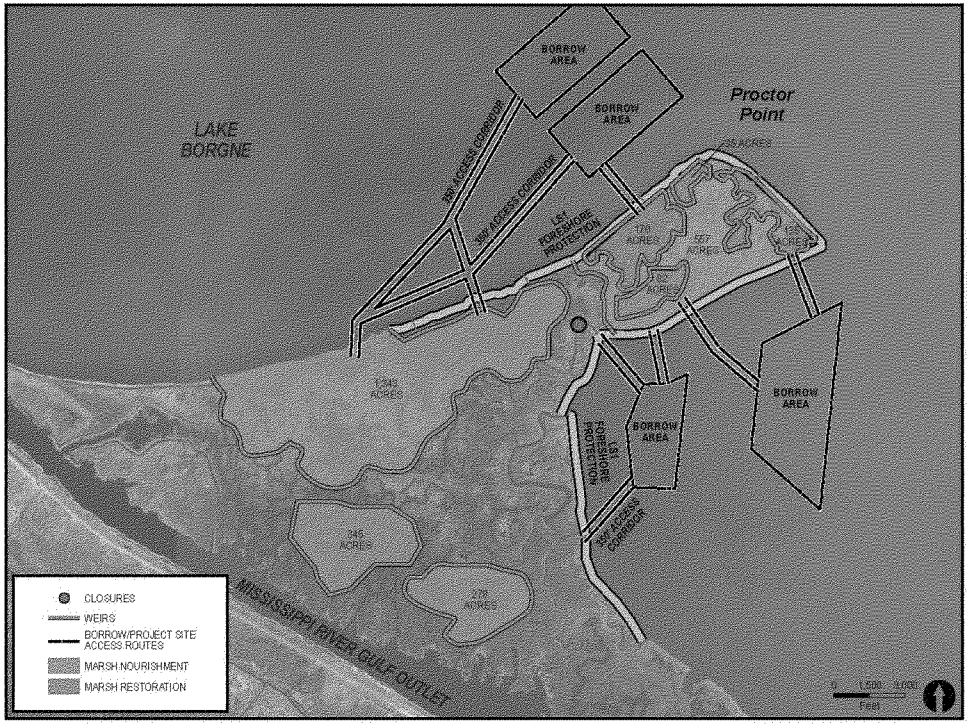
4. Access for dredge pipeline and dike construction equipment would be via access corridors depicted in the plan view, and/or via Bayou Bienvenue, existing pipeline canals, natural bayous, and Lake Borgne.

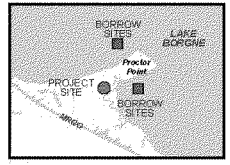
488

Figure 29:

MISSISSIPPI RIVER GULF OUTLET (MRGO) ECOSYSTEM RESTORATION PLAN

Project Footprint Detail: LM2 Foreshore Protection Detail: LS1





Approximately 422 acres of marsh restoration proposed with 2,524 additional acres nourished.

Approximately 8.9 miles of shoreline protection.

Approximately 4.9 million cubic yards of borrow material would be required.

PROJECT NOTES:

1. Feature 008 SP length is 47,114'.

2. Total impact footprint is approximately 275 acres.

3. Approximately 8 access corridors, 100' x 500' anticipated.

4. Approximately 7 fishdips / gaps anticipated at existing waterways.

5. Assume existing elevation within the marsh creation site is an average -0.5' and that adjacent marsh is approx +1.5' (avg). Figure that approx 422 acres of open water will be filled to an elevation conducive to marsh creation.

6. Maximum slurry elevation will be +4.0', and effluent will be discharged immediately south of the proposed marsh creation sites.

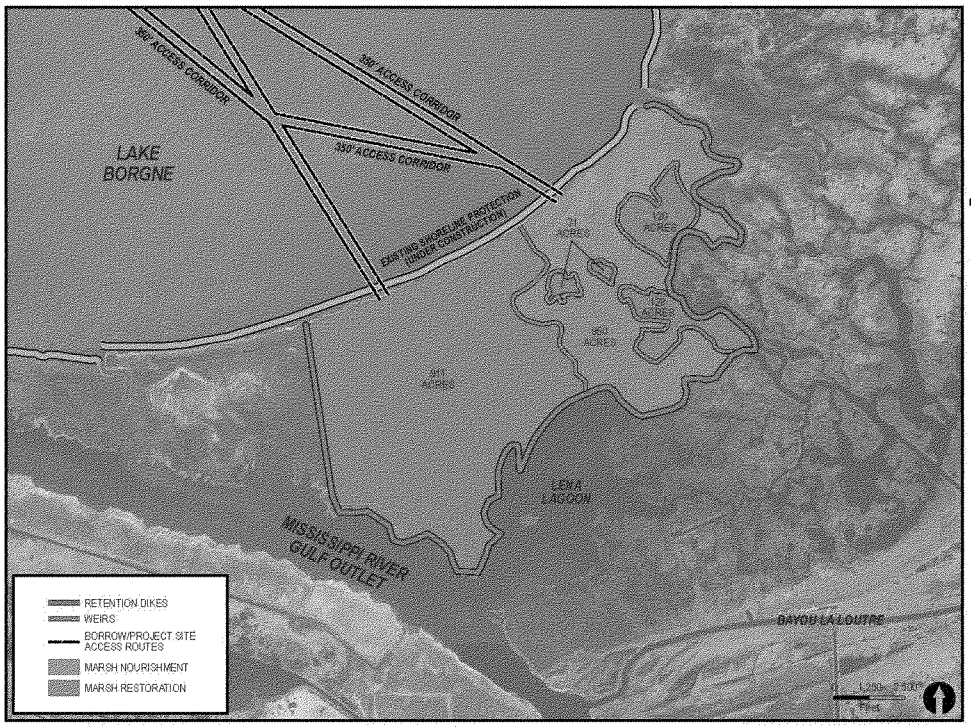
7. Borrow will be obtained from Lake Borgne Borrow Area no. 3 and/or Borrow Area no. 4. It is estimated that approx 4.9 million cyds. of borrow will be required for this marsh creation feature, and that approx 807 acres of borrow will need to be cleared.

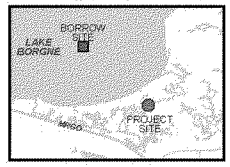
8. Access for dredge pipeline shall be via access corridors depicted in the plan view and/or MRGO/GIWW.

Figure 30:

MISSISSIPPI RIVER GULF OUTLET (MRGO) ECOSYSTEM RESTORATION PLAN

Project Footprint Detail: LM3





Approximately 911 acres of marsh restoration with an additional 950 acres of marsh nourishment.

Approximately 4.6 million cubic yards of borrow would be required.

PROJECT NOTES:

1. Existing elevation within the marsh creation site is an average -0.5' and the adjacent marsh is approximately +1.5' (average). Approximately 911 acres of open water would be filled to an elevation conducive to marsh creation, and an additional 950 acres of existing marsh would be nourished. Either the Lake Borgne rim and/or proposed foreshore would be in place to serve as retention for dredge material along the Lake Borgne shoreline area. Thus, it is possible that additional retention dikes would be required along Lake Borgne.

2. Maximum slurry elevation would be +4.0' and effluent would be returned to Bayou Bienvenue via spill box weirs, or if possible, discharged immediately south of the proposed marsh creation site. Retention dikes would be from adjacent borrow with a 2' freeboard (+6.0') to be maintained, minimum 5' crown width and slopes no steeper than 1 on 3 and minimum 40' interior berm.

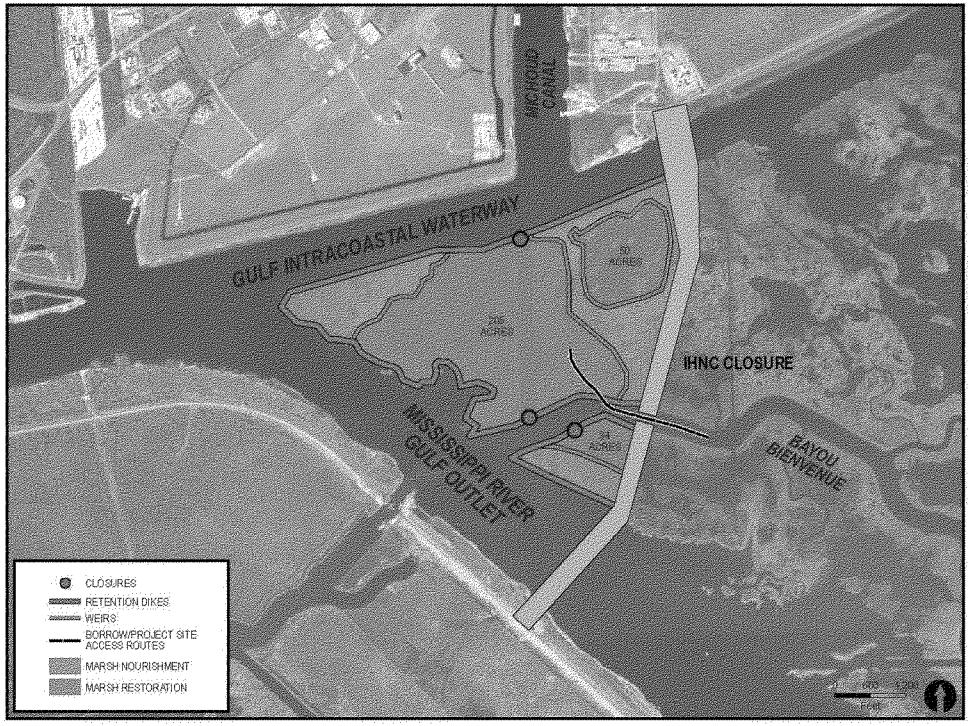
3. Borrow would be obtained from Lake Borgne Borrow Site #2. It is estimated that approximately 4.6 million cubic yards would be required for this marsh creation/nourishment feature, requiring approximately 295 acres. Thus, approximately 590 acres of borrow would have to be cleared for the marsh creation/nourishment feature to account for possible cultural impacts, pipelines, wells, etc.

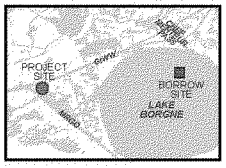
4. Access for dredge pipeline and dike construction equipment would be via access corridors depicted in the plan view and via the GIWW/MRGO and/or Lake Borgne.

Figure 31:

MISSISSIPPI RIVER GULF OUTLET (MRGO) ECOSYSTEM RESTORATION PLAN

Project Footprint Detail: LM4





Approximately 289 acres of proposed marsh creation with an additional 95 acres of marsh nourishment.

Approximately 1.35 million cubic yards of borrow material would be required.

PROJECT NOTES:

1. Existing elevation within the marsh creation site is an average -0.5' and the adjacent marsh is approximately +1.5' (average). Approximately 289 acres of open water would be filled to an elevation conducive to marsh creation; and approximately 95 acres of adjacent wetlands would be nourished.

2. Maximum slurry elevation would be +4.0' and effluent would be returned to Bayou Bienvenue via spill box weirs, or if possible, discharged into the MRGO, adjacent to the proposed marsh creation site . Retention dikes would be from adjacent borrow with a 2' freeboard (+6.0') to be maintained, minimum 9' crown width and slopes no steeper than 1 on 3 and minimum 40' interior berm; and a low level weir along the MRGO.

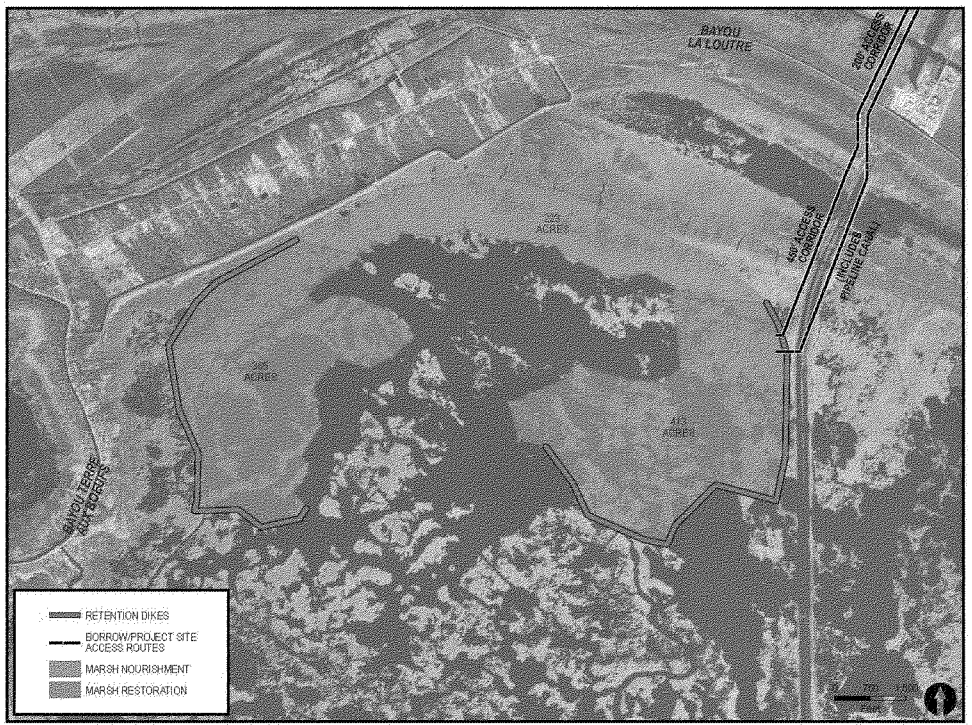
3. Borrow would be obtained from Lake Borgne Borrow Site #6. It is estimated that approximately 1.35 million cubic yards would be required for this marsh creation/nourishment feature, requiring approximately 90 acres. Thus, approximately 180 acres of borrow would have to be cleared for the marsh creation/nourishment feature to account for possible cultural impacts, pipelines, wells, etc.

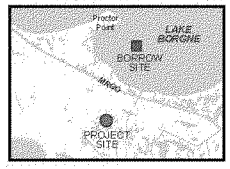
4. Access for dredge pipeline and dike construction equipment would be via access corridors depicted in the plan view and/or via Bayou Bienvenue, as well as MRGO/GIWW and Lake Borgne.

Figure 32:

MISSISSIPPI RIVER GULF OUTLET (MRGO) ECOSYSTEM RESTORATION PLAN

Project Footprint Detail: TM1





Approximately 760 acres of proposed marsh restoration with an additonal 223 acres of marsh nourishment.

Approximately 3.2 million cubic yards of borrow material would be required.

PROJECT NOTES:

1. Existing elevation within the marsh creation site is an average elevation of -0.5 and the adjacent marsh (to be re-nourished) is approximately +1.5. (average). The two marsh creation sites depicted area include approximately 760 acres of open water. An additional 223 acres with an average existing elevation of 1.5' to be re-nourished to approximately 2.5'.

2. Maximum slurry elevation in the three marsh restoration sites would be +4.0 and the effluent would be allowed to overflow interior dikes to nourish the remaining area within the perimeter.

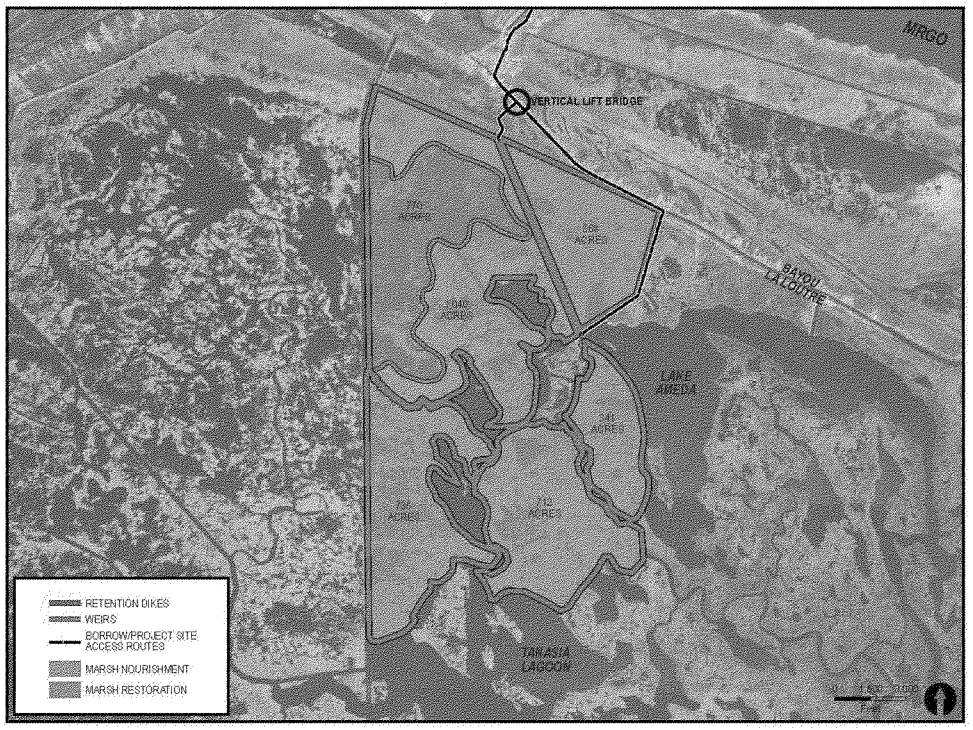
3. Borrow for marsh creation and nourishment would be obtained from Lake Borgne Borrow Site #2. It is estimated that the borrow pit would need to provide approximately 3.2 million cubic yards; requiring approximately 200 acres of borrow. Thus, approx 400 acres of actual borrow would have to be cleared.

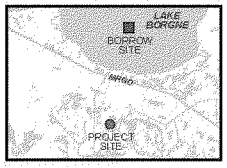
4. Retention dikes and weirs would be from adjacent borrow, and would be approximately +6' and +4' respectively, including 2' free board. Crown widths would be a minimum of 5' and slopes no steeper than 1 on 3 and a minimum of 40'. Interior berm would be maintained between the toe of the dikes/weirs and inside borrow.

Figure 33:

MISSISSIPPI RIVER GULF OUTLET (MRGO) ECOSYSTEM RESTORATION PLAN

Project Footprint Detail: TM2





Approximately 770 acres of proposed marsh restoration with an additional 3,400 acres to be re-nourished.

Approximately 7.4 million cubic yards of borrow material would be required.

PROJECT NOTES:

1. Existing elevation within the marsh creation site is an average -0.5' and that adjacent marsh is approximately +1.5' (average). Approximately 770 acres of open water would be filled to an elevation conducive to marsh creation; and approximately 3,400 acres would be nourished.

2. Maximum slurry elevation would be +4.0', and effluent would be returned to Bayou Bienvenue via spill box weirs, or if possible, discharged immediately south of the proposed marsh creation site. Retention dikes would be from adjacent borrow with a 2' freeboard (+6.0') to be maintained, minimum 5' crown width and slopes no steeper than 1 on 3 and minimum 40' interior berm.

3. Borrow will be obtained from Lake Borgne Borrow Pit #2. It is estimated that the borrow pit would need to provide approximately 7.4 million cubic yards of material required for this marsh creation feature, requiring approximately 460 acres of borrow. Thus, approximately 920 acres of actual borrow would have to be cleared for this marsh creation feature.

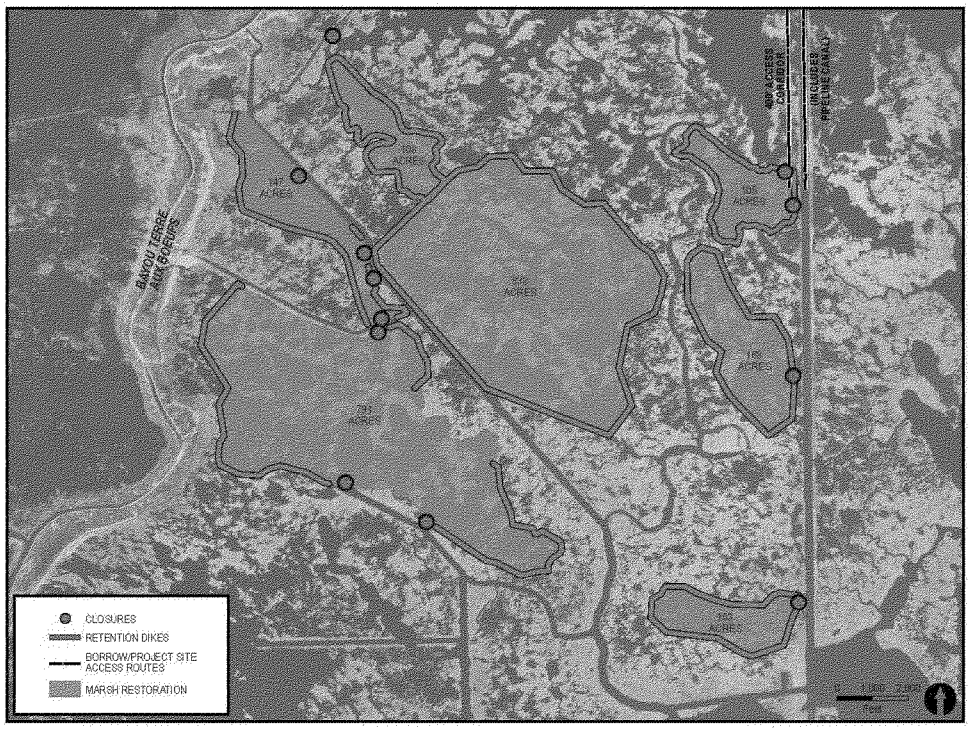
4. Access for dredge pipeline and dike construction equipment would be via access corridors depicted in the plan view and MRGO.

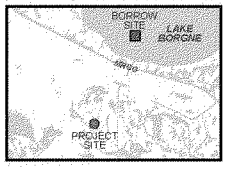
493

Figure 34:

MISSISSIPPI RIVER GULF OUTLET (MRGO) ECOSYSTEM RESTORATION PLAN

Project Footprint Detail: TM7





Approximately 2,255 acres of proposed marsh creation.

Approximately 8.1 million cubic yards of borrow material would be required.

PROJECT NOTES:

1. Existing elevation within the marsh creation sites is an average of -0.5'. The surrounding marsh is approximately +1.5 (average). Approximately 2,255 acres would be filled to an elevation conducive to marsh creation.

2. Maximum slurry elevation would be +4.0' and effluent discharge would overflow onto the surrounding marsh for re-nourishment.

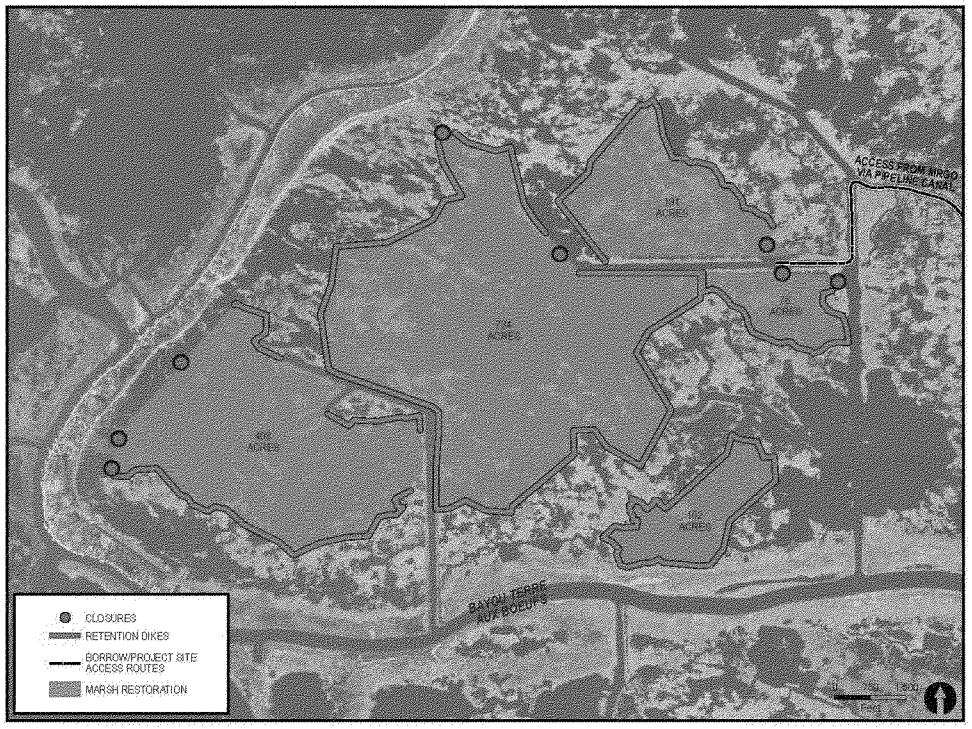
3. Retention dikes would be built from adjacent borrow and built to +8.0' (maintained) to allow for 2' of freeboard. The dikes would have a minimum crown width of 5' and slopes no steeper than 1 on 3 and minimum 40' interior berm for stability.

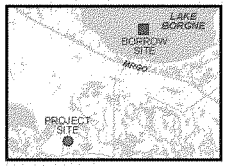
4. Marsh creation borrow would be from Lake Borgne Borrow Site #2. It is estimated that the borrow pit would provide approximately 8,100,000 cubic yards required for this marsh creation as depicted, and an additional 4,500,000 cubic yards for re-nourishment.

5. Access for equipment and dredge pipeline would be through existing pipeline canals.

Figure 35:

MISSISSIPPI RIVER GULF OUTLET (MRGO) ECOSYSTEM RESTORATION PLAN
Project Footprint Detail: TM8





Approximately 1,511 acres of proposed marsh restoration.

Approximately 5.5 million cubic yards of borrow material would be required.

PROJECT NOTES:

1. Existing elevation within the marsh creation sites is an average of -0.5' and the surrounding marsh is approximately +1.5 (average). Approximately 1,511 acres would be filled to an elevation conducive to marsh creation.

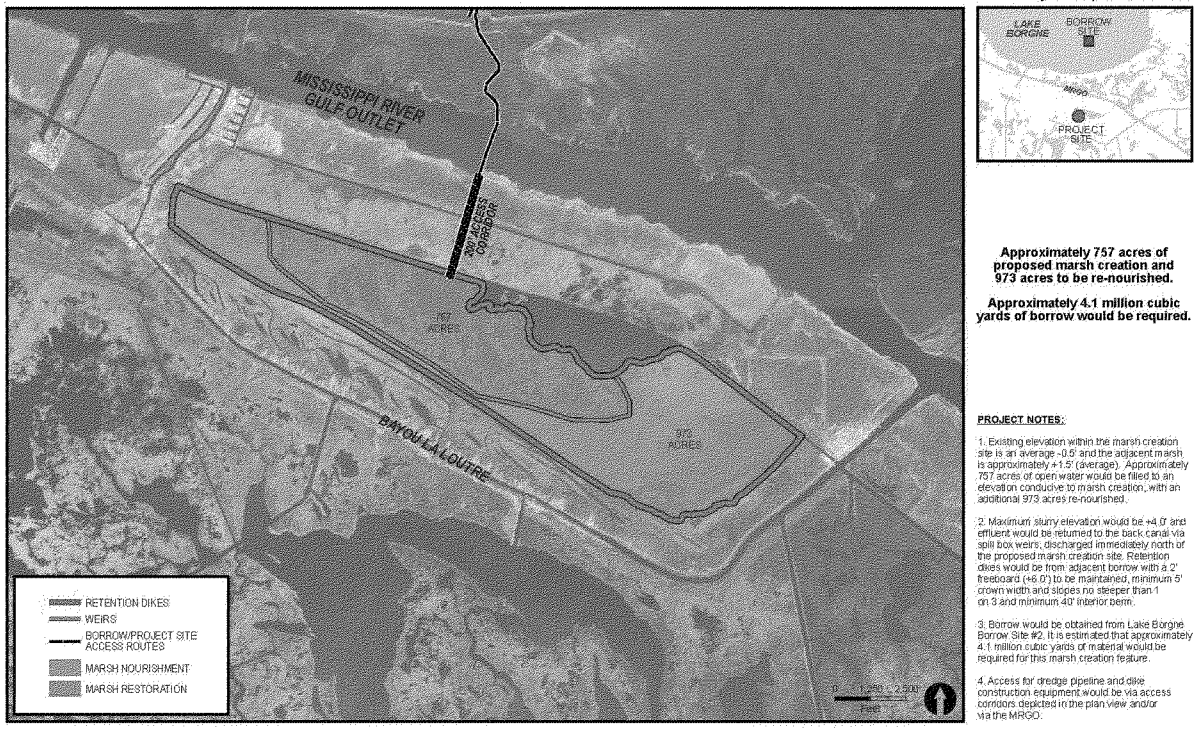
2. Maximum slurry elevation would be +4.0' and effluent discharge would overflow onto the surrounding marsh for re-nourishment.

3. Marsh creation borrow would be from Lake Borgne Borrow Site #2. It is estimated that the borrow pit would provide approximately 5,500,000 cubic yards required for this marsh creation as depicted. Average pumping distance to site from Lake Borgne Borrow Site #2 is approximately 10 miles.

4. Access for equipment and dredge pipeline would be through existing pipeline canals and specified access corridors, as well as local, state, and public highways.

Figure 36:

MISSISSIPPI RIVER GULF OUTLET (MRGO) ECOSYSTEM RESTORATION PLAN
Project Footprint Detail: HM1



Approximately 757 acres of proposed marsh creation and 973 acres to be re-nourished.

Approximately 4.1 million cubic yards of borrow would be required.

PROJECT NOTES:

1. Existing elevation within the marsh creation site is an average -0.5' and the adjacent marsh is approximately +1.5' (average). Approximately 757 acres of open water would be filled to an elevation conducive to marsh creation, with an additional 973 acres re-nourished.

2. Maximum slurry elevation would be +4.0' and effluent would be returned to the back canal via spill box weirs; discharged immediately north of the proposed marsh creation site. Retention dikes would be from adjacent borrow with a 2' freeboard (+6.0') to be maintained, minimum 5' crown width and slopes no steeper than 1 on 3 and minimum 40' interior berm.

3. Borrow would be obtained from Lake Borgne Borrow Site #2. It is estimated that approximately 4.1 million cubic yards of material would be required for this marsh creation feature.

4. Access for dredge pipeline and dike construction equipment would be via access corridors depicted in the plan view and/or via the MRGO.

Figure 37:

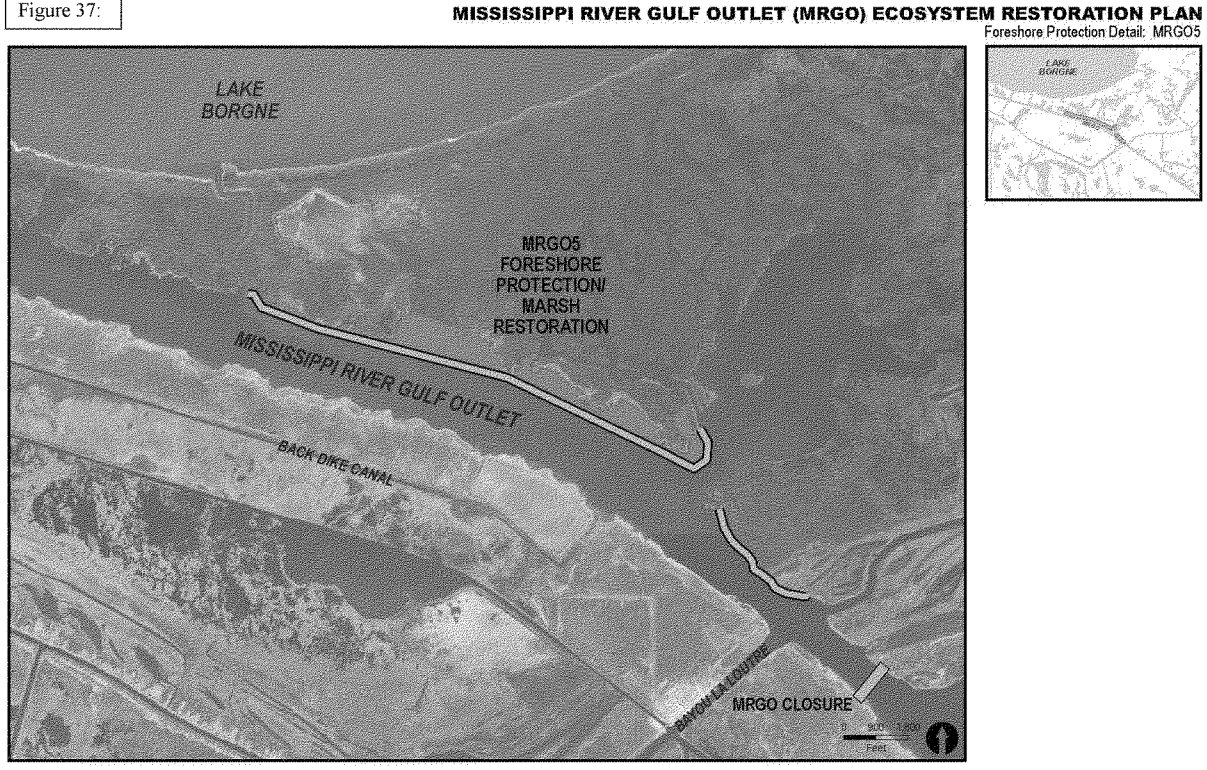

MISSISSIPPI RIVER GULF OUTLET (MRGO) ECOSYSTEM RESTORATION PLAN
Foreshore Protection Detail: MRGO5
LAKE BORGNE
MRGO5 FORESHORE PROTECTION/ MARSH RESTORATION
MISSISSIPPI RIVER GULF OUTLET
BACK DIKE CANAL
BAYOU LA LOUTRE
MRGO CLOSURE
0 900 1,800
Feet

Figure 38:

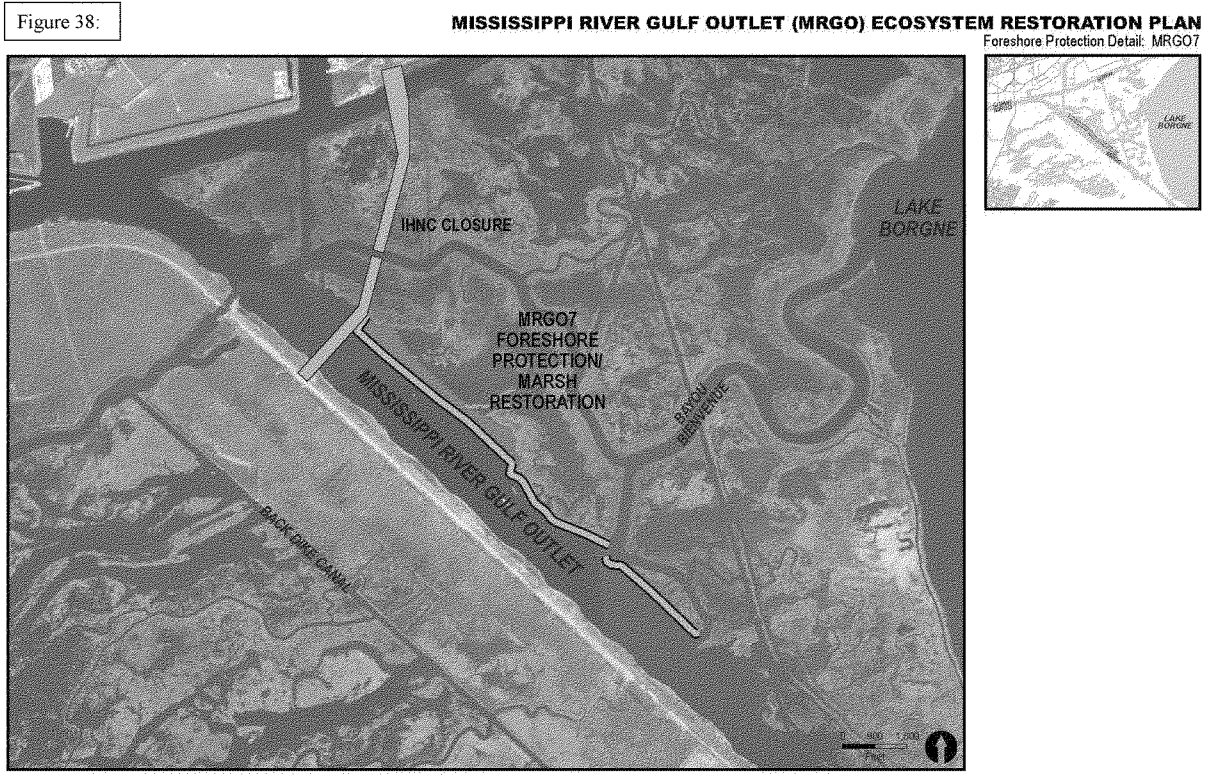

MISSISSIPPI RIVER GULF OUTLET (MRGO) ECOSYSTEM RESTORATION PLAN
Foreshore Protection Detail: MRGO7
LAKE BORGNE
IHNC CLOSURE
LAKE BORGNE
MRGO7 FORESHORE PROTECTION/ MARSH RESTORATION
BAYOU BIENVENUE
MISSISSIPPI RIVER GULF OUTLET
BACK DIKE CANAL

Figure 39:

MISSISSIPPI RIVER GULF OUTLET (MRGO) ECOSYSTEM RESTORATION PLAN

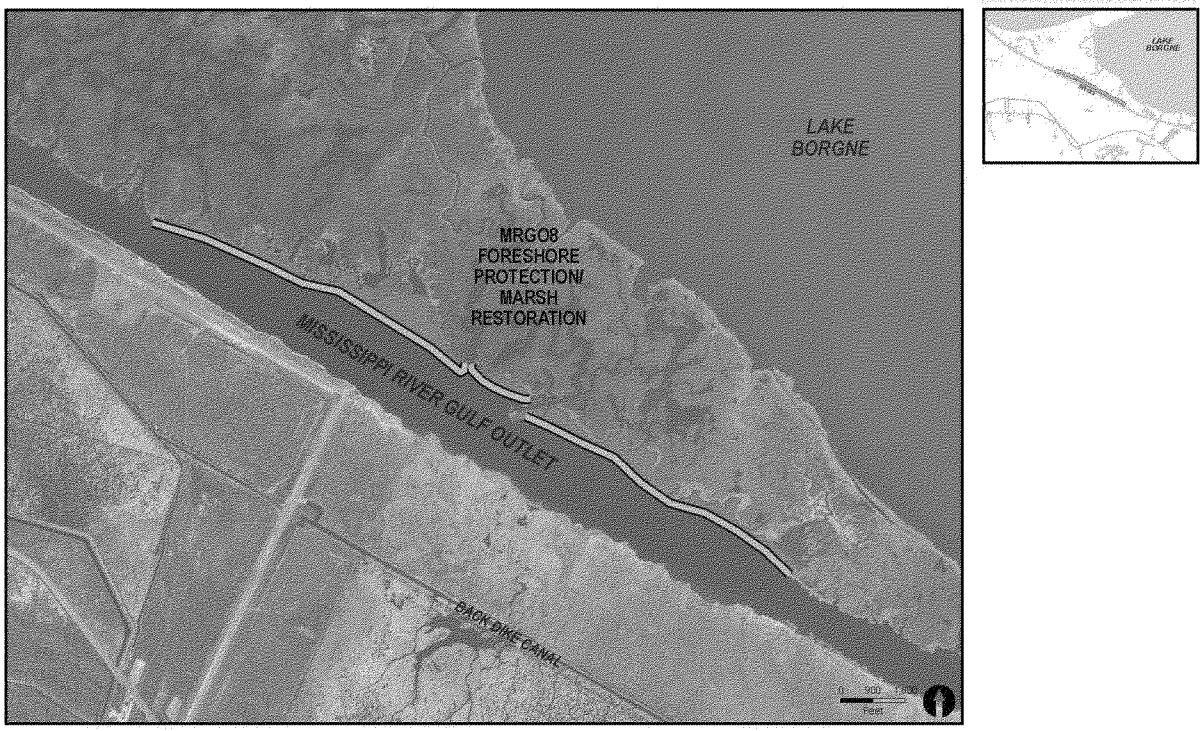


Figure 40:

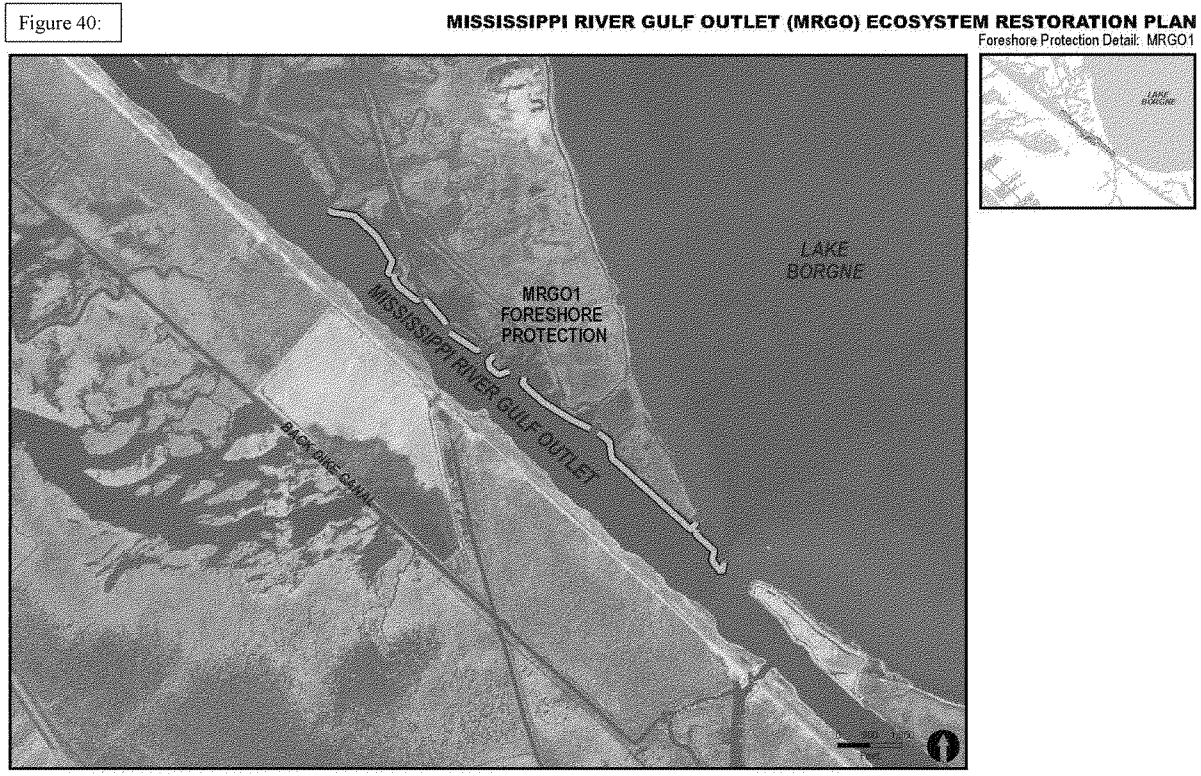

MISSISSIPPI RIVER GULF OUTLET (MRGO) ECOSYSTEM RESTORATION PLAN
Foreshore Protection Detail: MRGO1
LAKE BORGNE
MRGO1 FORESHORE PROTECTION
MISSISSIPPI RIVER GULF OUTLET
BACK BAR CANAL
LAKE BORGNE

Figure 41:

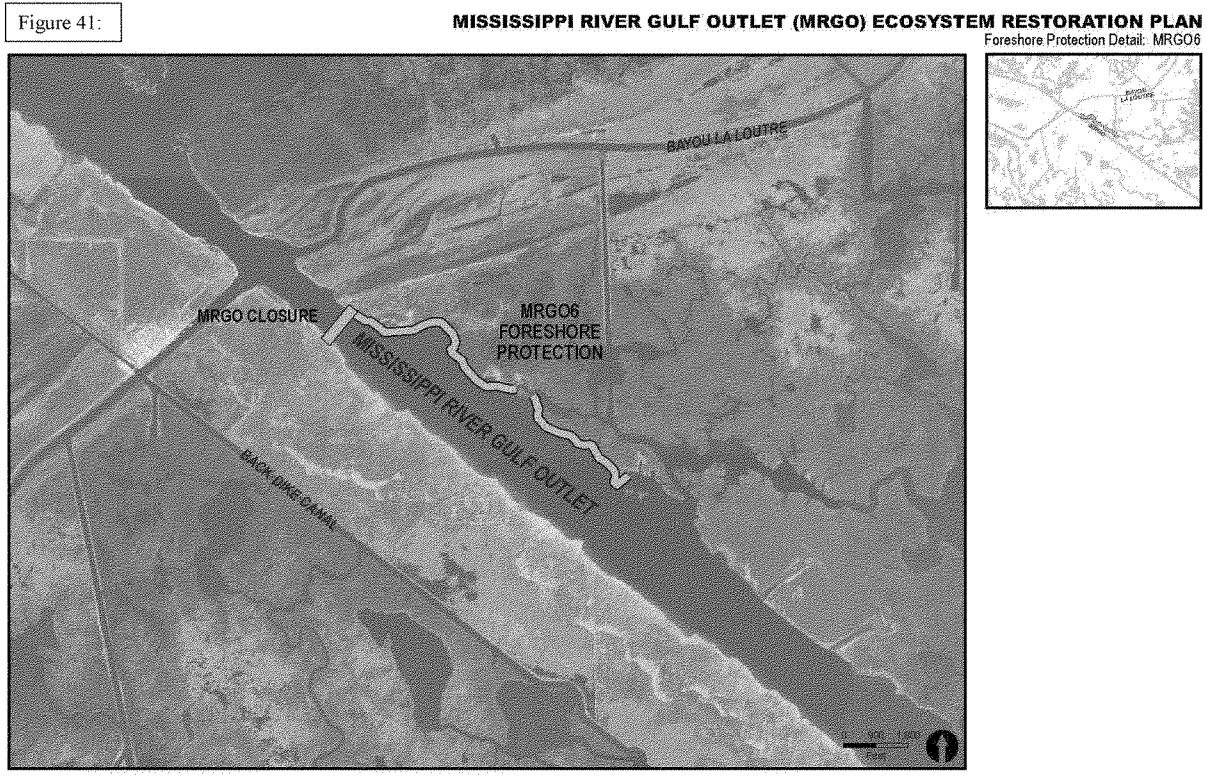

MISSISSIPPI RIVER GULF OUTLET (MRGO) ECOSYSTEM RESTORATION PLAN
Foreshore Protection Detail: MRGO6
BAYOU LA LOUTRE
MRGO CLOSURE
MRGO6
FORESHORE
PROTECTION
MISSISSIPPI RIVER GULF OUTLET
BACK DIKE CANAL

Figure 42:

MISSISSIPPI RIVER GULF OUTLET (MRGO) ECOSYSTEM RESTORATION PLAN

Foreshore Protection Detail: MRGO2

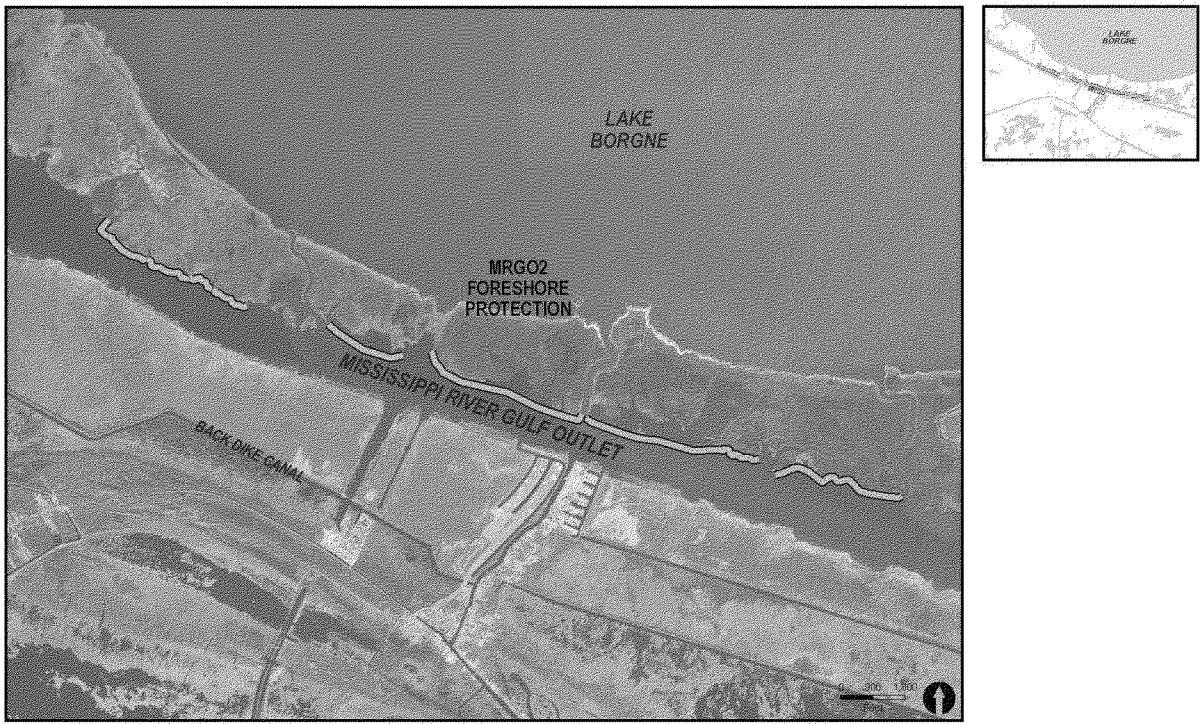


Figure 43:

MISSISSIPPI RIVER GULF OUTLET (MRGO) ECOSYSTEM RESTORATION PLAN

Foreshore Protection Detail: MRGO3

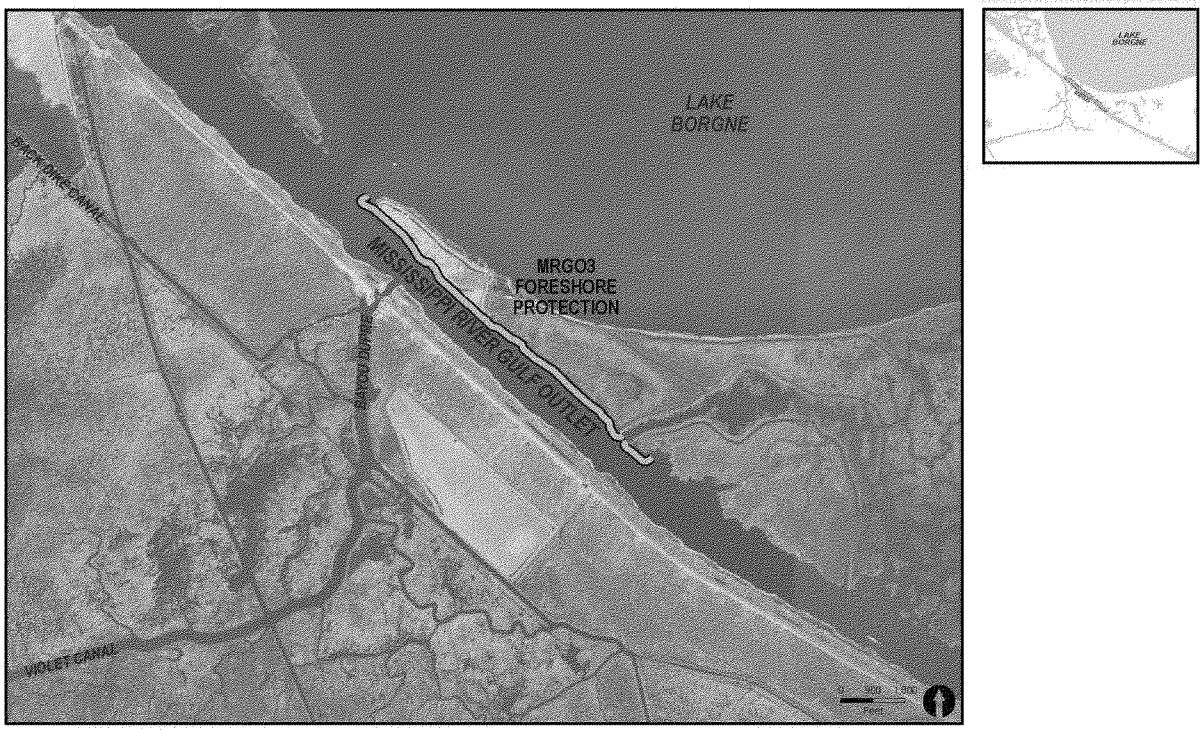
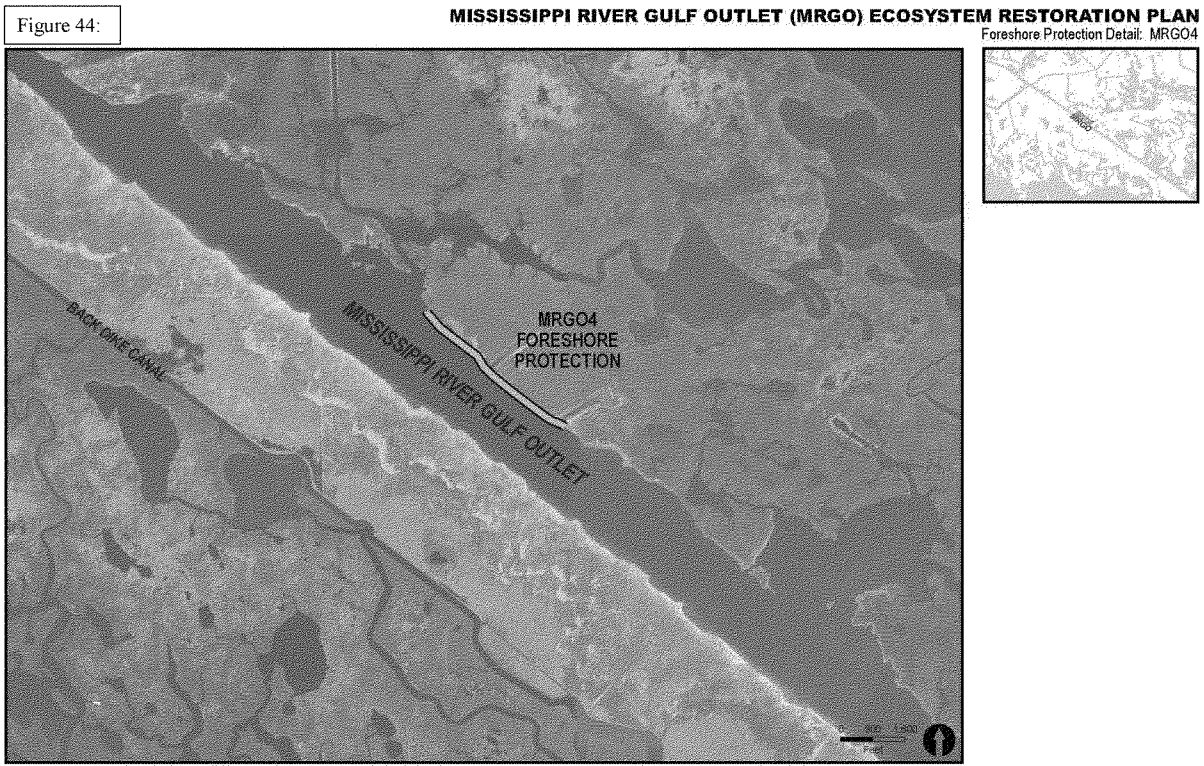
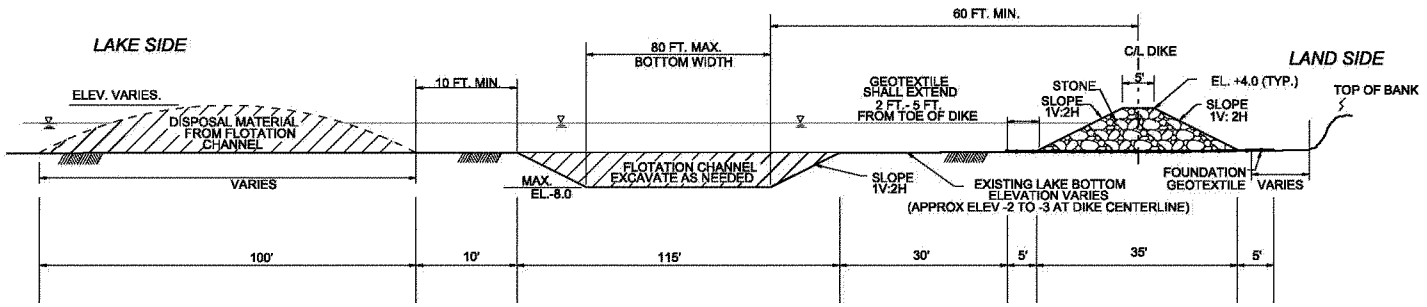


Figure 44:


MISSISSIPPI RIVER GULF OUTLET (MRGO) ECOSYSTEM RESTORATION PLAN
Foreshore Protection Detail: MRGO4
MRGO
BACK DIKE CANAL
MISSISSIPPI RIVER GULF OUTLET
MRGO4
FORESHORE
PROTECTION



THEORETICAL OFFSHORE DIKE SECTION WITH FLOTATION CHANNEL AND LAKE SIDE DISPOSAL

NOTE: FOR REACH WHERE FLOTATION MATERIAL IS TO BE PLACED LAKESIDE OF DIKE, SPOIL SHALL BE BACKFILLED UPON COMPLETION OF PROJECT.

Figure 45: Flotation Access Footprints

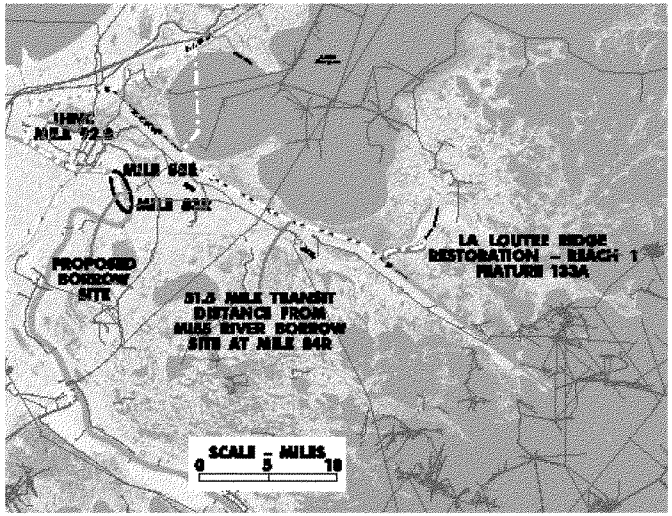


Figure 46: Barge route for delivery of MR sediment to feature BR1



Figure 47: USGS and NOAA Sand Survey For Lake Pontchartrain and Lake Borgne

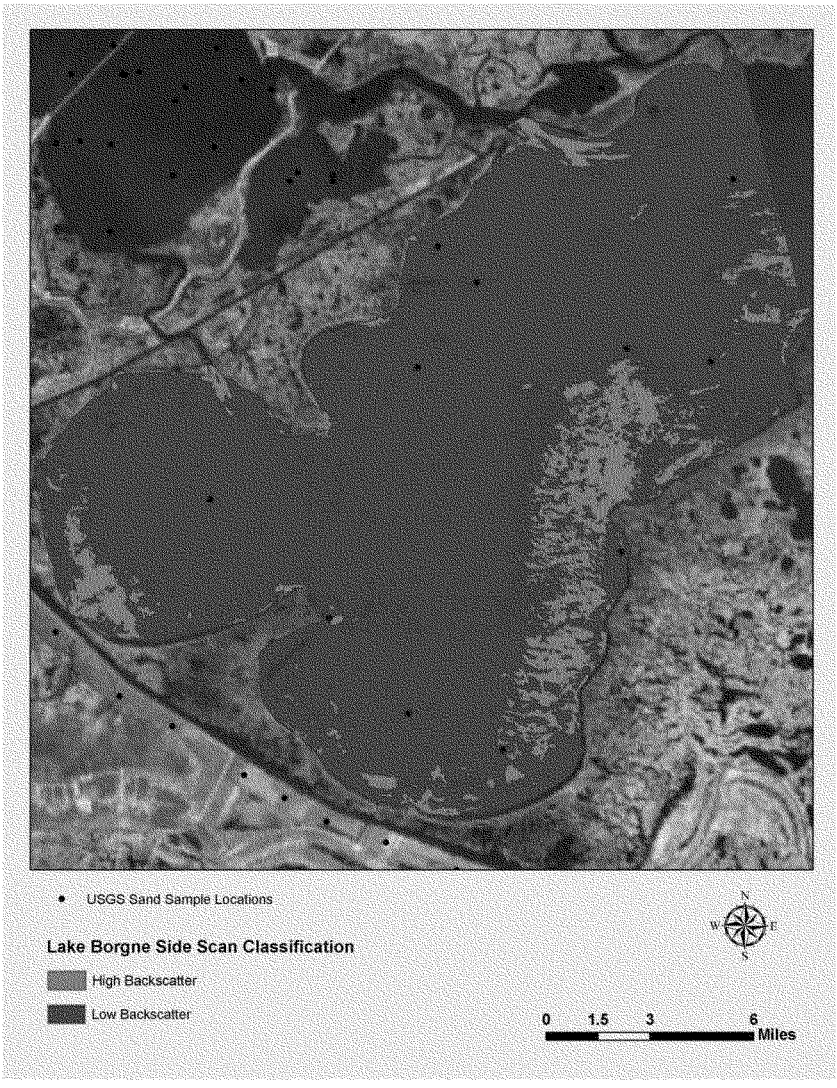


Figure 48: USGS Sand Survey For Lake Borgne

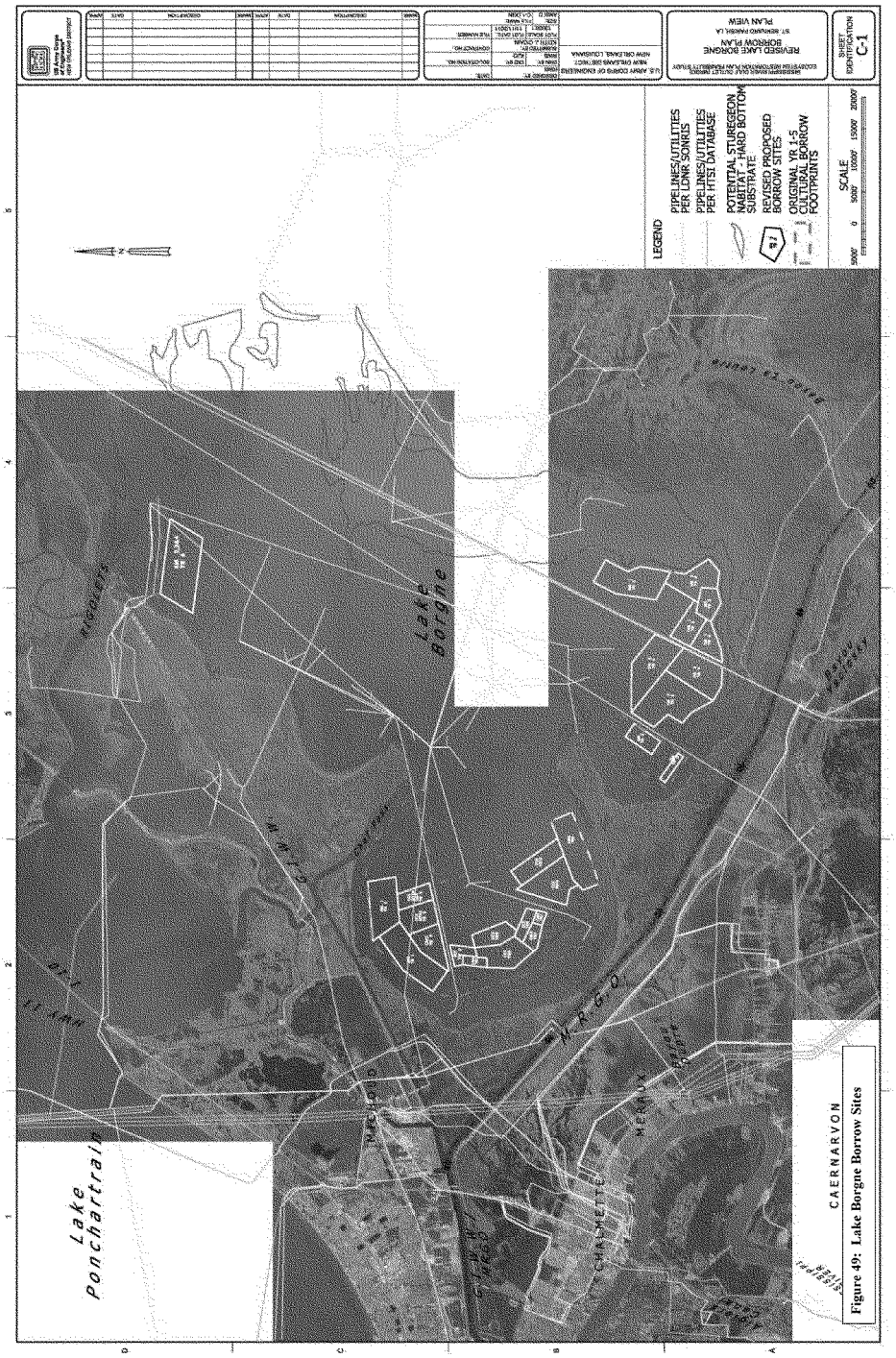


Figure 49: Lake Borgne Borrow Sites

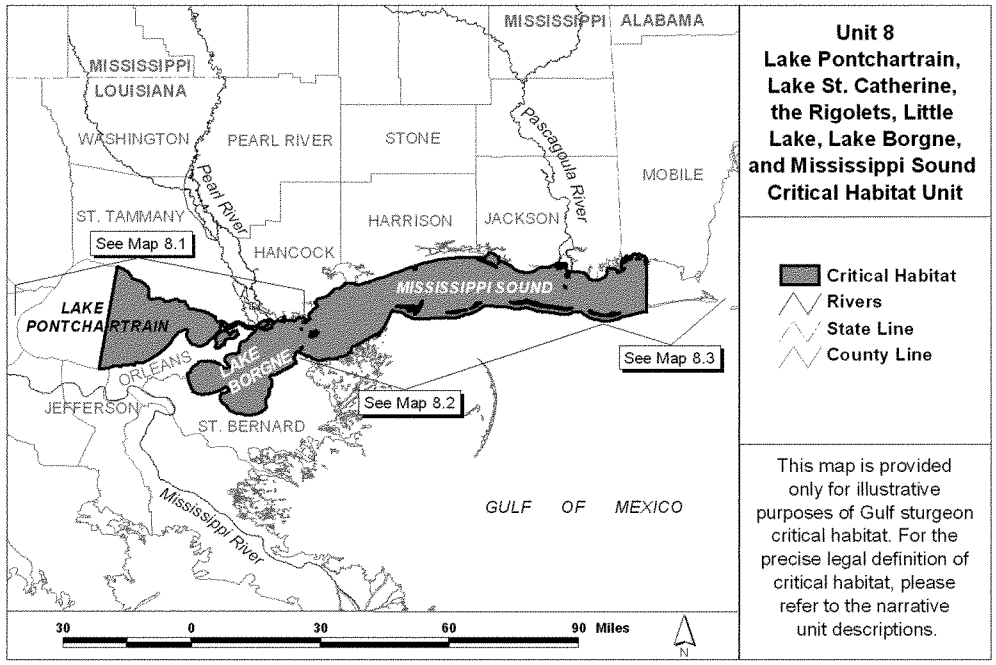


Figure 50: Louisiana Estuarine Critical Habitat

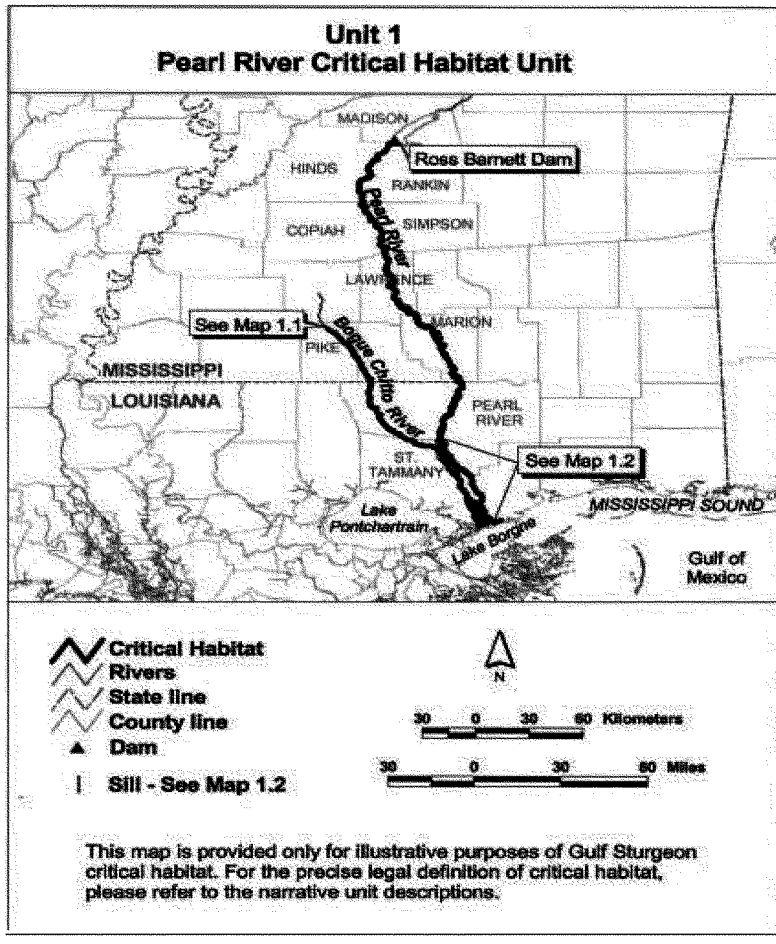


Figure 51. Louisiana Riverine Critical Habitat

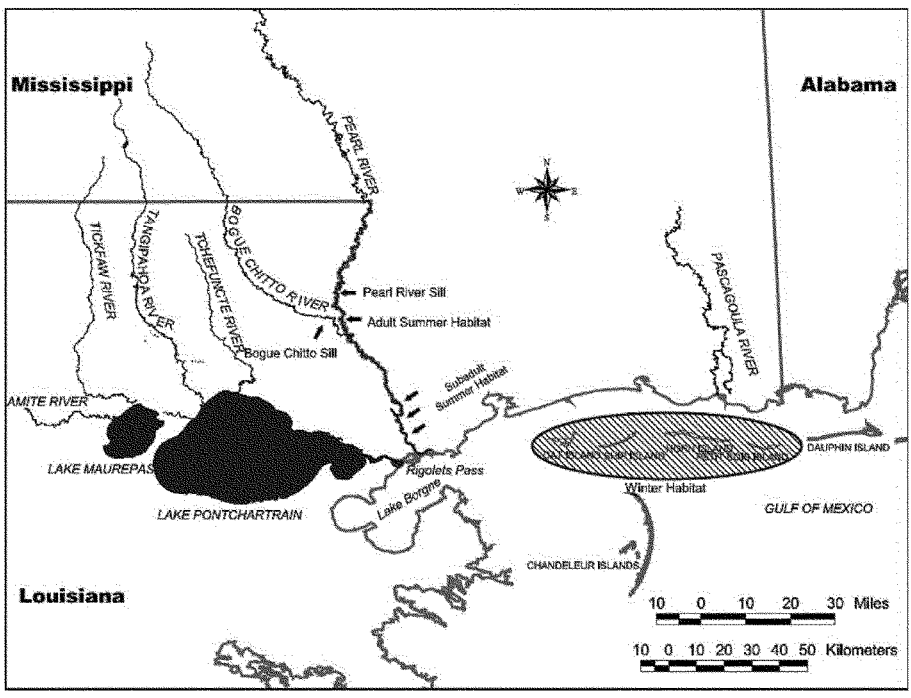


Figure 52: Pearl River Impediments to Gulf sturgeon migration

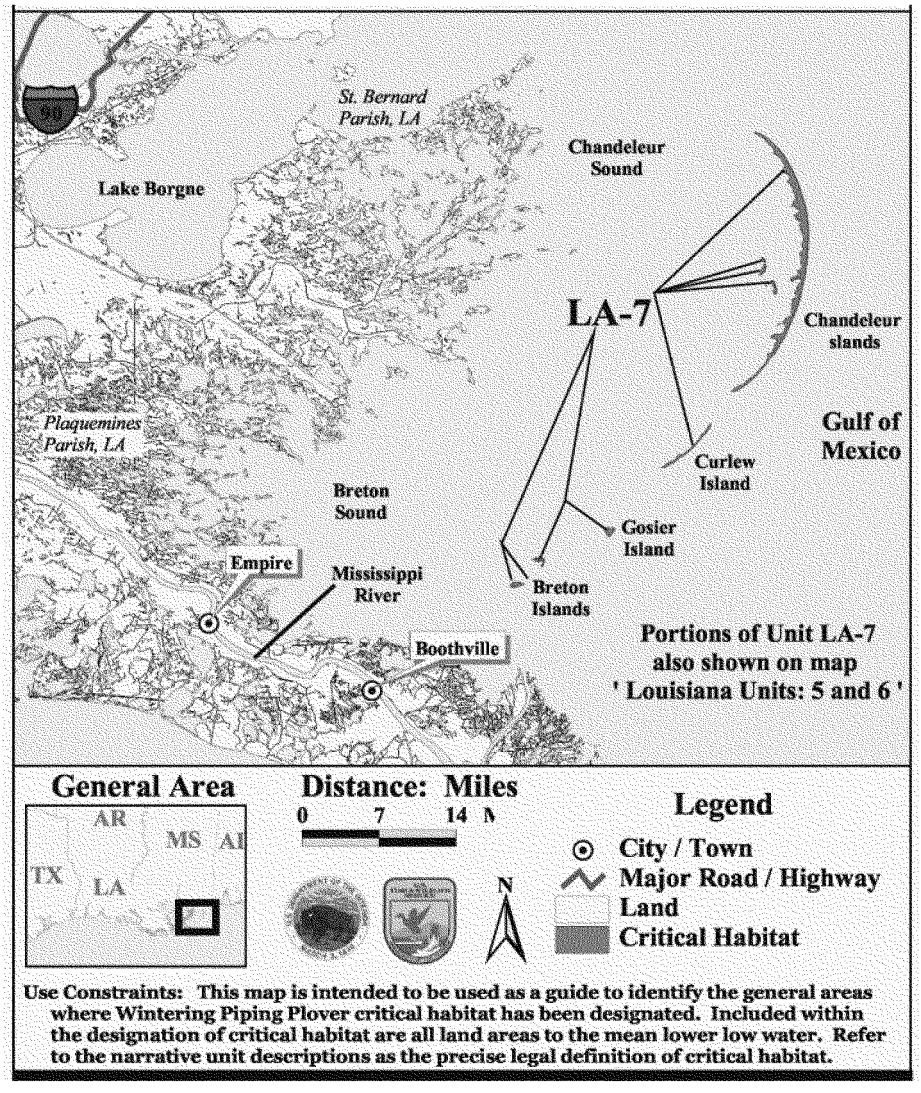


Figure 53: Unit LA-7 of Piping Plover Critical Habitat

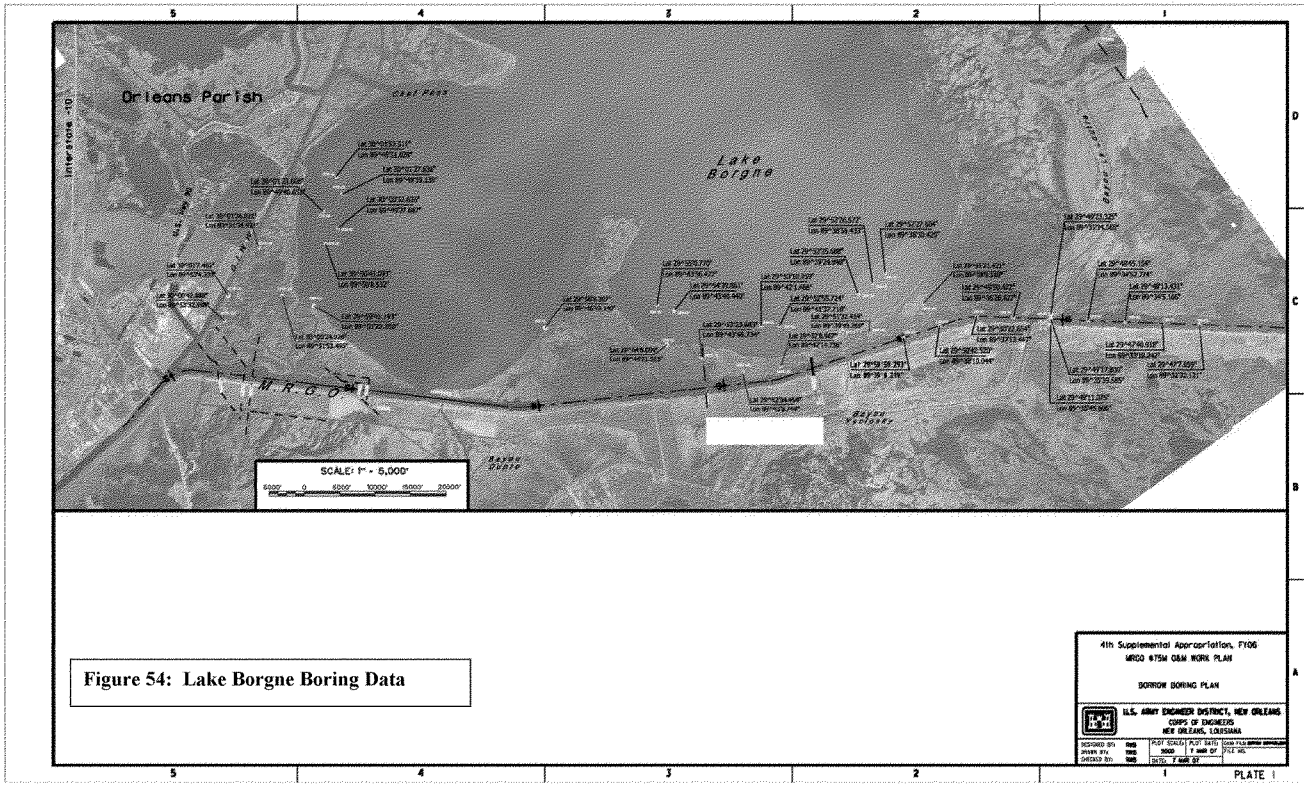


Figure 54: Lake Borgne Boring Data



Figure 55: Lake Borgne Boring Data

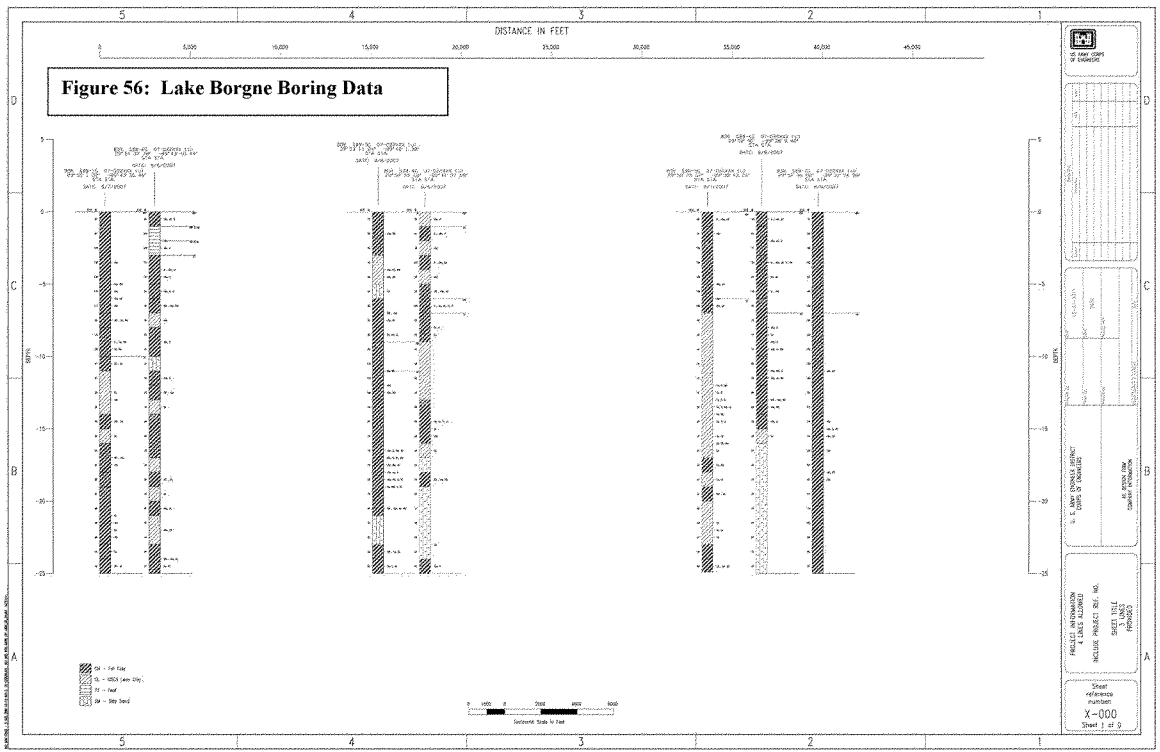


Figure 56: Lake Borgne Boring Data

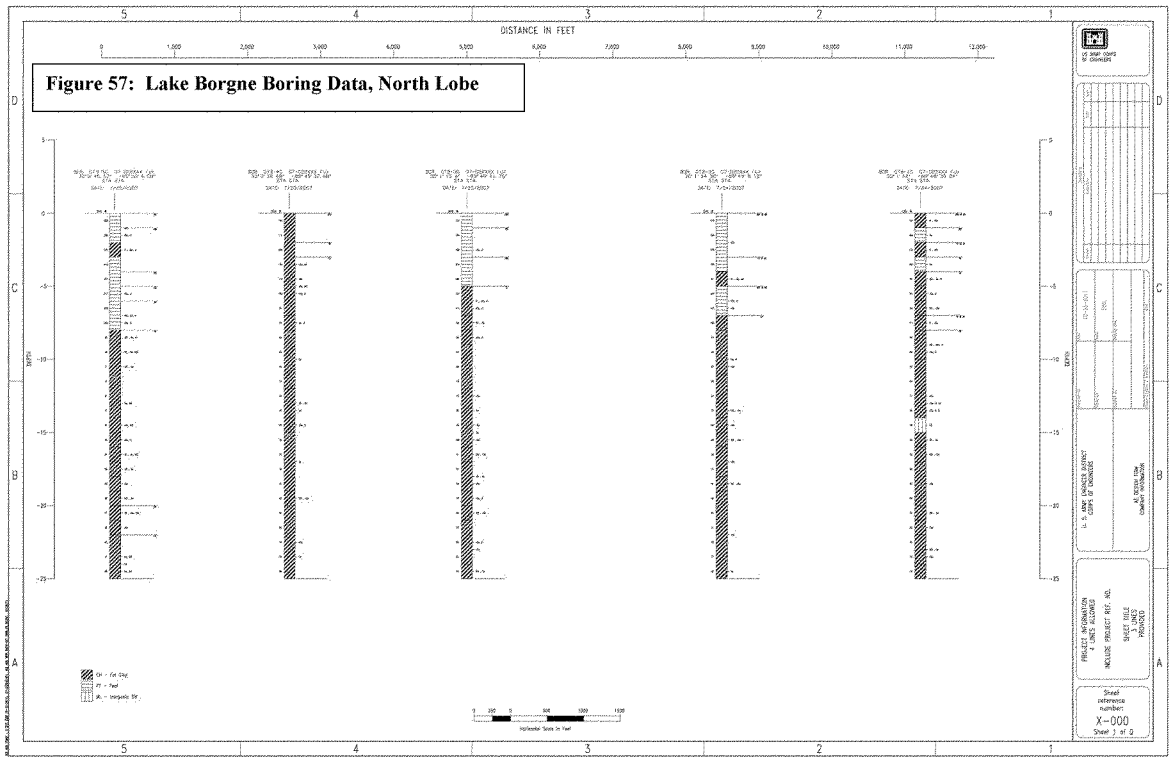


Figure 57: Lake Borgne Boring Data, North Lobe

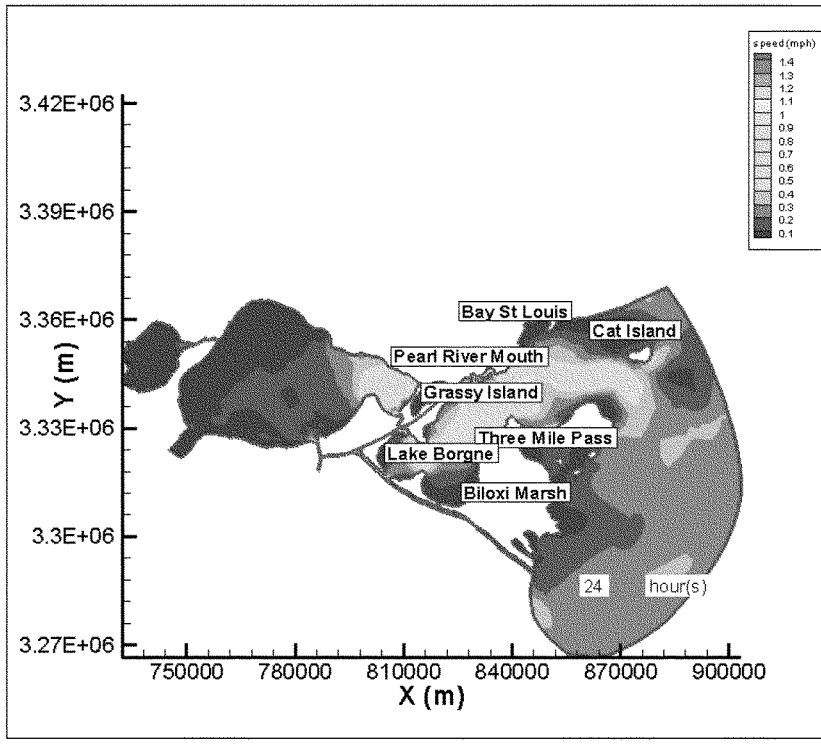


Figure 58: Lake Borgne Tidal Circulation

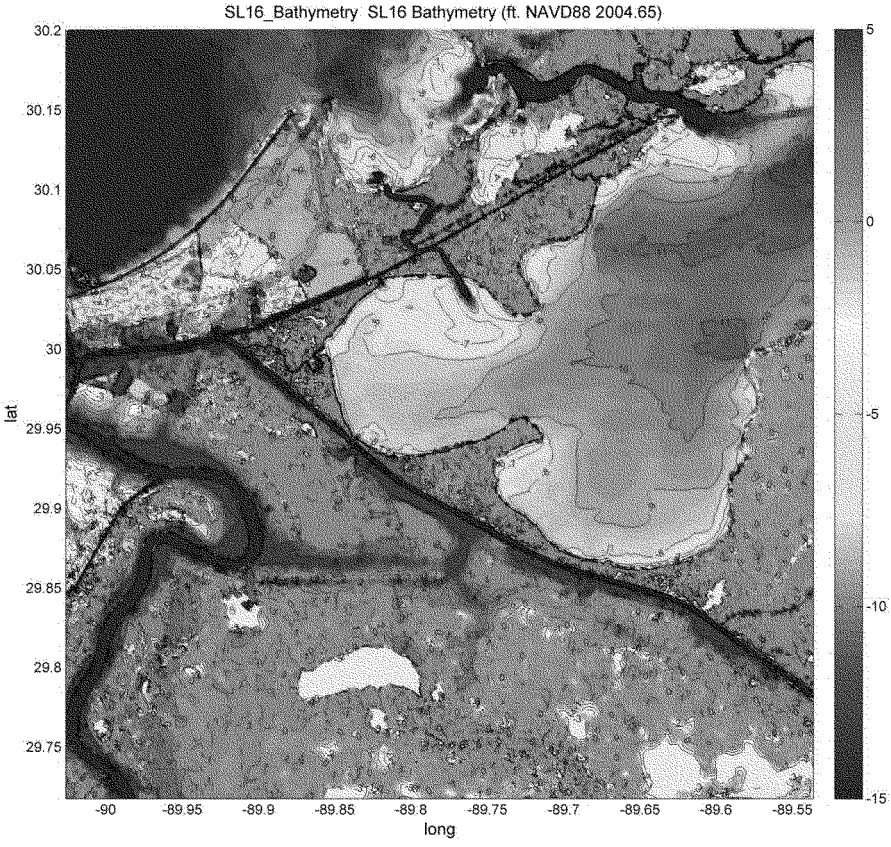


Figure 59: Lake Borgne Bathymetry

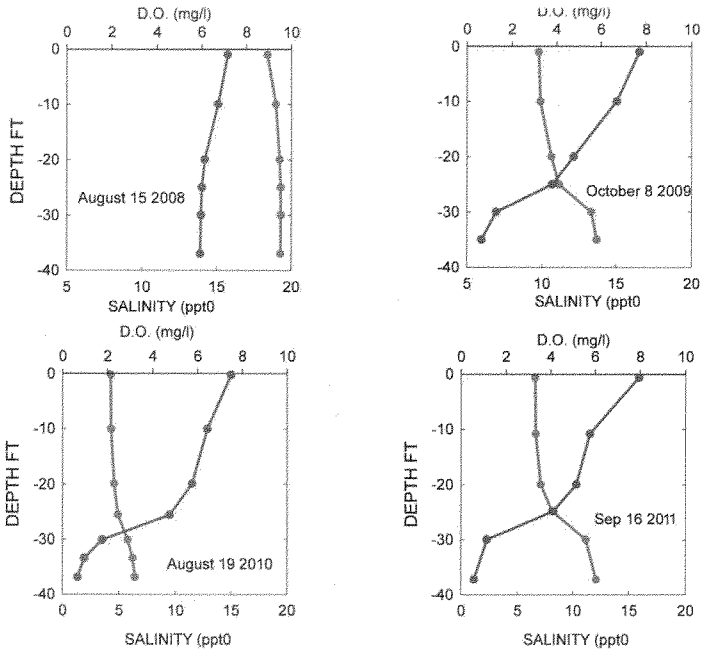


Figure 60: MRGO Water Quality Monitoring; Station T4 Summer DO and Salinity

LITERATURE CITED

Ackerman, B.B. 1995. Aerial surveys of manatees: a summary and progress report. Pages 13-33 *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.

Adams, S.R., G.R. Parsons, J.J. Hoover, and K. J. Killgore. 1997. Observations of swimming ability in shovelnose sturgeon (*Scaphirhynchus platorynchus*). Journal of Freshwater Ecology. 12:621-633

Adams, S.R., J.j. Hoover, and K. J. Killgore. 1999. Swimming endurance of juvenile pallid sturgeon, *Scaphirhynchus albus*. Copeia 1999:802-807

Altinok, I.; Galli, S. M.; Chapman, F. A. 1998. Ionic and osmotic regulation capabilities of juvenile Gulf of Mexico sturgeon, *Acipenser oxyrhynchus desotoi*. Comparative Biochemistry and Physiology 120(A):609-616.

Bettoli, P.W. Pallid Sturgeon Movements and Habitat Selection. 2006. Tennessee Wildlife Resources Agency

Carlson, D. M., W. L. Pflieger, L. Trial, and P. S. Haverland. 1985. Distribution, biology, and hybridization of *Scaphirhynchus albus* and *S. platorynchus* in the Missouri and Mississippi rivers. Environmental Biology of Fishes 14:51–59.

Carr, S. H.; Carr, T.; Chapman, F. A. 1996. First observations of young of the year Gulf of Mexico sturgeon (*Acipenser oxyrinchus de sotoi*) in the Suwannee River, Florida. Gulf of Mexico Science 14(1): 44-46.

Carr, S. H.; Tatman, F.; Chapman, F.A. 1996. Observations on the natural history of the Gulf of Mexico sturgeon (*Acipenser oxyrinchus de sotoi*, Vladykov 1955) in the Suwannee River, southeastern United States. Ecology of Freshwater Fish 5: 169-174.

Chapman, F. A.; Carr, S. H. 1995. Implications of early life stages in the natural history of the Gulf of Mexico sturgeon, *Acipenser oxyrinchus desoitoi*. Environmental Biology of Fishes 43: 407-413.

Chapman, F. A.; Hartless, C. S.; Carr, S. H. 1997. Population size estimates of sturgeon in the Suwannee River, Florida, U.S.A. Gulf of Mexico Science 14(2): 88-91.

Chatry,M., Dugas, R.J., Easley, K.A., 1983. Optimum salinity regime for oyster production on Louisiana's state seed grounds. Contrib. Mar. Sci. 26, 81–94.

Conant, R. and J. T. Collins. 1991. A field guide to reptiles and amphibians: eastern and central North America. Third edition. Houghton Mifflin Co., Boston, Massachusetts. 450 pp.

Committee on Sea Turtle Conservation (CSTC), National Research Council (U.S.). 1990. Decline of the Sea Turtles: Causes and Prevention. National Academy Press, Washington, D.C. xv + 259 pp.

Dugas, R. J. and W. S. Perret. 1975. The effects of 1973 spring floodwaters on oyster populations in Louisiana. Proc. 29th Ann. Conf. Southeast. Assoc. Game-Fish Comm: 208-214.

Dundee, Harold A. and Douglas A. Rossman. The Amphibians and Reptiles of Louisiana. Louisiana State University Press, Baton Rouge. © 1989.

Fearnley, S., Bohling, C., Miner, M., Martinez, L., Kulp, M., and Penland, S., 2009b, Hurricane impact and recovery shoreline change analysis and historic island configuration (Age of Discovery): 1700's to 2005, *in* Lavoie, D., ed., Sand resources, regional geology, and coastal processes of the Chandeleur Island coastal system – An evaluation of the resilience of the Breton National Wildlife Refuge: U.S. Geological Survey Scientific Information Report *in press*.

Forbes, S. A., and R. E. Richardson. 1905. On a new shovelnose sturgeon from the Mississippi River. Bulletin of the Illinois State Laboratory of Natural History 7:35–47.

Fox, D. A.; Hightower, J. E.; Parauka, F. M. 2000. Gulf sturgeon spawning migration and habitat in the Choctawhatchee River system, Alabama-Florida. Transactions of the American Fisheries Society 129: 811-826.

Funk, J.L., and J.W. Robinson. 1974. Changes in the channel of the lower Missouri River and effects on fish and wildlife. Missouri Department of Conservation, Aquatic Series No. 11.

Gagliano, S. M., H. J. Kwon, and J. L. van Beek. 1970. Hydrologic and geologic studies of coastal Louisiana. 2. Salinity regimes in Louisiana estuaries. Coastal Resources Unit, Center for Wetland Resources, LSUBR

Gardner, W. M., and P. A. Stewart. 1987. The fishery of the Lower Missouri River, Montana. Montana Department of Fish, Wildlife and Parks, Federal Aid to Fish and Wildlife Restoration, Project F-46-R-5, Study 3, Helena.

Gilbraith, D. M., M. J. Schwalbach, and C. R. Berry.1988. Preliminary report on the status of the pallid sturgeon, *Scaphirhynchus albus,* a candidate endangered species. South Dakota Cooperative Fish and Wildlife Research Unit, Department of Wildlife and Fisheries Sciences, South Dakota State University, Brookings.

Haig, S.M. 1985. The status of the Piping Plover in Canada. Report to the Committee on the Status of Endangered Wildlife in Canada (COSEWIC), National Museum of Canada, Ottawa, Ontario.

Haig, S.M. and J.H. Plissner. 1992. The 1991 international piping plover census. U.S. Fish and Wildlife Service, Twin Cities, Minnesota. 200 pp.

Haig, S.M. 1986. Piping Plover distribution. Endangered Species Information System Workbook Part 1. U.S. Fish and Wildlife Service, Washington D.C.

Haig, S.M. and L.W. Oring. 1988a. Genetic differentiation of piping plovers across North America. Auk 105(4): 260-267pp.

Haig, Susan M., and Elliott-Smith, E. 2004. Piping Plover. The Birds of North America Online. (A. Poole, Ed.) Ithaca: Cornell Laboratory of Ornithology; Retrieved from The Birds of North American Online database: http://bna.birds.cornell.edu/BNA/account/Piping_Plover/.

Hartman, D.S. 1979. Ecology and behavior of the manatee (*Trichechus manatus*) in Florida. American Society of Mammalogists Special Publication No. 5. 153 pp.

Hildebrand, H.H. 1963. Hallazgo del area de anidacion de la tortuga marina "lora," *Lepidochelys kempii* (Garman), en la costa occidental del Gulfo de Mexico. Ciencia, Mex. 22(4):105-112.

Hildebrand, H.H. Random Notes on Sea Turtles in the Western Gulf of Mexico. Western Gulf of Mexico Sea Turtle Workshop Proceedings, January 13-14, 1983. 1983 Oct:34-41.
Hirth, H.F. 1971. Synopsis of biological data on the green turtle *Chelonia mydas* (Linnaeus) 1758. FAO Fisheries Synopsis. 85:1-77.

Huff, J. A. 1975. Life history of Gulf of Mexico sturgeon, *Acipenser oxyfhynchus desotoi*, in Suwannee River, Florida. Florida Marine Research Publication 16, St. Petersburg. 33 pp.

Husar, S.L. 1977. The West Indian manatee (*Trichechus manatus*). U.S. Fish and Wildlife Service. Wildlife Resource Report No. 7: 1-22.

Intergovernmental Panel on Climate Change (IPCC), 2001, Climate change 2001-the scientific basis. Contribution of Working Group I to the Third Assessment Reporto of the Intergovernemental Panel on Climate Change (Houghton J.T., Ding, Y., Griggs, D.J., Noguer, M., van der Linden, P.J., Dai, X., Maskell, K., and Johnson, C.A., eds.): Cambridge, U.K., and New York,

Campridge University Press, 881p.

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., Qin, D., Manning, M., Chen, Z., Marquis, M., Averyt, K.B., Tignor, Mi., and Miller, H.L., eds.): Cambridge, U.K., and New York, Cambridge University Press, 996 p.

Kallemeyn, L. W. 1983. Status of the pallid sturgeon (*Scaphirhynchus albus*). Fisheries 8(1):3–9.

Killgore, K.J., J.J. Hoover, J.P. Kirk, S.G. George, B.R. Lewis, and C.E. Murphy. 2007. Age and growth of pallid sturgeon in the free-flowing Mississippi River. Journal of Applied Ichthyology. 23:452-456.

Killgore, K.J., J.J. Hoover, S.G. George, B.R. Lewis, C.E. Murphy, and W.E. Lancaster. 2007. Distribution, relative abundance and movements of pallid sturgeon in the free-flowing Mississippi River. Journal of Applied Ichthyology. 23:476-483.

Leary, T.R. 1957. A schooling of leatherback turtles, *Dermochelys coriacea*, on the Texas coast. Copeia 1957 (3):232.

Li, C., N. walker, A. Hou, I. Georgiou, H. Roberts, E. Laws, J. A. McCorquodale, E. Weeks, X. Li, and J. Crochet. 2008. Circular plumes in Lake Pontchartrain estuary under wind straining. Estuarine, Coastal, and Shelf Science 80: 161-172.

Louisiana Department of Wildlife and Fisheries (LDWF-1). Green Sea Turtle (*Chelonia mydas*). 2005. Accessed 25 February 2008. <http://www.wlf.louisiana.gov/experience/threatened/greenseaturtle.cfm>

Louisiana Department of Wildlife and Fisheries (LDWF-2). Hawksbill Sea Turtle (*Eretmochelys imbricata*). 2005. Accessed 26 February 2008. <http://www.wlf.louisiana.gov/experience/threatened/hawksbillseaturtle.cfm>

Louisiana Department of Wildlife and Fisheries (LDWF-3). Kemp's Ridley Sea Turtle (*Lepidochelys kempii*). 2005. Accessed 26 February 2008. <http://www.wlf.louisiana.gov/pdfs/experience/naturalheritage/rareanimal/kempridleyseaturtle.pdf>

Louisiana Department of Wildlife and Fisheries (LDWF-4). Leatherback Sea Turtle (*Dermochelys coriacea*). 2005. Accessed 26 February 2008. <http://www.wlf.louisiana.gov/pdfs/experience/naturalheritage/rareanimal/kempridleyseaturtle.pdf>

Louisiana Department of Wildlife and Fisheries (LDWF-5). Loggerhead Sea Turtle (*Caretta caretta*). 2005. Accessed 26 February 2008. <http://www.wlf.louisiana.gov/experience/threatened/loggerheadseaturtle.cfm>

May, J. R., Britsch, L. D., Dunbar, J. B., Rodriguez J. P., and Wlosinski L. B. 1984. "Geological Investigation of the Mississippi River Deltaic Plain," Technical Report GL-84-15, US Army Engineer Waterways Experiment Station, Vicksburg, MS. http://lmvmapping.erdc.usace.army.mil/

Mayden, R.L., and B.R. Kuhajda. 1997. Threatened fishes of the world: *Scaphirhynchus albus* (Forbes and Richardson 1905) (Acipenseridae). Environmental Biology of Fishes 48: 420-421.

Morrow, J. V., Jr.; Killgore, K. J.; Kirk, J.P.; Rogillio, H.E. 1996. Distribution and population attributes of Gulf sturgeon in the lower Pearl River system, Louisiana. Proceedings of Annual Conference of the SEAFWA, 79-90.

Morrow, J. V., Jr.; Kirk, J.P.; Killgore, K. J.; Rogillio, H. E.; Knight, C. 1998. Status and recovery potential of Gulf sturgeon in the Pearl River system, Louisiana-Mississippi. North American Journal of Fisheries Management 18: 798-808.

Morrow, J. V., Jr.; Kirk, J.P.; Killgore, K. J.; Rogillio, H. 1999. Recommended enhancements to the Gulf sturgeon recovery

and management plan based on Pearl River studies. North American Journal of Fisheries Management 19: 1117-1121.

Murphy, M. J.; Skaines, J. 1994. Habitat and movement of the Gulf sturgeon (*Acipenser oxyrhynchus desotoi*) in the Pascagoula River, Mississippi. Museum Technical Report No. 29. Mississippi Museum of Natural Science. Mississippi Department of Wildlife, Fisheries, and Parks. Jackson, MS. 20 pp.

Nicholls, J.L. 1989. Distribution and other ecological aspects of Piping Plovers (Charadrius melodus) wintering along the Atlantic and Gulf coasts. MS Thesis. Auburn University, Auburn, Alabama. 164 pp.

NMFS. 1995. Endangere3d Species Act section 7 consultation on the proposed shock testing of the SEAWOLF submarine off the Atlantic Coast of Florida during the summer of 1997. Biological Opinion, December 12. 50pp.

NMFS, NOAA, U.S. Department of Commerce. 1998. Designated Critical Habitat; Green and Hawksbill Sea Turtles; Final Rule. Federal Register vol. 63, no. 170. Wednesday, September 2, 1998.

NMFS and USFWS. 2007. Kemp's ridley sea turtle (*Lepidochelys kempii*). 5-year review: summary and evaluation. NMFS, Silver Spring, Maryland, and USFWS, Albuquerque, New Mexico. 50 pp.

NatureServe. 2002-2003. NatureServe Explorer: An online encyclopedia of life [web application]. Version 6.1. NatureServe, Arlington, Virginia. Available http://www.natureserve.org/explorer.

NatureServe. 2006. NatureServe Explorer: An online encyclopedia of life [web application]. Version 6.1. NatureServe, Arlington, Virginia. Available http://www.natureserve.org/explorer.

NatureServe. 2009. NatureServe Explorer: An online encyclopedia of life [web application]. Version 6.1. NatureServe, Arlington, Virginia. Available http://www.natureserve.org/explorer.

NOAA Fisheries, Office of Protected Resources (NOAA-1). Green Turtle (*Chelonia mydas*). U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service. Accessed 25 February 2008. <http://www.nmfs.noaa.gov/pr/species/turtles/green.htm>

NOAA Fisheries, Office of Protected Resources (NOAA-2). Hawksbill Turtle (*Eretmochelys imbricata*). U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service. Accessed 26 February 2008. <http://www.nmfs.noaa.gov/pr/species/turtles/green.htm>

NOAA Fisheries, Office of Protected Resources (NOAA-3). Kemp's Ridley Turtle (*Lepidochelys kempii*). U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service. Accessed 26 February 2008. <http://www.nmfs.noaa.gov/pr/species/turtles/kempsridley.htm>

NOAA Fisheries, Office of Protected Resources (NOAA-4). Leatherback Turtle (*Dermochelys coriacea*). U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service. Accessed 26 February 2008. <http://www.nmfs.noaa.gov/pr/species/turtles/leatherback.htm>

NOAA Fisheries, Office of Protected Resources (NOAA-5). Loggerhead Turtle (*Caretta caretta*). U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service. Accessed 26 February 2008. <http://www.nmfs.noaa.gov/pr/species/turtles/loggerhead.htm>

NOAA Fisheries, (1998) Office of Protected Resources. Endangered Species Act-Section 7 Consultation Deeping of

Galveston Bay Entrance Channel (Houston-Galveston Navigation Channels Project) Using a Hopper dredge. National Marine Fisheries Service

O'Connell, Martin T., Franze, Carol D., Spalding, Elizabeth A. and Poirrier, Michael A. Biological Resources of the Louisiana Coast: Part 2. Coastal Animals and Habitat Associations. Spring 2005.

Ogren, L.H. Biology and Ecology of Sea Turtles. 1988. Prepared for National Marine Fisheries, Panama City Laboratory. Sept. 7.

O'Shea, T.J. 1988. The past, present, and future of manatees in the southeastern United States: realities, misunderstandings, and enigmas. Pages 184-204 *in* Odum, R.R., K.A. Riddleberger, and J.C. Ozier (eds.). Proceedings of the Third Southeastern Nongame and Endangered Wildlife Symposium. Georgia Department of Natural Resources. Social Circle, Georgia.

O'Shea, T.J., B.B. Ackerman, and H.F. Percival (eds.). 1992. Interim report of the technical workshop on manatee population biology. Manatee Population Research Report No. 10. Florida Cooperative Fish and Wildlife Research Unit. Gainesville, Florida. 83 pp.

Palmatier, R. 1993. LEPIDOCHELYS KEMPII (Kemp's ridley). Nesting. Herpetological Review 24:149-150.

Phelps, Q.E., D.P. Herzog, R.C. Brooks, V.A. Barko, D.E. Ostendorf, J.W. Ridings, S.J. Tripp, R.E. Colombo, J.E. Garvey and R.A. Hrabik. 2009. Season comparison of catch rates and size structure using three gear types to sample sturgeon in the Middle Mississippi River. North American Journal of Fisheries Management 29:1487-1495.

Plotkin, P. and A.F. Amos. 1990. Effects of anthropogenic debris on sea turtles in the northwestern Gulf of Mexico. *in* R.S. Shomura and M.L. Godfrey (eds.). Proceedings of the Second International Conference on Marine Debris. NOAA Tech. Memo NMFS-SWFSC-154: 736-743.

Plotkin, P.T., M.K. Wicksten, and A.F. Amos. 1993. Feeding ecology of the loggerhead sea turtle *Caretta caretta* in the Northwestern Gulf of Mexico. Marine Biology 115: 1-15.

Pritchard, P.C.H. 1969. Sea turtles of the Guianas. Bull. Fla. State Mus. 13(2):1-139.

Rebel, T.P. 1974. Sea turtles and the turtle industry of the West Indies, Florida and the Gulf of Mexico. Univ. Miami Press, Coral Gables, Florida.

Reynolds, C. R. 1993. Gulf sturgeon sightings, historic and recent - a summary of public responses. U.S. Fish and Wildlife Service. Panama City, Florida. 40 pp.

Rogillio, H. E. 1993. Status survey of Gulf sturgeon in Louisiana. Louisiana Department of Wildlife and Fisheries. Project E1-1. 6 pp.

Schmulbach, J. C. 1974. An ecological study of the Missouri River prior to channelization. University of South Dakota, Completion Report, Project B-024-S, Vermillion.

Sears, C.J. 1995. Preliminary genetic analysis of the population structure of Georgia loggerhead sea turtles. Presented at the Fifteenth Annual Symposium of Sea Turtle Biology and Conservation, February 1995, Hilton Head, SC.

Sears, C.J., B.W. Bowen, R.W. Chapman, S.B. Galloway, S.R. Hopkins-Murphy, and C.M. Woodley. 1995. Demographic composition of the juvenile loggerhead sea turtle (*Caretta caretta*) feeding population off Charleston, South Carolina: evidence from mitochondrial DNA markers. Mar. Biol. 123:869-874.

Shaver, D.J. 1991. Feeding ecology of wild and head-started Kemp's ridley sea turtles in south Texas waters. Journal of Herpetology. Vol. 23. 1991.

Shaver, D. J. 1992. LEPIDOCHELYS KEMPII (Kemp's ridley sea turtle). Reproduction. Herpetological Review 23:59.

Shaver, D.J. 1994. Sea turtle abundance, seasonality and growth data at the Mansfield Channel,

Texas. In B.A. Schroeder and B.E. Witherington (compilers), Proceedings of the thirteenth annual symposium on sea turtle biology and conservation, NOAA Tech. Memo NMFS-SEFC-341: 166-169.

Schubel, J. R. 1977. Sediment and the quality of the estuarine environment: Some observations. Pg 399-424. In: I. H. Suffet (ed.). Fate of pollutants in the air and water environments. Part 1. Mechanism of interaction between environments and the mathematical modeling and the physical fate of pollutants. John Wiley and Sons, New York, NY.

Sulak, K. J.; Clugston, J. P. 1998. Early life history stages of Gulf sturgeon in the Suwannee River, Florida. V127: 758-771.

Sulak, K. J.; Clugston, J. P. 1999. Recent advances in life history of Gulf of Mexico sturgeon, Acipenser oxyrinchus dosotoi, in the Suwannee river Florida, USA: A synopsis. Journal of Applied Ichthyology. 15: 116-128.

U. S. Army Corps of Engineers (USACE). 1999. Environmental Assessment, Mississippi River – Gulf Outlet, Louisiana, Mile 43 to 41 North Bank Stabilization, St. Bernard Parish, Louisiana. EA No. 288. New Orleans, Louisiana.

U.S. Army Corps of Engineers (USACE). 2004. Louisiana Coastal Area (LCA), Louisiana Ecosystem Restoration Studys, New Orleans, LA

U.S. Fish and Wildlife Service. 1980. Information Report: Gulf of Mexico Sturgeon *Acipenser oxyrhynchus desotoi* (Vladykov). Jacksonville, Florida. 79 pp.

U.S. Fish and Wildlife Service. 1988. Great Lakes and Northern Great Plains Piping Plover Recovery Plan. US Fish and Wildlife Service, Twin Cities, MN. 160 pp.

U.S. Fish and Wildlife Service. 2001. Florida manatee recovery plan. Southeast Region, U.S. Fish and Wildlife Service, Atlanta, Georgia. 144 pp. + Appendices.

U.S. Fish and Wildlife Service. 2007. Pallid Sturgeon (*Scaphirhynchus albus*) 5-year review summary and evaluation. U.S. Fish and Wildlife Service, Bismarck, North Dakota. 120pp.

U.S. Fish and Wildlife Service. 2009. Biological Opinion. 2008 Operation of the Bonnet Carre Spillway. US Fish and Wildlife Service, Lafayette, LA.

U.S. Fish and Wildlife Service, Letter July 10, 2009(b) Lafayette, Louisiana Field Office.

U.S. Fish and Wildlife Service. 2010. Biological Opinion. Small Diversion at Convent/ Blind River. US Fish and Wildlife Service, Lafayette, LA.

U.S. Fish and Wildlife Service. (n.d.) Endangered Species Information System (ESIS): Piping Plover (Charadrius melodus).

U.S. Fish and Wildlife Service and Gulf States Marine Fisheries Commission. 1995. Gulf Sturgeon Recovery Plan. Atlanta, Georgia. 170 pp.

U.S. Fish and Wildlife Service. (n/d) Northern Florida Fact sheet for the Green Sea Turtle.

U.S. Fish and Wildlife Service. (n/d) Northern Florida Fact sheet for the Kemp's Ridley Sea Turtle.

U.S. Fish and Wildlife Service. (n/d) Northern Florida Fact sheet for the Loggerhead Sea Turtle.

U.S.G.S., Zganjar, Westphal, McCarty, Bridges, and Penland. Environmental Atlas of Lake Pontchartrain. "Shoreline Change Rates of Lake Borgne."

APPENDIX A

APPENDIX B

APPENDIX C

Entrainment of sturgeons by water diversions in the Lower Mississippi River – ERDC progress to date.

I. Background

Water diversions are used for flood control, water supply, and habitat restoration in the lower Mississippi River (LMR) but their impacts on imperiled sturgeon populations are unknown. Comprehensive risk assessments for entrainment of sturgeon by water diversions require substantial inputs including field data on local sturgeon populations, life history information, output from population modeling simulations, and results of experimental studies. These risk assessments, however, can provide probability of entrainment for specific environmental scenarios (e.g., time of year, river stage, and flow fields generated by a structure). Such probabilities can be eliminated or reduced through modified operations of structures (e.g., schedule of operation, rate of diversion, implementation of deterrents). Otherwise costly monitoring and rescue programs will be ongoing elements of O&M costs and concerns regarding long-term impacts to endangered sturgeon will go unresolved.

II. Project goals

The proposed study consisted of concurrent evaluations of fish communities in the Mississippi River and in outflow channels of proposed and existing diversions (Table 1) with pallid sturgeon being the focal species of interest. Data collected for existing diversions can be used to predict potential impacts of proposed diversions. Furthermore, the results of this study will provide an analytical framework to begin developing field approaches and experimental designs to evaluate entrainment at other structures (i.e., Old River Control Structure). The field portion of the study was developed as a collaborative enterprise between Nicholls State University and ERDC and conducted in a manner to address 3 focal tasks:

1). How many sturgeon occur in this reach of river?
2). What is the extent and circumstances of entrainment?
3). What are the impacts of entrainment to the population?

Tasks 1 and 3 were primarily the responsibility of ERDC and data obtained by Nicholls State University were used to evaluate the conditions specified in Task 2. A summary of the field activities conducted by Nicholls State University during the project period has been compiled and submitted as separate report.

A detailed explanation of ERDC field sampling approaches and methodologies implemented for evaluating Tasks 1 and 3 are provided in the original SOW submitted to the U.S. Army Corps of Engineers, New Orleans District.

III. Task 1. Population assessment

A. Sampling effort

Sampling efforts summarized for this project include efforts in the Lower Mississippi River proper between RM 0 and 320, all within the operational boundaries of the U.S. Army Corps of Engineers, New Orleans District. Although the primary study reach (i.e, diversion reach) ranges between RM 45 and 160 (Table 1, Fig 1), the inclusion of comparable upriver sampling efforts is necessary to provide polarity on relative abundance of both pallid and

Table 1. List of proposed and existing diversions in the Lower Mississippi River that were sampled by ERDC Fish Ecology Team during the entrainment study.

Water Diversion	River Mile	Status	Mississippi River Sampling	Outflow Channel Sampling	Latitude	Longitude
Convent/Blind River	160.0	Proposed	YES		30.036780	-90.838990
Hope Canal	145.0	Proposed	YES		30.051230	-90.657120
Bonnet Carre	128.0	Existing	YES	YES	30.002430	-90.441470
Davis Pond	119.0	Existing	YES	YES	29.932010	-90.321650
Violet Siphon	83.8	Existing	YES	YES	29.898210	-89.902960
Caernarvon	81.5	Existing	YES	YES	29.862830	-89.912000
White Ditch	64.5	Existing	YES	YES	29.711650	-89.979140
Naomi Siphon	63.9	Existing	YES	YES	29.701360	-89.983520
Myrtle Grove	59.0	Proposed	YES		29.639720	-89.949190
Magnolia (Myrtle Grove No. 2)	45.0	Proposed	YES		29.541650	-89.761730

DRAFT

shovelnose sturgeon within the immediate study zone. Four hundred and sixty-nine (469) total sampling gears (e.g., trotline, trawl, gillnet, hoopnet, electroshocker) were deployed at 85 sample stations along the 320 river mile reach (Fig. 2) with 74.1% of the sampling efforts conducted within the reach associated with existing or planned river diversions. Trotline and trawl were the predominant gear type utilized for all sampling efforts (Fig. 3; 87.5%) because both are very effective gears for targeting river sturgeon but each gear type generally targets individuals of different size ranges (Killgore et al. 2007; Phelps et al. 2009). Total sampling efforts included in this summary have been stratified across several years (Fig. 4) with 57.8 % of the analyzed efforts occurring within the past 5 years, and occurring primarily within the study reach associated with the river diversions. Sampling within the river occurred year-round (Fig. 5) with 73.1% of all efforts occurring during the cooler months of spring, fall and winter. The depicted monthly pattern is typical and generally reflects gear recruitment by river sturgeon. Our primary gears are very effective in catching sturgeon but catch rates, particularly with trotlines, are temperature dependent (Killgore et al 2007; Phelps et al. 2009) and are minimally effective during months associated with warmer water temperatures. In contrast, sampling for YOY with trawls is effective during all months.

B. Catch data

The spatial distribution of all sampled gears for the Lower Mississippi River are illustrated in Figure 6 which adequately depicts extensive sampling above, below and within the reach containing existing and planned river diversions. Our sampling documented 61 species of fishes with a total abundance of 13,262 individuals across all samples (Table 2). Seven species composed over 90% of the relative abundance with *Ictalurus furcatus* being the most abundant species and followed in descending order by *Anchoa mitchilli*, *Dorosoma cepedianum*, *Aplodinotus grunniens*, *Ictalurus punctatus*, *Scaphirhynchus platorynchus* and *Mugil cephalus*. *Scaphirhynchus albus* ranked 16th and represented 0.4% of the total relative abundance. Sturgeon were generally distributed from RM 319 downstream to RM 80 (Fig. 7) with abundances for each species varying throughout the sampled reach (Fig. 8). Pallid sturgeon size ranged 405-964 mm FL and shovelnose sturgeon size ranged 231-852 mm FL. Sturgeon specimens noted as "undetermined" were generally smaller in size and required additional examination in the laboratory to adequately determine species identification (Fig. 9). Pallid and shovelnose sturgeon, as well as evidence of recruitment (i.e., YOY, undetermined sturgeon), are noticeably present within the upper portion (RM 80-160) of the diversion reach (Table 2, Fig. 10). Post-larval sturgeon (i.e., YOY) have been documented at RM 160.7, 170.9 and 195.5, and have been represented by numerous specimens (not limited to a single individual in a single effort), over multiple years and during both spring and fall sampling events. Many of these samples are still in the state of being processed to evaluate taxonomic identity (B. Wallus) and may provide additional taxonomic resolution in near future. These data provide additional support for fall spawning in *Scaphyrinchus* species and confirms spawning in the lower extent of the Mississippi River. In addition, the small sized, developing sturgeon (e.g., *Scaphyrinchus* sp. 1, undetermined sturgeon) (Fig. 9, Table 2) occurring near the Caernarvon diversion (Fig. 10) further suggests upriver spawning and/or downstream drift from a favorable upriver site (i.e., Donaldsonville, White Castle). Regardless of the scenario of choice, these data provide support for increased potential of entrainment of small sized sturgeon in nearby diversion areas (e.g., Violet Siphon, White Ditch).

Killgore et al. (2007) compared CPUE of pallid and shovelnose sturgeon in reaches of the Middle and Lower Mississippi River using only catch from trotlines. In their study (Killgore et al. 2007), effort was considered as an "overnight set" such that a single 100', 60 hook trotline (ca. 16 hour soak period) was treated as a single effort and catch per unit effort (CPUE) of both pallid and shovelnose sturgeon were tabulated based on that set. For this evaluation, we followed the same methodology to compute CPUE and comparisons were restricted to only trotline captures. All but 1 pallid sturgeon (51 total individuals) and 14 shovelnose sturgeon (317 total) were captured by a gear other than trotline. CPUE of both pallid and shovelnose sturgeon varied across the study area with CPUE of shovelnose sturgeon generally exceeding that of pallid sturgeon when compared across stations sampled with trotlines (Fig. 12). Condensing these data into a river mile category (Table 3) illustrates that shovelnose sturgeon were more prevalent in the upstream reach. Although the ratio of pallid to shovelnose sturgeon varied across river mile categories, values for both species were fairly consistent between RM 120-180 with pallid/shovelnose ratios ranging from 1:1 to 1:2.85. Downstream of this area, abundances of both species declined to minimal numbers.

Literature Cited

Killgore, K.J., J.J. Hoover, S.G. George, B.R. Lewis, C. E. Murphy and W.E. Lancaster. 2007. Distribution, relative abundance and movements of pallid sturgeon in the free-flowing Mississippi River. Journal of Applied Ichthyology 23:476-483.

Phelps, Q.E., D.P. Herzog, R.C. Brooks, V.A. Barko, D.E. Ostendorf, J.W. Ridings, S.J. Tripp, R.E. Colombo, J.E. Garvey and R.A. Hrabik. 2009. Season comparison of catch rates and size structure using three gear types to sample sturgeon in the Middle Mississippi River. North American Journal of Fisheries Management 29:1487-1495.

DRAFT

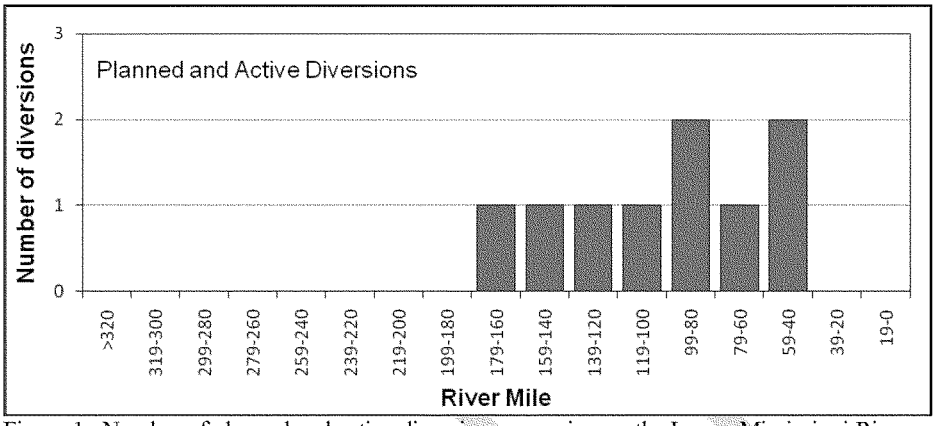


Figure 1. Number of planned and active diversions occurring on the Lower Mississippi River within 20 river mile delineations.

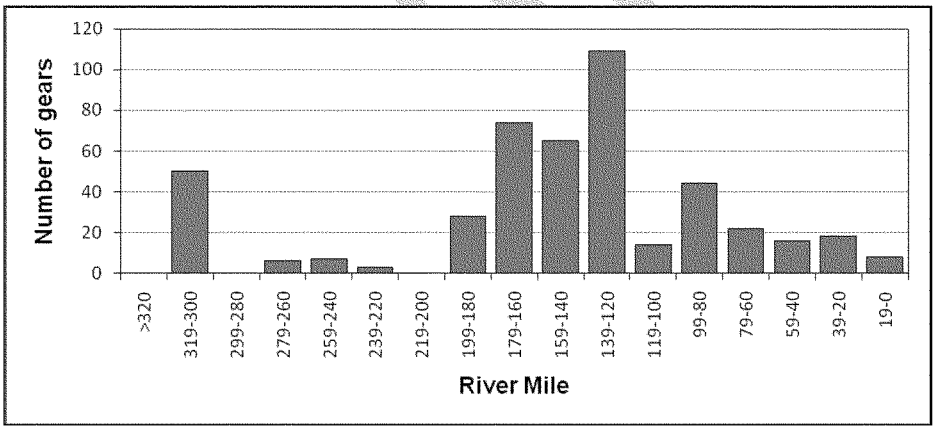


Figure 2. Total sampling effort by ERDC Fish Ecology team per river mile category on the Lower Mississippi River (RM 320-0).

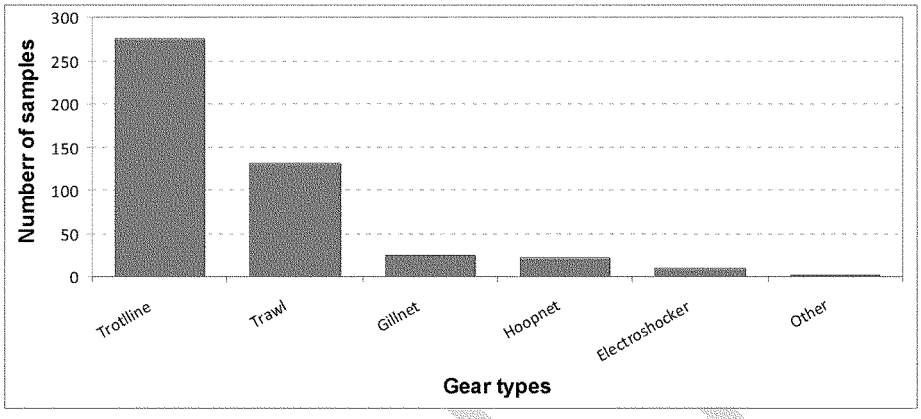


Figure 3. Breakdown of gears deployed during fish sampling efforts on the Lower Mississippi River (RM 320-0) (total N = 469).

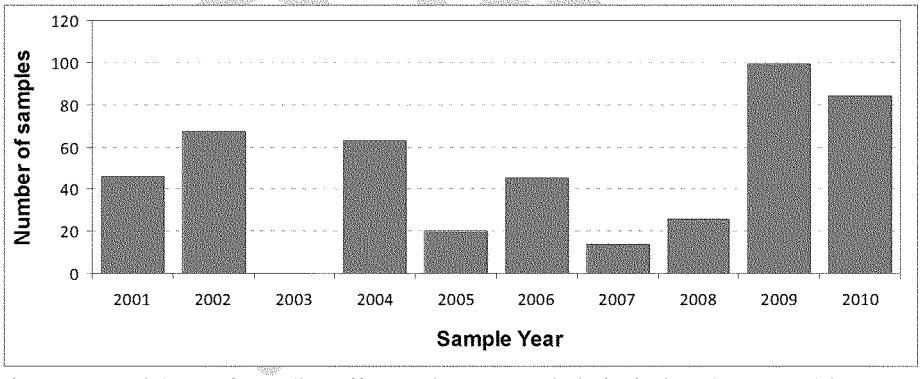


Figure 4. Breakdown of sampling effort on the Lower Mississippi River (RM 320-0) by year (total N = 469).

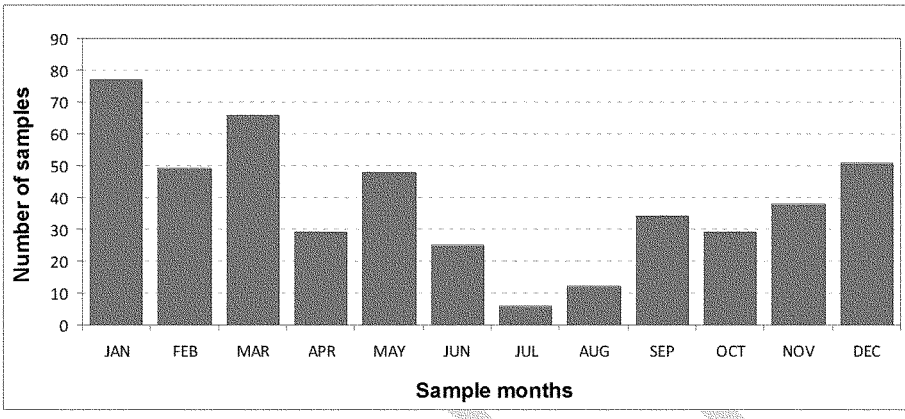


Figure 5. Distribution of sampling efforts in Lower Mississippi River (RM 320-0) across months the sample occurred (total N = 469).

DRAFT

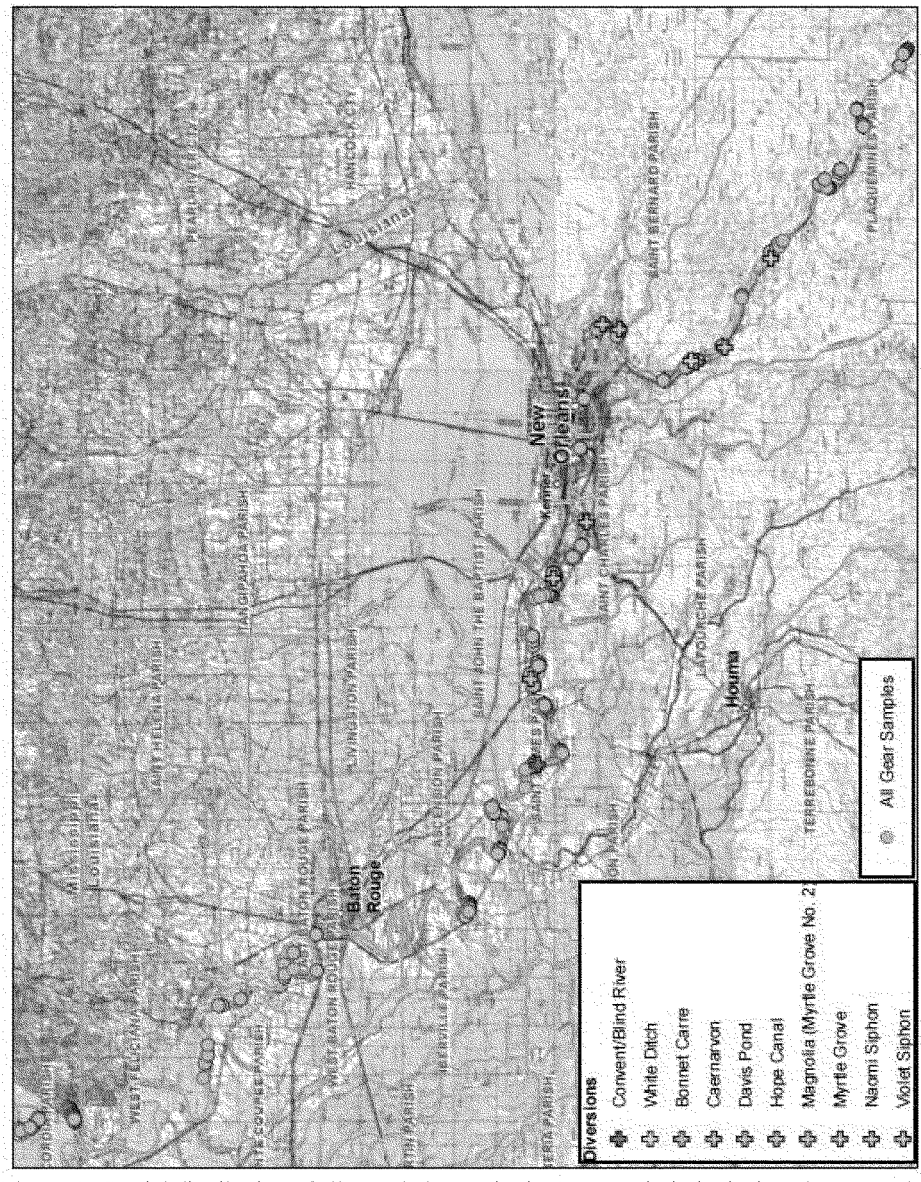


Figure 6. Spatial distribution of all sampled gears in the Lower Mississippi River (RM 320-0) and location of existing and proposed diversions within the study reach.

Table 2. Total species occurrence by 20 river mile delineation as documented by ERDC sampling efforts in the Lower Mississippi River during the 2001-2010 sample period. River reaches containing existing or proposed diversion are highlighted with Convent/Blind River (RM 179-160) and White Ditch (RM79-60) noted in red. The asterisks (**) listed "*Scaphirhynchus* sp. 2" denote occurrence records for YOY individuals within that reach but samples have not been completely processed.

Taxa	Common Name	River Mile																
		>320	319-300	299-280	279-260	259-240	239-220	219-200	199-180	179-160	159-140	139-120	119-100	99-80	79-60	59-40	39-20	19-0	TOTAL
Acipenseriformes																			
Acipenseridae																			
Scaphirhynchus albus	Pallid sturgeon	--	9	---		1		---	14	12	11	3		1					51
Scaphirhynchus platorynchus	Shovelnose sturgeon	--	201	---	4	7		---	36	31	29	6	2	1					317
Scaphirhynchus sp. 1	Undetermined sturgeon	--	1	---		5		---				1		2					9
Scaphirhynchus sp. 2	YOY sturgeon	--		---				---	**	23									23
Polyodontidae																			
Polyodon spathula	Paddlefish	--		---				---		4		37							41
Semionotiformes																			
Lepisosteidae																			
Lepisosteus oculatus	Spotted gar	--		---				---				24					9		33
Lepisosteus osseus	Longnose gar	--		---				---								1			1
Amiiformes																			
Amiidae																			
Amia calva	Bowfin	--		---				---	3					1					4
Osteoglossiformes																			
Hiodontidae																			
Hiodon alosoides	Goldeye	--		---	7	3	1	---				1							12
Anguilliformes																			
Anguillidae																			
Anguilla rostrata	American eel	--	1	---				---		6	12	16	4	17	1		1		60
Ophichthidae																			
Myrophis punctatus	Speckled worm eel	---		---				---								1			1
Ophichthus gomesii	Shrimp eel	---		---				---						1					1

Clupeiformes																		
Engraulidae																		
Anchoa mitchilli	Bay anchovy	---		---			82	---		16	50			148	43	3040			3379
Clupeidae																		
Alosa chrysochloris	Skipjack herring	---		---				---				122		2		1			125
Brevoortia patronus	Gulf menhaden	---		---				---						4					4
Dorosoma cepedianum	Gizzard shad	---		---	1			---		25		1184	17		23	2	47	4	1303
Dorosoma petenense	Threadfin shad	---		---				---	3		24	27	3			2			59
Cypriniformes																		
Cyprinidae																		
Ctenopharyngodon idella	Grass carp	---		---				---				2							2
Cyprinus carpio	Common carp	---		---				---		2		14				1			17
Hypophthalmichthys molitrix	Silver carp	---		---				---				3		1					4
Macrhybopsis aestivalis hyostoma	Shoal chub	---		---			4	---	1	9	5			6					25
Macrhybopsis storeriana	Silver chub	---	3	---			2	---	1	4	9	147							166
Notropis blennius	River shiner	---		---				---				2							2
Notropis shumardi	Silverband shiner	---		---				---			6	46							52
Notropis wickliffi	Channel shiner	---		---				---				1							1
Catostomidae																		
Carpiodes carpio	River carpsucker	---		---				---				7							7
Ictiobus bubalus	Smallmouth buffalo	---		---				---	1	2		53	1	3					60
Ictiobus cyprinellus	Bigmouth buffalo	---		---				---				4							4
Ictiobus niger	Black buffalo	---		---				---	2	1				1					4
Siluriformes																		
Ictaluridae																		
Ictalurus furcatus	Blue catfish	---	342	---	344	77	300	---	251	639	438	1277	36	433	157	39	329	73	4735
Ictalurus punctatus	Channel catfish	---	18	---				---	33	110	307	224	21	133	3	40	36	1	926
Noturus sp.	Unidentified madtom	---		---				---				1							1
Pylodictis olivaris	Flathead catfish	---	2	---	1			---	41	26	12	26	4	15	7				134

Mugiliformes																		
Mugilidae																		
Mugil cephalus	Striped mullet	---		---				---				10	6				240	1	257
Atheriniformes																		
Atherinidae																		
Menidia sp.	Unidentified silverside	---		---				---				10							10
Beloniformes																		
Belonidae																		
Strongylura marina	Atlantic needlefish	---		---				---				7							7
Cyprinodontiformes																		
Fundulidae																		
Lucania parva	Rainwater killifish	---		---				---				1							1
Perciformes																		
Moronidae																		
Morone chrysops	White bass	---		---			3	---			1	9	2				3		18
Morone mississippiensis	Yellow bass	---		---				---									1		1
Morone saxatilis	Striped bass	---		---				---				7		1			1	4	13
Perciformes																		
Centrarchidae																		
Lepomis cyanellus	Green sunfish	---		---				---				6							6
Lepomis gulosus	Warmouth	---		---				---				13							13
Lepomis humilis	Orangespotted sunfish	---		---				---				5							5
Lepomis macrochirus	Bluegill	---		---				---			1	32							33
Lepomis marginatus	Dollar sunfish	---		---				---				9							9
Lepomis megalotis	Longear	---		---				---				5							5
Lepomis microlophus	Redear	---		---				---				1							1
Lepoms sp.	Unidentified sunfish	---		---				---			1								1
Micropterus salmoides	Largemouth bass	---		---				---		1		58							59
Pomoxis annularis	White crappie	---		---				---				28							28

Pomoxis nigromaculatus	Black crappie	---		---				---				20					1		21
Percidae																			
Sander canadensis	Sauger	---		---				---		2	2	10							14
Sciaenidae																			
Aplodinotus grunniens	Freshwater drum	---	1	---	47	18	36	---	11	138	202	616	1	33	2	3	17		1126
Cynoscion nebulosus	Spotted seatrout	---		---				---									9		9
Pogonias cromis	Black drum	---		---				---									5		5
Sciaenops ocellatus	Red drum	---		---				---									2		2
Cichlidae																			
Oreochromis sp.	Unidentified tilapia	---		---				---									25		25
Gobiidae																			
Gobionellus shufeldti	Freshwater goby	---		---				---						1					1
Unidentified goby	unidentified goby	---		---				---						3					3
Pleuronectiformes																			
Paralichthyidae																			
Paralichthys lethostigma	Southern flounder	---		---				---						2		1	2		5
Achiridae																			
Trinectes maculatus	Hogchoker	---		---				---				5		14	2				21
TOTAL				578		404	111	428		397	1053	1110	4080	97	823	239	3131	728	83	13262
NUMBER OF DIVERSIONS											1	1	1	1	2	1	2			
Graptemys pseudogeographica kohnii	Mississippi map turtle										2	2								4
Trachemys scripta elegans	Red-eared slider												1							1
Macrobrachium ohione	Ohio River shrimp									400		1000	2922		3					4325
Orconectes palmeri longimanus	Western painted crayfish												5							5
Procambarus clarkii	Red swamp crayfish												1							1

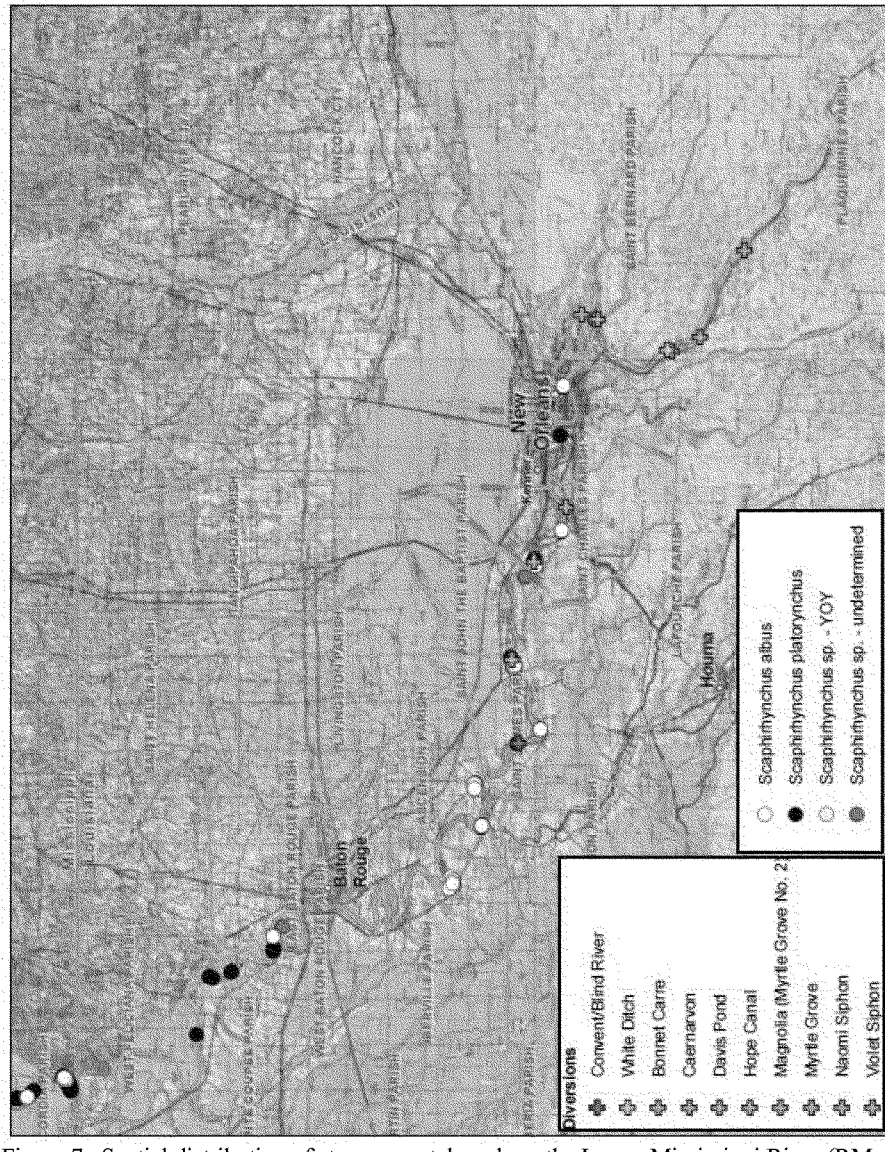


Figure 7. Spatial distribution of sturgeon catches along the Lower Mississippi River (RM 320-0).

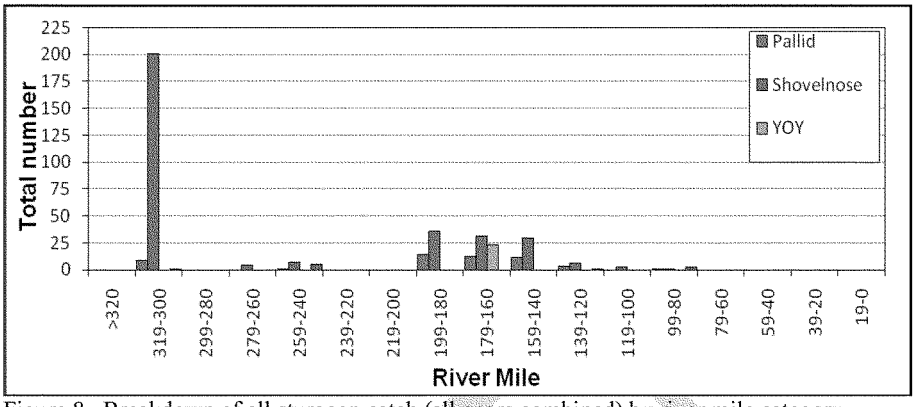


Figure 8. Breakdown of all sturgeon catch (all gears combined) by river mile category.

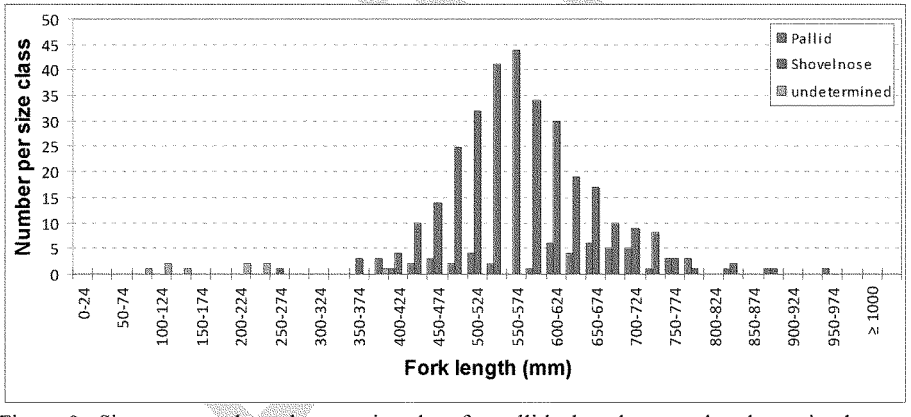


Figure 9. Size range and number per size class for pallid, shovelnose and undetermined sturgeon processed during sampling of Lower Mississippi River (RM 320-0).

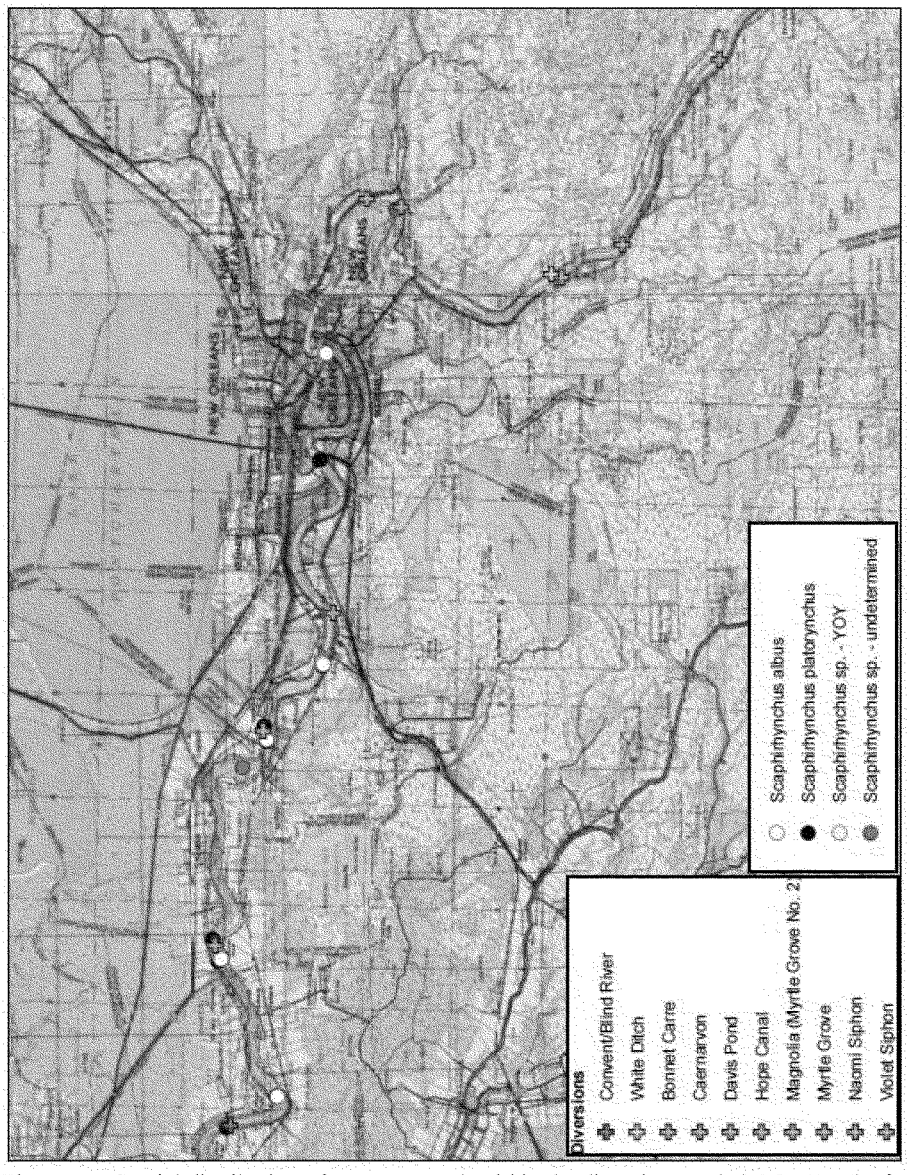


Figure 10. Spatial distribution of sturgeon catch within the diversion reach (RM 160-45) of the Lower Mississippi River containing existing and planned diversions.

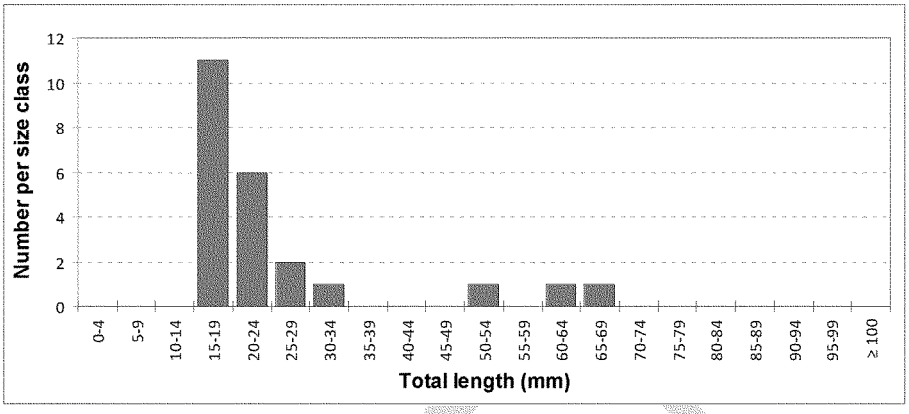


Figure 11. Length-frequency histogram for *Scaphirhynchus* young-of-the-year (YOY) processed while sampling the Lower Mississippi River (RM 320-0).

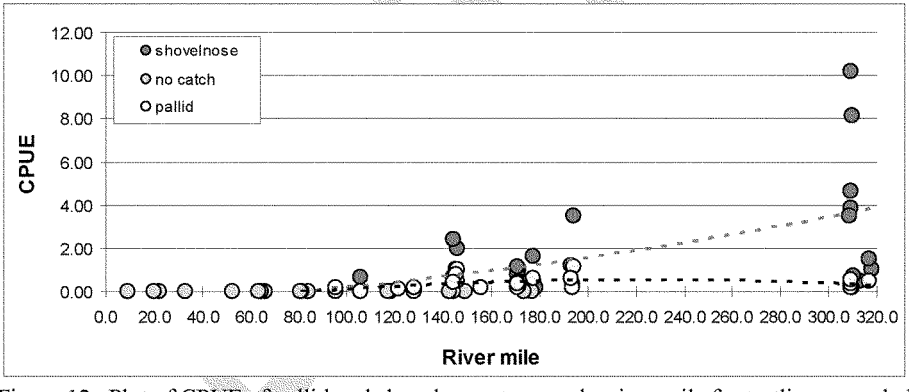


Figure 12. Plot of CPUE of pallid and shovelnose sturgeon by river mile for trotlines sampled in the Lower Mississippi River (RM 320-0). Dashed line represents best fit line (2nd order polynomial) through respective data points. Shovelnose sturgeon equation: $y = 3E\text{-}05x^2 - 0.0062x - 0.6581$, $R^2 = 0.3183$; pallid sturgeon equation: $y = -9E\text{-}06x^2 + 0.0042x - 0.1969$, $R^2 = 0.1527$.

Table 3. Ratio of pallid/shovelnose sturgeon by river mile category based on CPUE from trotline efforts within each category.

RM	Abundance		Diversions	CPUE		Pallid:Shovelnose	
	Pallid	Shovelnose		Pallid	Shovelnose	proportion	ratio
>320	0	0					
319-300	9	201		0.18	4.02	0.04	1:22.33
299-280	0	0					
279-260	0	0					
259-240	0	0					
239-220	0	0					
219-200	0	0					
199-180	13	37		0.57	1.61	0.35	1:2.85
179-160	12	29	1	0.23	0.56	0.41	1:2.42
159-140	12	29	1	0.29	0.71	0.41	1:2.45
139-120	3	3	1	0.08	0.08	1.00	1:1
119-100	0	2	1		0.20	0.00	
99-80	1	1	2	0.03	0.03	1.00	1:1
79-60	0	0	1				
59-40	0	0	2				
39-20	0	0	0				
19-0	0	0	0				

Draft

Entrainment of Fish Species by Freshwater Diversions of the Lower Mississippi River. Progress Report for the period July 1, 2009 to June 30, 2010
David L. Schultz

The purpose of this project is to document the fish species that can be found in freshwater diversions of the lower Mississippi River. Special emphasis and effort is devoted to documenting the entrainment of sturgeon species by diversions.

To date 55 days of sampling effort have been devoted to gillnetting, trawling, electrofishing, seining, and trotlining (Table 1). Seven freshwater diversions have been sampled. In the original plan of this project, five diversions were to be sampled, the Bonnet Carre' Spillway, the Davis Pond Diversion, the Violet Siphon, the Caernarvon Diversion, and the White Ditch Siphon. The first four of these have been sampled extensively. Twelve days of effort have been spent at the Bonnet Carre' Spillway (Table 2). Nineteen days of effort have been spent at the Davis Pond Diversion (Table 3). Ten days have been spent at the Violet Siphon (Table 4). Fifteen days have been spent at the Caernarvon Diversion (Table 5). The White Ditch Siphon began flowing in April 2010. It was sampled on one day in October 2009 after extensive negotiations with the landowner over liability issues. Since flow started, it has been sampled on two days (Table 6). As potential substitutes for White Ditch during the period when it was not flowing, the Naomi Siphon and the West Pointe a la Hache Siphon were sampled. The Naomi Siphon is nearly opposite the White Ditch Siphon on the west bank of the Mississippi River. The West Pointe a la Hache Siphon is approximately 30 miles south of the Naomi Siphon on the west bank. After sampling both, it was decided that the Naomi Siphon should be included in sampling effort for the remainder of this project. A total of 5 days have been spent in the West Pointe a la Hache and Naomi Siphon (Table 7). Tables 2 through 7 detail sampling effort by month and method for each diversion sampled.

Sampling methods were described in the original proposal for this project and will not be detailed here.

To date over 39,000 fish have been captured and identified to species by all methods at all diversions. Table 7 details fish species sampled at each diversion. No analysis of variation in species composition of samples among sample sites or among methods is detailed here.

Four sturgeon have been captured. All were captured in the Davis Pond Diversion. Three were identified as shovelnose sturgeon and one was identified as a pallid sturgeon. The shovelnose sturgeon were captured in July 2009 (by gillnetting), March 2010 (by trawl), and May 27 (by gillnetting). The pallid sturgeon was captured in November 2009 (by trawl). Meristic and morphometric data as well as tissue samples were taken from the one pallid sturgeon and the second shovelnose sturgeon sampled. The first sturgeon captured was taken on a day when Terry McCall, a biologist for the US Fish and Wildlife Service, was present and he took similar data and tissue samples to those we were directed to take for this project. Sturgeon captured were tagged with both PIT tags and Floy tags.

Sampling will continue through June 2011.

Table 1. Southern Mississippi River Diversion Total Sampling Effort. Sampling effort from July 1 2009 through June 30 2010.

Total Sampling Effort						
		Methods				
Month	**Days**	**Gillnet**	**Trawl**	**Seine**	**Electrofish**	**Trotline**
Jul-09	15	39	6	0	21	0
Aug-09	7	22	3	4	10	0
Sep-09	1	2	2	0	2	0
Oct-09	3	9	3	2	4	0
Nov-09	5	15	6	1	9	0
Dec-09	4	10	5	0	10	0
Jan-10	4	12	8	0	4	1
Feb-10	4	10	5	3	4	1
Mar-10	3	8	7	0	4	0
Apr-10	4	10	10	1	7	1
May-10	5	14	12	3	10	0
June-10	9	18	26	2	16	0
Total	55	151	67	14	85	3

Table 2. Bonnet Carre' Spillway Sampling Effort. Sampling effort from July 1 2009 through June 30 2010.

Bonnet Carre' Spillway Sampling Effort						
		Methods				
Month	**Days**	**Gillnet**	**Trawl**	**Seine**	**Electrofish**	**Trotline**
Jul-09	3	10			4	
Aug-09	2	8		4	2	
Sep-09						
Oct-09	1	4		2	1	
Nov-09	2	5	1	1	5	
Dec-09						
Jan-10						
Feb-10	1	2	1	3	1	
Mar-10						
Apr-10	1	4	2	1	1	
May-10	1	4	2	3	2	
June-10	1	2		2		
Total	12	39	6	16	16	0

Table 3. Davis Pond Diversion Sampling Effort. Sampling effort from July 1 2009 through June 30 2010.

Davis Pond Diversion Sampling Effort						
		Methods				
Month	**Days**	**Gillnet**	**Trawl**	**Seine**	**Electrofish**	**Trotline**
Jul-09	4	10	1		7	
Aug-09	1	4	1		1	
Sep-09	1	2	2		2	
Oct-09	1	2	2		1	
Nov-09	2	6	4		3	
Dec-09						
Jan-10	3	8	7		2	1
Feb-10	1	2	4		1	
Mar-10	1	2	3		1	
Apr-10	1	2	3		1	1
May-10	2	4	8		3	
June-10	2	4	11		3	
Total	19	46	46	0	25	2

Table 4. Violet Siphon Sampling Effort. Sampling effort from July 1 2009 through June 30 2010.

Violet Siphon Sampling Effort						
		Methods				
Month	**Days**	**Gillnet**	**Trawl**	**Seine**	**Electrofish**	**Trotline**
Jul-09	3	9	2		4	
Aug-09	2	4			3	
Sep-09						
Oct-09						
Nov-09						
Dec-09	1	4			4	
Jan-10						
Feb-10	1	2			1	
Mar-10						
Apr-10						
May-10	1	4			3	
June-10	2	4	4		5	
Total	10	27	6	0	20	0

Table 5. Caernarvon Diversion Sampling Effort. Sampling effort from July 1 2009 through June 30 2010.

Caernarvon Diversion Sampling Effort						
		Methods				
Month	**Days**	**Gillnet**	**Trawl**	**Seine**	**Electrofish**	**Trotline**
Jul-09	5	10	3		6	
Aug-09	2	6	2		4	
Sep-09						
Oct-09						
Nov-09	1	4	1		1	
Dec-09	2	4	4		3	
Jan-10						
Feb-10	1	4			1	1
Mar-10	1	2	3		2	
Apr-10	1	2	3		3	
May-10						
June-10	2	4	11		4	
Total	15	36	27	0	24	1

Table 6. White Ditch Siphon Sampling Effort. Sampling effort from July 1 2009 through June 30 2010.

Sampling Effort						
		Methods				
Month	**Days**	**Gillnet**	**Trawl**	**Seine**	**Electrofish**	**Trotline**
Jul-09						
Aug-09						
Sep-09						
Oct-09	1	3	1		2	
Nov-09						
Dec-09						
Jan-10						
Feb-10						
Mar-10						
Apr-10						
May-10	1	2	2		2	
June-10	1	2	2		1	
Total	3	7	5	0	5	0

Table 7. West Pointe a la Hache Siphon, and Naomi Siphon Sampling Effort. West Pointe at la Hache was sampled in December 2009. Naomi Siphon was sampled on all other dates through June 30 2010.

Sampling Effort						
		Methods				
Month	**Days**	**Gillnet**	**Trawl**	**Seine**	**Electrofish**	**Trotline**
Jul-09						
Aug-09						
Sep-09						
Oct-09	1	3	1		2	
Nov-09						
Dec-09						
Jan-10	1	4	1		2	
Feb-10						
Mar-10	1	4	1		1	
Apr-10	1	2	2		2	
May-10						
June-10	1	2	1		3	
Total	5	15	6	0	10	0

Table 8. Species Sampled at Freshwater Diversions of the Lower Mississippi.

		Sample Locations							
Species	**Common Name**	**Bonnet Carre' Spillway**	**Davis Pond Diversion**	**Violet Siphon**	**Caernarvon Diversion**	**White Ditch Siphon**	**Naomi Siphon**	**West Pointe a la Hache Siphon**	**Total**
Dasyatis sabina	Atlantic stingray		3		1				4
Scaphirhynchus albus	pallid sturgeon		1						1
Scaphirhynchus platorynchus	shovelnose sturgeon		3						3
Polyodon spathula	paddlefish	12	38		4				54
Atractosteus spatula	alligator gar	1	1	7	14	7	22		52
Lepisosteus oculatus	spotted gar	45	195	131	171	125	154	1	822
Lepisosteus osseus	longnose gar	9	29	3	50		32	8	131
Lepisosteus platostomus	shortnose gar	24	8		2		2		36
Amia calva	bowfin		5						5
Hiodon alosoides	goldeye	1	4		1				6
Hiodon tergisus	mooneye	1							1
Elops saurus	ladyfish	4	35	78	125	21			263
Anguilla rostrata	American eel	3	32	13	27	1			76
Anchoa mitchilli	bay anchovy	29	191	108	6208	171	2		6709
Alosa chrysochloris	skipjack herring	70	26	170	50	9			325
Brevoortia patronus	Gulf menhaden	285	60	1588	221	229	1		2384
Dorosoma cepedianum	gizzard shad	1210	594	190	192	47	153	61	2447
Dorosoma petenense	threadfin shad	1511	409	5	189	40	12		2166
Ctenopharyngodon idella	grass carp						2		2
Cyprinella lutrensis	red shiner								0
Cyprinella venusta	blacktail shiner				1				1
Cyprinus carpio	carp	70	58		6		3		137
Hybognathus hayi	cypress minnow		1						1
Hybognathus nuchalis	silvery minnow		10		8	11			29
Hypophthalmichthys molitrix	silver carp	20	18	3	9		1	1	52
Hypophthalmichthys nobilis	bighead carp	3							3

Lythrurus fumeus	ribbon shiner	4	6	1	8				19
Macrhybopsis storeriana	silver chub	3	6		1				10
Notemigonus crysoleucas	golden shiner	1	1		1				3
Notropis atherinoides	emerald shiner		7		13				20
Notropis shumardi	silverband shiner				4				4
Notropis volucellus	mimic shiner	5	2						7
Opsopoedus emilae	pugnose minnow	3	1		1				5
Pimephales vigilax	bullhead minnow	4							4
Carpiodes carpio	river carpsucker	87	2						89
Carpiodes cyprinus	quillback	10							10
Carpiodes velifer	highfin carpsucker	1							1
Cycleptus elongatus	blue sucker		1						1
Erimyzon oblongus	creek chubsucker	1							1
Ictiobus bubalus	smallmouth buffalo	180	555	2	56	16	75		884
Ictiobus cyprinellus	bigmouth buffalo	51	32	2	9	10	59		163
Ictiobus niger	black buffalo	33	5	3	2	1	31		75
Minytrema melanops	spotted sucker		1						1
Ameiurus natalis	yellow bullhead		2		8	1			11
Ameiurus nebulosus	brown bullhead				1				1
Ictalurus furcatus	blue catfish	110	4783	72	1220	92	126	5	6408
Ictalurus punctatus	channel catfish	232	498	13	405	17	42	2	1209
Pylodictis olivaris	flathead catfish	16	94	3	13	3	1	2	132
Bagre marinus	gafftopsail catfish			8					8
Aphredoderus sayanus	pirate perch	6							6
Mugil cephalus	striped mullet	126	655	290	228	64	44	49	1456
Mugil curema	white mullet		29		1				30
Membras martinica	rough silverside		1						1
Menidia beryllina	inland silverside	80	29	91	103	49	1	5	358
Strongylura marina	Atlantic needlefish	3		7	10	1			21
Fundulus chrysotus	golden topminnow		1				1		2
Fundulus grandis	Gulf killifish			77		1		80	158

Gambusia affinis	western mosquitofish	25	46	44	1	45	1		162
Heterandria formosa	least killifish	2				1			3
Poecilia latipinna	sailfin molly			29				4	33
Cyprinodon variegatus	sheepshead minnow			1				65	66
Lucania parva	rainwater killifish			36		3	2	1	42
Morone chrysops	white bass	93	236	18	94	2	31	12	486
Morone mississippiensis	yellow bass	17	7		14		1		39
Morone saxatilis	striped bass		12		8			1	21
Morone saxatilis x M. chrysops	hybrid striped bass		2		1				3
Chaenobryttus gulosus	warmouth sunfish	86	519	48	85	2	13	3	756
Lepomis cyanellus	green sunfish	20	215	4	17	1			257
Lepomis humilis	orangespotted sunfish	344	3		1		3		351
Lepomis macrochirus	bluegill sunfish	709	720	135	351	97	221	6	2239
Lepomis marginatus	dollar sunfish		13						13
Lepomis megalotis	longear sunfish	302	269	17	28				616
Lepomis microlophus	redear sunfish	20	17	1	151	24	13		226
Lepomis miniatus	redspotted sunfish	13	19		97	59	24		212
Micropterus punctulatus	spotted bass		2						2
Micropterus salmoides	largemouth bass	508	821	43	396	6	21		1795
Pomoxis annularis	white crappie	99	15		9	1	3		127
Pomoxis nigromaculatus	black crappie	131	275	12	84	9	134	8	653
Etheostoma asprigene	mud darter				1				1
Percina caprodes	logperch	3							3
Percina maculata	blackside darter	1							1
Sander canadensis	sauger	4	11		1				16
Caranx hippos	crevalle jack				4				4
Oligoplites saurus	leatherjacket			7					7
Lutjanus griseus	gray snapper		1						1
Aplodinotus grunniens	freshwater drum	168	1167	13	629	14	31	1	2023
Bairdiella chrysoura	silver perch			1					1

Cynoscion arenarius	sand seatrout			68		17			85
Leiostomus xanthurus	spot			8					8
Micropogonias undulatus	Atlantic croaker			64	4	54			122
Sciaenops ocellatus	red drum			3		2			5
Herichthys cyanoguttatus	Rio Grande cichlid	1							1
Oreochromis species	Tilapia - hybrid (aureus x mozambicus)							1	1
Dormitator maculatus	fat sleeper	1	268	5	7	1585	28	1	1895
Eleotris pisonis	spinycheek sleeper		7	3	1	1	1		13
Gobiomorus dormitor	bigmouth sleeper		1						1
Ctenogobius boleosoma	darter goby					1			1
Ctenogobius shufeldti	freshwater goby	2	8	17	17	1	3		48
Gobionellus oceanicus	highfin goby			3				2	5
Gobiosoma bosc	naked goby					1			1
Citharichthys spilopterus	bay whiff			3					3
Paralichthys lethostigma	southern flounder	1		8	2	1			12
Trinectes maculatus	hogchoker	2	6	1	8	3			20
Total		**6801**	**13077**	**3425**	**11347**	**2839**	**1291**	**317**	**39188**

Davis Pond Diversion Project update submitted by USFWS Baton Rouge Fish and Wildlife Conservation Office
July 1, 2010

Preliminary results and evaluation of potential entrainment of the endangered pallid sturgeon (*Scaphirhynchus albus*) and shovelnose sturgeon (*Scaphirhynchus Platorynchus*) in the Davis Pond Diversion.

- 16 Sturgeon were captured, uniquely identified, measured, weighed, photographed, tagged with passive integrated transmitters (PIT), Floy, and VEMCO Sonic transmitters, and released into the outflow channel.
- Additional samples (fin clip and blood) were collected for genetic analysis.
- 3 sturgeon were captured in Davis Pond outflow channel and 13 were captured in the Mississippi river, north and south of the 310 and I-10 bridges.
- Gill nets were used in Davis Pond; Hoop nets were used in the Mississippi River.
- Initial results indicate 14 shovelnose or shovelnose hybrids and 2 pallid sturgeon. These were morphometric field identifications and are still pending genetic confirmation. One Pallid sturgeon was captured from Davis pond and one from the Mississippi river.
- Six stationary receivers were positioned intermittently to continuously track the movements of all tagged fish. One receiver is located on the river side of the structure and the remaining 5 are in the output channel. One is directly below the structure, one at the power line, one between the rail and car bridge, one south of the car bridge, and the final one near the end of the channel before the ponding area.
- After initial work up and external attachment of the sonic transmitter, the sturgeon were released in the output channel near channel receivers 1 and 2. The release dates ranged from July 19th through December 14th. Once released, the sturgeon were monitored with periodic receiver downloads.
- **Movements-Lost**
    - As of the last data download on 6/22/2010, no fish have escaped from the outflow canal through the control structure. One detection appeared on the river side receiver, but it was also simultaneously recorded on the first receiver in the outflow channel and the fish was detected on other receivers later that same day. The record indicates that the deployment array is sufficient to detect fish in the event that they move back into the river.
    - One fish never moved from channel receiver 1 and contact with the transmitter was lost on November 12, 2009 but oddly regained in May and June 2010. The fish still never moved from wing wall.
    - One fish made random movements to all 5 channel receivers, but is also considered lost because contact was lost after 16 days of movement (12/14-12/29).
    - Two other fish are considered lost because of similar data records.

- **Movements-channel**
  - Three fish were detected in the outflow channel at the last download and appeared to make random movements up and down to most channel receivers.
- **Movements-Pond**
  - **Nine** fish traveled from the initial receiver, south past the last receiver into the ponding area beyond the bridges. One of these fish returned after a month and left again -1 returned after 4 months then left again. The amount of time spent in the channel (before passing the furthest receiver signal range) varies by individual fish from as little as 1 day to as long as a 1 month.

Total

- River: 0 Lost: 4 In channel: 3 Pond: 9

- Continuous monitoring and receiver downloads will determine if fish move back into the channel from the ponding area or out of structure into the river in the future. During the study period the Mississippi river has been at high water levels which cause high velocity of water through the structure. Therefore, the river has not been low enough to answer the question of entrainment at all environmental conditions.
- **Recaptures**
  - One pallid sturgeon that was captured, tagged, and released on 11/17/09 into the outflow channel was recaptured on 11/19/09 by Nicholls State University trawl gear. It was examined and deemed to be in good condition and released with transmitter intact.
  - One sturgeon was captured, tagged, and released on 12/14/09. It was recaptured on 5/27/09 by Nicholls in trawl gear without the transmitter but showed evidence of scarring where the transmitter tore through the dorsal fin tissue. The fish seemed otherwise in good condition.

- **Several sturgeon have used the entire channel and have moved freely back and forth to every receiver. This data indicates that the fish can physically navigate the waters and are not overpowered by current. Neither date nor time of day has seemed to detour movement in the channel. In addition, two sturgeon that went directly into the ponding area after release returned months later, ruling out the idea that they suffered initial mortality or were blocked from returning.**

Table 1: Capture date and location, species and morphometric data of the 16 Sturgeon released into the Davis Pond Diversion outflow channel.

Capture_Date	Location	Species	TL_mm	weight_g
7/9/2009	Diversion	Shovelnose	620	566
10/20/2009	River	Shovelnose	765	1046
10/22/2009	River	Shovelnose	781	2058
11/3/2009	Diversion	Shovelnose	715	1556
11/17/2009	Diversion	Pallid	*	770
11/19/2009	River	Shovelnose	562	304
	River	Shovelnose	825	1608
	River	Pallid	936	2754
11/23/2009	River	Shovelnose	656	752
	River	Shovelnose	610	686
	River	Shovelnose	647	749
	River	Shovelnose	579	374
	River	Shovelnose	625	416
12/14/2009	River	Shovelnose	507	350
	River	Shovelnose	757	1320
	River	Shovelnose	668	800

***No measurement available**

Scope of Work

Entrainment of Sturgeon by Water Diversions in the Lower Mississippi River

Background

Water diversions are used for flood control, water supply, and habitat restoration in the lower Mississippi River (LMR) but their impacts on imperiled sturgeon populations are unknown. Comprehensive risk assessments for entrainment of sturgeon by water diversions require substantial inputs including field data on local sturgeon populations, life history information, output from population modeling simulations, and results of experimental studies. These risk assessments, however, can provide probability of entrainment for specific environmental scenarios (e.g., time of year, river stage, and flow fields generated by a structure). Such probabilities can be eliminated or reduced through modified operations of structures (e.g., schedule of operation, rate of diversion, implementation of deterrents). Otherwise, costly monitoring and rescue programs will be ongoing elements of O&M costs and concerns regarding long-term impacts to endangered sturgeon will go unresolved.

Proposed study will consist of concurrent evaluations of fish communities in the Mississippi River and in outflow channels of proposed and existing diversions:

Water Diversion	Status	Sampling in the Mississippi River	Sampling in the Outflow Channels
Convent/Blind River	Proposed	+	
Hope Canal	Proposed	+	
Bonnet Carre	Existing	+	+
Davis Pond	Existing	+	+
Violet Siphon	Existing	+	+
Caernarvon	Existing	+	+
White's Ditch	Existing	+	+
Myrtle Grove	Proposed	+	

Objectives

Objectives of this study are:

i.) Population assessment of the federally endangered pallid sturgeon

ii) Documentation and quantification of sturgeon entrainment

iii) Population modeling of pallid sturgeon analyzing impacts of entrainment-based "take" by water diversions

Approach

The study will be divided into three distinct tasks utilizing contractual assistance to address the broad scope of effort. Tasks presented below are initial components required for a comprehensive risk assessment for the lowermost reach of the Mississippi River (Figure 1 – Conceptual model of study showing integration of tasks). They address the following questions:

1) How many sturgeon occur in this reach of river (Task 1)?
2) What is the extent and circumstances of entrainment (Task 2)?
3) What are the impacts of entrainment to the population (Task 3)?

This work will be coordinated with that of any related ongoing studies (e.g., telemetry studies of entrained fish, experimental studies of barriers and potential deterrents, population studies in other reaches of the Mississippi River). In particular, ERDC and Nicholls State will coordinate with USGS and USFWS to help them obtain adequate number of sturgeon for their telemetry studies.

Data collected for existing diversions can be used to predict potential impacts of proposed diversions (see Table on page 1). Furthermore, the results of this study will provide an analytical framework to begin developing field approaches and experimental designs to evaluate entrainment at Old River Control Structure for future studies.

Task 1: Population Assessment

Field Sampling

Field sampling of pallid sturgeon, shovelnose sturgeon, and associated species will be conducted in the lower reaches of the Mississippi River at sites corresponding to proposed and existing diversions. Sampling will be conducted according to standard protocol established in previous field assessments (Killgore et al., 2007a). Each sampling location will be identified as littoral or channel border/main channel habitat. Littoral locations will correspond to areas adjacent to the diversion where sturgeon are more susceptible to entrainment. Channel border/main channel locations will be near the diversion site but more typical of habitat occupied by pallid sturgeon (e.g., steep sloping banks, thalweg). A habitat classification scheme will be developed from these data. Two sampling gear types will be used to capture juvenile and adult fish: trotlines and gill nets. In addition, otter trawls will be used to sample young-of-year sturgeon at selected sites where sampling conditions are conducive for this type of gear. Replicate numbers of each gear type and consistent deployment techniques will used during each sampling event to facilitate statistical analysis of temporal and spatial trends.

Trotlines (61 m long, 60 dropper lines spaced every 0.9 m tied to 2/0 hooks) will be baited with worms (Canadian night crawlers), fished overnight along the bottom, and retrieved the following morning. Up to eight trotlines will be deployed per night at each site, each fishing approximately 16 hours. Trotlines will be evenly distributed between littoral and channel border/main channel locations. Experimental mesh gill nets (27.4 m by 1.8 m, six mesh panels ranging from 23 to 76 cm) will be set in littoral locations only. Two gill nets will be set at each site in the late afternoon and retrieved the following morning, usually over a 16-hour period. A 3.0-m Missouri benthic trawl, based on the design by Hertzog et al. (2005), will be as used to sample smaller benthic fishes. The distance traveled, average speed, and depth range will be recorded during each trawling event. Number of trawls per site will be dependent on available locations conducive for this type of gear (i.e., relatively un-obstructed river bottom in waters ranging from 1-15 m). Water quality (temperature, dissolved oxygen, pH, conductivity,

turbidity) and hydraulic (depth velocity) variables will be measured at each sampling location. GPS coordinates of sampling locations will also be recorded, entered into ARC-GIS program, and habitat characteristics will be described from maps and field measurements.

Fish Measurements

All fish captured will be identified to species, enumerated, and total length (also fork length for sturgeon) will be measured. Additional morphometric measurements and meristic counts will be taken on pallid sturgeon to verify species designation *a posteriori* as described by Murphy et al. (2007a). Prior to release, shovelnose and pallid sturgeon will be externally tagged with t-anchor bar spaghetti tags. A toll-free phone number along with the tag number will be inscribed on each tag. In addition, all pallid sturgeon specimens will be scanned for the presence of a Passive Integrated Transponder (PIT) tag, and if no tag is detected, a non-encrypted PIT tag will be inserted at the base of the dorsal fin. All pallid sturgeon will also be scanned for coded wire tags to determine if individuals are of hatchery origin.

Endoscopy

During spring sampling, pallid sturgeon will be anesthetized using tricaine methanesulfonate, and subjected to endoscopic evaluation of their coelom (coelioscopy) on the river bank. Once induced, fish will be moved to a surgery platform on the river bank and placed in right lateral recumbency with a flow pipes directed into the mouth to maintain anesthesia. Small straight hemostats will be used to puncture the linea alba and enter the coelom, taking care not to damage the underlying viscera. Using a 2.7 mm rod-lens telescope and gravity–fed sterile saline infusion, gender and reproductive stage will be determined. The incision will be closed with a simple interrupted suture of antibiotic-impregnated monofilament. Fish will recover in aerated river water and immediately released.

Ageing

Prior to release, an approximately 12-mm segment of the anterior-most fin ray of each pallid sturgeon, usually the right ray, will be removed The segment will be taken proximal to the body of the fish (approximately 5 mm from body surface) using wire cutters (for small fish with relatively thin rays) or a Dremel® rotary tool (for larger fish with relatively thick rays). This technique is intended to remove a usable segment of the oldest part of the ray while preserving normal articulation and most of the "leading" edge of the fin. The ray segment will be air dried and later cut perpendicularly on a Buehler Isomet® slow speed saw into a 0.46 to 0.58 mm section; two sections will be cut from each ray. Sections will be mounted on a microscope slide using clear fingernail polish and labeled with a unique identification number (typically the number of the PIT tag implanted in that fish). All sections will be examined by two experienced readers using a binocular microscope and variable magnification with light transmitted through the section. Using pectoral fin rays, a von Bertalanffy growth equation will be calculated for fork length (FL), and the instantaneous mortality rate (Z) will be estimated with a catch curve (Ricker 1975). Catch curves will be generated from the linear regression of the $\log_{10}$ number of individuals per year class (Ricker 1975).

Effective Population Size

The effective population size (N_e) is a statistic that can be estimated from genetic data sets and enables a robust estimate of the breeding size of the population giving rise to the population being sampled. In practice, effective population size is defined as the size of an idealized population that has the same rate of genetic drift or inbreeding (depending on method employed) as the sampled population. Effective population size is smaller than the census size of a population due to factors such as unequal reproductive success among all individuals that comprise that population. However, the lack of recaptures of tagged sturgeon (see Killgore et al. 2007) precludes population size estimates using traditional mark-recapture procedures. Effective population size provides the only realistic approach of obtaining this important demographic variable for population viability analysis.

This component of the study will provide genotypes from tissue samples taken in the field of up to 50 lower basin pallid sturgeon and 150 lower basin shovelnose sturgeon, as well as estimates of effective population size (N_e) for these sturgeon based on the genetic data set. The genotype data for pallid sturgeon samples will be determined using microsatellite data. This study will utilize the primers and methods from Ray et al. (2007). Once the genotypes for all samples have been determined, the genotype data will be analyzed in the program Lamarc to provide both maximum likelihood and Bayesian estimates of effective population size. Sample size will be higher for shovelnose sturgeon because this species is more abundant than pallid sturgeon. If necessary, we will use microsatellite data derived from shovelnose sturgeon to provide an estimate of the effective population size (Ne) of pallid sturgeon assuming a ratio of shovelnose to pallid sturgeon (e.g., 3:1 ratio).

Task 2: Documentation of Entrainment

Existing diversions provide opportunities to sample the outflow channels and associated habitats for entrained sturgeon. Five diversion structures are currently in operation or potentially operable. Each of the diversions has the potential to entrain most fish species found in the lower Mississippi River. Recent sampling of the Davis Pond Diversion has documented forty five species of fish in the outflow channel just below the diversion structure. It is likely that many more species are being entrained (Dyer 2007). For most species, entrainment may not be detrimental to the individuals or the regional population. Other species, particularly sturgeon, the principal target species of this study, may be negatively affected by entrainment since the existing diversions spill into habitats with lower water flow, warmer temperatures and lower oxygen content. The species composition of the entrained community is likely to vary with flow rate, water temperature, and season. In addition to targeting the entrainment of sturgeon, this project will also document all other fish species entrained and examine the relationship between entrainment and physical conditions.

The five existing freshwater diversions (Bonnet Carre, Davis Pond, Violet Siphon, Caenarvon, and White's Ditch) will be sampled on a rotating basis throughout the remainder of FY09 and throughout the 2010 fiscal year. Seasonal sampling is necessary to evaluate risk of entrainment at different water temperatures and river stages. At least two sampling events will occur each season, with each sampling event taking up to two weeks to complete. Sturgeon may be more likely to be entrained when actively moving throughout the river (lower water temperatures), whereas entrainment risk may be substantially lower when water temperatures increase during summer months and sturgeon movement decrease. A variety of sampling

methods has been shown to provide a less biased estimate of fish community composition (Cashner et al. 1994). In this study, sampling will consist of gillnetting, electrofishing, seining, and trotlining. Electrofishing will be the principal method of sampling, and where practical, seine and gill net samples will be taken. Trotlines will be deployed in the channel to target sturgeon. Habitat measurements, similar to that described for Task 1, will be taken during each sampling event. Fish taken during sampling will be identified to species in the field, counted, and returned to the water. Voucher specimens of each species taken in the diversions will be preserved in 10% formalin and deposited in the collection at the Tulane Museum of Natural History. Where laboratory identification is necessary, voucher specimens will be taken on ice or preserved in 10% formalin and identified in the Marine Biology Laboratory at Nicholls State University.

Task 3: Population Modeling and Risk Assessment

This task will integrate findings from Tasks 1 and 2 to evaluate risk of entrainment and impacts to sturgeon populations. Population modeling will consist of two efforts: short-term development of descriptive demographic models and long-term development of predictive viability models. Demographic models, based on age-structure of populations, will be used to evaluate existing status of the pallid sturgeon (e.g., declining, stable, or increasing) within the lower reach of the Mississippi River. Demographic variables needed for population modeling (Table 1) will be determined in Task 1. Entrainment-based losses, determined in Task 2, will be used in population viability analysis (PVA). PVA quantifies viability as predicted time-to-extinction (or extirpation): greater viability is reflected in longer (or indefinite) time-to-extinction. PVA has been successfully used to establish causes of extinction (e.g., Turvey and Risley, 2006) and to evaluate individual threats to survival (e.g., Brook et al., 2002). PVA is an approach that can be used to compare scenarios of entraining low numbers (e.g., 10) to high numbers (e.g., >>100) of sturgeon, and determine if a threshold is reached that constitutes a jeopardy opinion. Demographic models will be available after two years; viability models will be completed by Year 3.

Capture of sturgeon in the outflow of diversions will verify entrainment. However, the magnitude of entrainment will remain speculative. PVA will require input of different "take" levels to properly evaluate the range of alternatives in assessing risk to pallid sturgeon populations. It is likely that a combination of at least three different approaches will be used to determine different take scenarios: Statistic-based will utilize predictive models derived from the Task 2 field study to determine numbers of sturgeon entrained, if any, over a given time period. Hydraulic-based will use the statistical model as an initial starting point, estimate numbers of sturgeon on a volumetric scale (e.g., numbers per cubic meter), and multiply this value by the total volume of water diverted into the marshes. If information is available, volumetric estimates of sturgeon abundance will be supplemented from published rates of entrainment for a given volume of water during dredging or other diversion activities. Biology-based will incorporate swimming speeds, rheotactic behavior, and other types of avoidance behavior by sturgeon to modify the hydraulic-based estimates. Once a final model is developed, different levels of entrainment will be evaluated using the PVA to determine if a jeopardy opinion is warranted.

Products

Products will include a final report at the end of Year 3. However, interim products will be prepared:

- Sept 2009 – Progress report on number of sturgeon collected in the river and outflows of each diversion
- December 2009 – Power point presentation on progress to date
- January 2010 – Draft report on Year 1 activities for Task 1 and 2 including power point
- May 2010 – Draft population (age-structured) model
- December 2010 – Draft report on Years 1 and 2 for Tasks 1 and 2
- June 2011 – Draft population viability model with risk assessment
- September 2011 – Draft final report
-

Time and Cost Estimate

Fieldwork will begin in May 2009 and continue throughout FY10 and part of FY11 to accommodate a 12-month period. For Tasks 1 and 2, sampling will occur all four seasons during the first full year. Two field trips per season (except summer with just one trip) are planned, with each trip taking approximately 5-8 days to complete. Based on catch rates during Year 1, sampling periods and frequency may be adjusted during Year 2 to emphasize months when sturgeon are more likely to occur near diversion sites or when the operation of the structure is more likely to impose a higher entrainment risk. Task 3 (population modeling and risk assessment) will begin in Year 1 by compiling all demographic variables from literature and ERDC data bases, evaluate approaches to estimate take, begin a draft development of a PVA model, and continuing updating and refining models throughout the study for a completion date by the end of Year 3.

Task	Cost (x1000)		
	FY09	FY10	FY11
1 - Population Assessment[1]	100	220	30
2 – Documentation and Quantification of Entrainment[2]	56	72	20
3 – Population Modeling and Risk Assessment	40	50	75
Total	196	342	125

[1] Includes funding for Dr. Rob Wood at Saint Louis University to conduct genetic analysis

[2] Funding for Dr. David Schultz, Nicholls State University.

Literature Cited

Akcakaya, H.R. 2000. Population viability analyses with demographically and spatially structured models. Ecological Bulletin 48: 23-28.

Brook, B.W., D.W. Tonkyn, J.J. O'Grady, and R. Franklin. 2002. Contribution of inbreeding to extinction risk in threatened species. Conservation Ecology 6: 16 pp.

Cashner, R. C., Gelwick, F. P., and Matthews, W. J. 1994. Spatial and temporal variation in the Distribution of fishes of the Labranche Wetlands area of the Lake Pontchartrain estuary, Louisiana. Northeast Gulf Science 13(2): 107 – 120.

Divers, S. J., S. S. Boone, J. J. Hoover, K. A. Boysen, K. J. Killgore, C. E. Murphy, S. G. George, and A. C. Camus. 2009. Field endoscopy for identifying gender, reproductive stage and gonadal anomalies in free-ranging sturgeon (*Scaphirhynchus*) from the Lower Mississippi River. Journal of Applied Ichthyology (in review).

Dyer, H. P. 2007. Seasonal Fish Assemblages of Bayou Lafourche Upstream and Downstream of the Thibodaux Weir. Master's Thesis. Nicholls State University, Thibodaux, Louisiana.

Hertzog, D. P., V. A. Barko, J. S. Scheibe, R. A. Hrabik, and D. E. Ostendorf. 2005: Efficacy of a benthic trawl for sampling small-bodied fishes in large river systems. North Am. J. Fish. Manage. **25:** 594-603.

Killgore, K.J., J.J. Hoover, S.G. George, B.R. Lewis, C.E. Murphy, and W.E. Lancaster. 2007a. Distribution, relative abundance, and movements of pallid sturgeon in the free-flowing Mississippi River. Journal of Applied Ichthyology 23(4): 476-483.

Killgore, K.J., J.J. Hoover, J.P. Kirk, S.G. George, B.R. Lewis, C.E. Murphy. 2007b. Age, growth, and mortality of pallid sturgeon in the free-flowing Mississippi River. Journal of Applied Ichthyology. 23(4): 452-456.

Murphy, C.E., J.J. Hoover, S.G. George, and K.J. Killgore. 2007a. Morphometric variation among river sturgeons (*Scaphirhynchus* spp.) of the Middle and Lower Mississippi River. Journal of Applied Ichthyology. 23(4): 313-323.

Murphy, C.E., J.J. Hoover, S.G. George, B.R. Lewis, and K.J. Killgore. 2007b. Types and occurrence of morphological anomalies in *Scaphirhynchus* spp. of the Middle and Lower Mississippi River. Journal of Applied Ichthyology. 23(4): 354-358.

Ray, J.M., C.B. Dillman, R.M. Wood, B.R. Kuhajda, and R.L. Mayden. 2007. Microsatellite variation among river sturgeons of the genus Scaphirhynchus (Actinopterygii: Acipenseridae): a preliminary assessment of hybridization. Journal of Applied Ichthyology 23: 304-312.

Turvey, S.T. and C.L.. Risley. 2005. Modeling the extinction of the Stellar sea cow. Biological Letters 2: 94-97.

Table 1. List of parameters required for population viability analysis (sensu Akcakaya, 2000).	
Parameter	**Method/Source of Computation**
Density by age/stage	Effective Population Size
Survival/mortality by age/stage	Catch Curve
Fecundity	Literature
Age at first reproduction	Endoscopy
Spawning interval	Endoscopy
Immigration, emigration	Mark-recapture, literature
Initial population abundance	Effective Population Size
Habitat availability	GIS
Habitat utilization/preference	Field-Derived Habitat Assessment
Environmental fluctuations	Stage Data
Threats	Entrainment in outflows of diversions

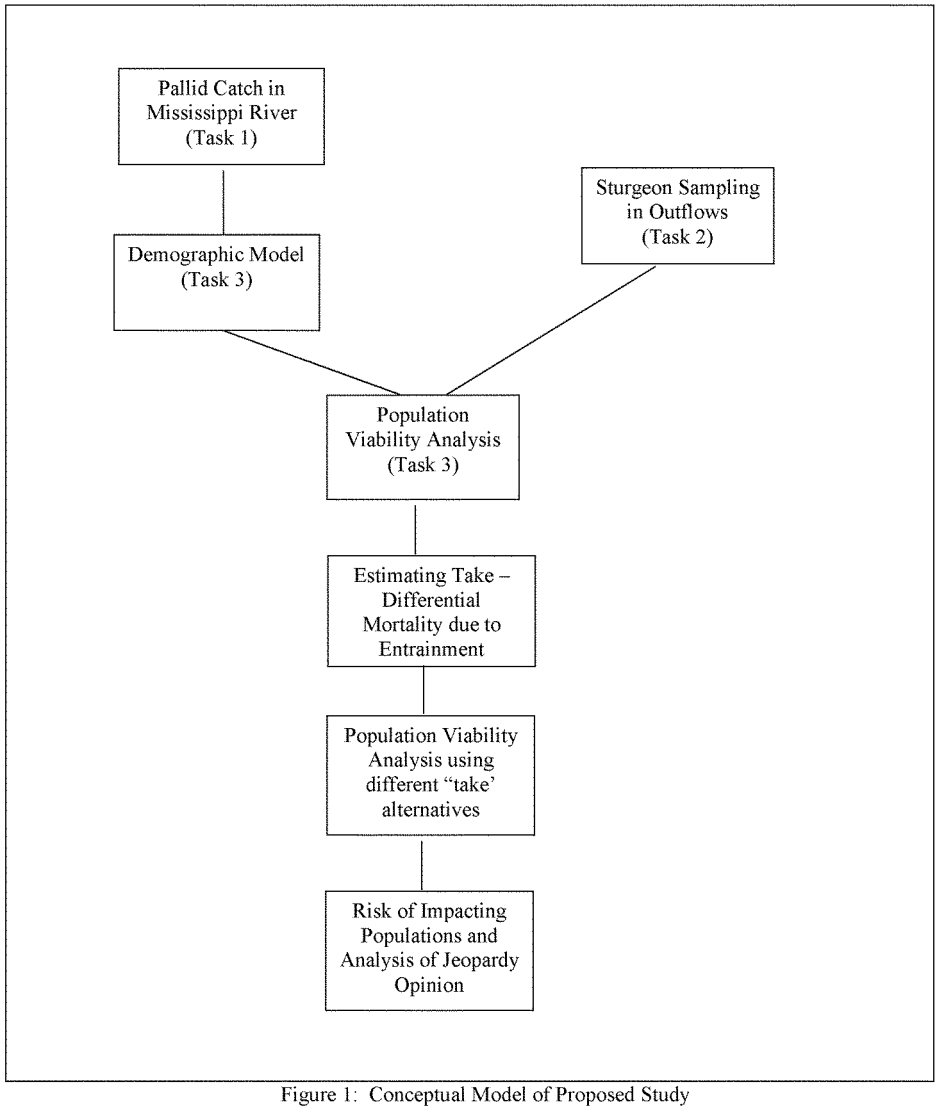


Figure 1: Conceptual Model of Proposed Study

Entrainment of Fish Species by Water Diversions in the Lower Mississippi River

A research proposal submitted to the U.S. Army Engineer Research and Development Center.

Freshwater Fishery Investigations: EL-12

David L. Schultz, Ph.D.
Department of Biological Sciences
Nicholls State University
P.O. Box 2021
Thibodaux, LA 70310
e-mail: dave.schultz@nicholls.edu
Voice: 985-448-4720
Fax: 985-493-2496
Nicholls State University DUNS Number: 065479529

Purpose
This project will sample fish populations in existing diversions projects of Mississippi River water in south Louisiana. Five diversions structures are currently in operation or potentially operable. Each of the diversions has the potential to entrain most fish species found in the lower Mississippi River (Barko et al. 2006). Recent sampling of the Davis Pond Diversion has documented forty five species of fish in the outflow channel just below the diversion structure. It is likely that many more species are being entrained (Dyer 2007). For most species, entrainment may not be detrimental to the individuals or the regional population. Other species, particularly sturgeon, the principal target species of this study, may be negatively affected by entrainment since the existing diversions spill into habitats with lower water flow, warmer temperatures and lower oxygen content. The species composition of the entrained community is likely to vary with flow rate, water temperature, and season. In addition to targeting the entrainment of sturgeon, this project will also document all other fish species entrained and examine the relationship between entrainment and physical conditions.

Objectives
1. Document the entrainment of fish species in diversions of the lower Mississippi River in south Louisiana.
2. Collect data and samples from entrained sturgeon to support the goals of estimating population size of sturgeon in the Mississippi River.
3. Collect physical data in each diversion, including a flow profile, dissolved oxygen content, temperature, turbidity, conductivity, and pH.
4. Examine the relationship between physical habitat characteristics and entrainment of fish species.

Project Implementation
Five existing freshwater diversions (Bonnet Carre, David Pond, Violet Siphon, Caenarvon, and White's Ditch) will be sampled on a rotating basis throughout the remainder the 2009 fiscal year (ending September 30) and throughout the 2010 fiscal year. In fy 2009, 40 days of sampling will be conducted. Each diversion will be sampled at least 4 times with 8 days of effort at each diversion. Seasonal sampling is necessary to evaluate risk of entrainment at different water temperatures and river stages. Sturgeon may be more likely to be entrained when actively moving throughout the river (lower water temperatures), whereas entrainment risk may be substantially lower when water temperatures increase during summer months and sturgeon movement decrease. In fy 2010, 60 days of sampling will be conducted. Each diversion will be visited at least twice in each quarter with 3 days of total sampling effort in each quarter.

Schedule
May/June 2009: Sample all diversions with 2 days of effort at each diversion.
July 2009: Sample all diversions with 2 days of effort at each diversion.
August 2009: Sample all diversions with 2 days of effort at each diversion.
September 2009: Sample all diversions with 2 days of effort at each diversion.
October 2009: Analyze the relationship between physical habitat characteristics and species composition of entrained communities.
November 2009: Report preliminary findings.
December 2009/January 2010: Sample all diversions with 3 days of effort at each diversion.
February/March 2010: Sample all diversions with 3 days of effort at each diversion.
May/June 2010: Sample all diversions with 3 days of effort at each diversion.
July/August 2010: Sample all diversions with 3 days of effort at each diversion.
October 2010: Analyze the relationship between physical habitat characteristics and species composition of entrained communities.
November 2010: Prepare and deliver final report.

Methods:
A variety of sampling methods has been shown to provide a less biased estimate of fish community composition (Cashner et al. 1994). In this study, sampling will consist of gillnetting, electrofishing, seining, and trotlining. While gillnets and trotlines are deployed samples of the fish community will be taken by electrofishing or seining. Electrofishing will be the principal method of sampling and where practical, seine samples will be taken. Fish taken during sampling will be identified to species in the field, counted, and returned to the water. Voucher specimens of each species taken in the diversions will be preserved in 10% formalin and deposited in the collection at the Tulane Museum of Natural History. Where laboratory identification is necessary, voucher specimens will be taken on ice or preserved in 10% formalin and identified in the Marine Biology Laboratory at Nicholls State University.

References:
Barko, V. A., D. P. Herzog, and M. T. O'Connell. 2006. Response of Fishes to Floodplain Connectivity During and Following a 500-Year Flood Event in the Unimpounded Upper Mississippi River. Wetlands 26(1): 244 – 257.

Cashner, R. C., Gelwick, F. P., and Matthews, W. J. 1994. Spatial and temporal variation in the Distribution of fishes of the Labranche Wetlands area of the Lake Pontchartrain estuary, Louisiana. Northeast Gulf Science 13(2): 107 – 120.

Dyer, H. P. 2007. Seasonal Fish Assemblages of Bayou Lafourche Upstream and Downstream of the Thibodaux Weir. Master's Thesis. Nicholls State University, Thibodaux, Louisiana.

Budget

Breakdown	Year 1 FY 2009	Year 2 FY 2010	Total
PI Salary	$14,022.00	$21,033.00	$35,055.00
PI Fringe	$3,505.50	$5,258.25	$8,763.75
Graduate Student Employees	$7,200.00	$10,800.00	$18,000.00
Undergrad Student Employees	$4,800.00	$7,200.00	$12,000.00
Total Salaries & Benefits	$29,527.50	$44,291.25	$70,124.25
Travel – *Domestic*	$5,000.00	$7,500.00	$12,500.00
Operating Services - *(maintenance)*	$600.00	$900.00	$1,500.00
Supplies	$2,000.00	$3,000.00	$5,000.00
Total Direct Costs	$34,527.50	$51,791.25	$82,624.25
Indirect Cost (F&A)	$13,271.00	$19,907.00	$31,294.00
Equipment	$8,000.00		$8,000.00
Total Cost	**$55,798.50**	**$71,698.25**	**$127,496.75**

Budget Justification:

The PI's 9 month academic salary is $56,961 or a daily rate of $292.11 During year 1, 48 days of work will be devoted to this project. This amounts to $14,022.00. During year 2, 72 days of work will be devoted to this project. This amounts to $21,033.

Fringe 25% is of salary.

Graduate students will be paid at a rate of $150 per day. FICA will be deducted from this amount during summer employment periods. During year 1, 48 days of work will be devoted to this project. This amounts to $7,200. During year 2, 72 days of work will be devoted to this project. This amounts to $10,800.
Undergraduate students (or a less experienced graduate student) will be paid at a rate of $100 per day. FICA will be deducted from this amount during summer employment periods. During year 1, 48 days of work will be devoted to this project. This amounts to $4,800. During year 2, 72 days of work will be devoted to this project. This amounts to $7,200.

Travel to and from field sites will average approximately $125 per day for 40 days of field work. This includes mileage and meals. Overnight stays near the field site will be used where efficiency can be gained in terms of mileage and work time.

Operating services will include maintenance, repair, and calibration of field equipment.

Supplies will include preservatives, specimen jars, and replacement nets.

The federal rate for indirect costs is 51% of salaries, excluding fringe.

Two flow meters will be required for this project. Marsh-McBurny Flomate 2000 flow meters with poles and cables will cost just under $4000 each.

Microsatellite Analysis and Effective Population Size Estimates of Pallid Sturgeon (Scaphirhynchus albus) from the Lower Mississippi River System.

A research proposal submitted to the U.S. Army Engineer Research and Development Center.

Freshwater Fishery Investigations: EL-12

Robert M. Wood, Ph.D.
Department of Biology
Saint Louis University
3507 Laclede Ave.
St. Louis, MO 63103-2010
e-mail: wood2@slu.edu
Voice: 314-977-3904
Fax: 314-977-3658

30 March 2009

Objectives

1. Provide genetic analyses of Pallid Sturgeon based on 14 microsatellite loci.
2. Use the microsatellite data to provide an estimate of the effective population size (N_e) of Pallid Sturgeon within the Lower Mississippi River Basin.
3. Use the microsatellite data coupled with age estimates of sampled Pallid Sturgeon to develop an estimate of effective population size by year class to determine whether the Lower Mississippi River Basin population of Pallid sturgeon is increasing in size, decreasing in size or is stable.
4. Use microsatellite data derived from Shovelnose Sturgeon to provide an estimate of the effective population size (Ne) of this species within the Lower Mississippi River Basin.
5. Use the data derived from Objective four (above) coupled with the assumed 3:1 ratio of shovelnose to Pallid as a means of validating the estimates derived in Objective 3 (above).
6. Evaluation of entrained vs. non-entrained Pallid Sturgeon to assess whether the microsatellite data provide any quantitative genetic distinction between these two groups.

Products

Genotypes of up to 50 Lower Basin Pallid Sturgeon and 150 Lower Basin Shovelnose sturgeon as well as estimates of effective population size (N_e) for these sturgeon based on the genetic data set. Estimates will include an aggregate estimate based on all samples of each species provided as well as an estimate by age class within each species to determine whether the Lower Mississippi River Basin population of Pallid sturgeon is increasing in size, decreasing in size or is stable. Statistics derived from analyses of the Shovelnose Sturgeon are critical as an external means of validating the Pallid Sturgeon population estimates and providing fundamental population level data for the Population Viability Analyses (PVA) being conducted by ERDC personnel.

Schedule (Month and Year)

May 09	Begin receiving samples from ERDC Biologists.
June 09	Begin genomic DNA preparation and microsatellite analyses of Pallid Sturgeon samples provided by ERDC.
July 09-Oct. 09	Continue with DNA preparation and microsatellite analyses of all tissues provided in FY 09.
Nov. 09-Dec. 09	Prepare initial estimates of population size and communicate findings in report form.

Jan. 10–Sept. 10	Completion of genotyping for all samples provided by ERDC.
Oct.10-Dec. 10	Analysis of data and preparation of final estimates of population size for each year class of both species contained in the samples.

Methods

The genotype data for Pallid Sturgeon samples will be determined using microsatellite data. This study will utilize the primers and methods from Ray et al. (2007). Once the genotypes for all samples have been determined, the genotype data will be analyzed in the program Lamarc to provide both maximum likelihood and Bayesian estimates of effective population size. The effective population size (N_e) is a statistic that can be estimated from genetic data sets and enables a robust estimate of the breeding size of the population giving rise to the population being sampled. In practice, effective population size is defined as the size of an idealized population that has the same rate of genetic drift or inbreeding (depending on method employed) as the sampled population. Effective population size is smaller than the census size of a population due to factors such as unequal reproductive success among all individuals that comprise that population. While a variety of approaches can be employed to estimate N_e the approaches used in the Lamarc statistical software package are currently considered to provide the most robust estimates of N_e given the types of data we are collecting and the sample sizes that will be available.

Stepwise process for data generation and analysis

1) Genomic extraction of fin or muscle tissue: a single extraction will provide enough DNA template for all genetic work to be conducted.
2) Polymerase chain reaction (PCR): amplification of target DNA. Each microsatellite locus must be amplified in a PCR reaction using fluorescent dye-labeled primers.
3) Determine size of microsatellite fragments: The labeled PCR product will be run on a Beckman Coulter CEQ 8000 automated sequencer and the fragment size (in number of bases) detected and scored by the software included with the sequencer.
4) Allele size verification of fragments. One individual for each microsatellite locus must be sequenced to confirm that fragment size detected is equivalent to the actual allele size (due to different migration rates on sequencer). All DNA sequence and microsatellite data will be generated at Saint Louis University.
5) Statistical analyses of data. Using software program Lamarc for estimates of population genetic parameters and the programs Genepop and Structure to integrate the newly acquired data with previously collected data from Ray et al. (2007).

References

Kuhner, M.K. 2006. Lamarc 2.0: maximum likelihood and bayesian estimation of population parameters. Bioinformatics, 22(6):768–770, March 2006.

Pritchard, J.K. , M. Stephens and P. J. Donnelly, 2000. Inference of population structure using multilocus genotype data. Genetics 155: 945-959.

Ray, J.M., R.M. Wood, C.B. Dillman, R. L. Mayden, and B.R. Kuhajda. 2007. Microsatellite analysis of the endangered river sturgeons (*Scaphirhynchus* species) from the lower Mississippi River Basin. Journal of Applied Ichthyology 23:304-312.

Raymond M. and F. Rousset. 1995. GENEPOP (version 1.2): population genetics software for exact tests and ecumenicism. J. Heredity, 86:248-249.

Budget:

Start of Grant Period	Year 1 FY09	Year 2 FY10	Total
PI Summer Salary	$0	$0	
Post Doc(s)	$0	$0	
Grad Student(s)	$3,090	$3,090	
Undergraduate(s)	$0	$0	
Technician(s)	$0	$0	
Total Personnel	$3,090	$3,090	$6,180
PI Fringe	$0	$0	
Post Doc Fringe	$0	$0	
Grad Health Insurance	$374	$393	
Technician Fringe	$0	$0	
Total Fringe	$374	$393	$767
A. Total Personnel	**$3,464**	**$3,483**	**$6,947**
Tuition	$0	$0	$0
Item 1	$0	$0	
Item 2	$0	$0	
Total Capital Equipment	$0	$0	$0
Domestic Travel	$600	$1,100	
Foreign Travel	$0	$0	
Total Travel	$600	$1,100	#REF!
Supplies	$12,835	$22,500	
Item 2	$0	$0	
Total Other Direct/Supplies	$12,835	$22,500	$35,335
Publication Costs	$0	$0	$0
B. Total General Expenses	**$13,435**	**$23,600**	**$37,035**
C. Total Direct (A+B)	$16,899	$27,083	$43,982

D. Indirect Cost**	**$8,027**	**$12,864**	**$20,891**
***Indirect Cost Base**	*$16,899*	*$27,083*	*$43,982*
E. Amount of Request	**$24,926**	**$39,947**	**$64,873**

Proposal to Evaluate the Potential for Pallid Sturgeon to Return to the Mississippi River From the Discharge Channel of the Davis Pond Freshwater Diversion

Submitted by: Glenn C. Constant
U. S. Fish and Wildlife Service
Baton Rouge Fish and Wildlife Conservation Office
(225)-578-8067
Glenn_Constant@fws.gov

Objective: The primary objective of this study will be to determine if pallid sturgeon can return to the Mississippi River after entering the diversion channel through the water diversion structure. Additionally, observing behavioral tendencies of these fish in response to natural and anthropogenic environmental variation will be useful in developing operational practices that minimize or eliminate the potential entrainment of pallid sturgeon in the system.

Justification: Given the severity of coastal land loss in Louisiana and the vital services that estuaries provide for flood protection and ecological balance, restoration efforts are of the highest priority to the State of Louisiana as well as the southern coastal United States. A necessary component of coastal restoration is a diversion concept that strives to mimic the function of natural delivery of water and sediment to the coast. With a limited number of options to redistribute those resources, freshwater diversions from the Mississippi River like the one at Davis Pond are important components of the overall plan and key to successful restoration efforts.

An equally important conservation issue in the LMR is the protection and recovery of endangered species. Pallid sturgeon inhabit the same stretch of the river that will be pivotal to coastal restoration efforts and it is important that every effort be made to find synergy between sturgeon recovery and coastal conservation. It is in that spirit that we propose to evaluate interaction between pallid sturgeon and the artificial environment that is created by the diversion structures. Unlike some water control structures that completely block fish passage, these structures are can be operated to allow unobstructed passage of fish back to the LMR under certain conditions. It is inevitable that some pallid sturgeon will encounter these structures and enter the discharge channel and it is unknown whether they are capable of returning to the LMR via the same route. Biologists are concerned about the uncertainty surrounding the risk associated with the structures and the potential influence on the viability of the population if fish are removed from the LMR sturgeon population. There is currently no way to quantify the impact of removing individual fish from the population; especially sexually mature adults, so the structures present an unknown threat. Any opportunity to minimize that threat will benefit both conservation efforts.

The Army Corps of Engineers is currently designing a study plan to assess the viability of the pallid sturgeon population in the LMR. When complete, the assessment will provide quantitative estimates of population size, mortality, and recruitment. The addition of information from this study will provide needed information to build risk estimates

associated with diversion structures and to factor that risk into the overall recovery of the species.

Methods: Pallid sturgeon will be collected in the LMR near the Davis Pond Diversion Structure with various types of fish collecting gear. Ultrasonic transmitters will be attached to as many as 20 pallid sturgeon which will then be released in the discharge channel of the structure. All pertinent information and measurements will be recorded and submitted to the appropriate entity as outlined in the endangered species collection permit and the Pallid Sturgeon Recovery Plan. Genetic samples from all fish collected will be submitted to the U. S. Fish and Wildlife Service Conservation Genetics Lab at the Warm Spring Fish Technology Center in GA.

Up to 8 ultrasonic receiving devices will be deployed in the discharge channel and at least 2 will be deployed in the Mississippi River near the intake side of the diversion. Receivers in the discharge channel will record continuously for a period of one year to detect sturgeon movement within the channel while receivers on the intake side will document the return of pallid sturgeon to the Mississippi River. We will retrieve the information from each receiver at least once monthly, and more frequently in the event that conditions are favorable for fish to leave the diversion channel.

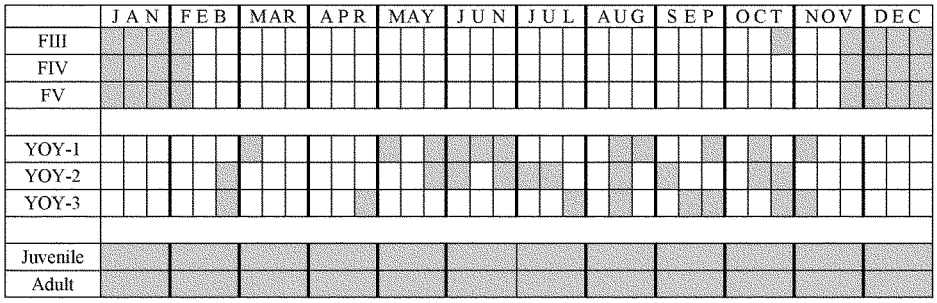
Reporting: Monthly reports of our findings will be submitted to the New Orleans District Corps of Engineers Office. A final report will be submitted at the end of one year and will include a detailed account of fish movement within and beyond the channel, possible correlations of fish movement and environmental conditions in the channel, and management recommendations for minimizing entrainment of pallid sturgeon in the system.

Budget:

Salary	2 GS-9 Fisheries Biologists 1/8 time	$20,780
Travel		$5,000
Supplies and Maintenance		$2,000
Equipment		
VR2 Receivers	10 @ $1475	$14,750
V9-2l Transmitters	20 @ $350	$7,000
Software and Peripherals		$750
	Subtotal	$50,280
	FWS Indirect	$8,547
Project Total		$58,827

r

Chronology of river sturgeon (*Scaphirhynchus* sp.) in the Lower Mississippi River delineated by life history stage. Determination of female reproductive status based on field endoscopic studies (Boysen et al. 2009, Divers et al. 2009) and direct field observations. Material for determining early life history chronology (young-of-year, YOY) is based on ERDC field sampling in the Mississippi River. Monthly samples characterized based on following calendar day breakdown: (early: 1-10; mid: 11-20; late: 21-31).



FIII: Yellow to green eggs

FIV: Black eggs

FV: Spawning female

- Female gonadal development based on Colombo et al. (2007)

YOY-1: 0-20 days old; ≤ 30 mm TL

- Includes drift period, dispersal and shift to exogenous feeding (Braaten et al. 2007; Braaten et al. 2008; Colombo et al. 2007; Kynard et al. 2002; Kynard et al. 2007); size for lower Mississippi River based on hatchery reared series (J. Dean, Natchitoches National Fish Hatchery, unpublished data).

YOY-2: 21-55 days old; 31-100 mm TL

- Continued development of fin rays, scutes, and barbels (Snyder 2002); size for lower Mississippi River based on hatchery reared series (J. Dean, Natchitoches National Fish Hatchery, unpublished data).

YOY-3: 56 days old (100 mm TL) – Age 1 (250-331 mm FL)

- Completion of full complement of adult characters (Snyder 2002).

Juvenile: Age 1+, not sexually mature

- Shovelnose: ≥ 250 mm FL (LMR) (Morrow et al. 1998)
- Pallid: ≥ 263 mm FL (LMR), ≥ 331 mm FL (MMR) (Killgore et al. 2007)

Adult: Sexually mature individuals

- Shovelnose: male 8 years old, 531-762 mm FL; female: 9 years old, 574-641 mm FL (Tripp et al. 2009).

- Pallid: male 5-7 years old, 540-625 mm FL; female: 9-12 years old, 686-748 mm FL (Keenlyne and Jenkins 1993); length at age conversion based on Killgore et al. (2007) (LMR)

LITERATURE CITED

Boysen, K.A., S.J. Hernandez-Divers, S.S. Boone, A.C. Camus, J.J. Hoover, K.J. Killgore, C.E. Murphy and S.G. George. 2009. Field endoscopy studies of sturgeon in the Lower Mississippi River. 35th Annual Meeting of the Mississippi American Fisheries Society, 11-13 February 2009, Biloxi, MS.

Bratten, P.J., D. B. Fuller and N. D. McClenning. 2007. Diet composition of larval and young-of-year shovelnose sturgeon in the Upper Missouri River. Journal of Applied Ichthyology 23:516–520.

Braaten, P. J., D. B. Fuller, L.D. Holte, R.D. Lott, W. Viste, T. F. Brandt and R.G. Legare. 2008. Drift dynamics of larval pallid sturgeon and shovelnose sturgeon in a natural side channel of the upper Missouri River, Montana. North American Journal of Fisheries Management 28: 808-826.

Colombo, R. E., J. E. Garvey, and P. S. Wills. 2007a. Gonadal development and sex-specific demographics of the shovelnose sturgeon (*Scaphirhynchus platorynchus*) in the middle Mississippi River. Journal of Applied Ichthyology 23:420–427.

Divers, S. J., S. S. Boone, J.J. Hoover, K.A. Boysen, K.J. Killgore, C.E. Murphy, S.G. George and A.C. Camus. 2009. Field endoscopy for identifying gender, reproductive stage and gonadal anomalies in free-ranging sturgeon (*Scaphirhynchus*) from the lower Mississippi River. Journal of Applied Ichthyology 25(Supplement 2): 68-74.

Keenlyne, K.D. and L.G. Jenkins. 1993. Age at sexual maturity of the pallid sturgeon. Transactions of the American Fisheries Society 122:393-396.

Killgore, K.J., J.J. Hoover, J.P. Kirk, S.G. George, B.R. Lewis and C.E. Murphy. 2007. Age and growth of pallid sturgeon in the free-flowing Mississippi River. Journal of Applied Ichthyology 23:452–456.

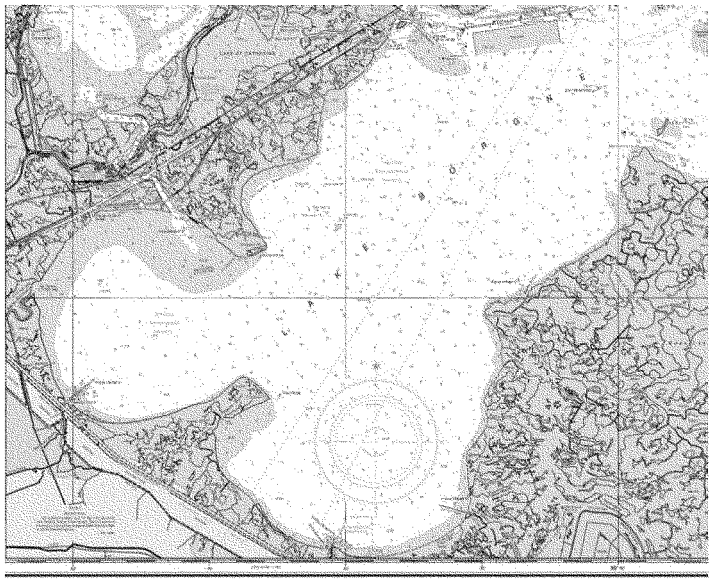
Kynard, B., E. Henyey and M. Horgan. 2002. Ontogenetic behavior, migration, and social behavior of pallid sturgeon, *Scaphirhynchus albus*, and shovelnose sturgeon, *S. platorynchus*, with notes on the adaptive significance of body color. Environmental Biology of Fishes 63: 389-403.

Kynard, B.E., E. Parker, D. Pugh and T. Parker. 2007. Use of laboratory studies to develop a dispersal model for Missouri River pallid sturgeon early life intervals. Journal of Applied Ichthyology 23:365–374.

Morrow, J.V., Jr., J.P. Kirk, K.J. Killgore and S.G. George. 1998. Age, growth, and mortality of shovelnose sturgeon in the lower Mississippi River. North American Journal of Fisheries Management 18:725-730.

Tripp, S. J., Q. E. Phelps, R. E. Colombo, J. E. Garvey, B.M. Burr, D.P. Herzog and R.A. Hrabik. 2009. Maturation and reproduction of shovelnose sturgeon in the middle Mississippi River. North American Journal of Fisheries Management 29: 730-738.

Characterization of Benthic Habitats Associated with Potential Borrow Sites and Access Channels in Lake Borgne, Louisiana.



A Report to the U.S. Army Engineer District, New Orleans

August 2007

Gary L. Ray, Ph.D.

U.S. Army Engineer Research and Development Center
3909 Halls Ferry Road
Vicksburg, MS 39180

Introduction

The U.S. Army Corps of Engineers District, New Orleans is proposing to nourish wetlands along the western shore of Lake Borgne, Louisiana using materials dredged from areas of unvegetated estuarine bay bottom in Lake Borgne, Louisiana. Dredging of the proposed borrow areas and associated access channels may impact the foraging habitat of the endangered Gulf sturgeon (*Acipenser oxyrinchus desotoi*). To evaluate the potential for such impacts, benthos and sediments were sampled from the proposed dredging sites and nearby reference sites, to determine if potential foraging habitat exists in the project area.

The Gulf sturgeon is a subspecies of Atlantic sturgeon occurring from western Florida to Louisiana (Van Den Avyle 1984, Wakeford 2001). It is an anadromus species which spends most of its life in estuarine and coastal waters, returning to fresh water to spawn. Fish migrate upstream in late winter or early spring then return to the sea in the fall. Over-wintering sturgeon do not migrate far from shore, but remain in relatively shallow inshore waters. Gulf sturgeon are believed to be indiscriminate benthic suctorial feeders (Gilbert 1989). This species feeds on a wide variety of benthic prey (Huff 1975, Mason and Clugston 1993, USFWS/ GSMFC 1995, Wakeford 2001, Fox et al. 2002, Harris 2003, and Brooks et al. 2004). Mason and Clugston (1993) report the prey of subadults to be brackish water amphipods (*Gammarus* sp. and haustorid amphipods), corophioid amphipods (e.g., *Cerapus* sp. and *Corophium tuberculatum*), chironomid and ceratopogonid fly larvae, grass shrimp (*Palaemonetes* spp.), and mysid shrimp. Polychaetes and tubificid oligochaetes were also plentiful in the diet. Subadults also fed on the callianassid shrimp *Lepidophthalmus louisianensis.* Fish immigrating from offshore had lancelets (*Branchiostoma caribaeum*), brachiopods (*Glottidia pyramidata*), shrimp, polychaetes, molluscs, starfish and sea cucumbers in the stomachs. Also working in the Suwannee River estuary, Harris (2003) indicated that brachiopods were particularly important in the diet of gulf sturgeon, although amphipods (*Ampelisca* spp.) and brittlestars (ophiouroids) were also frequent prey items. Based on these reports, especially those emphasizing the importance of brachiopods, lancelets, haustorid amphipods and the callianassid *L. louisianensis,* it would appear that sturgeon favor sandy-bottomed areas for feeding.

Previously, Lake Borgne and its biological resources have been described by the Louisiana Wildlife and Fisheries Commission (1971a, 1971b). Information concerning fish assemblages, sediments, and benthic assemblages can also be found in the Environmental Protection Agency's EMAP data for the Louisianan Province conducted from 1991 to 1994 (http://www.epa.gov/emap/index.html) and Ray (2006).

Methods

Four borrow areas and reference sites were sampled within Lake Borgne between the 21st and the 24th of May 2007. (Figures 1 and 2). A total of twenty (20) stations were sampled in both the northernmost borrow area (NB) and its accompanying reference site (NR) (Figure 1). The southern borrow areas (SB1, SB2 and SB3) and their reference sites (SR1, SR2, and

SR3) were less than half the size of the northern sites and fewer stations were sampled (Figure 2). SB1 and SB 2 were sampled at each of ten (10) stations. At SB3 site a potential problem with discarded ammunition from a former defense installation was encountered and only those areas outside of the contaminated area were sampled. This resulted in a total of six (6) stations for this site and its accompanying reference area. The size of the proposed access channels also varied and the number of stations sampled was proportional to their size. Access Channels A (ACA) and B (ABA) were the longest and were sampled at five locations situated equidistantly along their lengths. The remaining access channels, ACA, ADA, and AGA, were sampled at three locations also situated equidistantly along their lengths.

One Ponar grab (area = 0.05 m^2) sample was taken at each site (Total = 111 samples) for infauna. The samples were rinsed in the field through a 0.5 mm screen, placed in individual fabric bags, and fixed and stored in a ten percent buffered formalin solution. After transport to laboratory facilities at the U.S. Army Engineer Research and Development Center (ERDC), Vicksburg, MS, infaunal samples were rinsed over a 0.5 mm mesh sieve, stained with Rose Bengal, and stored in 70% ethanol. Samples were subsequently examined under 3X illuminated magnification and organisms sorted from the sediments. All organisms were identified to the lowest practical identification level and counted.

Alternate stations (every other one) were sampled for sediment grain size, sediment and organic content. Standard water quality measures (temperature, salinity, and dissolved oxygen concentration) were also measured at these stations using a YSI meter. The location of each sampling station was recorded using a hand-held GPS unit.

Sediment grain size samples were placed on ice and transported to ERDC where sediment total organic content was analyzed by loss upon ignition. In this procedure an aliquot of each sample was dried at 100 ^{o}C for 18 hours. Samples were weighed then placed in a muffle furnace at 500 ^{o}C for an additional 18 hours, reweighed and total organic content calculated as percentage loss between ash-free and dry-weight. Sediment grain size analysis was performed using a combination of wet-sieving and flotation procedures (Folk 1968, Galehouse 1971). Data analysis was conducted using Gradistat 4.0 (Blott 2000).

Community species composition was analyzed by multivariate statistical methods including Non-Metric Dimensional Scaling (NMDS) and Analysis of Similarity (ANOSIM). NMDS is an ordination technique that compares species composition among sample pairs and is particularly suited for infaunal data (Clarke and Warwick 2001). NMDS results are interpreted by examining the degree of difference in where data points fall on a 2- or 3-dimensional plot. Simply put, the proximity of any two data points on the plot is a measure of the degree of similarity between those two samples. The goodness-of-fit of the plot is measured by a stress value (upper right corner of plot). Plots with stress values of 0.1 or less indicate a high degree of fit (and therefore interpretability), while those with stress levels ranging between 0.1 and 0.2 should be interpreted with more care. Plots with stress values of 0.2 or greater should not be interpreted. NMDS was performed on the Lake Borgne data using the Bray-Curtis similarity index and logarithmically transformed ($\log_{10}$ x+1) abundance values to adjust

for the influence of very abundant taxa. All multivariate techniques were preformed using PRIMER statistical software following interpretive guidance found in Clarke and Warwick (2001).

Results

Physical-Chemical Environment

The physical environment of the sampling area was remarkably uniform. Depths ranged from 1.5 m – 3.0 m (Table 2), averaging slightly less (mean = 2.2 m) in the northern reach than in the south (mean = 2.6 m). Water temperatures varied from 24.0 ^{o}C to 26.3 ^{o}C and generally differed between surface and bottom by less than a degree. Salinities ranged from 9.1 ppt to 11.2 ppt with values in the north averaging slightly lower (mean = 9.3 ppt) than in the south (mean = 10.3 ppt). Surface and bottom values for salinity were almost always identical. Dissolved oxygen concentrations ranged from 6.0 mg/l to 8.0 mg/l, averaging 6.9 mg/l in the north and 7.4 mg/l in the south. Surface and bottom values for dissolved oxygen concentrations did not appear to differ in a consistent manner.

Sediments in the borrow areas were poorly sorted sandy mud with a mean grain size in the range of very coarse silts (Table 3A). Total silts and clays (mud) accounted for more than 64% of the sediment with the remainder dominated by very fine sand (~30%). Sediments in the proposed access channel sites differed somewhat with the innermost (shoreward) stations dominated by organic peat and the outermost resembling those of the borrow areas. Sediment organic content averaged less than 4% at all stations except those where peat was found and these had values as high as 43% (Table 3B).

Benthic Assemblages

The benthic assemblage of the study area was dominated by polychaetes (62%), bivalves (14%) and amphipods (11%). The most abundant species, the polychaete *Mediomastus ambiseta* accounted for more than 28% of all animals collected (Table 4). Other important polychaete species included *Parandalia americana, Streblospio benedicti, Sigambra bassi, Glycinde solitaria, Nereis succinea, Pectinaria gouldii,* and *Capitella* sp (Table 4). The most abundant bivalve mollusks were *Macoma mitchelli, Mulinia lateralis,* and *Mulinia pontchartrainensis.* The amphipods were dominated by *Ampelisca abdita, Ameroculodes sp.* A, and *Cerapus benthophilus*. Other numerically abundant species included the gastropod *Acetocina canaliculata,* two unidentified species of nemerteans, and the oligochaete *Tubificoides* sp. Together these eighteen species comprised nearly 94% of all animals encountered.

The relative abundance of the dominant species varied among sites with only *M. ambiseta, P. americana, S. benedicti, S. bassi , A. canaliculata, M. mitchelli,* and *G. solitaria* routinely being among the most abundant species within each site (Table 5). Comparison of species community structure using Nonmetric Dimensional Scaling (NMDS) and cluster analysis data indicated a high degree of similarity among sites however there was also a distinct geographic pattern present (Figure 3). Stations tended

to be most closely allied with those from the same geographic area along a north-south axis. This pattern was most distinctive for the northern versus southern reaches although there is also indication of similar differences among the southern sites. Analysis of Similarity (ANOSIM) tests supports this conclusion (Table 7). Although significant differences were found between all possible combinations of locations (e.g. North, South 1, etc.), the highest degree of difference (highest value for the test statistic R) was found between those combinations comparing North to South. Lesser R values were found for comparison of the southern locations.

Discussion

Species composition of the Lake Borgne benthic assemblage in May 2007 was typical of soft bottom, mesohaline (5.0 ppt–18 ppt) communities in the northern Gulf of Mexico. Many of the species identified as dominants in this study were also found as the most abundant species during sampling of this area by the Environmental Protection Agency's EMAP program in the early 1990's (Table 6). At that time the assemblage was dominated by oligohaline (0.5 ppt-5.0 ppt) species such as *Hobsonia florida* and the bivalve *Rangia cuneata*. A similar community has been reported from the upper Calcasieu Estuary (0 ppt -16 ppt) by Gaston and Nasci (1988). Dominants included *Streblospio benedicti, Hobsonia florida, Nereis succinea, Polydora spp.* and tubificid oligochaetes. Infaunal assemblages of the middle reaches of the Calcasieu Estuary (0 ppt-19 ppt) included many of the same species as the upper reaches but with increased abundances of *Mediomastus sp.* and *Corophium spp.* The lower bay was overwhelmingly dominated by *Mediomastus sp.* Junot et al. (1983) reported that *S. benedicti* and tubificid oligochaetes were most abundant at stations with the highest bottom salinity in lower Lake Pontchartrain, while *R. cuneata* and *Mulinia pontchartrainensis* were most abundant in the lowest salinities. Similar assemblages have also been reported from estuarine waters from Apalachicola Bay in Florida (Livingston 1984) to Texas (Armstrong 1987) and throughout the Gulf of Mexico (Engle and Summers 2000).

The relative risk that dredging will adversely affect foraging habitat for Gulf sturgeon seems low. Many authors report that Gulf sturgeon feed primarily on species such as brachiopods, lancelets, haustorid amphipods and the callianassid *L. louisianensis*, all species associated with sandy, polyhaline habitats. This habitat is absent from the study area. Mason and Clugston (1993) however, report prey to include brackish water amphipods such as *Cerapus* sp. and *Corophium tuberculatum*, chironomid and ceratopogonid fly larvae, mysid shrimp, polychaetes and tubificid oligochaetes. These species are most closely associated with muddy, mesohaline habitats similar to the Lake Borgne borrow areas and therefore hypothetically some portion of sturgeon foraging habitat may be impacted by the dredging. Fortunately, this habitat is also the single most common type present in the immediate area and large areas of Mississippi Sound. Because of the existing great spatial extent of this habitat in comparison to the absolute extent of disturbance connected to dredging, it seems unlikely that sturgeon would find it difficult to obtain prey. It is also likely that the dredged areas will be rapidly recolonized. The rate at which benthic communities recover after dredging varies widely depending on the habitat (Newell et al. 1998). The relatively species-poor benthic assemblages associated with low salinity estuarine sediments can recover in periods of time ranging

from a few months to approximately one year (Leathem et al. 1973; McCauley et al. 1976 and 1977; Van Dolah et al. 1979 and 1984; Clarke and Miller-Way 1992), while the more diverse communities of higher salinity estuarine sediments may require a year or more (e.g. Jones 1986). Based on characteristics of the existing benthic community it seems likely the Lake Borgne sites will recover in one to two years.

The major caveat to this estimate is the possibility that low dissolved oxygen (DO) concentrations could prevail if bathymetric changes result in reduced current flow in the dredged areas. Low DO levels (hypoxia) or anoxic conditions (no DO) can induce impacts ranging from physiological stress on individual organisms to the death of entire assemblages (Diaz and Rosenberg 1995). Borrow areas experiencing recurrent hypoxia or anoxia may develop depauperate benthic assemblages or be devoid of macroscopic life. In a study of a Danish fjord with seasonal oxygen depletion, Jorgensen (1980) found that in some areas, the benthos experienced periodic mass mortalities and were unable to completely recover between anoxic episodes.

Impacts such as these can be avoided or ameliorated by appropriate engineering design of the dredging sites. Borrow areas with large aspect (width to depth) ratios, i.e. wide and shallow, are more likely to be well flushed than ones with low aspect ratios, i.e. narrow and deep. The relatively higher surface area permits currents to flow more easily through the depression. Likewise, borrow areas with relatively gentle side slopes are more likely to be well flushed than ones with steep banks (Polis 1974; Koo 1973). Borrows sites in areas of strong currents or with connections to nearby channels also tend to be better flushed than ones where current flows are slow or connections are lacking (Swartz and Brinkhuis 1978; Murawski 1969).

References

Armstrong, N. E. 1987. The Ecology of Open-Bay Bottoms of Texas. U. S. Fish and Wildlife Service. Biological Report 85(7.12).

Blott, S. 2000. GRADISTAT Version 4.0: A grain size distribution and statistics package for the analysis of unconsolidated sediments by sieving or laser granulometer.

Brooks, R. A. 2004. Quantitative assessment of benthic food resources for juvenile Gulf sturgeon, *Acipenser oxyrinchus desotoi* in the Suwannee River estuary, Florida, USA. U.S. Geological Survey, Florida Integrated Science Center, Gainsville, FL. Available on-line at http://cars.er.usgs.gov/coastaleco/Quick_Response_Report.pdf

Clarke, D. G. and T. Miller-Way. 1992. An environmental assessment of the effects of open-water disposal of maintenance dredged material on benthic resources in Mobile Bay, Alabama. U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS, Miscellaneous Paper D-92-1, 40 p.

Clarke, K. R. and R. M. Warwick. 2001. Change in marine communities: An approach to statistical analysis and interpretation. Plymouth Marine Lab., Plymouth, U. K.

Diaz, R. J. and Rosenberg, R. 1995. Marine benthic hypoxia: A review of its ecological effects and the behavioral responses of benthic macrofauna. Oceanography and Marine Biology: An Annual Review 33: 245-303.

Engle, V. D. and J. K. Summers. (2000). Biogeography of benthic macroinvertebrates in estuaries along the Gulf of Mexico and western Atlantic coasts. Hydrobiologia 436: 17-33.

Folk, R. L. 1968. Petrology of Sedimentary Rocks. Hemphills, University of Texas, Austin, TX.

Fox, D., Hightower, J. and F. Parauka. 2002. Estuarine and nearshore marine habitat use by gulf sturgeon from the Choctawhatchee River system, Florida. *American Fisheries Society Symposium* 28,111-126

Galehouse, R. L. 1971. Sieve Analysis, in R. Carver (ed.), Procedures in Sedimentary Petrology, pp. 49-94. Wiley Interscience, New York, NY.

Gaston, G. R. and J. C. Nasci. 1988. Trophic structure of macrobenthic communities in the Calcasieu estuary, Louisiana. *Estuaries* 11, 201-211.

Gilbert, C. 1989. Species profiles: life histories and environmental requirements of coastal fishes and invertebrates (Mid-Atlantic Bight) – Atlantic and shortnose sturgeons. US Fish and Wildlife Service Biological Report 82(11.122). US Army Corps of Engineers TR EL-82-4.

Harris, J. E. 2003. Distribution of Gulf of Mexico Sturgeon (Acipenser oxyrinchus desotoi) in relation to environmental parameters and the distribution of benthic invertebrates in the Suwannee River estuary, Florida. PhD. Thesis, University of Florida, Gainsville, FL. Available on-line at http://etd.fcla.edu/UF/UFE0001162/harris_j.pdf.

Huff, J. 1975. Life history of Gulf of Mexico sturgeon, *Acipenser oxyrinchus desotoi*, in Suwannee River, Florida. *Florida Marine Research Publication* 16.

Jones, A. 1986. The effects of dredging and spoil disposal on macrobenthos, Hawkesbury Estuary, New South Wales. Marine Pollution Bulletin 17: 17-20.

Jorgenson, B. 1980. Seasonal oxygen depletion in the bottom waters of a Danish fjord and its effect on the benthic community. Oikos 34: 68-76.

Junot, J. A., Poirrier, M. A., and T. M. Soniat. 1983. Effects of saltwater intrusion from the Inner Harbor Navigation Canal on the benthos of Lake Ponchartrain, Louisiana. *Gulf Research Reports* 7, 247-254.

Koo, T. S. Y. 1973. Biological effects of borrow pits. Natural Resources Institute, University of Maryland, Reference Number 73-70. 6p.

Leathem, W., P. Kinner, D. Maurer, R. Briggs and W. Treasure. 1973. Effect of spoil disposal on benthic invertebrates. Marine Pollution Bulletin 4: 122-125.

Livingston, R. J. 1984. The Ecology of the Apalachicola Bay System; An Estuarine Profile. U. S. Fish and Wildlife Service. FWS/OBS-82/05.

Louisiana Wildlife and Fisheries Commission. 1971a. Cooperative Gulf of Mexico Estuarine Inventory and Study, Louisiana. Phase I. Area Description and Phase IV, Biology. Louisiana Wildlife and Fisheries Commission, New Orleans, LA.

Louisiana Wildlife and Fisheries Commission. 1971b. Cooperative Gulf of Mexico Estuarine Inventory and Study, Louisiana. Phase II. Hydrology and Phase III, Sedimentology. Louisiana Wildlife and Fisheries Commission, New Orleans, LA.

Mason, W., and J. Clugston. 1993. Foods of the gulf sturgeon in the Suwannee River, Florida. *Transactions of the American Fisheries Society* 122, 378-385

McCauley, J. E., D. R. Hancock and R. A. Parr. 1976. Maintenance dredging and four polychaete worms. p. 673-683 in Proceedings of the Specialty Conference on Dredging and Its Environmental Effects, Mobile, AL. American Society of Civil Engineers.

McCauley, J. E., R. A. Parr and D. R. Hancock. 1977. Benthic infauna and maintenance dredging: a case study. Water Research 11: 233-242.

Murawski, W. S. 1969. A study of submerged dredged holes in New Jersey estuaries with

respect to their fitness as finfish habitat. New Jersey Department of Conservation and Economic Development, Division of Fish and Game. 32p. + Maps.

Newell, R. C., Seiderer, L. J., and Hitchcock, D. R. 1998. The impact of dredging works in coastal waters: A review of the sensitivity to disturbance and subsequent recovery of biological resources on the sea bed. Oceanography and Marine Biology: An Annual Review 36: 127-178.

Polis, D. F. 1974. The environmental effects of dredge holes. Present state of knowledge. Report to the Water Resources Administration, Department of Natural Resources, State of Maryland. May 1974. 62p.

Ray, G. L. (2006). Characterization of Potential Gulf Sturgeon Prey Availability in Lake Borgne, Louisiana. A report to the U.S. Army Engineer District, New Orleans. July 2006. U.S. Army Engineer Research and Development Center, Vicksburg, MS.

Swartz, S. M. and Brinkhuis, B. H. 1978. The impact of dredged holes on oxygen demand in the Lower Bay, New York Harbor. Marine Sciences Research Center State University of New York, Stony Brook, NY: 80p.

US Fish and Wildlife Service and Gulf States Marine Fisheries Commission. 1995. *Gulf Sturgeon Recovery Plan.* Atlanta, GA.

US Geological Survey. 2006. Gulf Sturgeon Facts. Available online at http://cars.er.usgs.gov/Marine_Studies/Sturgeon_FAQs/sturgeon_faqs.html

Van Den Avyle, M. J. 1984. Species profiles: Life history and environmental requirements of coastal fishes and invertebrates (South Atlantic): Atlantic Sturgeon. U.S. Fish and Wildlife Service FWS/OBS-82/11. U.S. Army Corps of Engineers, TR EL-82-4.

Van Dolah, R. F., D. R. Calder, D. M. Knott and M. S. Maclin. 1979. Effects of dredging and unconfined disposal of dredged material on macrobenthic communities in Sewee Bay, South Carolina. South Carolina Marine Resources Center Technical Report No. 39, April 1979. 54 p.

Van Dolah, R. F., D. R. Calder and D. M. Knott. 1984. Effects of dredging and open-water disposal on benthic macroinvertebrates in a South Carolina estuary. Estuaries 7:28-37.

Wakeford, A. 2001. State of Florida conservation plan for gulf sturgeon *(Acipenser oxyrinchus desotoi).* Florida Marine Research Institute Technical Report TR-8, Florida Fish and Wildlife Conservation Commission, St. Petersburg, FL.

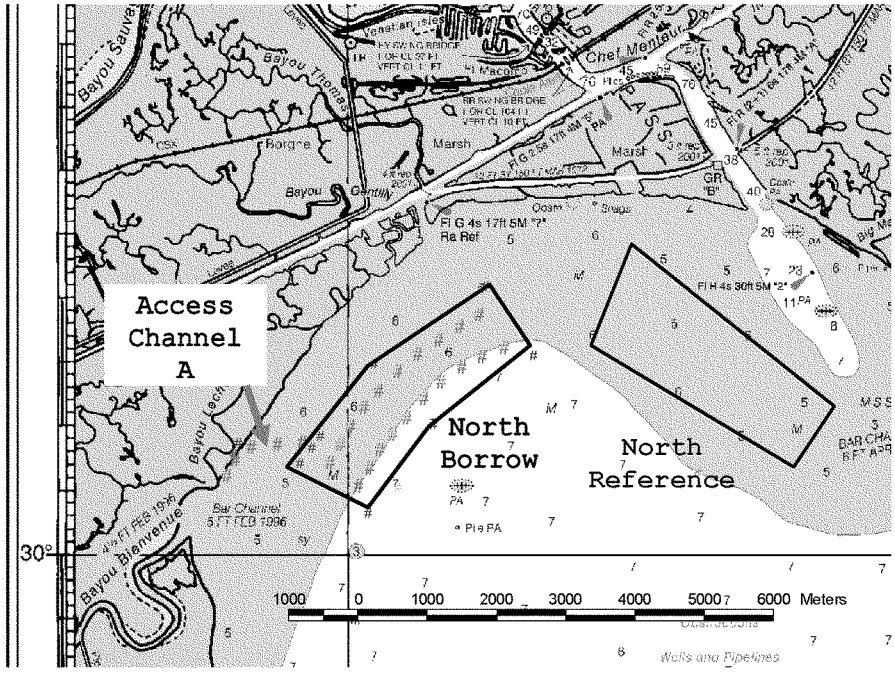


Figure 1. Northern Reach of Lake Borgne Study Area.

Borrow and Reference study sites indicated by boxes, stations indicated by # signs. Access channel site indicated by arrow.

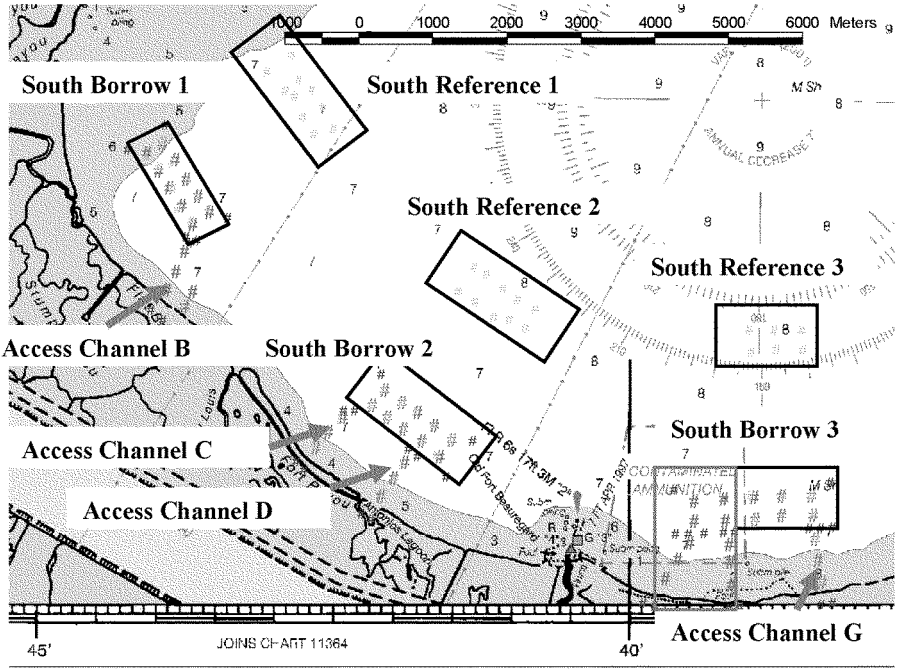


Figure 2. Southern Reach of Lake Borgne Study Area

Borrow and Reference study sites indicated by boxes, stations indicated by # signs. Access channel site indicated by arrow.Stations in red box were abandoned due to potential problem with discarded ammunition.

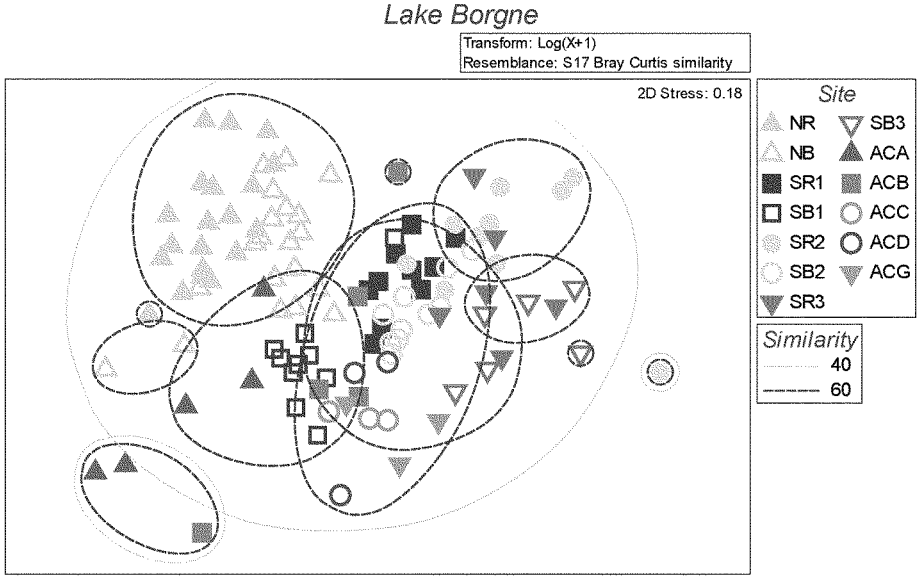


Figure 3. Nonmetric Dimensional Scaling and Cluster Analysis Biplot.

N= North, S = South, B = Borrow, R = Reference, AC = Access Channel. Circled data points indicate major cluster groups. Similarity is degree of similarity from cluster analysis. Data was Log_{10} (x+1) transformed prior to analysis using the Bray Curtis similarity index (both NMDS and Clustering).

Table 1. Lake Borgne Station Positions

	Latitude		Longitude	
Station	Degree	Minutes	Degree	Minutes
NR1	30	2.394	89	47.375
NR2	30	1.996	89	47.211
NR3	30	1.877	89	47.049
NR4	30	1.766	89	46.864
NR5	30	1.654	89	46.673
NR6	30	1.547	89	46.475
NR7	30	1.434	89	46.300
NR8	30	1.331	89	46.158
NR9	30	1.214	89	45.962
1NR	30	1.114	89	45.775
NR1	30	1.757	89	47.604
NR2	30	1.720	89	47.473
NR3	30	1.658	89	47.241
NR4	30	1.464	89	47.116
NR5	30	1.425	89	46.922
NR6	30	1.205	89	46.787
NR7	30	1.196	89	46.612
NR8	30	1.094	89	46.423
NR9	30	0.949	89	46.198
NR20	30	0.857	89	46.033
NB1	30	1.916	89	48.844
NB2	30	1.819	89	49.013
NB3	30	1.723	89	49.191
NB4	30	1.604	89	49.379
NB5	30	1.461	89	49.579
NB6	30	1.337	89	49.741
NB7	30	1.184	89	49.853
NB8	30	1.038	89	49.994
NB9	30	0.891	89	50.063
NB0	30	0.747	89	50.160
NB1	30	1.659	89	48.592
NB2	30	1.592	89	48.795
NB3	30	1.504	89	48.975
NB4	30	1.382	89	49.145
NB5	30	1.267	89	49.338
NB6	30	1.096	89	49.470
NB7	30	0.962	89	49.591
NB8	30	0.856	89	49.715
NB9	30	0.719	89	49.803
NB20	30	0.545	89	49.545
SR1_1	29	55.776	89	42.838
SR1_2	29	55.594	89	42.769
SR1_3	29	55.516	89	42.665
SR1_4	29	55.389	89	42.570
SR1_5	29	55.2SR1	89	42.484
SR1_6	29	55.647	89	43.044
SR1_7	29	55.508	89	42.891
SR1_8	29	55.472	89	42.809
SR1_9	29	55.317	89	42.740
SR1_10	29	55.192	89	42.650

	Latitude		Longitude	
Station	Degree	Minutes	Degree	Minutes
SB1_1	29	55.123	89	43.930
SB1_2	29	54.983	89	43.842
SB1_3	29	54.847	89	43.712
SB1_4	29	54.731	89	43.644
SB1_5	29	54.635	89	43.542
SB1_6	29	54.997	89	44.076
SB1_7	29	54.949	89	43.951
SB1_8	29	54.791	89	43.840
SB1_9	29	54.645	89	43.799
SB!_10	29	54.555	89	43.684
SR2_1	29	54.217	89	41.300
SR2_2	29	54.173	89	41.200
SR2_3	29	54.056	89	41.060
SR2_4	29	53.984	89	40.932
SR2_5	29	53.907	89	40.787
SR2_6	29	54.033	89	41.434
SR2_7	29	53.963	89	41.293
SR2_8	29	53.845	89	41.136
SR2_9	29	53.834	89	41.001
SR2_10	29	53.765	89	40.871
SB2_1	29	53.310	89	42.058
SB2_2	29	53.220	89	41.911
SB2_3	29	53.151	89	41.794
SB2_4	29	53.047	89	41.644
SB2_5	29	52.949	89	41.488
SB2_6	29	53.194	89	42.160
SB2_7	29	53.111	89	42.030
SB2_8	29	53.022	89	41.889
SB2_9	29	52.936	89	41.729
SB2_10	29	52.836	89	41.621
SR3_1	29	53.757	89	38.985
SR3_2	29	53.755	89	38.771
SR3_3	29	53.750	89	38.538
SR3_4	29	53.593	89	38.957
SR3_5	29	53.616	89	38.749
SR3_6	29	53.601	89	38.535
SB3_3	29	52.541	89	38.975
SB3_4	29	52.530	89	38.706
SB3_5	29	52.537	89	38.459
SB3_8	29	52.357	89	38.934
SB3_9	29	52.382	89	38.705
SB3_10	29	52.397	89	38.444
ACA1	29	0.9SR1	89	50.429
ACA2	29	0.912	89	50.635
ACA3	29	0.861	89	50.874
ACA4	29	0.754	89	51.004
ACA5	SR1	0.643	89	51.096
ACB1	SR1	54.3SR1	89	43.770
ACB2	SR1	54.196	89	43.840
ACB3	SR1	54.047	89	43.903

Table 1. Lake Borgne Station Positions (Cont.)

	Latitude		Longitude	
Station	Degree	Minutes	Degree	Minutes
ACB4	29	54.053	89	43.662
ACB5	29	53.944	89	43.766
ACC1	29	53.103	89	42.422
ACC2	29	53.011	89	42.535
ACC3	29	52.893	89	42.637
ACD1	29	52.769	89	41.902
ACD2	29	52.665	89	41.965
ACD3	29	52.522	89	42.071
ACG1	29	52.215	89	38.426
ACG2	29	52.054	89	38.421
ACG3	29	51.901	89	38.377

Table 2. Station Water Quality and Sample Information

				Bottom			Surface			Sample	
Date	Time	Station	Depth (m)	Temp (C^o)	Salinity(ppt)	DO (mg/l)	Temp (C^o)	Salinity(ppt)	DO (mg/l)	Infauna	Sediment
5/21/07	820	SR3_1	2.5	24.0	10.5	7.10	24.1	10.5	7.12	X	X
5/21/07		SR3_2	-----	-----	-----	-----	-----	-----	-----	X	-----
5/21/07		SR3_3	2.5	24.5	11.1	7.29	24.1	11.1	7.20	X	X
5/21/07		SR3_4	-----	-----	-----	-----	-----	-----	-----	X	-----
5/21/07	930	SR3_5	2.7	24.0	10.6	7.16	24.1	10.6	7.36	X	X
5/21/07		SR3_6	-----	-----	-----	-----	-----	-----	-----	X	-----
5/21/07	1000	SB3_3	2.5	24.5	11.1	7.29	24.6	11.1	7.20	X	X
5/21/07		SB3_4	-----	-----	-----	-----	-----	-----	-----	X	-----
5/21/07	1022	SB3_5	2.3	24.5	11.2	7.59	24.6	11.2	7.49	X	X
5/21/07		SB3_8	-----	-----	-----	-----	-----	-----	-----	X	-----
5/21/07	1046	SB3_9	2.6	24.6	11.0	7.40	24.7	11.1	7.41	X	X
5/21/07		SB3_10	-----	-----	-----	-----	-----	-----	-----	X	-----
5/21/07	1102	ACG1	2.5	24.6	11.0	7.25	24.7	11.0	7.39	X	X
5/21/07		ACG2	-----	-----	-----	-----	-----	-----	-----	X	-----
5/21/07	1129	ACG3	1.5	24.8	10.8	7.38	24.9	10.8	7.55	X	X
5/21/07	1312	ACD1	2.7	25.2	9.8	7.55	25.2	9.8	7.35	X	X
5/21/07		ACD2	-----	-----	-----	-----	-----	-----	-----	X	-----
5/21/07	1206	ACD3	2.1	25.1	9.9	7.56	25.2	9.9	7.71	X	X
5/21/07	1424	ACC1	2.8	25.5	9.9	7.87	25.4	9.9	7.70	X	X
5/21/07		ACC2	-----	-----	-----	-----	-----	-----	-----	X	-----
5/21/07	1452	ACC3	2.3	26.2	10.1	7.82	26.3	10.1	7.96	X	X
5/21/07	1514	SB2_1	2.9	25.7	9.9	7.86	25.7	9.9	7.82	X	X
5/21/07		SB2_2	-----	-----	-----	-----	-----	-----	-----	X	-----
5/21/07	1548	SB2_3	2.8	25.4	9.8	7.82	25.4	9.8	7.92	X	X
5/21/07		SB2_4	-----	-----	-----	-----	-----	-----	-----	X	-----
5/21/07	1418	SB2_5	3	25.6	10.0	7.92	25.6	10.0	7.93	X	X
5/21/07		SB2_6	-----	-----	-----	-----	-----	-----	-----	X	-----
5/21/07	1405	SB2_7	2.7	25.3	9.8	8.01	25.3	9.8	8.05	X	X

Table 2. Station Water Quality and Sample Information (Cont.)

				Bottom			Surface			Sample	
Date	Time	Station	Depth (m)	Temp (C°)	Salinity(ppt)	DO (mg/l)	Temp (C°)	Salinity(ppt)	DO (mg/l)	Infauna	Sediment
5/21/07		SB2_8	-----	-----	-----	-----	-----	-----	-----	X	-----
5/21/07	1341	SB2_9	2.8	25.2	9.8	7.66	25.2	9.9	7.80	X	X
5/21/07		SB2_10	-----	-----	-----	-----	-----	-----	-----	X	-----
5/22/07		SR2_1	2.7	24.5	10.1	7.61	24.5	10.1	7.60	X	X
5/22/07		SR2_2	-----	-----	-----	-----	-----	-----	-----	X	-----
5/22/07	852	SR2_3	2.5	25.1	10.9	7.47	25.1	10.9	7.38	X	X
5/22/07		SR2_4	-----	-----	-----	-----	-----	-----	-----	X	-----
5/22/07	932	SR2_5	2.9	24.8	10.6	7.16	25.1	10.6	7.13	X	X
5/22/07		SR2_6	-----	-----	-----	-----	-----	-----	-----	X	-----
5/22/07	1014	SR2_7	2.9	25.4	10.8	7.50	25.4	10.8	-----	X	X
5/22/07		SR2_8	-----	-----	-----	-----	-----	-----	-----	X	-----
5/22/07	957	SR2_9	2.7	25.2	10.8	7.53	25.2	10.8	7.37	X	X
5/22/07		SR2_10	-----	-----	-----	-----	-----	-----	-----	X	-----
5/22/07	1106	SR1_1	2.5	25.1	10.0	7.50	25.2	10.0	7.35	X	X
5/22/07		SR1_2	-----	-----	-----	-----	-----	-----	-----	X	-----
5/22/07	1057	SR1_3	2.8	25.1	10.3	7.52	25.2	10.3	7.46	X	X
5/22/07		SR1_4	-----	-----	-----	-----	-----	-----	-----	X	-----
5/22/07	1035	SR1_5	2.6	25.0	10.2	7.41	25.0	10.2	7.35	X	X
5/22/07		SR1_6	-----	-----	-----	-----	-----	-----	-----	X	-----
5/22/07	1147	SR1_7	2.5	25.3	10.2	7.54	25.3	10.2	7.41	X	X
5/22/07		SR1_8	-----	-----	-----	-----	-----	-----	-----	X	-----
5/22/07	1131	SR1_9	2.5	25.2	10.3	7.51	25.3	10.3	7.49	X	X
5/22/07		SR1_10	-----	-----	-----	-----	-----	-----	-----	X	-----
5/22/07	1502	SB1_1	2.5	26.2	9.7	7.29	26.2	9.7	7.13	X	X
5/22/07		SB1_2	-----	-----	-----	-----	-----	-----	-----	X	-----
5/22/07	1447	SB1_3	2.3	25.9	9.9	7.10	25.9	9.9	7.21	X	X

Table 2. Station Water Quality and Sample Information (Cont.)

				Bottom			Surface			Sample	
Date	Time	Station	Depth (m)	Temp (C^o)	Salinity(ppt)	DO (mg/l)	Temp (C^o)	Salinity(ppt)	DO (mg/l)	Infauna	Sediment
5/22/07		SB1_4	-----	-----	-----	-----	-----	-----	-----	X	-----
5/22/07	1453	SB1_5	2.7	25.8	10.0	7.43	25.9	10.0	7.43	X	X
5/22/07		SB1_6	-----	-----	-----	-----	-----	-----	-----	X	-----
5/22/07	1412	SB1_7	2.5	26.0	9.7	7.33	26.0	9.7	7.21	X	X
5/22/07		SB1_8	-----	-----	-----	-----	-----	-----	-----	X	-----
5/22/07	1358	SB1_9	2.6	25.8	9.9	7.36	25.8	9.9	7.27	X	X
5/22/07		SB1_10	-----	-----	-----	-----	-----	-----	-----	X	-----
5/22/07	1334	ACB1	2.7	25.9	9.9	7.31	25.9	9.9	7.39	X	X
5/22/07		ACB2	-----	-----	-----	-----	-----	-----	-----	X	-----
5/22/07	1323	ACB3	2.4	25.8	10.3	7.48	25.9	10.3	7.20	X	X
5/22/07		ACB4	-----	-----	-----	-----	-----	-----	-----	X	-----
5/22/07	1303	ACB5	2.3	25.8	10.2	7.30	25.8	10.2	7.30	X	X
5/24/07	642	NR1	2.2	24.4	9.3	6.64	24.7	9.5	6.63	X	X
5/24/07		NR2	-----	-----	-----	-----	-----	-----	-----	X	-----
5/24/07		NR3	2.1	24.9	9.3	6.64	24.9	9.3	6.62	X	X
5/24/07		NR4	-----	-----	-----	-----	-----	-----	-----	X	-----
5/24/07	725	NR5	2.1	25.8	9.3	6.06	24.7	9.3	6.06	X	X
5/24/07		NR6	-----	-----	-----	-----	-----	-----	-----	X	-----
5/24/07	744	NR7	2.1	24.4	9.3	6.40	24.9	9.3	6.42	X	X
5/24/07		NR8	-----	-----	-----	-----	-----	-----	-----	X	-----
5/24/07	807	NR9	2.2	24.7	9.3	6.64	24.7	9.3	6.42	X	X
5/24/07		NR10	-----	-----	-----	-----	-----	-----	-----	X	-----
5/24/07	936	NR11	2.3	25.0	9.3	6.96	24.9	9.3	6.86	X	X
5/24/07		NR12	-----	-----	-----	-----	-----	-----	-----	X	-----
5/24/07	922	NR13	2.3	25.1	9.3	6.73	24.9	9.3	6.64	X	X
5/24/07		NR14	-----	-----	-----	-----	-----	-----	-----	X	-----

Table 2. Station Water Quality and Sample Information (Cont.)

				Bottom			Surface			Sample	
Date	Time	Station	Depth (m)	Temp (C°)	Salinity(ppt)	DO (mg/l)	Temp (C°)	Salinity(ppt)	DO (mg/l)	Infauna	Sediment
5/24/07	908	NR15	2.3	25.1	9.3	6.79	25.0	9.30	6.59	X	X
5/24/07		NR16	-----	-----	-----	-----	-----	-----	-----	X	-----
5/24/07	832	NR17	2.3	25.1	9.3	6.77	24.5	9.3	6.67	X	X
5/24/07		NR18	-----	-----	-----	-----	-----	-----	-----	X	-----
5/24/07		NR19	2.5	25.1	9.3	6.61	24.6	9.3	6.67	X	X
5/24/07		NR20	-----	-----	-----	-----	-----	-----	-----	X	-----
5/24/07	953	NB1	2.1	25.1	9.3	-----	25.1	9.3	-----	X	X
5/24/07		NB2	-----	-----	-----	-----	-----	-----	-----	X	-----
5/24/07	1013	NB3	2.1	25.1	9.3	-----	25.1	9.3	-----	X	X
5/24/07		NB4	-----	-----	-----	-----	-----	-----	-----	X	-----
5/24/07	1032	NB5	-----	25.1	9.3	-----	25.1	9.3	-----	X	X
5/24/07		NB6	-----	-----	-----	-----	-----	-----	-----	X	-----
5/24/07	1053	NB7	2.3	24.5	9.4	7.28	24.5	9.3	7.16	X	X
5/24/07		NB8	-----	-----	-----	-----	-----	-----	-----	X	-----
5/24/07	1111	NB9	2.1	24.8	9.1	7.40	24.7	9.1	7.18	X	X
5/24/07		NB0	-----	-----	-----	-----	-----	-----	-----	X	-----
5/24/07	1334	NB1	2.1	25.3	9.4	7.27	25.3	9.4	7.24	X	-----
5/24/07		NB2	-----	-----	-----	-----	-----	-----	-----	X	X
5/24/07	1309	NB3	2.1	25.1	9.1	7.58	25.1	9.1	7.34	X	-----
5/24/07		NB4	-----	-----	-----	-----	-----	-----	-----	X	X
5/24/07	1242	NB5	2.1	25.0	9.1	7.15	25.0	9.1	7.03	X	-----
5/24/07		NB6	-----	-----	-----	-----	-----	-----	-----	X	-----
5/24/07	1218	NB7	2.7	24.9	9.2	7.08	25.0	9.2	7.19	X	X
5/24/07		NB8	-----	-----	-----	-----	-----	-----	-----	X	-----
5/24/07	1146	NB9	2.5	25.2	9.1	7.17	25.0	9.1	7.14	X	X
5/24/07		NB20	-----	-----	-----	-----	-----	-----	-----	X	-----

Table 2. Station Water Quality and Sample Information (Cont.)

				Bottom			Surface			Sample	
Date	Time	Station	Depth (m)	Temp (C^{o})	Salinity(ppt)	DO (mg/l)	Temp (C^{o})	Salinity(ppt)	DO (mg/l)	Infauna	Sediment
5/24/07	1353	ACA1	2.7	25.5	9.2	7.15	25.6	9.2	6.94	X	X
5/24/07		ACA2	-----	-----	-----	-----	-----	-----	-----	X	-----
5/24/07	1412	ACA3	2.3	25.5	9.1	7.31	25.5	9.1	8.24	X	X
5/24/07		ACA4	-----	-----	-----	-----	-----	-----	-----	X	-----
5/24/07	1426	ACA5	2.1	25.6	9.1	7.25	25.7	9.10	7.68	X	X

Table 3A. Sediment Texture and Organic Content Summary

SITE	MGS (um)	SORTING	% C. SAND	% M. SAND	% F. SAND	% VF SAND	% SILT	% CLAY	% ORGANIC
NR	33.6	2.665	0.07%	0.23%	3.71%	30.75%	65.04%	0.20%	2.83
NB	28.6	2.624	0.01%	0.10%	0.42%	25.56%	73.63%	0.26%	3.72
SR1	33.3	2.629	0.04%	0.26%	2.40%	31.72%	65.38%	0.22%	2.82
SB1	34.1	2.806	0.16%	1.62%	3.32%	30.38%	64.34%	0.20%	3.35
SR2	31.4	3.045	0.06%	1.80%	3.56%	28.82%	65.54%	0.24%	2.94
SB2	30.4	2.906	0.08%	0.34%	4.04%	26.62%	68.68%	0.24%	3.04
SR3	30.7	2.547	0.00%	0.10%	0.53%	29.93%	69.27%	0.20%	2.77
SB3	28.4	2.645	0.10%	0.10%	1.03%	24.40%	74.13%	0.23%	3.53
ACA	25.6	2.923	2.13%	0.73%	1.10%	17.27%	78.53%	0.27%	24.05
ACB	31.2	2.610	0.63%	0.47%	1.47%	27.37%	69.83%	0.23%	7.94
ACC	31.8	2.631	1.25%	0.65%	1.75%	25.90%	70.20%	0.25%	6.15
ACD	28.8	2.736	0.80%	0.40%	0.95%	24.35%	73.20%	0.30%	14.02
ACG	33.5	2.499	0.05%	0.15%	0.85%	30.15%	68.60%	0.20%	2.76

MGS = Mean Grain Size (um)
Sorting – Folk and Ward Sorting Coefficient
C. Sand = Coarse Sand
M. Sand = Medium Sand
F. Sand = Fine Sand
VF Sand = Very Fine Sand
N = North; S = South; AC = Access Channel

Table 3 B. Access Channel Station Sediment Organic Contents

Station	Organic Content
ACA1	4.73
ACA3	43.83
ACA5	23.59
ACB1	3.26
ACB3	5.15
ACB5	15.40
ACC1	2.74
ACC3	9.55
ACD1	2.70
ACD3	25.34
ACG1	3.76
ACG3	1.77

Table 4. Species List and Relative Abundance

Species	Group	Total	Percent
Mediomastus ambiseta	Polychaete	3397	28.96
Parandalia americana	Polychaete	997	8.50
Ampelisca abdita	Amphipod	953	8.13
Streblospio benedicti	Polychaete	826	7.04
Sigambra bassi	Polychaete	742	6.33
Acetocina canaliculata	Gastropod	711	6.06
Macoma mitchelli	Bivalve	668	5.70
Glycinde solitaria	Polychaete	586	5.00
Mulinia pontchartrainensis	Bivalve	444	3.79
Mulinia lateralis	Bivalve	419	3.57
Ameroculodes sp. A	Amphipod	208	1.77
Nemertea 1	Nemertean	175	1.49
Nereis succinea	Polychaete	169	1.44
Pectinaria gouldii	Polychaete	149	1.27
Cerapus benthophilus	Amphipod	148	1.26
Tubificoides (LPIL)	Oligochaete	131	1.12
Capitella (LPIL)	Polychaete	130	1.11
Nemertea 2	Nemertean	128	1.09
Cyclaspis(LPIL)	Cumacean	88	0.75
Leitoscoloplos foliosus	Polychaete	74	0.63
Amygdalum papyrium	Bivalve	61	0.52
Edotea (LPIL)	Isopod	56	0.48
Americamysis bahia	Mysid Shrimp	56	0.48
Hobsonia florida	Polychaete	50	0.43
Hyperetone foliolosa	Polychaete	43	0.37
Tanypus (LPIL)	Chironomid Larva	39	0.33
Paraprionospio pinnata	Polychaete	35	0.30
Polydora cornuta	Polychaete	31	0.26
Chone americana	Polychaete	27	0.23
Enteroneusta (LPIL)	Enteropneust	26	0.22
Tagelus plebius	Bivalve	23	0.20
Brachiodontes exustus	Bivalve	19	0.16
Gyptis brevipalpa	Polychaete	19	0.16
Diopatra cuprea	Polychaete	16	0.14
Turbellaria (LPIL)	Turbellarian	13	0.11
Harpacticoida (LPIL)	Copepod	12	0.10
Nematoda (LPIL)	Nematode	10	0.09
Ensis minor	Bivalve	7	0.06
Rictaxis punctostriatus	Gastropod	6	0.05
Hargeria rapax	Tanaid	6	0.05
Spiochaetopterus costarum oculatus	Polychaete	4	0.03
Corophium lacustre	Amphipod	4	0.03
Hydrobiidae (LPIL)	Gastropod	3	0.03
Cyathura polita	Isopod	3	0.03
Lepidophthalmus jamaicense	Callianassid Shrimp	3	0.03
Argulus (LPIL)	Brachiuran	3	0.03
Cerithidea (LPIL)	Gastropod	2	0.02
Melita (LPIL)	Amphipod	2	0.02
Cumacea sp. 3	Cumacean	2	0.02
Macoma constricta	Bivalve	1	0.01
Rangia cuneata	Bivalve	1	0.01
Oxyurostylis smithi	Cumacean	1	0.01
Pinnixia (LPIL)	Crab	1	0.01

Table 5. Rank Abundance of Infaunal Species

Species	NB	NR	SR1	SB1	SR2	SB2	SR3	SB3	ACA	ACB	ACC	ACD	ACG
Mediomastus ambiseta	1	1	4	1	5	1	2	2	1	1	1	1	1
Parandalia americana	2	5	1	8	1	5	5			9	8		
Ampelisca abdita	4	2		6					3	3			
Streblospio benedicti				3		8		6	2	5	4	2	2
Sigambra bassi		8	6	4	4	3	3	1		6	3	3	
Acetocina canaliculata			3		3	2	1	4		2	2	4	
Macoma mitchelli	5	3	5	2		6			5	4			4
Glycinde solitaria		7	2	5	2	4	4	3		7	6	5	3
Mulinia pontchartrainensis	3	6											
Mulinia lateralis	6	4		7				5	4	8			
Ameroculodes sp. A			7			7					5		
Nemertea 1	7	9					6						
Nereis succinea									6				
Pectinaria gouldii											9		
Tubificoides (LPIL)	8												
Capitella (LPIL)	9												
Nemertea 2	10												
Cyclaspis (LPIL)											7		
Edotea (LPIL)									7				
Tanypus (LPIL)													5

Table 6. Comparison of species composition of Lake Borgne samples from this and previous studies. Values represent percent of total abundance for selected species.

Taxa	This Study	EPA 1991	EPA 1992	EPA 1993	EPA 1994
Mediomastus sp.	28.96	6.43	32.98	3.72	42.03
Streblospio benedicti	7.04	40.49	21.38	0.00	3.86
Parandalia sp.	8.50	0.00	4.32	11.74	6.76
Hobsonia florida	0.43	14.67	0.99	0.59	15.46
Mulinia lateralis	3.57	1.36	4.15	1.37	0.00
Mulinia pontchartrainensis	3.79	0.36	1.77	0.59	3.38
Nemertea	2.58	0.09	1.56	0.00	1.93
Rangia cuneata	*	6.43	0.04	3.52	6.28

*Substantial numbers of *Rangia cuneata* shells were present in northern reach of the sampling area but few live specimens were encountered.

Table 7. ANOSIM Test Results for Location

Pairwise Tests	R Statistic	Significance Level %
North, South 1	0.532	0.1
North, South 2	0.711	0.1
North, South 3	0.808	0.1
South 1, South 2	0.174	0.1
South 1, South 3	0.551	0.1
South 2, South 3	0.258	0.1

Global Test
Sample statistic (Global R): 0.542
Significance level of sample statistic: 0.1%

		DateTime	Depth	Temp	SpCond	Salinity	ODO Conc	ODO%	pH
		M/D/Y	ft	C	uS/cm	ppt	mg/L	%	
T1V1	90								
T1V1	90								
T1V2	180								
T1V2	180								
T1V2	180								
T1V2	180								
T1V3	290								
T1V3	290								
T1V3	290								
T1V3	290								
T1V3	290								
T1V3	290								
T1V4	400								
T1V4	400								
T1V4	400								
T1V4	400								
T1V4	400								
T1V4	400								
T1V5	485								
T1V5	485								
T2V1	120								
T2V1	120								
T2V2	190								
T2V2	190								
T2V3	340								
T2V3	340								
T2V3	340								
T2V3	340								
T2V3	340								
T2V4	445								
T2V4	445								
T2V4	445								
T2V4	445								
T2V4	445								
T2V5	570								
T2V5	570								
T3V1	80								
T3V1	80								
T3V1	80								
T3V1	80								
T3V2	150								
T3V2	150								
T3V2	150								
T3V2	150								
T3V2	150								
T3V2	150								
T3V3	250								
T3V3	250								
T3V3	250								
T3V3	250								
T4V1	90	9/16/2011 14:10	27.098	27.59	15971	9.3	2.48	33.2	7.25
T4V1	90	9/16/2011 14:11	20.094	27.59	12158	6.92	5.44	71.7	7.42
T4V1	90	9/16/2011 14:12	10.064	27.51	11745	6.67	5.87	77.2	7.46

T4V1	90	9/16/2011 14:13	0.514	28.29	11620	6.59	7.21	96	7.62
T4V2	180	9/16/2011 14:16	37.263	27.07	20303	12.08	0.58	7.8	7.19
T4V2	180	9/16/2011 14:18	29.994	27.46	18874	11.16	1.15	15.5	7.15
T4V2	180	9/16/2011 14:19	24.854	28	14091	8.12	4.11	54.9	7.26
T4V2	180	9/16/2011 14:20	19.992	27.62	12420	7.09	5.15	68	7.34
T4V2	180	9/16/2011 14:21	10.872	27.47	11689	6.64	5.77	75.8	7.41
T4V2	180	9/16/2011 14:22	0.621	28.55	11626	6.59	7.95	106.4	7.72
T4V3	270	9/16/2011 14:25	22.53	27.71	13101	7.51	4.31	57.1	7.38
T4V3	270	9/16/2011 14:26	20.276	27.69	12587	7.19	4.81	63.6	7.38
T4V3	270	9/16/2011 14:27	10.236	27.61	11710	6.65	6.01	79.1	7.48
T4V3	270	9/16/2011 14:28	0.642	28.7	11633	6.59	8.48	113.7	7.83
T5BVV1	80	9/16/2011 13:00	30.138	25.54	14625	8.48	0.39	5.1	7.05
T5BVV1	80	9/16/2011 13:02	25.34	26.58	12587	7.2	2.99	38.8	7.13
T5BVV1	80	9/16/2011 13:03	20.201	26.74	11698	6.65	5.24	68	7.26
T5BVV1	80	9/16/2011 13:04	10.268	27.05	11685	6.64	5.59	72.9	7.32
T5BVV1	80	9/16/2011 13:06	0.531	27.82	11598	6.58	7.42	98.1	7.55
T5BVV2	160	9/16/2011 13:08	32.659	25.66	15648	9.12	0.54	6.9	7.17
T5BVV2	160	9/16/2011 13:09	29.706	25.81	15036	8.73	0.57	7.4	7.13
T5BVV2	160	9/16/2011 13:10	25.018	26.59	12730	7.29	2.74	35.6	7.14
T5BVV2	160	9/16/2011 13:11	20.139	26.99	11945	6.8	4.95	64.5	7.25
T5BVV2	160	9/16/2011 13:12	10.28	26.99	11711	6.65	5.55	72.2	7.31
T5BVV2	160	9/16/2011 13:13	0.224	28.01	11603	6.58	8.72	115.5	7.68
T5BVV3	240	9/16/2011 13:14	19.088	27	11839	6.73	4.64	60.4	7.44
T5BVV3	240	9/16/2011 13:14	9.928	27.13	11737	6.67	5.82	76	7.43
T5BVV3	240	9/16/2011 13:15	0.368	28.01	11609	6.58	8.9	117.9	7.76
T5AV1	80	9/16/2011 13:00	30.138	25.54	14625	8.48	0.39	5.1	7.05
T5AV1	80	9/16/2011 13:02	25.34	26.58	12587	7.2	2.99	38.8	7.13
T5AV1	80	9/16/2011 13:03	20.201	26.74	11698	6.65	5.24	68	7.26
T5AV1	80	9/16/2011 13:04	10.268	27.05	11685	6.64	5.59	72.9	7.32
T5AV1	80	9/16/2011 13:06	0.531	27.82	11598	6.58	7.42	98.1	7.55
T5AV2	160	9/16/2011 13:08	32.659	25.66	15648	9.12	0.54	6.9	7.17
T5AV2	160	9/16/2011 13:09	29.706	25.81	15036	8.73	0.57	7.4	7.13
T5AV2	160	9/16/2011 13:10	25.018	26.59	12730	7.29	2.74	35.6	7.14
T5AV2	160	9/16/2011 13:11	20.139	26.99	11945	6.8	4.95	64.5	7.25
T5AV2	160	9/16/2011 13:12	10.28	26.99	11711	6.65	5.55	72.2	7.31
T5AV2	160	9/16/2011 13:13	0.224	28.01	11603	6.58	8.72	115.5	7.68
T5AV3	240	9/16/2011 13:14	19.088	27	11839	6.73	4.64	60.4	7.44
T5AV3	240	9/16/2011 13:14	9.928	27.13	11737	6.67	5.82	76	7.43
T5AV3	240	9/16/2011 13:15	0.368	28.01	11609	6.58	8.9	117.9	7.76
T6V1	80	9/16/2011 10:55	38.085	27.12	8664	4.81	3.92	50.6	7.45
T6V1	80	9/16/2011 10:56	29.982	27.36	8294	4.59	4.58	59.3	7.47
T6V1	80	9/16/2011 10:56	20.259	27.8	7376	4.04	4.82	62.7	7.5
T6V1	80	9/16/2011 10:58	10.974	28.56	6318	3.42	4.49	59	7.5
T6V1	80	9/16/2011 10:59	0.695	30.79	6096	3.28	7.34	100.2	7.67
T6V2	160	9/16/2011 11:04	42.059	27.05	8923	4.96	2.56	33.1	7.31
T6V2	160	9/16/2011 11:05	34.994	27.12	8735	4.85	4.59	59.3	7.39
T6V2	160	9/16/2011 11:06	30.023	27.52	7964	4.39	4.71	61.1	7.43
T6V2	160	9/16/2011 11:07	20.023	27.82	7290	3.99	4.91	64	7.46
T6V2	160	9/16/2011 11:08	10.357	28.54	6434	3.49	4.9	64.4	7.48
T6V2	160	9/16/2011 11:10	0.604	30.73	6051	3.26	8.05	109.8	7.75
T6V3	240	9/16/2011 11:14	30.115	27.52	8125	4.49	4.05	52.6	7.49
T6V3	240	9/16/2011 11:17	20.011	27.86	7346	4.03	4.68	61	7.47
T6V3	240	9/16/2011 11:18	10.516	28.26	6587	3.58	4.35	57	7.47
T6V3	240	9/16/2011 11:19	0.598	31.28	6158	3.32	8.32	114.5	7.75
LB		9/16/2011 12:24	6.439	26.79	12313	7.03	4.68	60.9	7.41

LB		9/16/2011 12:25	0.308	26.89	12197	6.95	4.97	64.7	7.38
VC									
VC									
VC									
VC									
VC									
T-1V1	100								
T-1V1	100								
T-1V2	200								
T-1V2	200								
T-1V2	200								
T-1V2	200								
T-1V3	300								
T-1V3	300								
T-1V3	300								
T-1V3	300								
T-1V3	300								
T-1V4	405								
T-1V4	405								
T-1V4	405								
T-1V5	500								
T-1V5	500								
T-2V1	144								
T-2V1	144								
T-2V2	240								
T-2V2	240								
T-2V2	240								
T-2V2	240								
T-2V2	240								
T-2V3	365								
T-2V3	365								
T-2V3	365								
GIWWwestV1		9/16/2011 9:48	40.057	27.04	9329	5.21	0.34	4.4	7.08
GIWWwestV1		9/16/2011 9:51	34.697	27.22	8726	4.85	1.13	14.6	7.13
GIWWwestV1		9/16/2011 9:52	30.255	27.48	8135	4.49	2.26	29.4	7.2
GIWWwestV1		9/16/2011 9:55	10.436	28.47	6075	3.28	6.6	86.5	7.66
GIWWwestV1		9/16/2011 9:57	0.459	28.74	5974	3.22	7.89	104	7.82
GIWWwestV2		9/16/2011 10:00	41.193	27	9765	5.47	0.47	6.1	7.31
GIWWwestV2		9/16/2011 10:00	35.101	27.24	8738	4.85	0.57	7.4	7.3
GIWWwestV2		9/16/2011 10:02	30.113	27.56	8012	4.42	2.64	34.3	7.33
GIWWwestV2		9/16/2011 10:04	20.118	28.22	6510	3.54	6.02	78.7	7.6
GIWWwestV2		9/16/2011 10:04	10.299	28.43	6107	3.3	6.44	84.5	7.67
GIWWwestV2		9/16/2011 10:05	0.633	28.58	5919	3.19	7.31	96.1	7.78
GIWWwestV3		9/16/2011 10:09	30.963	27.5	7710	4.24	2.23	28.9	7.44
GIWWwestV3		9/16/2011 10:10	19.682	28.28	6450	3.5	5.97	78.1	7.62
GIWWwestV3		9/16/2011 10:11	10.062	28.37	6131	3.32	6.63	86.9	7.71
GIWWwestV3		9/16/2011 10:12	0.556	28.58	5829	3.14	8.05	105.7	7.84
GIWWeastV1		9/16/2011 11:46	6.714	26.39	9094	5.07	5.13	65.5	7.43
GIWWeastV1		9/16/2011 11:47	0.258	27.41	9138	5.09	6.62	86	7.57
GIWWeastV2		9/16/2011 11:29	27.383	26.51	9859	5.53	5.24	67.3	7.48
GIWWeastV2		9/16/2011 11:29	20.466	26.84	8662	4.81	5.34	68.6	7.5
GIWWeastV2		9/16/2011 11:31	9.701	27.04	8075	4.46	5.51	70.9	7.52
GIWWeastV2		9/16/2011 11:31	0.188	27.24	7597	4.18	5.65	72.9	7.54
GIWWeastV3		9/16/2011 11:34	22.552	26.65	9176	5.12	5.31	68.1	7.48
GIWWeastV3		9/16/2011 11:34	20.028	26.81	8706	4.84	5.36	68.8	7.49

GIWWeastV3	9/16/2011 11:36	9.805	27.08	7957	4.39	5.6	72.1	7.52
GIWWeastV3	9/16/2011 11:36	0.455	27.25	7488	4.11	5.72	73.8	7.54
DEQ3	9/16/2011 15:17	6.354	27.88	5037	2.69	5.75	74.4	7.77
DEQ3	9/16/2011 15:18	0.805	30.28	4412	2.33	10.63	143.2	8.25
DEQ5	9/16/2011 15:44	6.744	27.97	2070	1.05	3.78	48.5	7.54
DEQ5	9/16/2011 15:46	0.667	29.25	2077	1.05	6.51	85.5	7.57
DEQ6	9/16/2011 11:46	6.714	26.39	9094	5.07	5.13	65.5	7.43
DEQ6	9/16/2011 11:47	0.258	27.41	9138	5.09	6.62	86	7.57
DEQ13	9/16/2011 15:35	4.762	27.57	2749	1.42	2.81	35.9	7.5
DEQ13	9/16/2011 15:36	0.491	31.86	2497	1.27	12.58	172.9	8.37
DEQ14	9/16/2011 16:09	14.293	30.18	4722	2.5	9.12	122.7	8.17
DEQ14	9/16/2011 16:10	10.783	30.25	4719	2.5	9.24	124.5	8.19
DEQ14	9/16/2011 16:10	0.652	30.31	4705	2.49	9.33	125.8	8.2

APPENDIX H

APPENDIX H

DRAFT CONCEPTUAL ECOLOGICAL MODEL

DRAFT

CONCEPTUAL ECOLOGICAL MODEL

Mississippi River Gulf Outlet Ecosystem Restoration Feasibility Study, Louisiana And Environmental Impact Statement

1.0 INTRODUCTION 4

2.0 PROJECT BACKGROUND 4

2.1 STUDY AREA 4
2.2 GOALS AND OBJECTIVES 5
2.2.1 GOALS 5
2.2.2 OBJECTIVES 5

3.0 CONCEPTUAL ECOLOGICAL MODEL DEVELOPMENT 6

3.1 OVERVIEW 6
3.2 CONCEPTUAL ECOLOGICAL MODEL BACKGROUND 7
3.3 METHODOLOGY 7
3.4 MODEL COMPONENTS 8
3.5 CEM DISCUSSION 10
3.5.1 IDENTIFICATION OF DRIVERS 10
3.5.1.1 NATURAL HYDROLOGIC PROCESS DEGRADATION (HYDROLOGIC BARRIERS, CONNECTIVITY) 10
3.5.1.2 RIDGE HABITAT DEGRADATION (HYDROLOGIC BARRIERS) 10
3.5.1.3 BARRIER ISLAND DEGRADATION 11
3.5.2 ECOLOGICAL STRESSORS 11
3.5.2.1 STORM SURGE 11
3.5.3 ECOLOGICAL EFFECTS 11
3.5.3.1 HABITAT CHANGE 11
3.5.3.2 LAKE PONTCHARTRAIN DEAD ZONE EXPANSION 12
3.5.3.3 REDUCED FRESHWATER, NUTRIENT, SEDIMENT INPUT 12
3.5.3.4 WETLAND LOSSES (LAND LOSS RATES) 12
3.5.3.5 SALTWATER INTRUSION (SALINITY) 12
3.5.3.6 SHORELINE EROSION (LAND LOSS RATE) 13
3.5.3.7 SUBSIDENCE 13
3.5.4 MEASURES 13
3.5.4.1 FRESHWATER DIVERSIONS 13
3.5.4.2 HYDROLOGIC MODIFICATION 13
3.5.4.3 MARSH CREATION 14
3.5.4.4 SWAMP RESTORATION 14
3.5.4.5 SHORELINE PROTECTION 15
3.5.4.6 RIDGE RESTORATION 15
3.5.4.7 FOREST HABITAT RESTORATION/CREATION 15
3.5.4.8 BARRIER ISLAND RESTORATION 16

DRAFT

3.5.4.9 SUBMERGED AQUATIC VEGETATION (SAV) PILOT PROJECTS 16
3.5.4.10 ESTABLISHMENT OF ARTIFICIAL OYSTER REEFS IN THE BILOXI MARSHES 16
3.6 ATTRIBUTES AND PERFORMANCE MEASURES 20
3.6.1 LAND COVER 20
3.6.2 VEGETATION MONITORING 20
3.6.3 ELEVATION 21
3.6.4 WATER QUALITY 22

DRAFT

1.0 INTRODUCTION

The purpose of the Mississippi River Gulf Outlet (MRGO) Ecosystem Restoration Feasibility Study, Louisiana and Environmental Impact Statement (EIS) is to develop a comprehensive ecosystem restoration plan to restore the areas affected by the former MRGO navigation channel and the Lake Borgne ecosystem.

This Feasibility Study is authorized by Section 7012 and 7013 of WRDA 2007, which requires the completion of a Feasibility Study and the incorporation of the study findings into a signed Chief of Engineers Report which must be submitted to Congress by the Secretary of the Army for approval and subsequent funding.

This conceptual ecological model was developed to explain the major alterations that have occurred within the study area, to identify attributes of the natural system that are likely to respond to restoration features, and identify measures to monitor performance of the restoration feature and determine level of success in counteracting natural system alterations.

2.0 PROJECT BACKGROUND

2.1 STUDY AREA

The study area is approximately 3.86 million-acre (over 6,000 square-miles) including portions of the Mississippi River Deltaic Plain within coastal southeast Louisiana and parts of southwest Mississippi. The study area encompasses the Lake Borgne estuarine complex and the St. Bernard delta complex **(Figure 1).** The St. Bernard delta is one of the oldest deltaic complexes within the Mississippi Deltaic Plain Region (**Figure 2**). Natural deltaic evolution processes (Figure 3) and other man-made factors have caused direct, indirect and cumulative impacts in this region, including land loss, shoreline erosion, saltwater intrusion, habitat modification and impacts to wildlife and fisheries resources.

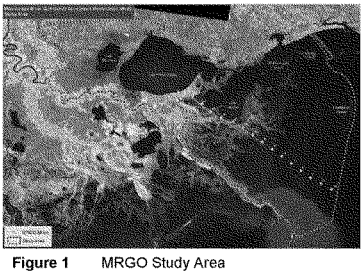


Figure 1 MRGO Study Area

Construction and operation of the MRGO has contributed to some, but not all, of these impacts.

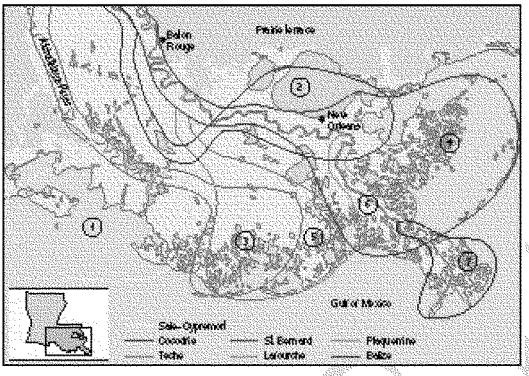


Figure 2 Seven delta lobes of the Mississippi River delta formed over the last 7000 yrs. (CLEAR, 2007, Chapter 11).

2.2 Goals and objectives

2.2.1 Goals

The goals of the MRGO Ecosystem Restoration Study are to restore the Lake Borgne ecosystem and the areas affected by the former MRGO navigation channel; to restore natural features of the ecosystem that would reduce or prevent damage from storm surge and; achieve ecosystem sustainability to the greatest degree possible.

2.2.2 Objectives

The objectives for the study include the following:

- Meet or maximize the ability to meet salinity targets as defined in the 1984 Bonnet Carre Feasibility Report and agreed upon by the MRGO Salinity working group.
- Restore approximately 9,500 acres of bald cypress swamp habitat in the Central Wetlands.
- Restore approximately 6,800 acres of fresh/intermediate marsh
- Restore approximately 18,100 acres of brackish marsh..
- Restore 3,900 acres of additional marsh.
- Restore unique natural features directly impacted by the MRGO navigation channel such as ridge habitat along Bayou LaLoutre.
- Restore critical landscape features that provide hurricane and storm damage risk reduction in the study area (ie. areas identified as critical in the LACPR technical report).

DRAFT

3.0 CONCEPTUAL ECOLOGICAL MODEL DEVELOPMENT

3.1 OVERVIEW

The New Orleans District (CEMVN) requested assistance from the Engineer Research and Development Center (ERDC) Environmental Laboratory (EL) in the development of a conceptual model to guide plan formulation and assessment of restoration plans for the MRGO. ERDC EL Investigators facilitated a meeting of the Habitat Evaluation Team (HET) to elicit information for development of the Model. The CEMVN subsequently requested that the ERDC EL make recommendations regarding appropriate metrics and predictive models for the MRGO Ecosystem Restoration Plan Feasibility Study.

The development of the CEM drew from other well-documented Conceptual Ecological Modeling frameworks developed for this system formulated under the Louisiana Coastal Area (LCA) Ecosystem Restoration Study and Louisiana Coastal Protection and Restoration (LACPR). The former MRGO navigation channel can be shown to be responsible for direct impacts (by dredging and filling during channel construction) to an estimated 19,000 acres of wetlands and to have significantly influenced saltwater intrusion with subsequent secondary and tertiary impacts (see Draft Feasibility Scoping Report, February 2010). However it is noteworthy to point out that the study area is largely degradational even in the absence of the MRGO (see Figure 3). As a result, a number of restoration measures have been proposed through CWPPRA, CIAP and other restoration programs to address degradation within the study area, some of which are targeted to achieving restoration objectives specific to MRGO impacts.

Resources in the study area and their degradation processes are discussed in several documents, and suitable summaries are presented in the main report and appendices for the Louisiana Coastal Area[1] and the Louisiana Coastal Protection and Restoration[2] studies. A Conceptual Ecological Model or nesting of Conceptual Ecological Models for MRGO can be readily adapted from those existing sources, which provide adequate descriptions of the features, processes and stressors discussed later in this report. An additional resource is the Coastal Louisiana Ecosystem Assessment and Restoration (CLEAR) model website[3], which includes a number of conceptual ecological models for the Louisiana coast and offer graphical depictions that can help with presentations. It is important to note that in addition to developing a comprehensive ecosystem restoration plan for the study area, processes and conditions related to the construction, operation, and maintenance of the MRGO are of particular interest.

[1] Louisiana - Ecosystem Restoration Study - November 2004; http://www.lca.gov/main_report.aspx
[2] Coastal Restoration Plan; http://lacpr.usace.army.mil/default.aspx?p=LACPR_Draft_Technical_Report
[3] http://www.clear.lsu.edu/conceptual_ecological_models/

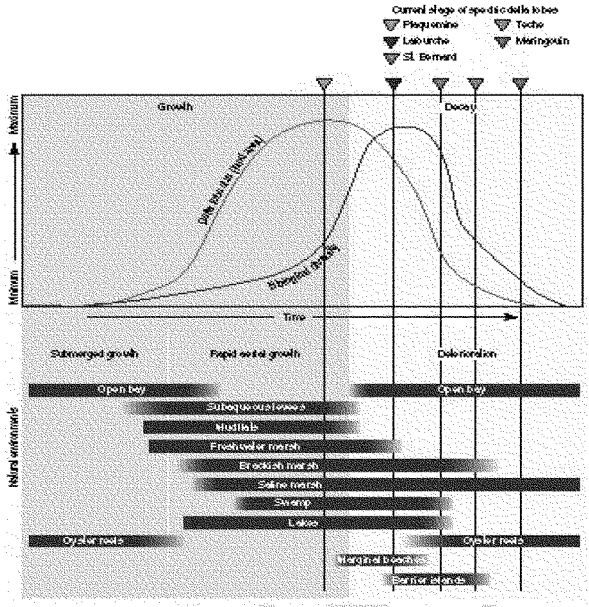


Figure 3 Conceptual model of the delta cycle depicting the growth and decay of a delta lobe. (CLEAR, 2007, Chapter 11)

3.2 Conceptual Ecological Model Background

Conceptual ecological models are simple, qualitative models that are represented by a diagram depicting a sequence of relationships between major anthropogenic and natural stressors, biological indicators, and target conditions for the indicators. Conceptual ecological models provide project teams a means of achieving the following:

- Simplification of complex ecological relationships through organization and depiction in a system of components and interactions;
- Integration of more comprehensively implicit ecosystem dynamics;

3.3 Methodology

A suitable CEM for the MRGO should identify and discuss the important features within the study area, processes linking those features, drivers (stressors) that influence conditions and processes, measures that can be employed and how they affect features

or processes, and desired states (objectives). Finally, the model should distinguish those elements attributable to or clearly linked to the MRGO.

As part of the workshop, EL facilitators sought input in the identification of the features, drivers, key issues and objectives related to the MRGO study area. These are summarized below, including: 1) the most current study objectives and 2) measures and issues (or drivers) identified by workshop participants as significant to the system, addressing specific objectives or having the greatest impact. Additionally, each issue was discussed carefully in terms of its relative importance to the system, apparent key thresholds, certainty of knowledge or data, predictability and the extent and character of any indirect or direct impact, if any; MRGO has had on each issue, driver or process considered. Measures identified and documented in the Feasibility Scoping Report were discussed similarly, including their relation to objectives (significance), how well impacts or effects are understood or quantified (certainty and predictability), and any known interactions between measures and issues. EL facilitators carefully documented discussions and propose the following objectives, measures, issues/drivers, metrics and models.

3.4 Model Components

The conceptual ecological model developed for the proposed project follows the top-down hierarchy of information using the components established by Ogden and Davis (1999). The schematic organization of the conceptual ecological model is depicted in Figure 2 and includes the following components:

- Drivers- This component includes major external driving forces that have large-scale influences on natural systems. Drivers may be natural (e.g., eustatic sea level rise) or anthropogenic (e.g., hydrologic alteration) in nature.

- Ecological Stressors- This component includes physical or chemical changes that occur within natural systems, which are produced or affected by drivers and are directly responsible for significant changes in biological components, patterns, and relationships in natural systems.

DRAFT

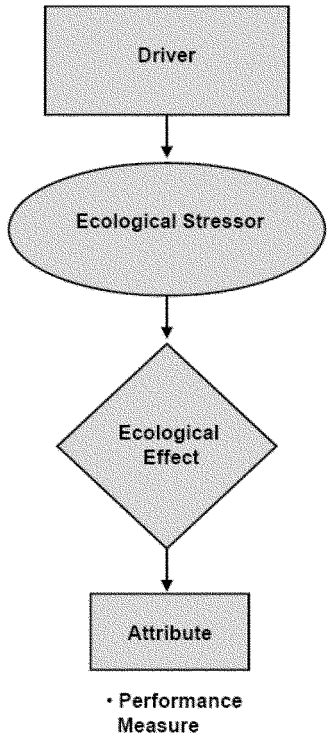


Figure 4 Conceptual Ecological Model Schematic Diagram

- Ecological Effects- This component includes biological, physical, or chemical responses within the natural system that are produced or affected by stressors. Conceptual ecological models propose linkages between one or more ecological stressors and ecological effects and attributes to explain changes that have occurred in ecosystems.

- Attributes- This component (also known as indicators or end points) is a frugal subset of all potential elements or components of natural systems representative of overall ecological conditions. Attributes may include populations, species, communities, or chemical processes. Performance measures and restoration objectives are established for each attribute. Post-project status and trends among attributes are measured by a system-wide monitoring and assessment program as a means of determining success of a program in reducing or eliminating adverse effects of stressors.

- Performance measures- This component includes specific features of each attribute to be monitored to determine the degree to which attribute is

responding to projects designed to correct adverse effects of stressors (i.e., to determine success of the project).

This CEM does not attempt to explain all possible relationships or include all possible factors influencing the performance measure targets within natural systems in the study area. Rather, the model attempts to simplify ecosystem function by containing only information deemed most relevant to ecosystem monitoring goals.

3.5 CEM DISCUSSION

3.5.1 Identification of Drivers

The team worked to identify specific drivers (issues) that contributed to the conditions of the study area. Each of the following issues includes important processes, drivers or components identified by the HET as critical to the MRGO Ecosystem Restoration Plan. Effects on each of these components by MRGO (before and after closure structure) and also by proposed measures listed above have been compared (Table 1). The purpose of this table is to support the HET in determining which components (issues) have been or continue to be affected by MRGO, to what extent each proposed restoration measure may influence all components of concern within the study area whether or not affected by MRGO and which measures will address those issues specifically affected by MRGO. Elements in this table should form the basis for a complete Conceptual Ecological Model.

3.5.1.1 Natural Hydrologic Process Degradation (hydrologic barriers, connectivity)

Construction of levees, oil and gas canals and navigation channels has altered natural hydrology, affecting freshwater, sediment, and nutrient transport. Dredged material banks block the movement of sediment re-suspended during storms, which play a major role in sustaining land elevations (Reed et al. 1997). Channels and canals promote saltwater intrusion and increase tidal processes that impact the marsh by accelerating erosion. East-west canals impede sheetflow and cause ponding of water on the marsh. Because of the presence of dredged material banks, partially impounded areas have fewer but longer periods of flooding and reduced water exchange when compared to unimpounded marshes (LCA 2004). This impoundment results in increased waterlogging and frequently in plant death.

3.5.1.2 Ridge Habitat Degradation (hydrologic barriers)

Ridges are natural levees formed from sediments delivered over the banks of rivers and bayous during floods. These ridges assist in defining a watershed and in maintaining its

natural hydrology. Ridges sustain upland shrubs and trees, providing unique habitat for certain plant and animal species. Intact ridges prevent intrusion of saltwater into fresher marsh. Natural factors such as subsidence have contributed to the destruction of the ridges. The construction of the MRGO directly affected the Bayou La Loutre ridge, by cutting the channel through the ridge.

3.5.1.3 Barrier Island Degradation

The barrier islands in the Louisiana portion of the study area are the remains of an abandoned Mississippi River Delta; and their degradation is the result of the natural deltaic processes. The formation of Cat Island in Mississippi was also influenced by this abandoned delta, and is distinct from other Mississippi barrier islands (Schmid 2001). Barrier islands act as a buffer to reduce the effects of ocean waves and currents on associated estuaries and wetlands. Louisiana's barrier islands are eroding at a rate of up to 20 meters per year: according to recent U.S. Geological Survey (USGS) estimates, several will disappear by the end of the century (LACPR 2008). Although Cat Island has lost 39% of the land area it had in 1848, it is the most stable of the Mississippi barrier islands. Interior elevations and the orientation of Cat Island prevent breaching and overwash by storm waves except along spits of the eastern shore (Morton 2007). The disappearance of the barrier islands exposes coastal wetlands to the full force and effects of wave action, saltwater intrusion, storm surge, and tidal currents, accelerating wetlands deterioration.

3.5.2 Ecological Stressors

3.5.2.1 Storm Surge

Coastal storms, particularly tropical cyclone events, also exert a stochastic but severe influence on the study area. Data obtained from the National Oceanic and Atmospheric Administration (NOAA) Coastal Services Center indicate that the storm centers of at least 14 tropical cyclones with a Saffir-Simpson Hurricane Scale of Category 2 or higher have passed within 50 miles of the study area during the interval 1851-2007, and at least 52 such tropical cyclones have passed within 100 miles of the study area during the same interval. The most recent tropical cyclones to affect the study area were Hurricanes Katrina and Rita, which occurred in August 2005 and September 2005, respectively, and Hurricanes Gustav and Ike, which occurred in September 2008.

3.5.3 ECOLOGICAL EFFECTS

3.5.3.1 Habitat Change

Habitat diversity is important for a healthy ecosystem. Erosion, storm surge inundation, and salinity changes from decreased freshwater inputs or saltwater intrusion can cause

habitat switching and loss of habitat. In some areas, loss of habitats with high friction factors, such as swamp forests, can lead to higher storm surge risk

3.5.3.2 Lake Pontchartrain Dead Zone Expansion

Hypoxic/anoxic conditions ("dead zones") occur in Lake Pontchartrain and the Gulf of Mexico. These conditions are caused primarily by excess nitrogen in combination with stratification of more saline waters. Due to the control of the Mississippi River, nutrients pass though the study area and into the northern gulf, rather than into adjacent wetlands, which would absorb these nutrients.

3.5.3.3 Reduced Freshwater, Nutrient, Sediment Input

The construction of levees along the Mississippi River and its distributaries has virtually eliminated the periodic floods that provided vital freshwater, sediment and nutrients to the study area. These flood control measures have seriously altered hydrogeomorphic, biogeochemical, and ecological processes. Without inputs of freshwater, sediment and nutrients, coastal land loss is accelerated and natural subsidence is exacerbated.

3.5.3.4 Wetland Losses (land loss rates)

As previously described in the sections on existing and future without project conditions, perhaps the most serious and complex problem in the study area is land loss. Land loss is a critical problem not only because of ecosystem degradation but also because of its role in increasing susceptibility to storm surge. Relative sea level rise, tropical storms, shoreline erosion, modification of natural hydrology, and other factors contribute to land loss in the study area. The sustainability of the coastal ecosystems is threatened by the inability of many wetlands to maintain their surface elevation. Any alterations which allow marsh soils to be excessively waterlogged cause soil chemical changes that even the most resilient marsh plants cannot survive. Once plants die, roots no longer provide structure and integrity to marsh soils, and land loss results.

3.5.3.5 Saltwater Intrusion (salinity)

Saltwater intrusion changes the salinity gradient, which results in habitat changes. Salinity levels exist along a gradient, which declines as the saltwater moves inland from the Gulf of Mexico. A distinct zonation of plant communities, or vegetative habitat types, differing in salinity tolerance exists along that gradient, with the species diversity of those zones increasing from salt to fresh environments. Changes to the salinity gradient are caused by a number of factors, including: the construction of levees, channels and canals, and drainage systems. Tropical storm events can introduce saltwater into fresher areas, damaging large amounts of habitat in a short period of time.

3.5.3.6 Shoreline Erosion (land loss rate)

Tropical storm events and natural tidal processes are natural causes of erosion. Navigation channels subject inland areas to more dramatic tidal forces and wave action, increasing erosion. Rims of firmer soil around lakes, bays, and natural ridges along waterways are susceptible to wind-induced erosion. When these firmer soils are eroded away, organic marsh soils are directly exposed to open water wave attack.

3.5.3.7 Subsidence

The water control structures that allowed coastal areas to be developed also contribute to subsidence and wetland loss. Continued land loss and ecosystem degradation cause developed areas to become more susceptible to storm surge, threatening communities and valuable infrastructure.

3.5.4 MEASURES

The following specific measures have been proposed and assessed as part of the Feasibility Scoping Report and the Preliminary Draft Environmental Impact Statement. Each of these measures has been determined to address the drivers discussed above.

3.5.4.1 Freshwater diversions

Diverting freshwater from the Mississippi River into the study area could nourish existing marshes to increase their productivity and build wetlands, maintain and restore salinity gradients, and reintroduce and distribute sediment and nutrients throughout the ecosystem. The benefits that diversions produce increase over time and continue as long as the diversion is operated and maintained. In addition, diversion operations can be adaptively managed to respond to environmental changes and optimize benefits.

3.5.4.2 Hydrologic modification

Several channels and canals within the Louisiana portion of the study area were identified during the scoping process for potential filling, plugging, installing water control structures (such as weirs and sills), or bank gapping. Bank gapping can be used to help restore natural hydrology and provide nutrients and sediment to facilitate organic deposition, improve biological productivity, and prevent further habitat deterioration (LCA 2004). Weirs and sills provide partial closure and aid sedimentation and salinity

control. Filling can serve the dual purpose of water control and land building (depending upon the depth of fill). Plugging can be accomplished with lateral fill or full closure structures. Plugging methods are primarily water control structures and do not provide the land creation benefits of filling. Plugging, however, is usually a substantially less expensive option than filling.

3.5.4.3 Marsh creation

One way to address marsh loss is through the placement of dredged material. Marsh restoration involves the placement of dredged material in shallow open water areas and extensively broken marsh to raise the area to marsh elevation. Following compaction and dewatering, the area is planted with marsh vegetation. Retention dikes, deflection dikes, and/or closures may be used to contain material within the restoration area. Dredged material is allowed to overflow to nourish and consolidate existing marsh vegetation within the restoration area.

Marsh nourishment refers to the placement of a thin layer of dredged material on broken marsh. The placement of this material facilitates the recruitment and consolidation of marsh vegetation after dewatering. Unlike marsh restoration features, no plantings are associated with marsh nourishment features.

Newly created or nourished marsh will provide the following benefits: add new sediment and nutrients to the system; combat subsidence; reduce breaching and erosion; reduce wave fetch from open water areas from previously broken marsh; and allow for more vertical accumulation of vegetation.

3.5.4.4 Swamp Restoration

In addition to marsh restoration, there were additional suggestions to restore cypress swamp habitat in the study area. Swamp would be restored through the placement of dredged material, similar to marsh restoration features described above. Swamp restoration features would have a higher dewatered and settled elevation than marsh restoration features to support cypress habitat.

Swamp nourishment is proposed for areas that are currently at marsh elevation, and consists of placing a thin layer of dredged material to nourish the area, raise elevation, and encourage the recruitment of cypress-tupelo community species.

Shore protection measures are generally placed in a linear fashion parallel to the shoreline and are designed to harden the shoreline or to dampen wave energy. Shore protection measures can range from substantial off-shore breakwaters/artificial reefs to simple on-shore vegetative planting. Some shoreline protection measures could have an incidental benefit for storm risk reduction due to dissipated wave energy or the protection of critical landscape features.

3.5.4.5 Shoreline Protection

The prevention of shoreline erosion is essential to addressing the larger problem of coastal land loss. High waters, wave action, wind induced currents, tidal flow, channel bathymetry, and residual tidal circulation can contribute to shoreline erosion.

Shoreline protection includes the placement of materials, such as sand, shell, rock, or construction debris on-shore or off-shore. Construction methods included the establishment of artificial reefs and breakwaters off-shore as well as the placement of rock or sand on-shore. These measures dissipate wave energy and thus prevent shoreline erosion and land loss, as well as potentially contribute to storm surge risk reduction.

Shore protection measures are generally placed in a linear fashion parallel to the shoreline and are designed to harden the shoreline or to dampen wave energy. Shore protection measures can range from substantial off-shore breakwaters/artificial reefs to simple on-shore vegetative planting. Some shoreline protection measures could have an incidental benefit for storm risk reduction due to dissipated wave energy or the protection of critical landscape features.

3.5.4.6 Ridge restoration

Historically, ridges were formed as natural levees of major and minor distributaries that diverge from larger distributaries as they trend toward the coast. Deposits of mostly linear dredged material that crisscross the coast may also be considered ridges if they mimic natural levees. Natural ridges in the study area include the Bayou La Loutre ridge and the Bayou Terre aux Boeufs ridge. Several reaches of the Bayou La Loutre and Bayou Terre aux Boeufs ridges were proposed for restoration as part of the initial array of measures considered. Ridge restoration would consist of the placement of dredged material to a height suitable for upland habitat. Various footprints were evaluated for several reaches of these historic ridges.

3.5.4.7 Forest habitat restoration/creation

Measures to restore or create forested habitat included vegetative planting with an emphasis on woody vegetation. Vegetative planting measures were developed as stand alone measures on existing spoil banks and in conjunction with other previously described measures such as ridge restoration (see also section on **Ridge Restoration**) and swamp creation/restoration (see section on **Marsh or Swamp Creation/Restoration)**. These measures may contribute to storm surge risk reduction.

Forests are an important resource in the study area and represent unique habitats. Both wetland and upland forested habitat has historically been found in the study area but have declined in quantity. During public scoping meetings, measures to restore or create forest habitat were suggested.

3.5.4.8 Barrier island restoration

Barrier island restoration was considered for all barrier islands in the study area. These measures may contribute to storm surge risk reduction and salinity control. Barrier Islands in the study area consist of the Chandeleur Chain (including Chandeleur Island and Breton Island) and Cat Island (located between the Mississippi Sound and the Chandeleur Sound). Restoration of these islands was proposed as part of the initial array of measures considered.

Through LACPR and MsCIP, the contribution of surge reduction provided by the barrier islands, in their historic, existing, and altered states, has been subject to sensitivity analyses that indicate that some surge reduction is realized by the barrier islands. Additional benefits were also predicted by creating longer and higher islands. It can only be speculated as to how much actual damage reduction the barrier islands provide, but the disappearance of the barrier islands provides the means for a dramatically increased wave climate, along the coasts of Mississippi and Louisiana.

3.5.4.9 Submerged aquatic vegetation (SAV) pilot projects

Submerged Aquatic Vegetation (SAV) beds improve water quality and provide other ecosystem function benefits such as increased habitat availability for critical fisheries resources. Worldwide, SAV populations have been declining. For example, in 1969, an estimated 20,000 acres of SAVs were documented in Mississippi Sound and coastal bays. As of 1998, only 2,000 acres were documented (Moncrieff et. al. 1998).

During public scoping meetings, pilot projects to investigate various methods of SAV planting in the Mississippi Sound and in Lake Pontchartrain were suggested. SAV restoration measures are presented as pilot projects because of uncertainties surrounding the re-establishment of SAV beds. For example, it is unknown if efforts to create habitat conditions that are suitable for SAV are sufficient for restoration or if more targeted approaches, such as planting, would also be necessary to re-establish SAV beds.

3.5.4.10 Establishment of artificial oyster reefs in the Biloxi Marshes

The establishment of artificial oyster reefs in the Biloxi Marshes was suggested during public scoping meetings. Generally, oyster communities are a part of the Lake Borgne ecosystem and some reef designs could dissipate wave energy and thus prevent shoreline erosion or land loss and contribute to storm surge risk reduction.

Artificial oyster reefs were considered both for oyster production and shoreline protection purposes. Three alternative designs for artificial oyster reefs were evaluated as shoreline protection measures, i.e. a bio-engineered reef, using crushed stone, or incorporating a berm for oysters in addition to a traditional rock shoreline protection measure. These measures demonstrate the opportunity to incorporate benefits for oysters into shoreline protection designs.

DRAFT

Table 1. Effects of MRGO and Selected Ecosystem Restoration Measures on Selected Issues and Drivers in the MRGO Study Area.

Measure / Issue / Driver	MRGO Before Closure[1]	FWOP+ MRGO Closure[2]	FWOP+ Additional Measures[3]	River Diversions[4]	Hydrologic Restoration	Marsh Creation Dredging	Shoreline Protection[5]	Ridge Restoration	Forest Creation/ Restoration	Barrier Islands Restoration	SAV Restoration	Oyster Reefs Creation	Swamp Restoration
Reduced Freshwater, Nutrients, Sediment Input	NA	NA	D↓ I↓	D↓	D↑/↓ I↑/↓	NA	NA	NA	NA	NA	NA	NA	NA
Wetland Losses	D↑ I↑	D↑ I↑	D↑ I↑	I↓	I↓	D↓	D↓	I↓	D↓	D↓ I↓	I↓	I↓	D↓
Saltwater Intrusion	D↑	I↓	D↓ I↓	D↓	D↓ I↓	I↓	NA	I↑/↓	NA	D↓	NA	NA	I↓
EFH Degradation	D↑ I↑	D↑ I↓	D↑ I↓	I↑/↓	D↑/↓ I↑/↓	D↓	D↑/↓	I↑/↓	NA	D↓	D↓	D↓	D↓
Natural Hydrologic Process Degradation	D↑	D↑[6]	D↑[6]	D↓	D↓	I↓	NI	I↓	NA	D↓	NI	NI	I↓
Ridge Habitat Degradation	D↑	D↓	D↑ I↑	NA	I↓	I↓	NI	D↓	NA	I↓	NI	NI	I↓
Barrier Islands Degradation	I↑	I↓	NA	NA	NA	NA	NI	NA	NA	D↓	I↓	NI	NA
Shoreline Erosion	I↑	I↑	I↑	I↓	I↓	I↓	D↓	D↓ I↓	NA	I↓	I↓	I↓	I↓
Subsidence	NA	NA	NA	I↓	I↓	I↑/↓	NA	I↑	NA	NA	NI	NI	I↑/↓
Sea Level Rise	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NI	NA	NA
Storm Surge	NA	NA	NA	I↓	I↓	D↓	NA	D↓	D↓	D↓	I↓	NA	D↓
Marine Habitat Degradation	D↑ I↑	I↓	D↓ I↓	D↓I↓	D↑/↓ I↑/↓	D↑/↓ I↑/↓	I	D↑/↓ I↑/↓	D↑/↓ I↑/↓	D↓	D↓	D↓	D↑/↓ I↑/↓
Freshwater Habitat Degradation	D↑ I↑	I↓	D↓I↓	D↓	D↓	D↓	I↓	I↓	I↓	I↓	D↓	NA	D↓
Lake P. Dead Zone Expansion	D↑ I↑	D↓I↓	D↓I↓	I↓	I↓	NI	NI	NI	NI	NI	NA	NA	NI

Key to Table 1. Cell Codes

DRAFT

NA = Not Applicable or measure not proposed for selected Issue/Driver	↑ Increases rate or amount (*not* "good" or "bad")
NI = Little to No Impact of Measure on Issue/Driver	↓ Decreases rate or amount (*not* "good" or "bad")
D = Direct impact of Measure on Issue/Driver	***Note:*** *Uncertainty, Predictability, and Strength of impact are not indicated in this table*
I = Indirect impact of Measure on Issue/Driver	

Table 1. Footnotes:

[1]MRGO Before Closure

[2]FWOP+ MRGO Closure

[3]FWOP+ Additional Measures

[4]River Diversion Measure Category includes large measures such as Violet Diversion.

[5]Shoreline Protection refers to Marsh, Lake and Channel shorelines only.

[6]Closure of MRGO will not restore natural hydrologic functions and may result in a hypoxic zone within the closed, unfilled MRGO channel due to anticipated reduction in current velocity.

DRAFT

629

3.6 Attributes and Performance Measures

Comment [U1]: Needs further development

3.6.1 Land Cover

Land cover has been identified as a key indicator of project success with respect to preventing habitat conversion and future land loss. Comparisons of pre-project land cover characteristics with post-project land cover characteristics would serve to determine if conversion of brackish marsh to saline marsh or open water within the study area experiences a post-project decline or ceases altogether. Additionally, post-project land cover analysis would determine if areas within the study area that had previously converted to freshwater marsh or open water experience a post-project reversion to intermediate/fresh marsh or regeneration of bald cypress swamp as a result of improved seedling survival.

- Spatial analysis has been identified as an assessment performance measure to determine the response of land cover to the proposed project. Spatial analysis would involve comparative analysis of pre-project and post-project aerial or satellite imagery and utilize thematic mapper analysis to determine relative changes in marsh habitat type and bald cypress swamp coverage within the study area.

A post-project relative increase in the total area of marsh and bald cypress swamp would be an indication of significant project success, while a post-project stabilization of marsh and bald cypress swamp coverage within the study area would be an indication of moderate project success. Conversely, a post-project decline in marsh acreage, especially intermediate/fresh marsh in the study area and bald cypress swamp coverage in the Central Wetlands area would indicate that the project did not succeed in preventing habitat conversion and, by extension, future habitat loss.

3.6.2 Vegetation Monitoring

Vegetation monitoring has been identified as a key indicator of project success with respect to increasing wetland and swamp vegetation productivity. Comparison of pre-project vegetation monitoring data with post-project vegetation monitoring data would serve to determine if biomass production in plant communities within the study area increases in response to project features. A post-project increase in biomass production would also indicate the introduction of nutrients and sediment into the wetlands and swamp as a result of the project.

Assessment performance measures identified for measuring wetland productivity includes percent cover of desirable vegetation type (i.e. dominance of freshwater plant species for fresh marsh).

Three assessment performance measures have been identified for measuring swamp productivity, including percent cover, diameter at breast height (dbh) and litterfall.

- Percent cover is the estimated percentage of the ground surface covered by vegetation. Canopy percent cover is the estimated percentage of the ground surface covered by tree canopies when the crowns are projected vertically. A high percent cover is indicative of significant productivity within the respective vegetation communities, and a higher canopy percent cover is indicative of significant productivity within woody species.

- Diameter at breast height (dbh) is the measurement of tree diameter at a height of 4.5 feet above the forest floor on the uphill side of the tree. A large annual increase in dbh is indicative of significant productivity with respect to the measured tree and adjacent forest community. Ongoing monitoring studies of bald cypress and tupelo trees within the western Maurepas Swamp by Dr. Gary Shaffer indicate that average annual dbh increase for trees within the eastern study area is approximately one millimeter per year, a growth level that is significantly lower than expected levels of 1-2 centimeters per year for healthy bald cypress or tupelo trees (Shaffer, personal communication, 2009).

- Litterfall is the measurement of the movement of leaves, twigs and other forms of organic matter from the biosphere to the litter layer found in soil via interception in collection traps. Large volumes of litterfall are indicative of significant biomass production within the constituent forest community. A post-project relative increase in productivity within the study area as evidenced by these three would be an indication of significant project success, while a post-project stabilization of these measures would be an indication of moderate project success. Conversely, a post-project decline in these measures within the study area would indicate that the project did not succeed in increasing swamp vegetation productivity.

3.6.3 Elevation

Elevation has been identified as a key indicator of project success with respect to reducing or reversing subsidence within the study area. Comparison of pre-project elevation levels with post-project elevation levels would serve to determine if sediment input and soil accretion is occurring within the study area in response to project features. A post-project increase in elevation would implicitly indicate the introduction of nutrients and sediment into the wetlands and swamp as a result of the project, and would also indicate an increase in vegetation productivity and the resulting litterfall that is a principal factor in soil accretion within the Central Wetlands Swamp. Two assessment performance measures have been identified for this attribute, including surface elevation table (SET) measurements and feldspar marker horizon measurements.

- Surface Elevation Table (SET) measurements provide a constant reference plane in space from which the distance to the sediment surface can be measured by means of pins lowered to the sediment surface. Repeated measurements of elevation can be made with high precision because the orientation of the table in space remains fixed for each sampling. Elevation change measured by the SET is influenced by both surface and subsurface processes occurring within the soil profile.

- Feldspar marker horizon measurements involve the placement of a cohesive layer of feldspar clay on the ground surface. Soil borings are extracted at the marker horizon location periodically to measure the amount of soil deposition and/or accretion that has occurred above the horizon since placement. Significant quantities of soil atop marker horizons are indicative of soil building within the area, which in turn indicates an increase in relative elevation. Post-project increases in elevation as evidenced by SET measurements or documented soil accretion atop a marker horizon within the study area would be an indication of significant project success, while a post-project stabilization of elevation as these measures would be an indication of moderate project success. Conversely, a post-project decline in elevation within the study area would indicate that the project did not succeed in offsetting subsidence and, by extension, habitat conversion and future land loss.

3.6.4 Water Quality

Comment [U2]: Needs development based on Water Quality Report

Surface water quality in interior locations in the study area has been identified as a key indicator of project success with respect to establishing hydrologic connectivity between the Amite River Diversion Canal and the adjacent swamp habitat. Comparison of pre-project water quality with post-project quality would serve to determine if freshwater throughput is introducing nutrients and flushing out saline waters within the study area in response to project features. A post-project improvement in water quality would implicitly indicate the introduction of freshwater and the associated nutrients and sediment into the swamps as a result of the project. Four assessment performance measures have been identified for this attribute, including total suspended solids (TSS), dissolved oxygen (DO), nutrients, and salinity.

- Total suspended solids (TSS) is a measurement of the total volume of sediment suspended in a given volume of water.

- Dissolved oxygen (DO) is a relative measure of the amount of oxygen that is dissolved in a given volume of water. Surface waters within the MRGO, wetlands and swamp in the study area are expected to exhibit lower DO concentrations

- Nutrients are chemical compounds or minerals contained in surface waters that are extracted by organisms for nourishment. Common nutrients in surface waters include nitrates, phosphates, and ammonia.

- Salinity is a measure of the concentration of dissolved salt in a given volume of water. Surface waters within the study area often exhibit elevated salinity levels Post-project improvements in water quality within the study area as evidenced by analysis of these measures would be an indication of significant project success, while a post-project stabilization or decline in elevation in water quality within the study area would indicate that the project did not succeed in reestablishing riverine input to the study area and the resulting reintroduction of nutrients and sediments associated with freshwater throughput.

DRAFT

In an effort to advance the discussion on this issue and help prepare for the aforementioned meeting, the HET should consider the following issues with specific regard to WVA:

1. Input Parameters: Some of the key inputs for the WVA must be derived from other sources, and in all likelihood will require the application of some other models. These include models relating to the development of marsh through mechanical means (D2M2), or from diversions (DBAT/NSED2/CLEAR); salinity and other water quality conditions (CE-QUAL/CLEAR); land loss rates and projections (USGS), and so on.
2. Subjectivity = non-repeatability: Data inputs and weighting for Suitability Index graphs and HSI equations are largely subjective, relying on expertise of the investigator and reported values gathered from the literature. There is no way to validate the model. The scale of this project will require an adaptive management approach in phasing and reassessing measures implementation and monitoring, which requires a more robust set of repeatable models for which changing inputs can be reliably collected. Because WVA represents a "snapshot" of relative habitat suitability with insufficient repeatability, this method would be best applied only at the project alternatives comparison phase. Alternatively, if adequately robust sub-models are chosen to provide inputs to WVA, this could still be applicable
3. Indices and Metrics: WVA combines a series of individual variable metrics into indices. Whereas this method can yield a credible representation of relative habitat quality, individual metrics of interest identified by the HET, such as salinity, land loss rates or Chorophyll A, may get lost. In addition, there are likely some significant debates over the scientific merit of some of the indices used in the model, and these will be fertile points for dissention.
4. Habitat types: WVA models were developed for fresh/intermediate marsh, brackish marsh, saline marsh, bottomland hardwoods, barrier island/headland, coastal chenier/ridge and fresh swamp habitats. These models may not be applicable to any of the critical open water habitats included in the CEM.
5. Spatial and temporal distribution: WVA does not seem to be able to address the quality associated with spatial distribution of habitats that represent the best overall suitability for the project area. These will require a separate model or set of models to adequately allow project alternatives comparison, particularly if alternatives contain the same types or quantities of habitats with differing locations. Additionally, it is not clear how WVA addresses the long-term implementation issues for a project this large. How will the distribution of benefits over 50-years be addressed?
6. Additional Impacts: WVA does not address some impacts that likely require quantification for this study. One significant concern is the effect of diversions and their operations on shoaling in the Mississippi River. Development of hypoxic conditions and general water quality conditions are not modeled or addressed by WVA. One of the stated objectives for the project was the restoration of historic circulatory conditions in the system. It is not clear what model or analysis would be necessary to address this objective, but WVA does not include this factor.

Considering some of the limitations of WVA, additional models and tools will need to be incorporated to fully represent all metrics identified by the HET. Additionally, the large scale of

the project area and the anticipated multi-year timeline for implementation suggest this model alone will be insufficient for use as a predictive planning tool for all habitat types of concern. We recommend that the proposed discussion meeting for WVA be expanded to address the broader issues listed above, and that the MRGO project adopt a long-term investment attitude when considering the data and tools needed for formulating and evaluating alternatives.

DRAFT

References:

2006 Louisiana Coastal Protection and Restoration, Preliminary Technical Report to United States Congress, July, 2006.

Barras, J.A., P.E. Bourgeois, and L.R. Handley. 1994. Land loss in coastal Louisiana, 1956-1990. National Biological Survey, National Wetlands Research Center Open File Report 94-01. Lafayette, LA.

Boshart, W.M. 1997. The conservation and restoration of a baldcypress swamp: an investigation of macronutrients, competition, and induced vegetation dynamics as related to nutria herbivory M.S. Thesis. Southeastern Louisiana University, Hammond, LA.

DRAFT Environmental Impact Statement (EIS) for the Mississippi River-Gulf Outlet (MRGO), Louisiana, and Lake Borgne – Wetland Creation and Shoreline Protection Project U.S. Army Corps of Engineers, New Orleans District, October 2008.

Draft Feasibility Scoping Report for MRGO Ecosystem Restoration Plan Feasibility Study, U.S. Army Corps of Engineers District, New Orleans (CEMVN), January, 2009.

Guide to Coastal Louisiana Ecosystem Assessment and Restoration (CLEAR) Ecosystem Forecasting System, www.clear.lsu.edu, updated: July, 2007.

Hatton, R. S. 1981. Aspects of marsh accretion and geochemistry: Barataria Basin, Louisiana. M.S. thesis. Louisiana State University, Baton Rouge, LA.

Integrated Final Report to Congress and Legislative Environmental Impact Statement for the Mississippi River – Gulf Outlet Deep-Draft De-authorization Study Volume 1 MAIN REPORT by U. S. Army Corps of Engineers New Orleans District November 2007.

Messina, M.G. and W.H. Conner (eds.). 1998. Southern Forested Wetlands: Ecology and Management. Lewis publishers, New York, NY.

Myers R.S., G.P. Shaffer, and D.W. Llewellyn. 1995. Baldcypress (Taxodium distichum (L.) Rich.) restoration in southeast Louisiana: Relative effects of herbivory, flooding, competition, and macronutrients. Wetlands 15:141-148.

Shaffer, G., W.B. Wood, S.S. Hoeppner, T.E. Perkins, J. Zoller, and D. Kandalepas. 2008. Degradation of Cypress-Tupelo Swamp to Marsh and Open Water in Southeastern Louisiana, USA: An Irreversible Trajectory? Abstract Society of Wetlands Annual Conference, Washington, DC.

U.S. Army Corps of Engineers. 2004. Louisiana Coastal Area (LCA) Ecosystem Restoration Study. Volume I: Main Report. New Orleans District. New Orleans, LA.

DRAFT

APPENDIX

I

Mississippi River - Gulf Outlet (MRGO) Ecosystem Restoration Study Louisiana and Mississippi

Revisions to the Comprehensive Aquatic Ecosystem Model (CASM)

Preliminary Evaluation of Proposed Freshwater Diversion In the Vicinity of Violet, Louisiana

Steven M. Bartell
Shyam K. Nair
Yegang Wu

E2 Consulting Engineers, Inc.
339 Whitecrest Drive
Maryville, TN 37801

Prepared for the

U.S. Army Corps of Engineers–New Orleans District
New Orleans, Louisiana

October 2010

Contents

Executive Summary 4
Introduction 8
Modeling Objectives 9
Model Description 10
  Physical Model Structure 10
  Food Web Structure 11
    Phytoplankton 12
    Periphyton 12
    Submerged Aquatic Vegetation 12
    Emergent Aquatic Vegetation 12
    Zooplankton 13
    Benthos 13
    Fish 13
Governing Equations 13
  Primary Producer Population Dynamics 14
    Factors Regulating Photosynthesis 15
  Consumer Population Dynamics 18
Parameter Estimation 21
  Abiotic Environmental Factors 21
    Light 21
    Salinity 23
    Water Temperature 23
    Nutrients 23
    Total Suspended Inorganic Solids 24
    Suspended Particulate Organic Carbon 24
    Surface Wind Velocity 24
  Biotic Components 24
    Phytoplankton 25
    Other Producer Populations 27
    Consumer Populations 27
  Water Quality Parameters 29
  Temperature-Dependent Processes 30
Long-Term Environmental Scenarios 31
Summarization of Revised Model Results 32
Baseline Simulation 33
Future Without-Project Results 37
  Description of Without-Project Alternatives 38
  Revised Results for WQ1 38
Future With-Project Results 38
  Description of With-Project Alternatives 39
  Revised Results for WQ6 39
Incremental Effects 40
Discussion 41
  Potential Model Bias 41

Sensitivity and Uncertainty 42
Summary 43
Recommendations 43
References 46
List of Figures 51
Figure 1. Locations of CASM stations used to represent physical complexity of the MRGO Project domain. (Redrawn from USACE 2010) 52
Figure 2. Revised food web structure of the CASM MRGO. (Not all interactions are shown) 53
Figure 3. Monthly salinity values at node 2 for alternative scenarios. 54
Figure 4. Monthly salinity values at node 78 for alternative scenarios. 54
Figure 5. Temporal values of dissolved inorganic N for node 2. 55
Figure 6. Temporal values of dissolved inorganic N for node 78. 55
Figure 7. Values of dissolved inorganic P used at node 2. 56
Figure 8. Nodal and spatially interpolated summarization of CASM MRGO results. . 57
Figure 9. Spatially interpolated summarization of CASM MRGO results for April oyster production for WQ1 and WQ6. 58
Figure 10. Spatially interpolated summarization of CASM MRGO results for December Gulf sturgeon production for WQ1 and WQ6. 59
Figure 11. Spatially interpolated summarization of CASM MRGO results for March sheepshead production for WQ1 and WQ6. 60
List of Tables 61
TABLE 1 Cell number, brief cell description, surface area, and average depth for UNO model nodes included in the CASM MRGO. 61
TABLE 2 Bioenergetics and Habitat Parameters for CASM MRGO Primary Producer Populations 62
TABLE 3 Bioenergetics and Habitat Parameters for CASM MRGO Consumer Populations 65
TABLE 4 Baseline Simulation of Plant Population Productivity ($gC/m^2/y$) 71
TABLE 5 Baseline Simulation of Consumer Population Productivity ($gC/m^2/y$) 74
TABLE 6 Simulation of Plant Population Productivity ($gC/m^2/y$) for WQ1 76
TABLE 7 Simulation of Consumer Population Productivity ($gC/m^2/y$) for WQ1 79
TABLE 8 Simulation of Plant Population Productivity ($gC/m^2/y$) for WQ6 81
TABLE 9 Simulation of Consumer Population Productivity ($gC/m^2/y$) for WQ6 84

Executive Summary

The Mississippi River – Gulf Outlet (MRGO) ecosystem restoration project includes the diversion of freshwater from the Mississippi River into the MRGO and Lake Bourne near the vicinity of Violet, Louisiana. Freshwater diversions have been planned to produce salinity regimes that are favorable to oysters and other valued marine resources.

The Comprehensive Aquatic Systems Model (CASM) was originally adapted to assess direct and indirect ecological effects of proposed freshwater diversions into Lake Bourne and associated coastal and marine areas that define the MRGO ecosystem. The CASM is a bioenergetics-based ecosystem model that simulates the daily production dynamics (gC/m^2) of modeled populations of aquatic plants and animals. The principal modeling objective was to assess the potential effects of alterations in salinity and other water quality parameters (e.g., nutrients) that will result from the proposed freshwater diversions on selected populations of valued ecological resources in the MRGO ecosystem.

Several aspects of the original CASM MRGO have been revised on the basis of review and evaluation provided by the USACE, NMFS, and LDWF. Importantly, changes were made to the input data that define grazing and predator:prey interactions in the CASM MRGO. Initial biomass values were adjusted in an attempt to generate more accurate spatial distributions of modeled populations. Importantly, the seasonal abundance of Gulf sturgeon was more realistically modeled by including parameters that reflected migration to tributaries. In addition, data provided by the LDWF permitted revisions to habitat factors for temperature and salinity that are assumed to characterize more localized populations of key benthic invertebrates and fish. Finally, the provision of spatial locations of hard-bottom substrate for a portion of the modeled domain permitted refinements in the spatial location of oyster production.

The CASM MRGO modeling study focused on key species of ecological, recreational, and commercial value including oysters, brown shrimp, white shrimp, blue crab, red drum, spotted sea trout, striped mullet, Gulf menhaden, bay anchovy, sheepshead, and Atlantic croaker. Gulf sturgeon was additionally included because of its endangered species status. To address different habitat requirements (e.g., salinity, depth,) juvenile (or immature) and adult stages were modeled as separate populations for oysters (i.e., spat), blue crab, brown shrimp, white shrimp, red drum, and spotted sea trout. The CASM MRGO also included zooplankton and zoobenthos as separate generalized consumer populations because of their importance as food resources in the model food web. Broadly defined populations of phytoplankton and periphyton (i.e., diatoms, green algae, bluegreen algae) were modeled as key primary producers in the CASM MRGO. The modeled food web also included four representative submerged aquatic plants: *Myriophyllum*, *Vallisneria*, *Halodule*, and *Thalassia*. The modeled emergent aquatic plant community consisted of individual populations of *Distichlis*, *Phragmites*, *Sagittaria*, *Juncus*, and *Spartina*. The resulting composition of primary producers and consumers defines a food web structure relevant to the MRGO ecosystem. The CASM MRGO exists

as perhaps the most complex aquatic food web model ever developed to describe coastal Louisiana ecosystems.

The CASM MRGO simulates the daily biomass of the modeled populations for 55-y for 23 selected inshore and offshore locations in the MRGO ecosystem. The CASM model domain includes approximately the southern half of Lake Pontchartrain, Lake Bourne, the Biloxi Marsh and extends eastward past Bay St. Louis and Biloxi, and southwards past the Chandeleur Islands into the Gulf of Mexico. The 23 locations represent a subset of the larger domain defined by the University of New Orleans (UNO) hydrology and hydraulics model. The UNO model was developed to characterize changes in salinity throughout this lager region projected for several MRGO future without-project and with-project conditions (i.e., freshwater diversions).
The biomass of modeled plant populations in CASM changes daily in response to varying input values of light, temperature, nutrients (nitrogen, phosphorus, silica) that influence photosynthesis. Plant growth is also determined by habitat factors that include depth, current velocity, and salinity. Population-specific values of photosynthetic rates, natural mortality, sinking, physical scour, nutrient requirements, and favorable habitat conditions define growth characteristics characteristic of each population. The modeled plant populations in the CASM are also subject to grazing. The necessary parameters for the plant populations in the CASM MRGO were derived from the technical literature.

Biomass values of consumer populations (i.e., zooplankton, benthic invertebrates, fishes) in the CASM change daily in response to feeding inputs minus losses to egestion, respiration (including specific dynamic action), excretion, gonad formation, and predation. Feeding inputs are determined by the availability of prey populations and the grazing and predator-prey interactions defined for the modeled food web. Feeding and respiration are also a function of water temperature. Population growth is also influenced by salinity, depth, and dissolved oxygen conditions specified for each consumer population. The necessary parameters for the consumer populations in the CASM MRGO were also derived from the technical literature.

The daily values of the environmental factors that determine the growth of the populations included in the CASM MRGO were developed from several sources. Importantly, the salinity values for each of the 23 locations modeled by the CASM MRGO were obtained from the UNO model results for selected without- and with-project (i.e., freshwater diversion) conditions. The UNO model also provided corresponding values of nitrogen, phosphorus, and total suspended solids to the CASM MRGO. Daily surface light intensities were summarized from 30 years of data recorded at the New Orleans International Airport. Water temperatures were developed from limited UNO results (i.e., node 18) and interpolations based on the Coastwide Reference Monitoring System (CRMS). Depths were obtained from recent USGS bathymetry surveys.

The UNO modeling results included a period from 1989 – 2007. To construct 55-y sequences of environmental inputs to the CASM MRGO, individual years within the UNO model range were selected at random (with replacement). The simplifying assumption is that the range of environmental conditions defined by the 1989 – 2007

period will represent the future conditions. The same sequence of years was used in developing the 55-y environmental data sets for the without- and with-project scenarios to provide meaningful comparisons of incremental effects.

A baseline CASM MRGO simulation was developed (calibrated) using the environmental inputs for year 1989 and adjusting initial biomass values and bioenergetics parameters for each modeled population to produce spatial-temporal patterns of population biomass consistent with values reported for the MRGO domain or similar estuarine and coastal marine ecosystems. Parameter values were adjusted only within ranges suggested by variations in reported values for similar populations and ecosystems. The calibrated CASM MRGO baseline simulation represents a working hypothesis concerning the ecological structure and function of the MRGO ecosystem as defined by the modeled populations and available data. As additional data become available, the reference calibration can be revised accordingly. Existing bias in the reference simulation is consistently carried through in the evaluation of proposed planning alternatives and permits meaningful comparison of incremental effects calculated for the with- and without-project scenarios.

The initial conditions and bioenergetics parameter values derived for the calibrated baseline simulation were used for all subsequent 55-y CASM MRGO simulations of without- (WQ1, WQ3) and with-project (WQ5, WQ6, and WQ8) environmental conditions. Net productivity ($gC/m^2/d$) and biomass (gC/m^2) values calculated for each of the modeled populations by the CASM MRGO were summarized for all modeled UNO nodes and selected years. Incremental differences between the combinations of without- and with-project conditions were calculated and summarized.

The UNO nodal summaries were estimated in two ways: (1) the values of productivity and biomass calculated for each of the individual nodes were simply multiplied by the reported area of the node. Nodal values were combined to represent areas of particular interest (e.g., east Lake Pontchartrain, Lake Bourne, Inner Biloxi Marsh, Outer Biloxi Marsh, and Chandeleur Sound). Population productivity and biomass values for the modeled populations were also summed across all 23 nodes to estimate the effects for the entire MRGO ecosystem. (2) Each of the 23 areas associated with the UNO nodes was subdivided into its corresponding number of 1-km^2 spatial cells. The values of population productivity and biomass calculated at the node location by the CASM MRGO were interpolated for each spatial cell in relation to the cell values of depth and salinity. The first method assumes spatial homogeneity within each area associated with each modeled UNO node and is consistent with the scale and resolution of the UNO model. The second landscape ("sea-scape") approach attempts to provide a more spatially realistic characterization within each nodal area. The landscape approach advances beyond the UNO model assumption of spatial homogeneity within each nodal area. This interpolation method is influenced by the accuracy of the depth and salinity values developed for each spatial cell.

Introduction

A version of the Comprehensive Aquatic Systems Model (CASM) has been developed to assess potential impacts (i.e., benefits, risks) of alternative diversions on food web dynamics for selected locations that define the MRGO project. The purpose of this CASM modeling study was to evaluate the potential ecological and food web implications of diverting Mississippi River water across the Central Wetlands Area (CWA) into Lake Bourne and aquatic systems associated the Mississippi River Gulf Outlet (MRGO).

The CASM is a flexible aquatic food web/ecosystem modeling platform that has been used to address both basic (e.g., DeAngelis et al. 1989) and applied (e.g., Bartell 2003, Bartell et al. 1999) questions in a variety of freshwater and coastal aquatic ecosystems. The CASM has been used to address challenges in theoretical ecology (DeAngelis *et al.*, 1989) and to assess potential ecological risks posed by chemical contaminants in aquatic ecosystems (Bartell *et al.*, 1999; Bartell *et al.*, 2000; Naito *et al.*, 2002). Theoretical foundations for modeling toxic effects and estimating risk in aquatic ecosystems derive from earlier peer-reviewed work based on the Standard Water Column Model (SWACOM) (O'Neill *et al.*, 1982; O'Neill *et al.*, 1983).

The following report describes revisions suggested in the development of the CASM_MRGO and subsequent application of the revised model in assessing the future ecological production dynamics under different freshwater diversion scenarios proposed near the Violet, Louisiana. The principal revisions to the original CASM MRGO included:

Evaluation and modification of initial biomass conditions to increase the opportunity for modeled populations to grow in areas of known abundance;

Revision of food web interactions to more realistically characterize known predator:prey relations among the modeled populations;

Revision of habitat factors (i.e., temperature and salinity) for selected model populations to reflect more regional or local tolerances or preferences;

Incorporation of hard bottom substrate information in the calculation of oyster and oyster spat production.

The revised CASM MRGO was used to simulate two future "with-out project" scenarios (WQ1, WQ3) and 3 future "with-project" scenarios (WQ5, WQ6, and WQ8). Incremental differences between all combinations of without- and with-project results were calculated and summarized in spreadsheets (not included in this report).

Modeling Objectives

The principal modeling objectives were to (1) develop a spatial version of the CASM that simulated ecological production dynamics of selected aquatic producer and consumer populations relevant to the MRGO, and (2) use the CASM MRGO to examine the potential food web implications of alternative Mississippi River diversions proposed near Violet, Louisiana.

The first modeling objective involved the collation and integration of existing data to develop an aquatic food web structure and define trophic interactions representative of coastal Louisiana aquatic systems defined by the MRGO project. Values of bioenergetics parameters were estimated for each of the selected modeled populations. This objective also entailed the acquisition of necessary environmental input data required by the CASM. Repeated simulations using adjusted values of the model parameters were used to calibrate the model to measured values of population biomass. The calibrated model serves as a hypothesis concerning ecological production and trophic dynamics of the modeled populations.

To meet the second objective, the calibrated model was used to assess possible effects of several future with- and without-project scenarios on the modeled MRGO food webs. The resulting incremental differences between with- and without-project scenarios were used to evaluate proposed river diversions.

Model Description

The CASM is a structurally complex aquatic ecosystem model that considers water chemistry characteristics, spatial and temporal scales, and food web structure. Water chemistry parameters modeled within CASM include dissolved inorganic nitrogen, dissolved inorganic phosphorus, dissolved silica, dissolved oxygen, dissolved organic matter, particulate organic matter, and water temperature. CASM simulates daily concentrations of water quality parameters based on an overall mass-balance approach that includes external inputs to the aquatic ecosystem, internal uptake, and recycling of nutrients. Moreover, CASM simulates daily production dynamics of each producer and consumer population for a period of one or multiple years. Production dynamics are computed as grams of carbon (g-C) and integrated over the water column as defined by the system depth. The resulting biomass is expressed as g-C/m^2. Parameters that define water chemistry are expressed as concentrations (e.g., mg/L).

Physical, chemical, biological, and ecological characteristics that represent the aquatic system of interest are determined based on site-specific data published in peer-reviewed literature and government documents. Community structure, population characteristics, and representative species within each population are selected based on ecological characteristics native to the aquatic system of interest and surrounding environment. Bioenergetics parameters are defined for each producer and consumer population. For producers, biomass production is dependent on initial biomass, growth rates, optimal temperature, light saturation, half-saturation constants (nitrogen, phosphorous, and silica), and sinking rates. For consumers, biomass production is dependent on initial biomass, maximum consumption, optimal temperature, respiration, excretion, and mortality. Biomass values of modeled populations, as well as water chemistry parameters, are determined by differential equations (implemented as difference equations) that are solved using a 0.1-d time step (Bartell *et al.*, 1999; Bartell *et al.*, 2000; DeAngelis *et al.*, 1989). Based on these equations, the model conserves biomass and other modeled materials (i.e., nutrients, dissolved carbon, and particulate carbon), where new carbon fixed via photosynthesis remains in the form of plant biomass, propagates through the food web, and finally enters the particulate organic matter pool. Consumer biomass exists as standing biomass, enters the food web, and then enters the particulate organic matter pool. Producer- or consumer-derived particulate organic matter may re-enter the food web, decompose, or accumulate.

The following sections describe the adaptation of the CASM to produce a version of the model capable of addressing the principal MRGO modeling objectives.

Physical Model Structure

The study area comprises approximately 3.8 million acres of land and surface waters defined by the Lake Pontchartrain basin and Lake Bourne (i.e., the MRGO ecosystem, UACE 2010). Previous hydrodynamic and hydraulic modeling described the MRGO

ecosystem using a set of nodes and connections in a "box-model" approach to describing flows, elevations, and the values of selected water quality parameters. The modeling domain represented by the CASM MRGO includes a subset of 23 of the nodes of the USACE (2010) model (Figure 1). Table 1 briefly describes each of the UNO model nodes included in the CASM MRGO.

A single CASM water column was modeled at each of the 23 UNO locations. No attempt was made to explicitly model hydrodynamics or transport. However, results of a previous physical modeling effort for the MRGO performed by the University of New Orleans (USACE 2010) were used to approximate daily transport across the modeled nodes as it affected values of transportable state variables (e.g., nutrients, plankton, suspended particulate matter, TSS) in the MRGO.

Segment-scale values of selected CASM MRGO outputs were constructed using the results simulated for the 23 nodal locations multiplied by the surface area of the corresponding segment. The surface areas of the segments associated with each modeled node were defined in the USACE (2010) H&H modeling activity. These values are defined for each corresponding location in an input data sets (MRGO_geo.dat) used by the CASM MRGO.

Food Web Structure

Given the stated modeling objectives, specifying a relevant food web structure was an important step in developing an initial version of the CASM for the MRGO ecosystem. A combined taxonomic/functional approach was used to revise and define the key aquatic food web components in evaluating the potential impacts of freshwater diversion alternatives (Figure 2). Not all of the predator:prey interactions included in the model are illustrated in Figure 2 because the resulting illustration would be difficult to interpret.

The revised CASM MRGO food web structure reflects a consensus based on discussions with the USACE and key stakeholders (e.g., NMFS, FWS, Louisiana Department of Wildlife and Fisheries). The primary concern focused on potential effects of freshwater diversion on marine benthic consumer populations, particularly oysters, shrimp, blue crab, as well as selected fishes (e.g., commercial, recreational, threatened or otherwise federally regulated).

The principal revisions to the CASM MRGO food web included the following:

Blue crab (juvenile) – adding oyster spat as a prey population;

Spotted seatrout (juvenile) – adding juvenile white shrimp, juvenile brown shrimp, Bay anchovy, Gulf menhaden, and Atlantic croaker as prey populations;

Spotted seatrout (adult) – removing juvenile red drum and adding juvenile white shrimp, juvenile brown shrimp, and Atlantic croaker as prey populations;

Red drum (juvenile) – adding Bay anchovy, Gulf menhaden, and striped mullet as prey populations;

Red drum (adult) – removing juvenile spotted seatrout and juvenile red drum and adding juvenile white shrimp, juvenile brown shrimp, juvenile blue crab, oyster spat, and striped mullet as prey populations;

Sheepshead – adding adult white shrimp, adult brown shrimp, oysters, and oyster spat as prey populations;

Gulf sturgeon – removing adult blue crab, adult brown shrimp, and adult white shrimp as prey populations;

Atlantic croaker – removing juvenile spotted seatrout, juvenile red drum, and striped mullet and adding zoobenthos, juvenile brown shrimp, and juvenile white shrimp as prey populations.

Phytoplankton

A broad taxonomic approach was used in specifying the phytoplankton assemblage included in the CASM MRGO. Given the model emphasis on consumer populations, phytoplankton was described by three populations: diatoms, chlorophytes, and cyanophytes (bluegreen algae).

Periphyton

The same broad taxonomic approach was used in specifying the periphyton assemblage included in the CASM MRGO. Periphyton was similarly described by three populations: diatoms, chlorophytes, and cyanophytes.

Submerged Aquatic Vegetation

Populations of submerged aquatic vegetation (SAV) were selected on the basis of known importance in the MRGO ecosystem. Four populations of varying growth characteristics and habitat requirements (e.g., salinity tolerances) were used to characterize the SAV community for the MRGO ecosystem: *Myriophyllum*, *Vallisneria*, *Halodule*, and *Thalassia*. *Myriophyllum* was selected in part because of its importance as an invasive species in Lake Pontchartrain.

Emergent Aquatic Vegetation

Populations of emergent aquatic plants contribute importantly to the ecological production of coastal marshes, wetlands, and estuarine habitats within the MRGO ecosystem. The CASM MRGO includes five populations that are characteristic of this plant community: *Distichlis*, *Sagittaria*, *Phragmites*, *Juncus*, and *Spartina*.

Zooplankton

A single generalized population of zooplankton was defined in the CASM MRGO. This single population represents an aggregation of herbivorous and carnivorous species that comprise a diverse zooplankton assemblage characteristic of coastal Louisiana waters.

The aggregation of a diverse zooplankton community into a single state variable can influence the accuracy of the overall CASM MRGO results. To address this potential limitation, in part, the environmental parameter values that influence zooplankton growth were defined to facilitate zooplankton production over a broad range of temperature and salinity values.

Benthos

One major focus of the modeling in this study was on propagation of potential impacts of freshwater diversions on production dynamics of a diverse benthic community. The CASM MRGO modeling study focused on key species of ecological, recreational, and commercial value including oysters, brown shrimp, white shrimp, and blue crab. To address different habitat requirements (e.g., salinity, depth,) juvenile (or immature) and adult stages were modeled as separate populations for oysters (i.e., spat), blue crab, brown shrimp, and white shrimp.

In addition, a generalized population of zoobenthos was defined to represent other benthic populations characteristic of coastal Louisiana waters, but not modeled explicitly in the CASM MRGO.

Fish

The CASM MRGO modeling study focused on key fish species of ecological, recreational, and commercial value including red drum, spotted sea trout, striped mullet, Gulf menhaden, bay anchovy, sheepshead, and Atlantic croaker. Gulf sturgeon was additionally included because of its endangered species status. To address different habitat requirements (e.g., salinity, depth,) juvenile (or immature) and adult stages were modeled as separate populations for red drum, and spotted sea trout.

Governing Equations

CASM was originally constructed as a set of coupled ordinary differential equations based on nonlinear and time-varying terms (DeAngelis *et al.*, 1989). One equation is defined for each of the modeled state variables, including all aquatic plant or consumer populations and water quality parameters. The number of water quality parameters has

remained consistent with previous CASM applications. However, the number of modeled populations varies according to the specified modeling objectives and food web structure.

The governing equations are based on a biomass (carbon) equivalent of energy – in other words, the equations fundamentally describe input-output bioenergetics that impacts the growth rate of each modeled population. Growth rates are integrated using a simple difference equation approximation.

Primary Producer Population Dynamics

Biomass production for primary producer populations is governed by a bioenergetics-based equation that describes changes in plant biomass (carbon) as a function of photosynthesis minus losses to catabolic processes (e.g., photorespiration, respiration, non-grazing or 'natural' mortality) and grazing. In the generic CASM framework, photosynthesis is a nonlinear function of light, temperature, and nutrient (nitrogen, phosphorous, silica) availability. Growth is additionally modified by habitat factors, including accumulated degree days, water depth, current velocity, and salinity (for estuarine applications). Within the revised version of CASM, daily biomass (g-C/m^2) for each modeled population (B_i) of periphyton and macrophytes is determined by the following equation:

$dB_i/B_i dt$ = photosynthesis – photorespiration – dark respiration – sinking – natural mortality – grazing

or

$$dB_i/B_i dt = [Pm_i \{h(T), f(I), g(N), hmod\}(1\text{-}presp_i)] - dresp_i\ h(T) - (s_i + m_i) - \Sigma[h(T)\ B_j\ C_{ij}\ w_{ij}\ a_{ij}\ h_{ij}\ B_i\ )/\ (B_j + \Sigma w_{ij}\ a_{ij}\ h_{ij}\ B_i)]$$

where, for population i,

B_i	biomass of population	gC/m^2
Pm_i	maximum photosynthetic rate of growth	1/d
$h(T)$	temperature dependence of photosynthesis	unitless
$f(I)$	light dependence of photosynthesis	unitless
$g(N)$	nutrient dependence of photosynthesis	unitless
$hmod$	habitat quality modifier of growth	unitless
$presp_i$	photorespiration rate	unitless
$dresp_i$	dark respiration rate	1/d
s_i	sinking rate (phytoplankton only)	1/d
m_i	mortality rate	1/d
C_{ij}	rate of consumption by grazer j	gC/m^2/d
w_{ij}	preference of consumer *j* for prey i	unitless
a_{ij}	assimilation of producer i by consumer j	unitless
h_{ij}	handling efficiency	unitless

The above bioenergetics equation describes growth dynamics for primary producer populations during optimal environmental conditions. The complex life history characteristics (e.g., overwintering stages, phenology) that partially determine opportunities for growth were represented using a degree-day approximation that defined the onset of population growth for each producer population. Estimates of population-specific degree-days for phytoplankton growth initiation were derived from a temporal analysis of population-specific productivity in the MRGO ecosystem. The simple adoption of a degree-day approach permits the inclusion of life history traits that are not readily formulated in terms of bioenergetics.

Factors Regulating Photosynthesis

In CASM, photosynthesis (growth rate) is a nonlinear function of available light, water temperature, and inorganic macronutrients. In addition, effects of other physical-chemical factors in determining overall habitat quality and plant growth are modeled as an additional constraint on photosynthesis. The following sections describe these functional aspects of photosynthesis in CASM.

Light Saturation

The effects of light availability and light saturation on photosynthesis are modeled using a formulation derived by Thomann and Mueller (1987).

$$f_I(I) = I / I_s \cdot \exp(- (I / I_s) + 1.0)$$

where,

I	=	light intensity	eins/m^2/d
I_s	=	light saturation intensity	eins/m^2/d

Population-specific values of I_s define the relationship between light intensity and the value of $f_I(I)$ for the modeled plant populations. Daily values of $f_I(I)$ range between zero and 1.0 for each modeled population. For all modeled plant populations, the value of I is attenuated surface light intensity, I_0. Emergent plant populations within other CASM applications are assumed to be exposed to unattenuated I_0.

In the field, the following factors play a role in determining complex underwater light regimes:

1) Variations in surface light intensity,
2) Wavelength-specific reflectance,
3) Attenuation of direct and diffuse light by water, and
4) Absorption and reflectance of light by both dissolved and particulate organic and inorganic compounds.

In CASM, daily values of I_0 are attenuated by water color, suspended particulate organic carbon, phytoplankton biomass, and suspended inorganic matter. Constant attenuation

coefficients (m^{-1} per mg/L) are defined for each of these particulates. A separate coefficient (m^{-1}) is defined for water color. The sum of these coefficients is used to attenuate surface light with increasing depth using a negative exponential function (i.e., Beer's Law). Light attenuation varies in relation to changing concentrations of phytoplankton, particulate organic carbon, and inorganic sediments.

Nutrient Limitation

CASM addresses the effects of nutrient availability on photosynthesis. The model includes effects of nitrate, phosphate, and silica (diatoms only). A multiplier of photosynthesis (0-1) is calculated using a simple Monod expression for each potentially limiting nutrient:

$$f_{NO3} = NO_3/(k_N + NO_3)$$

$$f_{PO4} = PO_4/(k_P + PO_4)$$

$$f_{Si} = Si/(k_S + Si)$$

The values of NO_3, PO_4, and Si are the dissolved concentrations (mg/L) of nitrate, phosphate, and silica respectively. The k_N, k_P, and k_S values define the Monod (or 'half-saturation') constants, where f_{NO3}, f_{PO4}, and f_{Si} are equal to 0.5.

The overall effect of nutrient limitation is defined using a Liebig minimum approach:

$$f_N = \min(f_{NO3}, f_{PO4}, f_{Si})$$

Nutrient limitation is assumed to only affect photosynthesis rates of phytoplankton and periphyton. Population-specific values of k_N (algae and diatoms), k_P (algae and diatoms), and k_S (diatoms only) are required as input parameters to CASM. It is assumed that submerged aquatic and emergent vegetation derive nutrients from sediments and that these plants are seldom nutrient-limited; therefore, half-saturation constants are not required as input parameters for SAV or emergent plant populations modeled in the CASM.

CASM does not directly simulate accumulation of dissolved nutrients by modeled producers. Rather, the summed products of population-specific gross photosynthetic rates ($gC/m^2/d$) are converted to equivalent nutrient concentrations using a constant C:N:P stoichiometry (140:16:1) in order to derive the necessary conversions. Decomposition and nutrient remineralization by consumers are similarly governed by this assumed stoichiometry, with the understanding that variations in these ratios occur in aquatic ecosystems (e.g., Cross *et al.*, 2005). These conversions to nutrient equivalents are used in calculating changes in available nutrients and preserving the mass-balance of NO_3, PO_4, and dissolved Si during model simulations.

Photorespiration

Photorespiration occurs in the presence of light, resulting in excretion of dissolved organic matter (carbon) and release of carbon dioxide. Photorespiration applies to modeled populations of phytoplankton, periphyton, and submerged aquatic plants in CASM. Photorespiration is modeled as a complement to light limitation of photosynthesis (Park and Clough. 2004) and is expressed as a population-specific fraction of photosynthesis:

$$\text{photorespiration} = (1.0 - \text{presp}_i) \cdot Ps_i$$

where,

presp_i is the photorespiration coefficient for population I (unitless).

Carbon excreted via photorespiration is added to the dissolved organic carbon pool. CASM does not simulate the complex aquatic chemistry of carbon dioxide. It is assumed that dissolved carbon dioxide concentrations are sufficient to support photosynthesis and that carbon dioxide produced as a result of respiration is simply returned to the dissolved pool or lost from the modeled system.

Dark Respiration

Dark respiration requires oxygen for the production of maintenance energy, a catabolic process that releases carbon dioxide. The biomass-equivalent of respiration is modeled within CASM as

$$\text{dark respiration} = \text{dresp}_i \, bp_i$$

where,

dresp_i	= dark respiration rate	1/d
bp_i	= biomass of producer	$g\text{-}C/m^2$

Producer Habitat Quality

The bioenergetics-based approach underlying CASM describes ecological production in terms of physiological ecology and food web interactions. CASM addresses complex life histories and other biological/ecological aspects of plant growth by specifying additional habitat quality modifiers. Daily values of water depth, current velocity, and salinity define habitat quality for plants modeled by CASM. For example, rooted aquatic plants are not commonly observed where current velocities exceed 1 m/s. Moreover, in addition to light attenuation, water depth influences habitat quality for SAV and emergent aquatic plants.

Simple trapezoidal functions are used to define the habitat quality modifiers (water depth, current velocity, salinity). Values of each function range from zero (uninhabitable) to 1.0

(optimal habitat). For each population, thresholds that define lower and upper values are estimated for each factor. Within ranges defined by the threshold values, two additional parameters define the range over which growth is optimal. In CASM, the habitat factors are calculated separately for depth, velocity, and salinity. The geometric mean value of these three factors defines a habitat modifier (hmod) used in the overall equation for photosynthesis.

Periphyton Sloughing

In lotic systems, physical sloughing is an important process in determining periphyton biomass. Sloughing has been modeled in substantial detail within other ecological models (e.g., Park and Clough. 2004). The net result of these detailed formulations is a need for extensive site-specific parameter estimation. To include periphyton sloughing within CASM, it was assumed that periphyton is largely adapted to average current velocities in the inhabited system. As current velocity increases towards a value equal to its mean plus two standard deviations, a sloughing modifier increases exponentially in value from zero (no sloughing) to 1.0 (complete loss of biomass to sloughing). Current velocities used to calculate the sloughing parameter are input on a segment-specific basis using the results of a hydrodynamic simulation of the overall system. Similar approaches to modeling periphyton scouring based on deviations from average current velocity have also been used by Horner *et al.* (1990) and Saravia *et al.* (1998). To maintain mass balance, periphyton biomass lost due to sloughing enters the settled particulate organic carbon pool, which is subject to decomposition and advective transport.

With the exception of major tropical storms, current velocities used in the CASM MRGO will not likely result in substantial physical sloughing of modeled periphyton. However, inclusion of this aspect of periphyton population dynamics permits future examination of velocities associated with freshwater diversions on periphyton production within relevant MRGO wetlands (e.g., the Central Wetlands Area).

Consumer Population Dynamics

Biomass production for consumer populations modeled in the CASM is a function of consumption (ingestion and assimilation of food or prey) minus losses to respiration, excretion, natural mortality, and predation. These processes are nonlinear functions of temperature (respiration) and food availability (consumption, predation). Modeled consumer populations are distinguished by population-specific rates of feeding, respiration, excretion, locomotion costs, prey preferences, prey assimilation, and temperatures for maximum feeding and respiration. The daily value of biomass (g-C/m^2) for each modeled population (B_i) of zooplankton, benthic invertebrates, and fish is determined by the following equation:

$dB_i/B_i dt$ = consumption – respiration – excretion – egestion – natural mortality – (specific dynamic action) – predation – reproduction

or

$$dB_i/B_i dt = \sum[(Cm_i\, h(T)\, w_{ij}\ a_i\ h_{ij}\, B_j)/(B_i + \sum w_{ij}\, a_{ij}\, h_{ij}\, B_j) - (u_i + f_i + rsda_i)] - r_i\, h(T) - m_i - \sum[(Cm_j\, h(T)\, w_{ij}\, a_{ij}\, h_{ij}\, B_j)/(B_j + \sum w_{ij}\, a_{ij}\, h_{ij}\, B_i)] - sp_i$$

where, for population i

B_i	biomass	gC/m^2
Cm_i	maximum consumption rate	1/d
$h(T)$	temperature dependence of consumption	unitless
w_{ij}	preference of consumer i for prey j	unitless
a_{ij}	assimilation efficiency for consumer i and prey j	unitless
h_{ij}	handling efficiency	unitless
r_i	standard respiration rate	1/d
u_i	excretion rate	1/d
f_i	egestion rate	unitless
m_i	natural mortality rate	1/d
$rsda_i$	specific dynamic action	unitless
sp_i	loss to gonad formation	1/d

The consumption term in this equation calculates grazing or predation as a normalized product of predator and prey biomass. Predator and prey biomass are modified by the preference of predator i for prey j (w_{ij}), the assimilation of prey j by predator i (a_{ij}), and a handling efficiency for predator i consuming prey j (h_{ij}) (DeAngelis *et al.*, 1975; DeAngelis *et al.*, 1989). The food consumed by each population is either assimilated, excreted, or egested. The egested (or unused food) fraction is remineralized by a temperature-dependent decomposition process. Recycled nutrients are added to the dissolved nutrient pools by assuming a constant C:N:P stoichiometry for plant and animal organic matter.

The mathematical nature of the consumption term introduces a density dependence in the overall production of consumer populations in CASM (DeAngelis *et al.*, 1975). At low predator abundances, the biomass of the available predator determines the flux of ingested material into the predator populations. As the predator biomass increases, the flux becomes increasingly determined by the biomass of the prey. Such density dependence can influence the growth of individual populations and structure of complex food webs in CASM.

CASM includes a standard respiration rate and specific dynamic action. The standard (or basal) respiration is a nonlinear function of water temperature; postulated increases in respiration as a function of crowding (Park and Clough., 2004, Kitchell *et al.*, 1974) are not addressed in CASM. Specific dynamic action is equal to the energetic costs of

digestion. Total respiration is the sum of standard respiration and specific dynamic action:

$$Rs_j = [(f_T(T) \cdot Rmax_j + RSDA_j) \cdot B_j]$$

where,

$f_T(T)$	= temperature dependence of standard respiration	unitless
$Rmax_j$	= maximum standard respiration rate	1/d
$RSDA_j$	= specific dynamic action	1/d
B_j	= biomass of consumer population j	gC/m^2

and

$$RSDA_j = r_{SDAj} \Sigma (Cs_j - F_j)$$

Specific dynamic action is calculated as a fraction (r_{SDAj}) of consumption minus egestion (i.e., assimilation) for each consumer population j.

Consumer metabolism includes the excretion of carbon and its equivalent in nitrogen, phosphorus, and silica. Excreted carbon enters the dissolved organic carbon pool, and excreted nutrients enter the respective dissolved nutrient pools. The fraction of biomass lost to excretion is determined by population-specific estimates of a constant excretion rate r_{Uj} (1/d):

$$U_j = r_{Uj} \cdot B_j$$

The amounts of N and P added to the dissolved nutrient pools per unit carbon are based upon a constant stoichiometry of C:N:P (and Si).

Consumer Habitat Quality

Habitat quality preferences were also included in CASM for consumer populations. Environmental factors that determine habitat quality include dissolved oxygen concentration, water depth, current velocity, and salinity. Similar to the primary producer populations, trapezoidal functions and the defining parameters were used to quantify habitat quality [range of 0 to 1] in relation to daily values of all factors. Population-specific preferences and limiting values were derived from the technical literature to define these functions for the modeled consumer populations (e.g., Jowett and Richardson, 1990). In addition to temperature modifiers, the geometric mean of daily habitat modifiers was used to reduce consumption from its maximum rate.

In the revised CASM MRGO, data were provided by the LDWF (e.g., Sable, Harden, Bourgeois, pers. communication) that described relative abundance (e.g., catch per unit effort) and corresponding values of water temperature and salinity in the CSA1 and CSA2 areas. These data were used to revise estimated temperature and salinity

requirements/preferences for several species, including blue crab, white shrimp, brown shrimp, Bay anchovy, Gulf menhaden, striped mullet, red rum spotted seatrout, sheepshead, and Atlantic croaker (Table 3). Periodic trawling samples collected from 1988 – 2007 were analyzed. Minimum and maximum values were defined based on these data. Comparisons of relative abundance and corresponding values of temperature and salinity indicated that the 25th and 75th percentile values of water temperature provided reasonable estimates of Te_2 and Te_3 (Table 3). These percentile values of salinity were also used as estimates of PSU_{ol} and PSU_{ou} in the description of salinity tolerances/preferences (Table 3). It was not possible to discriminate immature and adult abundances in the data that were analyzed. Therefore, the resulting temperature and salinity habitat factors were applied to both immature and adult populations of CASM MRGO species represented by these two life stages.

Use of more local data to derive habitat suitability factors for temperature and salinity reduced the ranges of tolerances and preferences for many of the modeled species. The combined result of these revisions tended to reduce overall habitat suitability (in time and space) and correspondingly reduce net annual production compared to the original parameterization of the CASM MRGO.

Parameter Estimation

With a food web structure representative of the MRGO ecosystem and determined appropriate for addressing the modeling objectives, the next step in developing the CASM MRGO involved estimation of the necessary bioenergetics parameter values and other input data required by the model. The following sections describe the derivation of the CASM MRGO inputs.

Abiotic Environmental Factors

In the CASM, production of biomass by producer and consumer populations is strongly influenced by environmental factors including surface light intensity, light extinction, water temperature (including thermal stratification), water depth, current velocity, nutrient availability, dissolved oxygen, total suspended solids, particulate organic matter (suspended and settled), salinity, and surface wind velocity.

The following sections describe the derivation of the individual abiotic factors as they were implemented for the CASM MRGO.

Light

The relationships between surface light intensity and the availability of light as a function of water depth are key factors in determining the trophic dynamics of the CASM MRGO. The CASM requires daily values of photosynthetic active radiation (PAR, wavelengths 400 to 900 nm) incident at the water surface, I_0. The units of PAR used in the model are

einsteins/m^2/d. These values can derive from field measures, if available. Alternatively, the daily values can be calculated (external to the CASM) as a function of site latitude (i.e., solar declination) and corresponding time-varying day-length.

Surface Light Intensity

Thirty years (1960-1990) of hourly measures of surface light intensity were obtained for a location at the New Orleans International Airport from the National Solar Radiation Database (http://rredc.nrel.gov/solar/old_data/nsrdb). These data were used to calculate daily average surface light intensities required by the CASM. The same incident light values were used for all modeled locations.

Light Attenuation

Light attenuation is modeled as a function of depth in the CASM according to

$$I_z = I_0 \exp(-\lambda z)$$

Where:

I_z	light intensity at depth z
I_0	surface light intensity
λ	light extinction coefficient (m^{-1})
z	water depth (m)

Several factors influence the value of λ including the light extinction properties of pure water, the color of water in the system of interest, and both organic (e.g., dissolved organic carbon, suspended particulate organic carbon, phytoplankton) and inorganic particulate matter (e.g., suspended inorganic sediments) (e.g., Lee and Rast, 1997). To simulate the contribution of these factors to light extinction, the previous equation can be re-written as

$$I_z = I_0 \exp(-\lambda_s[C_{DOC} + C_{POC} + C_{PHYTO} + C_{TIS} + C_{TDS}] + \lambda_w + \lambda_c) z$$

λ_s	light extinction per unit concentration of attenuating constituent
C_{DOC}	concentration of dissolved organic carbon (gC/m^3)
C_{POC}	concentration of particulate organic carbon (gC/m^3)
C_{PHYTO}	concentration of phytoplankton carbon (gC/m^2)
C_{TIS}	concentration of total suspended inorganic solids (g/m^3)
C_{TDS}	concentration of total dissolved solids (g/m^3)
λ_w	light extinction coefficient of pure water (m^{-1})
λ_c	light extinction coefficient of water color (m^{-1})
z	depth

For applications to most aquatic systems, the relative contribution to light extinction by pure water is considered negligible and this term is not included in the model. Extinction

by water color is modeled as a system-specific constant value. Importantly, the concentrations of the other factors that influence light extinction are dynamic in space and time and modeled light extinction coefficients vary correspondingly in the CASM.

Implementation of the light extinction calculation requires both estimates of the varying concentrations of these components and the mass-specific attenuation by each component Based on Park and Clough (2004), attenuation of surface light was determined by the following extinction coefficients:

- Dissolved organic carbon 0.03 (m^{-1} per mg/L),
- Particulate organic carbon 0.12 (m^{-1} per mg/L),
- Phytoplankton biomass 0.014 (m^{-1} per gC/m^2),
- Total suspended inorganic solids 0.03 (m^{-1} per mg/L), and
- Water color 0.04 – 0.10 (m^{-1}).

For each modeled day and location, the simulated values of these five parameters were used to calculate an overall light extinction coefficient (m^{-1}).

Salinity

Changes in salinity are of principal interest in evaluating the potential ecological effects produced by the proposed alternatives for freshwater diversion near Violet, LA. The major objective of the UNO modeling effort was to characterize the spatial and temporal changes in salinity that result from the Violet diversions (USACE 2010). The nodal salinity results from the UNO model for 1989-2007 were used to develop the daily values required by the CASM MRGO.

Water Temperature

The key bioenergetics-based growth processes (e.g., photosynthesis, consumption, respiration) included in the model are influenced by water temperature. Therefore, realistic daily water temperatures are important for model performance.

Values of water temperature were available for node 18 for 1990-2008 as a result of the UNO modeling (USACE 2010). Temperature data were developed for other CASM MRGO nodes through interpolation using the node 18 data and selected sampling stations monitored as part of the CWPPRA CRMS.

Nutrients

The availability of dissolved inorganic N, dissolved inorganic P, and dissolved silica directly influence primary production by the aquatic plants modeled by the CASM.

Dissolved Inorganic Nitrogen

Daily values of dissolved inorganic N (DIN) were provided by the UNO H&H model for the years of 1989-2007 (USACE 2010).

Dissolved Inorganic Phosphorus

Daily values of dissolved inorganic P (DIP) were estimated from the values of total P provided by the UNO H&H model for the years of 1989-2007 (USACE 2010).

Silica

Concentrations of dissolved silica were not available for use in the preliminary CASM MRGO simulations. It was necessarily assumed that silica was present in sufficient concentration and that diatom growth was not limited by silica. This assumption might bias the model towards over-estimating diatom growth.

Total Suspended Inorganic Solids

Nodal daily values of TSS were provided by the UNO H&H model (USACE 2010) and pre-processed to generate corresponding values of TIS and POC used by the CASM MRGO.

Suspended Particulate Organic Carbon

The allochthonous input of particulate organic carbon (POC) were derived by assuming that approximately 8 percent of the total suspended solids (TSS) constituted particulate organic carbon. CASM includes biogenic sources of suspended POC generated during model simulation as the result of egestion by consumers and plankton mortality. Particulate organic carbon serves as a food source for certain consumer populations in the CASM (e.g., zooplankton, oysters, menhaden). Suspended POC also contributes to the attenuation of surface light intensity in the model. Suspended and sedimented POC are subject to decomposition by modeled planktonic and sediment bacteria populations.

Surface Wind Velocity

Surface wind velocities are used by the CASM to calculate external inputs of oxygen across the air:surface water interface. Daily average wind velocities were provided by the UNO model for node 18 (USACE 2010). The node 18 values were applied across the other nodes in the CASM MRGO.

Biotic Components

The technical ecological literature was used to derive values of the bioenergetics parameters and define trophic interactions for the modeled populations of producers and

consumers in the CASM MRGO. Derivation of model bioenergetics parameter values was based on the assumption that physiological process rates reported for other similar aquatic systems applied to the populations included in the CASM MRGO. Similarly, the trophic interactions including prey preferences reported in other similar aquatic systems were assumed to relevant for the CASM MRGO.

The overall strategy used to estimate model parameters was to select values within reported ranges that produced biomass values consistent with available data for corresponding CASM MRGO producers and consumers. Initial values of were developed for each modeled population based on published information. The initial values of individual parameters were systematically increased or decreased in repeated simulations to determine the combination that provided the best attainable match to the limited available data. The resulting model calibration to the MRGO data represents a hypothesis concerning trophic dynamics within this complex coastal ecosystem. A usefully calibrated CASM MRGO provides a mechanistic basis for examining the implications of freshwater diversions on subsequent changes in MRGO ecosystem food webs.

Phytoplankton

Derivation of the growth parameters for the modeled phytoplankton populations was based on published values of photosynthesis (growth rate), optimal temperatures, light saturation, photorespiration, dark respiration, nutrient limitation, sinking, and mortality (Table 2).

Photosynthetic Rates

Maximum photosynthetic (growth) rates vary widely among phytoplankton, although values within a range of ~1-3 d^{-1} are commonly reported (e.g., Saravio *et al.* 1998, Robarts1987, Lehman *et al.* 1975, Goldman and Carpenter 1974, Sorokin and Kraus, 1958). In calibrating the CASM to the MRGO ecosystem, phytoplankton biomass, selected growth rates ranged from 2.90 - 3.10 for the phytoplankton. Diatoms and chlorophytes had the higher growth rates, followed by cyanophytes (Table 2).

Optimal Temperatures

The seasonal pattern of water temperatures and general observations of temperature tolerances for the modeled taxa were used to define temperature regimes conducive to growth (Table 2). Diatoms were assumed to grow at cooler temperatures corresponding to their observed periods (e.g., early spring, late fall) of maximum growth. Cyanophytes were assumed to grow optimally under warmer conditions associated with summer bluegreen algal blooms. Optimal temperature regimes for chlorophytes were defined as intermediate to the regimes developed for diatoms and bluegreen algae.

The bioenergetics-based governing equations have proven useful in describing patterns of plant population growth (e.g., Park and Clough 2004). However, these equations cannot address life history traits that are not easily formulated in terms of energetics (e.g., sexual reproduction, overwintering stages, cysts, etc.). Such traits can influence the timing of

entry of a seasonally nascent population into an actively growing phytoplankton community. To account for these kinds of life history characteristics and their influence on growth, the concept of accumulated degree-days was used to model phytoplankton production in the CASM MRGO. The degree-day concept has proven useful in simulating the phenology of aquatic plants (Best *et al.* 2005). In CASM, degree-days are calculated as the simple running sum of daily water temperature values. Threshold values of accumulated degree-days were developed for each modeled population: 300 for diatoms, 1,200 for chlorophytes and 2,500 for bluegreens. When the accumulated degree-days exceed a population threshold, the population is permitted to grow according to its bioenergetics parameters. Until that time, it is assumed that the population is seasonally dormant. Specification of these population-specific thresholds permits more realistic description of temporal patterns phytoplankton growth using the CASM without having to model complex life histories that are not readily defined in terms of energy (biomass).

Light Saturation Constants

Values were derived for the modeled phytoplankton populations based on Robarts (1987) and Lehman et al. (1975). Bluegreen algae were assigned the value of 4 einsteins/m^2/d, which is characteristic of higher light intensities associated with their generally observed seasonally maximum growth and vertical distribution nearer the surface of the water column. A higher value (8 einsteins/m^2/d) was derived for chlorophytes and diatoms.

Photorespiration

Birmingham *et al.* (1982) provided estimates of photorespiration for diatoms, green algae, blue-green algae, and other algae. Their estimates ranged from 1.3 to 8.7% of gross photosynthesis. Photorespiration values ranging from 2.0 – 3.1% were determined to provide the realistic results for the calibration to the MRGO ecosystem (Table 1).

Dark Respiration

Buzzelli *et al.* (2000) used basal (dark) respiration rate of 0.1/d in a model of algal production in the Florida Everglades. Burris (1977) measured somewhat higher rates of dark respiration of 0.11/d to 0.42/d of gross photosynthesis for several marine algae. Values of 0.2 – 0.35 d-1 assigned to modeled populations contributed to the calibration of phytoplankton for the CASM MRGO (Table 1).

Nutrient Limitation

Values of half-saturation (Monod) constants were assigned to model algae populations based on reported values for silica (Paasche, 1973), nitrogen (Son and Fujino, 2003; Reuter *et al.*, 1986; Lehman *et al.*, 1975; Carpenter and Guillard, 1971), and phosphorus (Son and Fujino, 2003; Bothwell, 1985; Bothwell, 1988; Buzzelli *et al.*, 2000; Lehman *et al.*, 1975).

Note that the half-saturation values defined for silica (diatoms) are not actually used in the calculations because dissolved silica data were not available. In the absence of these data, it was simply assumed that diatom growth was not limited by silica.

Sinking Rates

Phytoplankton sinking rates were derived from values reported in Lehman *et al.* (1975) and Titman and Kilham (1976) for a variety of freshwater taxa. The greatest rate was defined for the modeled diatom population. Cyanophytes were assigned lower sinking rates on the basis of smaller size and gas vacuoles (cyanophytes). Chlorophytes were assigned a sinking rate greater than cyanophytes, but less than diatoms (Table 2).

Other Producer Populations

A parallel approach was used to estimate the population-specific parameters for periphyton, SAV, and emergent aquatic plants (Table 2).

Consumer Populations

The same approach to estimating model parameters for primary producers was used to derive population-specific values of parameters for the zooplankton, benthic invertebrates, and fish included in the CASM MRGO (Table 3).

Consumption Rates

Zooplankton feeding rates were derived primarily from Peters and Downing (1984), Schindler (1968), and Richman and Dodson (1983). Consumption rates for benthic invertebrates were based on allometric interpolations derived from zooplankton feeding rates. Maximum consumption rates for modeled populations of spotted sea trout, red drum, striped mullet, sheepshead, gulf sturgeon, and Atlantic croaker were estimated using data reported by Hanson *et al.* (1997). Sable *et al.* (draft manuscript) provided data and information used to estimate consumption rates for blue crab, white shrimp, brown shrimp, and Bay anchovy. Additional data sources were examined oysters (Sellers and Stanley, 1984), white shrimp (Muncy, 1984), brown shrimp (Lassuy, 1983), and spotted sea trout (Johnson and Seaman, 1986).

Optimal Temperatures

The basic ecology of modeled consumer populations and the seasonal pattern of daily water temperature input to CASM were used to define temperature preferences for the consumer populations (Table 3). Preferences were defined in such a way that commonly observed seasonal patterns of biomass resulted for the modeled consumers.

Standard Respiration Rates

Respiration rates for zooplankton were derived using results from Schneider (1992) and Schindler (1968). Benthic invertebrate respiration rates were estimated based on

Hamburger and Dall (1990). Standard respiration rates for the modelled fish populations were derived from Hanson *et al.* (1997) and Sable *et al.* (draft manuscript).

Specific Dynamic Action

Values of specific dynamic action for modeled benthic invertebrate and fish populations were estimated using data reported by Hanson *et al.* (1997) and Sable *et al.* (draft manuscript). The previously identified studies used to estimate maximum rates of consumption and respiration for the modeled fish populations in the CASM MRGO were also used to estimate rates of specific dynamic action for these same populations.

Egestion Rates

Estimates of egestion rates for modeled fish populations were derived using data reported by Hanson *et al.* (1997). The previously identified studies used to estimate maximum rates of consumption and respiration for the modeled fish populations in the CASM MRGO were also used to estimate egestion rates of for these same populations.

Excretion Rates

Zooplankton excretion rates were estimated using the results of Mayzaud (1976), Hargrave and Geen (1968), and Wen and Peters (1994). Excretion rates for modeled fish populations and selected benthic invertebrate populations were estimated using data reported by Hanson *et al.* (1997) and Sable *et al.* (draft manuscript). The previously identified studies used to estimate maximum rates of consumption and respiration for the modeled fish populations in the CASM MRGO were also used to estimate excretion rates for these same populations.

Mortality Rates

Zooplankton mortality rates were based on studies by Eiane *et al.* (2002) and Ohman and Hirche (2001). Benthic invertebrate mortality rates were extrapolated from zooplankton mortality rates. Mortality rates for modeled fish populations were based on estimates for 30 lotic and lentic fish species used for modeling effects of commercial navigation on fish entrainment (Bartell and Campbell, 2000).

Trophic Interactions

CASM permits specification of grazing and predator-prey interaction among the modeled populations of aquatic producers and consumers (DeAngelis et al. 1989). A non-zero prey preference value, w_{ij}, is specified for each trophic interaction between prey i and consumer j. The magnitudes of the w_{ij} values are somewhat arbitrary, because the calculation of each trophic interaction involves normalization across all prey items consumed by a grazer or predator. However, in practice, values of wij range from 0-1, with higher values indicating increased preference. If available, diet composition data can be used to derive w_{ij} values. Qualitative descriptions of diet preferences can be used with

professional judgment to develop these input parameters as well. Current versions of the CASM assume that specified prey preferences are constant; ontogenetic shifts in diet are not included, unless different life stages of consumers are modeled explicitly, as in the CASM MRGO.

Assimilation Efficiencies

CASM also permits specification of assimilation efficiency for each grazing or predator-prey interaction. The a_{ij} parameters are analogous to the prey preference parameters, expect these parameters quantify the fraction of consumer prey converted to new consumer biomass. In CASM, the assimilation efficiency multiplies the calculated amount of food ingested minus losses to egestion. The a_{ij} parameters characterize food quality derived from published values (Richman and Dodson 1983; Lampert 1987). The a_{ij} parameters are constant during a CASM simulation.

Prey Handling Efficiencies

CASM also permits specification of a prey handling efficiency for each grazing or predator-prey interaction. The h_{ij} parameters are analogous to the prey preference parameters, expect these parameters quantify the fraction of prey not ingested as a result of behavioral or mechanical inefficiencies that make the prey more difficult to ingest. In CASM, the assimilation efficiency multiplies the calculated amount of food ingested. Handling efficiencies were not considered in modeling the trophic interactions among MRGO consumers and their prey items. All values of h_{ij} were set equal to 1.0, which means that handling efficiencies were 100% - that is, no prey biomass was lost to ingestion because of difficulties associated with ingestion.

The revised prey preferences, assimilation efficiencies, and handling efficiencies are included in a single input file for the CASM MRGO: web_casmMRGO_02.dat.

Water Quality Parameters

CASM also simulates daily changes in concentrations (mg/L) of dissolved oxygen, dissolved inorganic phosphorus, dissolved inorganic nitrogen, dissolved organic carbon, and particulate organic carbon. The equations describing the dynamics of these model state variables are:

Dissolved oxygen (DO)

> dDO/dt = input from plant photosynthesis – uptake by plant and consumer respiration ± advective transfer ± air:water surface exchange

Dissolved inorganic phosphorous (DIP)

dDIP/dt = allochthonous input + remineralization by consumers – uptake by plants ± advective transfer

Dissolved inorganic nitrogen (DIN)

dDIN/dt = allochthonous input + remineralization by consumers – uptake by plants ± advective transfer

Dissolved organic carbon (DOC)

dDOC/dt = release from plants + excretion by consumers + decomposition of POC – decomposition of DOC ± advective transfer

Particulate organic carbon (POC)

dPOC/dt = plant mortality + consumer mortality + egestion by consumers – decomposition of POC ± advective transfer

Temperature-Dependent Processes

The CASM MRGO calculates the effects of temperature on modeled physiological processes using the function developed by Thornton and Lessem (1978). The original function used by the CASM that was derived from O'Neill *et al.* (1972) overestimated physiological rates at low temperatures for populations with low values of Topt – a defining parameter for the temperature function. While requiring more parameters, the formulation developed by Thornton and Lessem (1978) results in more accurate predictions over broader ranges of preferred temperatures.

The function is a product of two sigmoid relationships: one curve (gcta) defines increasing functional response to increasing temperature; the second curve (gctb) describes decreasing response for sub-optimal temperatures.

$$f_T(T) = \text{gcta} \cdot \text{gctb}$$

where,

$$\text{gcta} = (\text{xk1} \cdot \text{t4}) / (1.0 + \text{xk1} \cdot (\text{t4} - 1.0))$$

$$\text{gctb} = (\text{xk4} \cdot \text{t6}) / (1.0 + \text{xk4} \cdot (\text{t6} - 1.0))$$

and,

$$\text{t4} = \exp[\text{t5} \cdot (\text{T} - \text{te1})]$$

$$\text{t5} = \text{tt5} \cdot \ln[\text{xk2} \cdot (1.0 - \text{xk1}) / (0.02 \cdot \text{xk1})]$$

$$t6 = \exp[t7 \cdot (te4 - T)]$$

$$t7 = tt7 \cdot \ln[\, xk3 \cdot (1.0 - xk4) / (0.02 \cdot xk4)]$$

$$tt5 = 1.0 / (te2 - te1)$$

$$tt7 = 1.0 / (te4 - te3)$$

For each population, four pairs of temperature and temperature response values define the overall shape of the f_T: (te1, xk1), (te2, xk2), (te3, xk3), and (te4, xk4). Values of te1, te2, te3, and te4 are in units of °C. Values of xk1, xk2, xk3, and xk4 range from zero to 1.0.

To reduce the number of required model parameters while maintaining a realistic description of water temperature effects on plant respiration, the O'Neill *et al.* (1972) equation was used:

$$h(T) = V^{x} * \exp(x[1 - V])$$

where $V = (T_m - T)/(T_m - T_o)$. T_m defines an upper lethal temperature specified for each population and process rate; T_o specifies the temperature at which the maximum rate (i.e., photosynthesis, respiration, and feeding) is observed for each population. The value of x is a non-linear scalar of the ln Q_{10} $(T_m - T_o)$, where the value of $Q_{10} = 2.0$.

Long-Term Environmental Scenarios

The longer term implications of freshwater diversions on food web dynamics within MRGO ecosystem were examined within a framework of projected environmental variability over a 55-y planning horizon. The UNO model results for 1990-2007 provided a series of years that included drought conditions (e.g., 1999-200), hurricane (2005), and comparatively normal conditions. The year numbers (e.g., 2001) were sampled at random with replacement to build the 55-y sequence needed for the longer-term evaluation of the freshwater diversions. Separate 55-y sequences were developed for baseline conditions, two without-project alternatives (WQ1, WQ3), and three with-project alternatives (WQ5, WQ6, and WQ8). The same sequence of 55 sampled years was used in developing the environmental inputs for all proposed alternatives. The main emphasis was on the projected effects of WQ1 and WQ6 and the incremental differences between these two proposed alternatives.

Figure 3 illustrates monthly salinity values produced by the UNO model for a 10-y period during the 55-y period of simulation for node 2 (Lake Borgne) that is directly affected by the proposed diversions. The results are summarized for the baseline simulation, two without-project scenarios (WQ1, WQ3) and three with-project scenarios (WQ5, WQ6, WQ8). The results show the relative importance of year-to-year variability in salinity in

comparison to reductions in salinity associated with the various planning alternatives. Periods defined by drought conditions and associated lower river flows and higher salinities (e.g., months ~169 – 180) show the greater relative importance of the freshwater diversions in reducing salinities. Not surprisingly, the relative effects of the diversions on salinity decrease with distance from the diversion (e.g., node 78, Figure 4).

One concern associated with the proposed diversions is the potential for increased nutrients from the Mississippi River to enter the MRGO ecosystem and pose eutrophication problems. The UNO model results indicate the potential for increased concentrations of dissolved inorganic N to enter the system (Figure 5). The greatest increases in nutrients are anticipated for Lake Borgne in the vicinity of the diversion proposed near Violet, LA. The model results for node 2 show the increases in DIN for the same modeled time period as the salinity reductions described previously (Figure 3). As noted for salinity, the effects of nutrient enrichment diminish with distance from the vicinity of the diversion. Figure 6 shows monthly variations in DIN for node 78. The effects of the diversions are not significant in comparison to other sources of monthly variations in DIN during the time period.

Similar results were obtained from the UNO model for dissolved inorganic P. For node 2 (Lake Borgne), the diversions can increase DIP inputs (Figure 7) compared to the simulated baseline conditions. However, as noted for DIN, the relative increases in DIP also decrease with distance from the vicinity of the proposed diversion.

The CASM MRGO simulations are based on the UNO model results. Therefore, the potential increases in algal productivity will be reflected in the results of the CASM MRGO simulations for the modeled without- and with-project conditions.

These initial scenarios were intended to examine the implications of historical patterns of environmental variability and do not address changes anticipated in relation to climate change or subsidence.

Summarization of Revised Model Results

Individual CASM MRGO simulations were performed for each of the 23 modeled UNO nodes using the revised version of the model and its parameter values. The results were summarized in two ways as in the original model (Figure 8). The first summarization was based on simply multiplying the nodal model result by the area of the corresponding spatial cell to estimate the total effect for each cell and the entire CASM MRGO model domain (i.e., Figure 1). A second method was developed where the nodal value was interpolated in relation to values of salinity and depth defined for 1 km^2 grid cells that spanned the model domain (Figure 8). Figure 9 shows the average monthly results for one without- and with-project scenario for oysters obtained from the spatial grid cell summarization. The first (nodal) summarization provides a rapid assessment of the effects of the modeled alternatives and the values presented in tabular form in this report

are based on these nodal summaries. The second method permits examination of spatial-temporal effects in more detail (e.g., Figure 9). The CASM MRGO has the capability to produce such maps of productivity for all populations and all modeled scenarios (at a daily time resolution, if desired) for all 55 modeled years.

Baseline Simulation

None of the model revisions applied directly to the modeled populations of primary producers. Any resulting differences in the production dynamics of phytoplankton, periphyton, and SAV (compared to the original model) were caused by direct (e.g., grazing) and indirect (e.g., N and P remineralization) effects determined by the revisions to the consumer populations.

The values of the baseline abiotic environmental variables were used in combination with the modeled aquatic populations and their associated calibrated bioenergetics parameters to simulate one year of ecological production dynamics for each of the 23 locations included in the CASM MRGO. The 1-y reference simulation was developed using salinity results from the UNO baseline simulation in combination with water quality parameters from the WQ1 scenario (USACE 2010). The baseline UNO simulation did not include water quality parameters in its model results.

Phytoplankton Production

As emphasized previously, the reference simulation represents calibration of modeled phytoplankton production to available data through adjustments of phytoplankton bioenergetics parameters (i.e., Table 2). Table 4 lists the annual production ($gC/m^2/y$) of the modeled phytoplankton populations for each of the 23 modeled locations generated by the revised model. The revised model results range from essentially zero growth (diatoms, nodes 73, 74) to >2,900 $gC/m^2/y$ (diatoms in the deeper water stations 20, 21). In general, the modeled bluegreen algae appear in greater abundance than the green algae or the diatoms, except in the deeper stations. This increased production might reflect the higher temperature tolerances defined for this population in addition to the modeled bluegreens being defined as less preferred by phytoplankton grazers. The overall model phytoplankton values represent the integration of nonlinear relationships between light intensity, nutrient availability, and grazing. The deeper modeled locations offer a potentially greater euphotic zone depth and it's not surprising that higher production values result for these stations. Light inhibition and higher water temperatures characteristic of the shallower locations (e.g., Biloxi Marsh, nodes 73 and 74), plus more intense grazing, including filtration by oysters, can explain the lower production values for these locations.

Periphyton Production

The modeled annual production of periphyton is similar in spatial pattern, but is generally less than the modeled phytoplankton production (Table 4). This pattern results in part from the defined depth for periphyton growth for each modeled node. In addition, shading by phytoplankton and SAV can account for the lower values of periphyton production. Finally, the periphyton is subject to grazing by the zoobenthos and all of the modeled benthic invertebrates (except oysters). In contrast to the phytoplankton, diatoms and green algae dominate the periphyton.

Periphyton production maybe over-estimated in Nodes 20 – 22. The comparatively high values of productivity might result from a low abundance of potential grazers or not specifying depth limitations for periphyton spatial distribution within the modeled domain (Table 2).

SAV Production

The revised model might continue to underestimate the spatial production of submerged aquatic vegetation, although the current results appear consistent with the parameter values defined for these populations (Table 4). SAV production decreased slightly across the modeled species and locations in the revised model. However, the populations more tolerant to salinity (e.g., *Halodule*, *Thalassia*) shower greater modeled growth for locations with higher salinity values. The less salt tolerant populations (e.g., *Myriophyllum*, *Vallisneria*) grow mainly in the locations characterized by lower salinity values. The high production values for *Myriophyllum* in Lake Pontchartrain and associated areas appear consistent with reports of high abundance of this invasive species in these areas.

It must be recognized that the initial model development focused mainly on the populations of benthic invertebrates (e.g., oysters, crab, and shrimp) and selected fishes. During the rapid development of the initial CASM MRGO, comparatively less effort was directed at estimation of growth parameters for the included populations of SAV. Possible revisions to the CASM MRGO should include re-examination of the parameters developed for the SAV.

Emergent Aquatic Plant Production

Revisions to the model had no influence on the production of emergent aquatic plants. The revised baseline CASM MRGO results suggest that emergent aquatic plant production is largely dominated by *Phragmites* (Table 4). In general, *Spartina*, *Sagittaria*, and *Distichlis* contribute in that order to emergent plant production in the MRGO ecosystem. This order appears determined mainly by the lower temperatures tolerated by *Phragmites* and *Spartina*, which extends their growing seasons compared to the other two populations (Table 2). The modeled values of Phragmites are more variable across the MRGO ecosystem because salinity tolerances were available for this population. Salinity parameters were not derived for the other three populations. All four populations respond

similarly to changes in depth (Table 2). The modeled values compare with estimates of 1,162 – 2,895 g/m^2/y reported for Louisiana salt march plants (White *et al.* 1978).

Similar to the modeled SAV, less effort was directed in estimating model parameters for these populations of emergent aquatic plants. Future applications of the model to evaluate the potential effects of freshwater diversion on these populations across the Central Wetlands Area or other potentially affected wetlands in the MRGO ecosystem would benefit from additional evaluation and refinement of the growth and habitat parameters defined initially for these plants.

Zooplankton and Zoobenthos Production

The revised model zooplankton production values ranged from ~25-470 gC/m^2/y and are generally greater than the original model (Table 5). Higher zooplankton values were generally associated with deeper water locations (e.g., nodes 16, 17, 20, 21) that simply provided greater habitat volume. The spatial pattern of zooplankton production is also influenced by the intensity of predation imposed on this generalized population by many of the modeled consumer populations in the CASM MRGO, as well as the availability of phytoplankton, which serves as the principal food source for the modeled zooplankton.

Except for the deeper water locations, the baseline modeled production of zoobenthos generally exceeded zooplankton production (Table 5), although the range of production values (~22-634 gC/m^2/y) was not that different. The derived maximum consumption rates for zooplankton and zoobenthos do not differ substantially (Table 3) and their habitat factors overlap substantially.

Both zooplankton and zoobenthos are subject to intense predation pressure in the CASM MRGO. Therefore, it is reasonable that the production dynamics of these two generalized populations are similar. The revisions to the habitat factors appeared to have somewhat reduced grazing pressures on zooplankton and zoobenthos. This result is consistent with a reduction in the spatial and temporal availability of quality habitat conditions for predator populations that consume zooplankton and zoobenthos.

Benthic Invertebrate Production

Table 5 summarizes the baseline production of immature and adult populations of oysters, blue crab, brown shrimp, and white shrimp. Habitat suitability factors were not adjusted in the revisions to the CASM MRGO. However, it appears that reductions in the biomass of populations (e.g., red drum) that feed upon oysters and oyster spat resulted in an increase in the production of oysters and oyster spat in the revised model.

Modeled adult blue crab production was between ~ 48 and 214 gC/m^2/y in the original model results (Table 5). Values in the revised model range from ~37 – 306 gC/m^2/y. The original modeled values of immature blue crab production ranged from ~ 24-2,055 gC/m^2/y. The revisions to the model resulted in substantial reductions in immature blue crab production that ranged from ~0.2 – 100 gC/m^2/y (Table 5).

Revised modeled adult brown shrimp varied between ~ 0.2 – 66 gC/m^2/y compared to ~ 18-255 gC/m^2/y in the original model (Table 5.) Juvenile brown shrimp ranged from ~0.1 – 61 gC/m^2/y compared to the original model (~ 3-117 gC/m^2/y). Reductions to the temperature and salinity tolerances determined from the CSA data compared to the original parameter estimates appear to have correspondingly reduced the production of brown shrimp in the revised model.

A similar reduction of baseline production resulted for modeled white shrimp (Table 5). Modeled adult white shrimp ranged from ~ 31 – 174 gC/m^2/y in the revised model compared to ~ 66-332 gC/m^2/y in the original model. In general the modeled abundance of white shrimp was greater than brown shrimp. This result contrasts with current commercial catches that are predominately brown shrimp. However, historically, white shrimp dominated the catch. The impacts of historical (or current) commercial shrimp harvests on annual production are not included in the CASM MRGO. The model suggests that apart from the possible historical effects of harvesting, environmental conditions as characterized by the model might favor the production of white shrimp.

Importantly, the CASM MRGO does not move biomass of crabs or shrimp across the modeled nodes to simulate migration. However, the model does transfer biomass from inshore to offshore locations at the specified times to mimic migration.

Efforts continue to compare the original and revised model results for oyster, crab, and shrimp production to values reported for areas relevant to the CASM MRGO.

Fish Production

The revised CASM MRGO retains the original model populations of sea trout, red drum, bay anchovy, Gulf menhaden, sheepshead, striped mullet, Gulf sturgeon, and Atlantic croaker. Juvenile and adult populations are included for sea trout and red drum. With the possible exceptions of juvenile and adult sea trout and sheepshead, revising the fish habitat factors (Table 3) and food web interactions (Figure 2) reduced net annual production across the modeled fish populations (Table 5).

Given their revised habitat tolerances (Table 3), the production of adult sea trout increased from 13 to 16 of the 23 modeled locations in the MRGO model domain (Table 5). In these areas, revised modeled adult production ranged from ~ 5 – 182 gC/m^2/y, compared to the original model values of ~1-111 gC/m^2/y. The revised model produced adults in nodes 1-3, where the original model showed no production. Juvenile sea trout were productive in all but the deepest model locations (nodes 20-22) and revised modeled values were between ~10 – 344 gC/m^2/y, compared to the original ~109-411 gC/m^2/y.

Juvenile red drum remain comparatively abundant in the revised baseline simulation, but the number of nodes where juvenile drum were present decreased. In addition to the original deeper modeled locations (nodes 20-22), juvenile drum were absent from nodes 4, 5, 9, 16, and 18. Revised model production values for juvenile red drum were between

~ 2 – 132 ~ gC/m^2/y, compared to the original model values of 261-1,127 gC/m^2/y. Revised adult red drum modeled values of production ranged from ~ 1 – 7 gC/m^2/y (Table 5), compared to the ~5-243 gC/m^2/y of the original model.

The revised baseline simulated productivities of bay anchovy ranged from ~ 9 – 190 gC/m^2/y (Table 5), compared to the ~33-542 gC/m^2/y in the original model. Being a dominant forage fish in the Gulf of Mexico and a valuable commercial fishery, it is realistic that the revised model retains produces comparatively high values for bay anchovy, even thought the absolute values are less than in the original model.

Modeled baseline productivities for Gulf menhaden, another key forage fish, ranged from ~ 8 – 209 gC/m^2/y (Table 5), compared to the ~12-344 gC/m^2/y in the original model. Both bay anchovy and Gulf menhaden are subject to intense predation pressures in the CASM MRGO.

Sheepshead were among the least productive of the fishes in the original baseline CASM MRGO simulation. However, their relative abundance increased in the revised baseline simulation (Table 5). Production values ranged from ~ 7 – 77 gC/m^2/y in the revised model, compared to ~0 - 16 gC/m^2/y in the original model.

Striped mullet baseline production ranged from ~7-297 gC/m^2/y and production occurred in all 23 nodes in the original model. In the revised model, mullet production ranged from 0.1-12 gC/m^2/y (Table 5). Mullet did not grow in nodes 16, 18, and 20-22 in the revised model.

Baseline simulated productivity for Gulf sturgeon ranged from ~0.1-1.9 gC/m^2/y in the revised model (Table 5), compared to ~1-45 gC/m2/y in the original model. The lower baseline values appear more realistic in the revised model, given that the Gulf sturgeon is a federally listed species. Given the derived habitat preferences for modeled Gulf sturgeon, these fish are absent from the deeper water modeled locations (i.e., nodes 16, 20-22) in the baseline simulation.

Simulated baseline productivity for the Atlantic croaker ranged from 3-166 gC/m^2/y in the revised model (Table 5), in contrast to the original model values ~4-251 gC/m^2/y across the MRGO model domain. The highest value (166.2 gC/m^2/y) occurred for a deeper water (15 m) location (node 20).

Future Without-Project Results

An important aspect of planning for ecosystem restoration lies in assessing future conditions in the absence of constructed projects. The following sections describe four future "without-project" scenarios developed in relation to the proposed diversions near Violet, LA.

Description of Without-Project Alternatives

The four without-project planning alternatives (WQ1-WQ4) can be described as:

WQ1 130 cfs from the CWA Waste Water Treatment Program, with 4,500 cfs diversion at Lake Maurepas, and the Lake Borgne structure open;

WQ2 130 cfs from the CWA Waste Water Treatment Program, with 4,500 cfs diversion at Lake Maurepas, and the Lake Borgne structure closed;

WQ3 130 cfs from the CWA Waste Water Treatment Program, with diversion at Lake Maurepas to keep salinity < 1ppt, and the Lake Borgne structure open;

WQ4 130 cfs from the CWA Waste Water Treatment Program, with diversion at Lake Maurepas to keep salinity < 1 ppt, and the Lake Borgne structure open;

Revised Results for WQ1

The revised CASM MRGO was used to project the effects of each without-project alternative for the 55-y planning horizon. The effects were based on the values of salinity and other water quality parameters provided by the UNO model for each of these scenarios.

The WQ1 alternative is currently the recommended without-project alternative. Table 6 lists the first year results for plant population annual productivity ($gC/m^2/y$) calculated by the revised model for the WQ1 without-project alternative. The corresponding effects on modeled consumer populations for WQ1 are listed in Table 7. These results are based on the nodal summaries of the CASM MRGO simulations for each of the 23 locations in the CASM MRGO model domain.

The results are not described in detail in this report; detailed spreadsheet summaries have been provided separately. However, as noted in the original model application, inspection of the revised results suggests minimal differences between the baseline simulation and the results for WQ1. There are small increases or decreases in the productivity of the modeled plant populations (i.e., Tables 4 and 6) and consumer populations (Tables 5 and 7). These small differences reflect the differences in salinity between the baseline UNO model results and the corresponding results for the WQ1 alternative because the baseline and WQ1 CASM MRGO simulations use the same other water quality parameters as WQ1.

Future With-Project Results

To assess the implications of chloride management on ecological production within the modeled MRGO ecosystem, simulations were performed with the revised model using

adjusted daily input values of salinity and other affected parameters (e.g., DIN, DIP, TSS) defined by the different project management alternatives.

Description of With-Project Alternatives

Four with-project alternatives were evaluated using the UNO physical model (USACE 2010). The four with-project planning alternatives (WQ5-WQ8) are be briefly described as:

WQ5 130 cfs from the CWA Waste Water Treatment Program, with 4,500 cfs diversion at Lake Maurepas, and the Lake Borgne structure open, with 1,000/7,000 cfs diversion near Violet, LA;

WQ6 130 cfs from the CWA Waste Water Treatment Program, with 4,500 cfs diversion at Lake Maurepas, and the Lake Borgne structure closed, with 1,000/7,000 cfs diversion near Violet, LA;

WQ7 130 cfs from the CWA Waste Water Treatment Program, with diversion at Lake Maurepas to keep salinity < 1ppt, and the Lake Borgne structure open, with 1,000/7,000 cfs diversion near Violet, LA;

WQ8 130 cfs from the CWA Waste Water Treatment Program, with diversion at Lake Maurepas to keep salinity < 1 ppt, and the Lake Borgne structure open, with 1,000/7,000 cfs diversion near Violet, LA;

Revised Results for WQ6

The revised CASM MRGO was used to project the effects of each with-project alternative over the 55-y planning period. The effects were based on the values of salinity and other water quality parameters provided by the UNO model for each of these scenarios.

The currently recommended with-project alternative is WQ6. Table 8 lists the first year results for plant population annual productivity ($gC/m^2/y$) for the WQ6 without-project alternative. The corresponding effects on modeled consumer populations for WQ6 are listed in Table 8. These results are based on the nodal summaries of the CASM MRGO simulations for each of the 23 locations in the CASM MRGO model domain.

The results are not described in detail. However, comparison of the revised baseline plant population production (Table 4) with plant production for WQ6 (Table 8) indicates general decreases in the production of *Halodule* and *Thalassia* that would be expected with decreases in salinity for these populations characteristic of more saline environments. The revised model results also indicate shifts in the spatial distribution and abundance of *Phragmites* that correspond to spatial-temporal changes in salinity as determined by WQ6.

The responses of the consumer populations to WQ6 compared to the baseline simulation vary among populations and locations (Tables 7 and 9). For example, oyster production for WQ6 increases in some nodes and decreases in others compared to the baseline results. Production for WQ6 increases for oysters, blue crab, brown shrimp, and white shrimp in the node (73) that corresponds to Biloxi Marsh. WQ6 effects on production for the modeled fish species also varies among locations with both increases and decreases compared to the baseline conditions. Importantly, the model results for this proposed diversion do not suggest drastic alterations in production and appear consistent with the moderate changes in salinity (and other water quality parameters) associated with this proposed diversion.

Incremental Effects

USACE planning decisions are routinely based on comparing the anticipated outcomes for future without-project and with-project conditions. The incremental differences between without- and with-project results have been calculated from the CASM MRGO simulations for all combinations of without- (i.e., WQ1-WQ4) and with-project (i.e., WQ5-WQ8) proposed alternatives.

The CASM MRGO results vary by modeled population, location (node), and year. Various summaries organized by population or location, as well as total system summaries have been prepared in the form of spreadsheets. The summaries are too large and complex to be conveniently presented in tabular form in this report. The spreadsheet summary files can be made available (e.g., electronically) by USACE or the authors of this report. Incremental effects have been computed using both the nodal summary method and the spatial interpolation approach (Figure 8).

In addition, it is possible to generate maps of the incremental effects at user-defined time scales (e.g., annual, monthly, daily) for any of the modeled populations. The incremental effects could be determined from the spatially interpolated model results for net production. For example, Figure 9 illustrates the spatial distribution of the WQ1 without-project and the WQ6 with-project revised model production for oysters in April. The results for oysters reflect the incorporation of hard substrate data that were available for the revised analysis. The combination of WQ1 and WQ6 suggests minimal differences for modeled production of Gulf sturgeon in December (Figure 10). Sheepshead production in March appears enhanced by WQ6 (Figure 11). These example maps of productivity were developed using the results for model year 15.

Discussion

The revised CASM MRGO was based on a review and evaluation of modeled food web structure, additional analysis of available and relevant environmental data, published values of bioenergetics parameters, revised initial biomass values, and revised habitat requirements for the modeled populations of aquatic consumers. Hard-bottom substrate data were also used in the spatial interpolation of oyster and oyster spat production. There were no modifications made for any of the populations of primary producers.

Potential Model Bias

Simplifications and assumptions are implicit in the development and application of any ecological model and the CASM MRGO is no exception. The modeled MRGO ecosystem food web structure, while complex compared to existing models, represents an assemblage of species identified in relation to their ecological, recreational, and commercial importance. The modeled food web is not a comprehensive description of all species known to inhabit the MRGO ecosystem. The absence of other important species and their associated trophic interactions from the model can bias the results of the CASM MRGO. Zooplankton and zoobenthos comprise a large number of species with different life history characteristics and ecological interactions. Given the modeling objectives and focus on specific valued ecological resources (e.g., oysters, crab, shrimp, selected fishes), aggregation of these lower trophic level species into two model state variables is justifiable. However, such aggregation can influence the accuracy of the model results.

Bioenergetics parameter values were not directly available for all the CASM MRGO species. For example, feeding, respiration, egestion, and excretion rates for several modeled fishes were estimated using relationships based on average body size as defined in Hanson et al. (1997). Photosynthesis rates and other plant growth parameters for phytoplankton and periphyton were based on previous applications of the CASM (e.g., (Bartell et al., 2009). In some cases, absent species-specific estimates, the same bioenergetics parameter values were used for similar species (e.g., white shrimp, brown shrimp).

Habitat preferences or tolerances (e.g., salinity, temperature, dissolved oxygen, depth) were originally derived using the technical literature and revised for several populations based on local (i.e., CSA) data. The analysis of these data suggested revisions to the temperature and salinity tolerances or preferences for many of the modeled consumer populations of invertebrates and fish (Table 3). The combined effects of the refined habitat suitability factors generally reduced the modeled production of the affected CASM MRGO populations in comparison to the original model results.

This revised version of the CASM MRGO addresses the location of hard-bottom substrate type in its detailed spatial interpolation of the nodal results for oysters. However, the nodal calculations still assume favorable substrate conditions. As a result, the model might continue to overestimate oyster production in areas of the model domain for which

substrate data were not available. Similarly, areas of actual hard substrate not addressed by the revised model can influence the simulated growth of organisms that prefer soft or muddy substrates (e.g., shrimp). If additional substrate data become available, further refinements can be made for the nodal calculations and the spatial interpolations that generate the maps of population production.

The original model did not include the seasonal migration of Gulf sturgeon from coastal waters to tributaries. As a result, the original model likely overestimated sturgeon production in the model spatial domain. The revised model includes parameters that limit the presence of these fish in the Gulf to the months of September through April (based on descriptions provided at www.nmfs.noaa.gov/pr/species/fish/gulfsturgeon.htm). This revision seemingly reduces bias and results in much lower Gulf sturgeon population biomass values, consistent with the listed status of this fish.

The 50-y projections of future biomass production for without- and with-project planning alternatives were based on an assumed 50-y sequence of environmental data. The sequence was developed by selecting 50 individual years at random from the 1989-2007 set of UNO model results. This implies that annual variations in environmental conditions are independent and ignores any possible cycles in local climate conditions (e.g., El Nino). Future modifications to the overall CASM MRGO assessment framework could include several alternative 50-y environmental sequences based on different assumptions of longer term cycles (e.g., drought, above average precipitation, etc.). Development of such scenarios would require evaluation of longer term climate data to identify relevant cycles in climate conditions and their likely influence on the environmental parameters included in the CASM MRGO. However, resources were not available to address this issue in the current model revision.

The preceding simplifications and assumptions potentially introduce bias into the model results. However, the important point is that the current model bias affects both the future without- and with-project scenarios. The corresponding incremental effects produced by the CASM MRGO can be used to evaluate different combinations of proposed planning alternatives.

Sensitivity and Uncertainty

The results of the CASM MRGO are influenced by the simplifications and assumptions just described. In addition, the CASM MRGO results are influenced by the accuracy and precision of the UNO model calculations. The precision of salinity values projected for the proposed diversions (e.g., WQ6-WQ8) is estimated at approximately (+/-) 18% (USACE 2010). Therefore, the CASM MRGO results are imprecise at least to this degree. Given the simplifications and assumptions in the model, it is likely that the precision associated with the CASM MRGO are greater than 18%.

The general result of the revisions to the CASM MRGO was reduced biomass production for many of the modeled populations of fish and benthic invertebrates. Reduced

production might be explained in part by assuming that revisions to temperature and salinity habitat factors suggested by the CSA data applied to both juvenile and adult populations of modeled species, e.g., blue crab, shrimp, red drum, and spotted seatrout. Assessment of the results of the revised model in relation to available data and the original model results will continue to further determine the accuracy and reliability of the revised CASM MRGO.

Distributions of other model inputs values (e.g., bioenergetics parameters, habitat preferences) could be developed and Monte Carlo simulations performed to quantify the effects of these sources of uncertainty and identify sensitive model parameters. The results of these analyses can then be used to guide the collection of additional data to refine and improve the CASM MRGO. The necessary sensitivity and uncertainty analysis has not yet been undertaken because of the rapid development and application of the model.

Summary

The revised CASM MRGO application remains as a useful approach for assessing the ecological impacts of freshwater diversions on the spatial-temporal production dynamics of important populations of benthic invertebrates and fish in coastal Louisiana. The revisions to the model food web structure, initial biomass conditions, and habitat factors for temperature and salinity changed the absolute magnitudes of production for many of the model species compared to the original model simulations. Further evaluation of the accuracy of the revised model results requires additional model:data comparisons.

The revised CASM MRGO has been used to assess the outcomes of proposed without- and with-project alternatives in relation to ecosystem restoration actions proposed near Violet, LA. The incremental effects (e.g., WQ1-WQ6) have been calculated and submitted electronically to the USACE for consideration in evaluating the efficacy of the proposed freshwater diversions.

Recommendations

The revised model benefited from the data and insights provided principally by the USACE, LDWF, and NMFS. However, simplifications and assumptions remain in revised MRGO version of the Comprehensive Aquatic Systems Model. Importantly, the revised model can be used to project the effects of freshwater diversions on modeled populations of producers and consumers.

Having addressed several of the concerns identified in the original modeling effort, several remaining issues are offered as potential future refinements to the CASM MRGO:

- Physical transport of dissolved and suspended constituents (e.g., nutrients, POC, plankton) can influence spatial-temporal patterns of productivity in hydrodynamically complex systems such as the MRGO ecosystem. Future refinements to the model could include more direct linking of a physical model to the CASM MRGO. The CASM has been integrated with the USACE Adaptive Hydrology Model (ADH) in separate applications for Navigation Pool 5 on the Upper Mississippi River (Bartell *et al.*, in prep.) and the Caernarvon Diversion on the Lower Mississippi River (Savant *et al.*, in prep). Similar integration may be possible to provide more realistic physical transport for the CASM MRGO.

- The modeled food web and associated bioenergetics parameters represents one hypothesis concerning ecological structure and function. The model reflects consensus opinion concerning important populations of producers and consumers and realistic estimates of model parameters as determined by calibration. However, critical model parameters, for example, maximum growth rates and light saturation constants for phytoplankton, and maximum consumption and respiration rates for consumers (especially oysters, Gulf sturgeon), might be measured directly for the MRGO populations. Detailed sensitivity/uncertainty analysis of model results to current parameter values could help guide the selection of key parameters to measure under field conditions.

- Evaluation and refinement of the environmental input factors based on additional data, if available, might further improve model performance. For example, in the absence of nutrient loading data and more sophisticated physical transport, daily concentrations of DIN, DIP, and silica (diatoms) provide initial conditions that influence phytoplankton growth. It might be possible to develop nutrient loading values based on more realistic models of flow in combination measured concentrations from major nutrient sources. Measured concentrations in the model domain that currently drive the model could then be more properly used in refined calibration of the CASM MRGO or as additional indicators of overall model performance.

- One of the greatest limitations in evaluating current model performance is the comparative absence of benthic invertebrate and fish standing stock information for the MRGO ecosystem. Currently available data represent catch per unit effort and are difficult to translate into standing stock values needed evaluate the model, although it might prove possible to develop some estimates of fish biomass (e.g., Boswell *et al.* 2010).

Implementation of any or all of these recommendations can improve performance of the CASM MRGO. At the same time, specification of performance criteria would greatly facilitate further evaluation of the current model and guide any future refinements. In basic research, models are developed with the intent of falsifying them. Model failures generate new testable hypotheses that can advance science and in turn improve the model. In management, the contrasting emphasis is on model reliability within specified performance criteria. The question, "how good is good enough?" needs to be translated

into objective performance criteria (i.e., model:data comparisons) that are usually based on some goodness of fit estimator. Development of such criteria for the CASM MRGO could improve the efficiency of continued model refinement and evaluation until the model performance is deemed adequate.

References

Bartell, S.M. 2003. A framework for estimating ecological risks posed by nutrients and trace elements in the Patuxent River. *Estuaries* 26:385–397.

Bartell, S.M. and Campbell, K.R. (2000). Ecological risk assessment of the effects of the incremental increase of commercial traffic (25, 50, 75 and 100 percent increase of 1992 baseline traffic) on fish. U.S. Army Corps of Engineers, ENV Report 16. Rock Island District, Rock Island, IL.

Bartell, S.M.; Lefebvre, G.; Kaminski, G.; Carreau, M.; and Campbell, K.R. 1999. An ecosystem model for assessing ecological risks in Québec rivers, lakes, and reservoirs. *Ecological Modelling* 124:43–67.

Best, E.P.H.; Kiker, G.A.; Rycyzyn, B.A.; Kenow, K.P.; Fischer, J.; Nair, S.K.; and Wilcox, D.B. (2005) Aquatic plant growth model refinement for the Upper Mississippi River – Illinois Waterway System Navigation Study. ENV Report 51. 87 p.

Birmingham, B.C.; Coleman, J.R.; and Colman, B. (1982) Measurement of photorespiration in algae. *Plant Physiol.* 69:259–262.

Boswell, K.M., Wilson, M.P., MacRae, P.S.D., Wilson, C.A., and Cowan, J.H., Jr. (2010) Seasonal estimates of fish biomass and length distributions using acoustics and traditional nets to identify estuarine habitat preferences in Barataria Bay, Louisiana. *Marine and Coastal Fisheries: Dynamics, Management, and Ecosystem Science* 2:83-97.

Bothwell, M.L. (1988) Growth rate responses of lotic periphytic diatoms to experimental phosphorus enrichment: The influence of temperature and light. *Can. J. Fish. Aquat. Sci.* 45:261–270.

Bothwell, M.L. (1985) Phosphorus limitation of lotic periphyton growth rates: An intersite comparison using continuous-flow troughs (Thompson River system, British Columbia). *Limnol. Oceanogr.* 30(3):527–542.

Brand, S.B.; and Mason, D.M. 2003. Effect of nutrient loding on Atlantic Menhaden (*Brevoortia tyrannus*) growth rate potential in the Patuxent River. *Estuaries* 26:(2A)298-309.

Brylawski, B.J.; and Miller, T.J. 2006. Temperature-dependent growth of the blue crab (*Callinectes sapidus*): a molt process approach. *Can. J.Fish. Aquat. Sci.* 63:1298-1308.

Burris, J.E. (1977) Photosynthesis, photorespiration, and dark respiration in eight species of algae. *Marine Biology* 39:371–379.

Buzzelli, C.P.; Childers, D.L.; Dong, Q.; and Jones, R.D. (2000) Simulation of periphyton phosphorus dynamics in Everglades National Park. *Ecological Modelling* 134:103–115.

Brylawski, B.J.; and Miller, T.J. 2006. Temperature-dependent growth of the blue crab (*Callinectes sapidus*): a molt process approach. *Can. J.Fish. Aquat. Sci.* 63:1298-1308.

Caffey, R.H.; and Schexnayder, M. Reconciling fisheries management and wetland restoration in coastal Louisiana.

Collins, M.R. 1985. Species Profiles: Life histories and environmental requirements of coastal fishes and invertebrates (South Florida)—Striped Mullet. U.S. Army Corps of Engineers Report No. TR EL-82-4.

Cross, W.F., Benstead, J.P., Frost, P.C., and Thomas, S.A. (2005) Ecological stoichiometry in freshwater benthic systems: recent progress and perspectives. *Freshwater Biology* 50:1895–1912.

DeAngelis, D.L.; Bartell, S.M.; and Brenkert, A.L. 1989. Effects of nutrient cycling and food chain length on resilience. *American Naturalist* 134:788–805.

DeAngelis, D.L., Goldstein, R.A., and O'Neill, R.V. (1975) A model for trophic interaction. *Ecology* 56:881–892.

Dutka-Gianelli, J.; and Murie, D.J. 2001. Age and growth of sheepshead, *Archosargus probatochephalus* (pisces:sparidae), from the northwest coast of Florida. *Bulletin of Marine Science* 68:(1)69-83.

Eiane, K.; Aksnes, D.L.; Ohman, M.D.; Wood, S.; Martinussen, M.B. (2002) Stage-specific mortality of *Calanus* spp. under different predation regimes. *Limnol. Oceanogr.* 47(2):636–645.

Etnier, D.A. and Starnes, W.C. (1993) The Fishes of Tennessee. The University of Tennessee Press, Knoxville, TN.

Goldman, J.C. and Carpenter, E.J. (1974) A kinetic approach to the effect of temperature on algal growth. *Limnol. Oceanogr.* 19(5):756–766.

Guerin, J.L.; and Stickle, W.B. 1997. Effect of salinity on survival and bioenergetics of juvenile lesser blue crabs, *Callinectes sinilis*. *Marine Biology* 129:63-69.

Hamburger, K.; and Dall, P.C. (1990) The respiration of common benthic invertebrate species from the shallow littoral zone of Lake Esrom, Denmark. *Hydrobiologia* 199:117–130.

Hanson, P.C, Johnson, T.B., Schindler, D.E., and Kitchell, J.F. (1997) Wisconsin Fish Bioenergetics Model 3.0 for Windows. University of Wisconsin Sea Grant Institute, WISCU-T-97-001. Madison, WI.

Hargrave, B.T. and Geen, G.H. (1968) Phosphorus excretion by zooplankton. *Limnol. Oceanogr.* 13:332–342.

Hartman, K.J. and Brandt, S.B. (1995) Comparative energetics and the development of bioenergetics models for sympatric estuarine piscivores. *Canadian Journal of Fisheries and Aquatic Sciences* 52:1647-1666.

Hopkinson, C.S.; Gosselink, J.G.; and Parrondo, R.T. 1978. Aboveground production of seven marsh plant species in coastal Louisiana. *Ecology* 59(4)760-769.

Horner, R.R., Welch, E.B., Seeley, M.R., and Jacoby, J.M. (1990). Responses of periphyton to changes in current velocity, suspended sediment and phosphorus concentration. *Freshwater Biology* 24:215-232.

Jennings, C.A. 1985. Species profiles: Life histories and environmental reuirements of coastal fishes and invertebrates (Gulf of Mexico)—Sheepshead. U.S. Army of Engineers Report No. TR-EL-82-4.

Johnson, D.R.; Seaman, Jr., W.; and Parson, J. 1986. Species Profiles: Life histories and environmental requirements of coastal fishes and invertabrates (South Florida) Spotted Seatrout. U.S. Army Corps of Engineers Report No. TR EL-82-4.

Jowett, I.G., and Richardson, J. (1990) Microhabitat preferences of benthic invertebrates in a New Zealand river and the development of in-stream flow-habitat models for *Deleatidium* spp. *New Zealand Journal of Marine and Freshwater Research* 24:19-30.

Kostecki, P.T. 1984. Habita suitability index models: spotted seatrout. U.S. Army Corps of Engineers Report No. FWS/OBS-82/10.75.

Lampert, W. (1987) Laboratory studies on zooplankton-cyanobacteria interactions. *New Zealand Journal of Marine and Freshwater Research* 21:483–490.

Lantry, B.F. and Stewart, D.J. (1993) Ecological energetics of rainbow smelt in the Laurentian Great Lakes – an interlake comparison. *Transactions of the American Fisheries Society* 122:942-950.

Lassuy, D.R. 1983. Species Profiles: Life histories and environmental requirements (Gulf of Mexico)—Atlantic Croaker. U.S. Army Corps of Engineers Report No. TR EL-82-4. P 12.

Lehman, J.T.; Botkin, D.B.; and Likens, G.E. (1975) The assumptions and rationales of a computer model of phytoplankton population dynamics. *Limnol. Oceanogr.* 20(3):343–364.

Mayzaud, P. (1976) Respiration and nitrogen excretion of zooplankton. IV. The influence of starvation on the metabolism and the biochemical composition of some species. *Marine Biology* 37:47–58.

Muncy, R.J. 1984. Species Profiles: Life histories and environmental requirements (Gulf of Mexico)—White shrimp. U.S. Fish and Wildlife Service Report No. FWS/OBS-82/11.20.

Naito, W., Miyamoto, K., Nakanishi, J., Masunaga, S., and Bartell, S.M. (2003) Evaluation of an ecosystem model in ecological risk assessment of chemicals. *Chemosphere* 53, 363–375.

Naito, W., Miyamoto, K., Nakanishi, J., Masunaga, S., and Bartell, S.M. (2002) Application of an ecosystem model for ecological risk assessment of chemicals for a Japanese lake. *Water Research* 36, 1–14.

Pezeshki, S.R.; DeLaune, R.D. and Patrick,Jr., W.H. 1987. Effects of flooding and salinity on photosynthesis of *Sagittaria lancifolia*. *Mar. Ecol. Prog. Ser.* 41:87-91.

Ohman, M.D. and Hirche, H.-J. (2001) Density-dependent mortality in an oceanic copepod population. *Nature* 412:638–641.

O'Neill, R.V., Bartell, S.M., and Gardner, R.H. (1983) Patterns of toxicological effects in ecosystems: a modeling approach. *Environmental Toxicology and Chemistry* 2:451-461.

O'Neill, R.V., Gardner, R.H., Barnthouse, L.W., Suter, G.W., Hildebrand, S.G., and Gehrs, C.W. (1982) Ecosystem risk analysis: a new methodology. *Environmental Toxicology and Chemistry* 1:167–177.

Paasche, E. (1973) Silicon and the ecology of marine plankton diatom. II. Silicate-uptake kinetics in five diatom species. *Marine Biology* 19:262–269.

Park, R.A., Cough, J.S., and Wellman, M.C. (2004) AQUATOX (Release 2): Modeling environmental fate and ecological effects in aquatic ecosystems. Volume 1: User's Manual. EPA-823-R-04-001. Office of Water, U.S. Environmental Protection Agency, Washington, D.C. 20460.

Peters, R.H.; and Downing, J.A. (1984) Empirical analysis of zooplankton filtering and feedings rates. *Limnol. Oceanogr.* 29(4):763–784.

Richman, S.; and Dodson, S.I. (1983) The effect of food quality on feeding and respiration by *Daphnia* and *Diaptomus*. *Limnol. Oceanogr.* 28(5):948–956.

Robarts, R.D. (1987) Temperature effects on photosynthetic capacity, respiration, and growth rates of bloom-forming cyanobacteria. *New Zealand Journal of Marine and Freshwater Research* 21:391–399.

Sable, S.; Rose, K.A.et al. 2010. Individual modeling of hypoxia and habitat effects on a tidal marsh community. (Draft manuscript).

Saravia, L.A.; Momo, F.; and Lissin, L.D.B. (1998) Modelling periphyton dynamics in running water. *Ecological Modelling* 114:35–47.

Schindler, D.W. (1968) Feeding, assimilation and respiration rates of *Daphnia Magna* under various environmental conditions and their relation to production estimates. *J. Animal Ecology* 39:369–385.

Schneider, G. (1992) A comparison of carbon-specific respiration rates in gelatinous and non-gelatinous zooplankton: a search for general rules in zooplankton metabolism. *Helgolander Meeresunters.* 46:377–388.

Sellers, M.A. and Stanley, J.G. 1984. Species Profiles: Life histories and environmental requirements (Gulf of Mexico)—American oyster. U.S. Fish and Wildlife Service Report No. FWS/OBS-82/11.23.

Son, D.H. and Fujino, T. (2003) Modeling approach to periphyton and nutrient interaction in a stream. *Journal of Environmental Engineering* 129(9):834–843.

Thomann, R.V. and Mueller, J.A. (1987) *Principles of surface water quality modeling and control.* Harper Collins, New York, NY. 644 p.

Thornton, K.W. and Lessem, A.S. (1978) A temperature algorithm for modifying biological rates. *Transactions of the American Fisheries Society* 107:284–287.

Titman, D. and Kilham, P. (1976) Sinking in freshwater phytoplankton: Some ecological implications of cell nutrient status and physical mixing processes. *Limnol. Oceanogr.* 21(3):409–417.

United States Environmental Protection Agency (UESPA). 1998. Guidelines for ecological risk assessment.

USACE (2010). Mississippi River – Gulf Outlet (MRGO) Ecosystem Restoration Study. Louisiana and Mississippi. Hydraulics and Hydrology. Preliminary hydrodynamic and hydraulic modeling for a proposed freshwater diversion in the vicinity of Violet, Louisiana. Draft. February 15, 2010.

Vaughan, D.S.; Shertzer, K.W.; and Smith, J.W. 2007. Gulf menhaden (*Brevoortia patronus*) in the U.S. Gulf of Mexico: fishery characteristics and biological reference points for management. *Fisheries Research* 83:263-275.

Walters, C.; Martell, S.J.D.; and Mahmoudi, B. 2006. An ecosim model for exploring ecosystem management options for the Gulf of Mexico: implications of including multistanza life history models for policy predictions. Mote Symposium #6.

Wen, Y.H. and Peters, R.H. (1994) Empirical models of phosphorus and nitrogen excretion rates by zooplankton. *Limnol. Oceanogr.* 39(7):1669–1679.

List of Figures

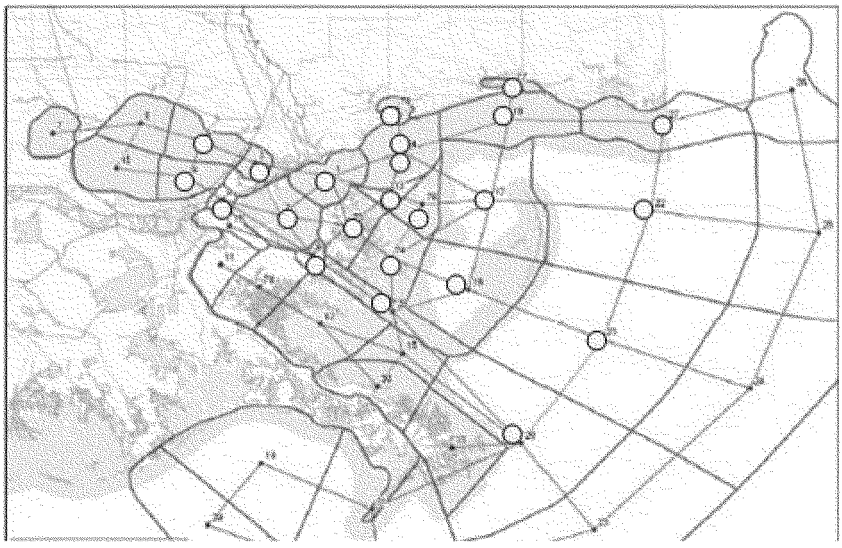


Figure 1. Locations of CASM stations used to represent physical complexity of the MRGO Project domain. (Redrawn from USACE 2010)

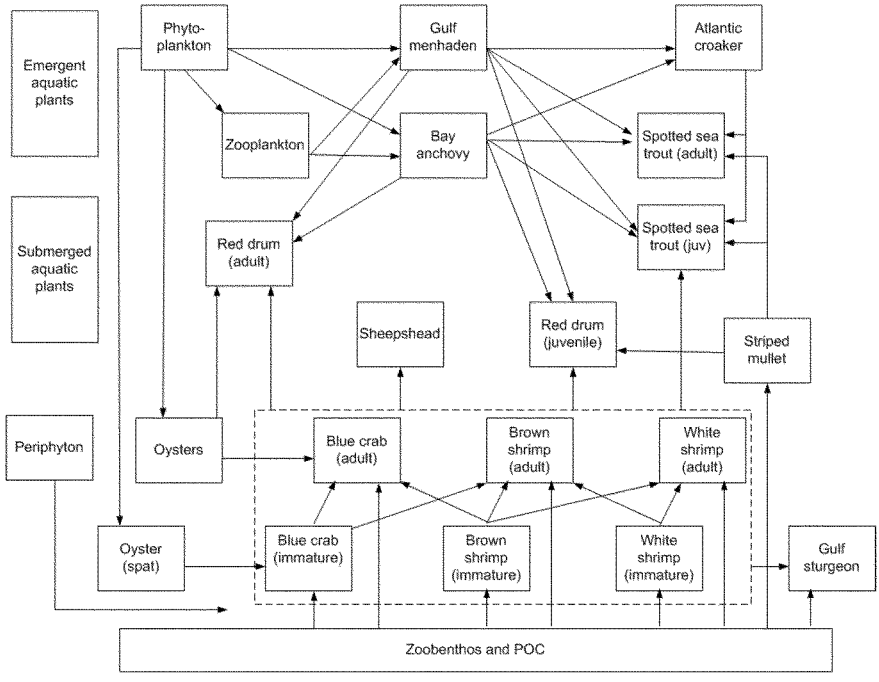


Figure 2. Revised food web structure of the CASM MRGO. (Not all interactions are shown).

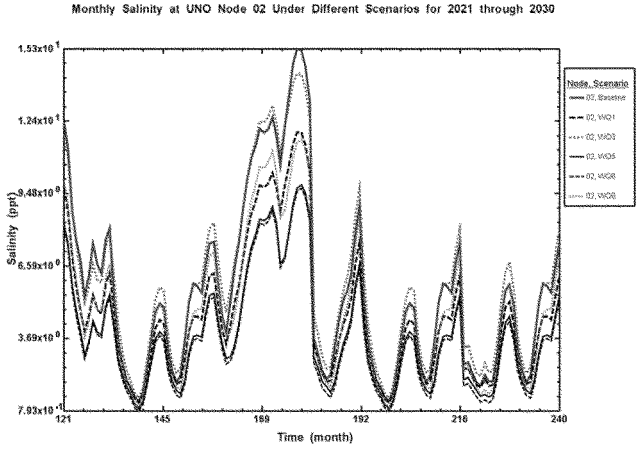


Figure 3. Monthly salinity values at node 2 for alternative scenarios.

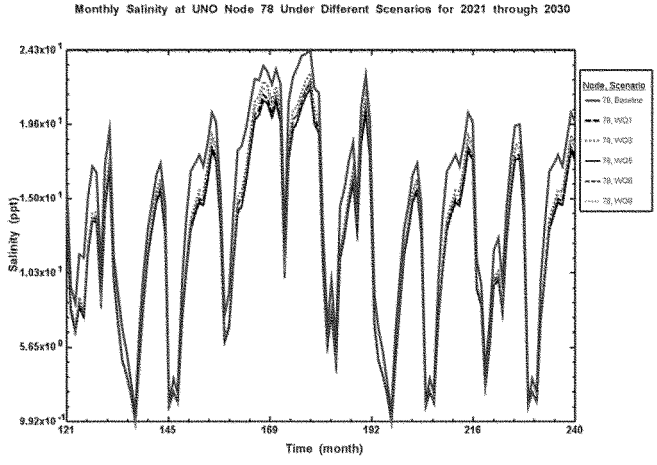


Figure 4. Monthly salinity values at node 78 for alternative scenarios.

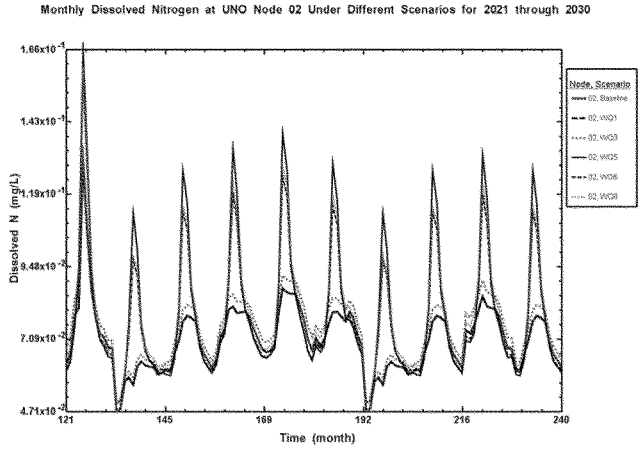


Figure 5. Temporal values of dissolved inorganic N for node 2.

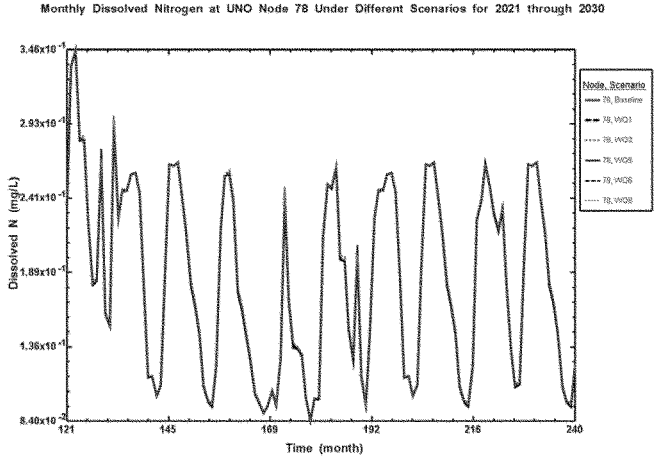


Figure 6. Temporal values of dissolved inorganic N for node 78.

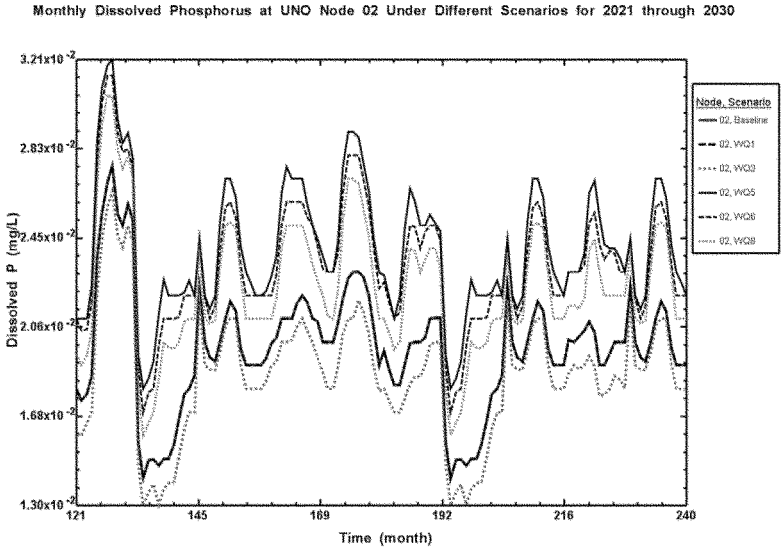


Figure 7. Values of dissolved inorganic P used at node 2.

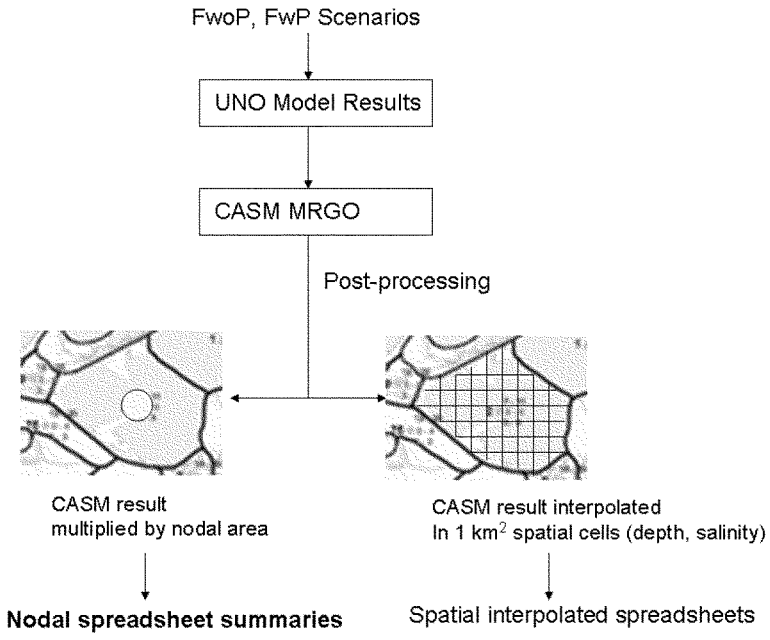


Figure 8. Nodal and spatially interpolated summarization of CASM MRGO results.

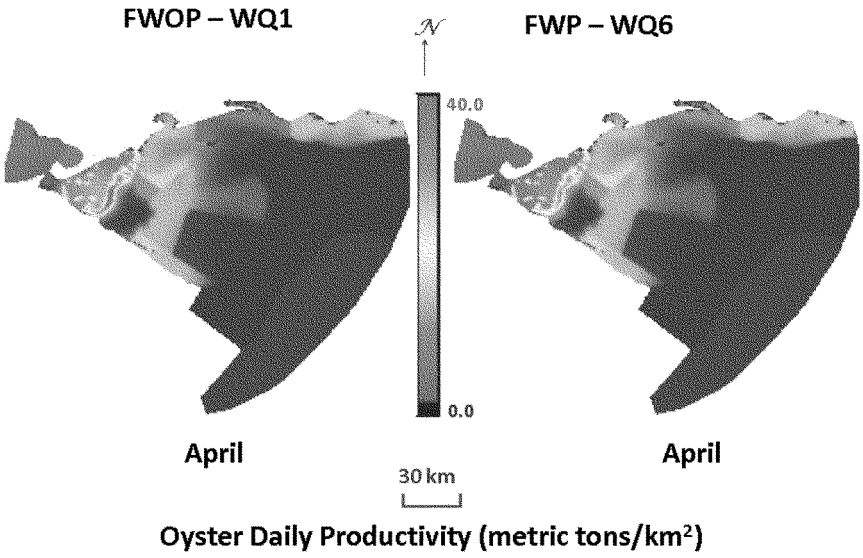


Figure 9. Spatially interpolated summarization of CASM MRGO results for April oyster production for WQ1 and WQ6.

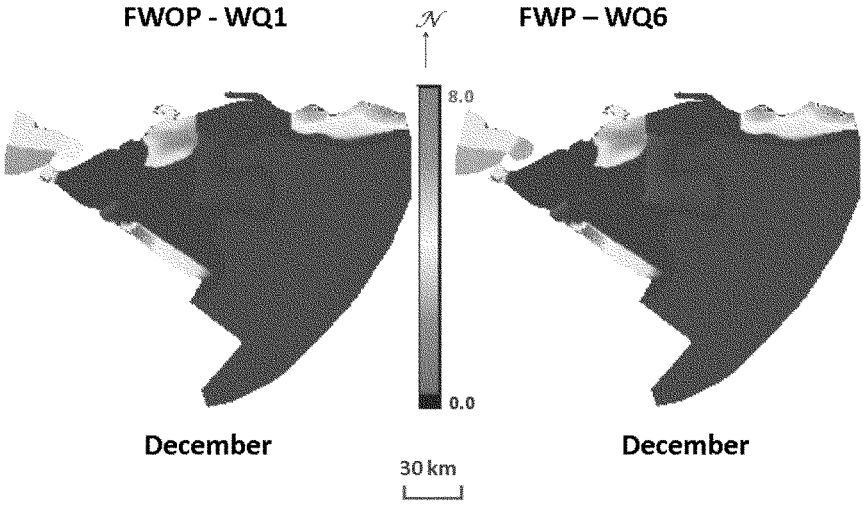


Figure 10. Spatially interpolated summarization of CASM MRGO results for December Gulf sturgeon production for WQ1 and WQ6.

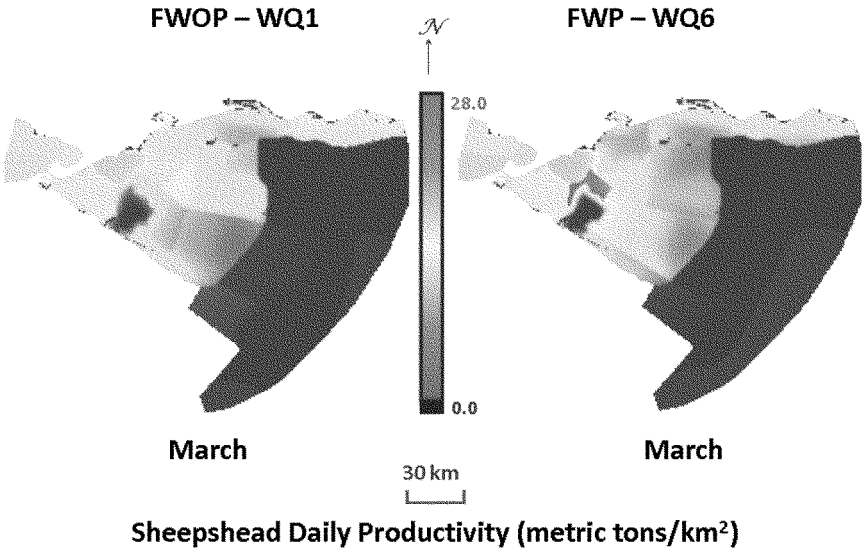


Figure 11. Spatially interpolated summarization of CASM MRGO results for March sheepshead production for WQ1 and WQ6.

List of Tables

TABLE 1 Cell number, brief cell description, surface area, and average depth for UNO model nodes included in the CASM MRGO.

Cell Number	Cell Name	Surface area (km^2)	Depth (m)
1	Lake Bourne N	325	2.8
2	Lake Bourne S	340	2.7
3	L. Pontchartrain E	200	2.6
4	L. Pontchartrain SE	350	3.8
5	L. Pontchartrain NE	350	4.0
8	MRGO BM	55	6.5
9	MRGO N	50	6.5
13	BM N	85	1.1
14	Bay St. Louis	316	3.5
28	MRGO S	500	4.2
73	BM LB	124	1.0
74	BM BS	240	1.0
76	B St. L	50	2.5
77	Biloxi River	50	2.0
78	BM E	110	1.5
80	Subdivision of 14	258	3.5
16	SE of Biloxi Marsh	1,120	1.5
17	NE of Biloxi Marsh	1,340	2.0
18	Biloxi R	700	2.6
27	Pascag R	800	3.1
22	Off Pasc R	3,850	20.0
21	Off Hope E	2,880	20.0
20	Off P a Loutre	3,015	15.0

TABLE 2 Bioenergetics and Habitat Parameters for CASM MRGO Primary Producer Populations

Producer Community	CASM population	Growth Rate (1/d)	Te_1 (°C)	Te_2 (°C)	Te_3 (°C)	Te_4 (°C)	Light Saturation (Eins/m2/d)	Sinking Rate (m/d)
Phytoplankton	Diatoms	3.10	6	18	28	40	8	0.60
	Chlorophytes	2.95	10	20	30	42	8	0.20
	Cyanophytes	2.90	12	22	32	40	4	0.05
Periphyton	Diatoms	2.50	6	18	28	40	4	-
	Chlorophytes	2.70	10	20	30	40	5	-
	Cyanophytes	2.80	12	22	32	40	5	-
SAV	Myriophyllum	0.16	8	20	30	42	8	-
	Vallisneria	0.18	10	20	36	42	8	-
	Halodule	0.14	10	22	36	42	8	-
	Thalassia	0.18	10	22	36	42	8	-
Emergents	Distichlis	0.06	12	20	36	42	50	-
	Sagittaria	0.06	10	20	36	42	50	-
	Phragmites	0.05	10	20	36	42	50	-
	Juncus	0.05	8	20	36	42	50	-
	Spartina	0.06	8	20	36	42	50	-

669

TABLE 2 Bioenergetics and Habitat Parameters for CASM MRGO Primary Producer Populations (Continued)

Producer Community	CASM population	k_P (mg/L)	k_N (mg/L)	k_S (mg/L)	Mortality (1/d)	Photo-respiration (unitless)	Dark respiration (1/d)	
Phytoplankton	Diatoms	0.008	0.06	0.60	0.05	0.024	0.080	
	Chlorophytes	0.008	0.04	-	0.02	0.026	0.070	
	Cyanophytes	0.010	0.02	-	0.01	0.028	0.060	
Periphyton	Diatoms	0.009	0.06	0.60	0.05	0.025	0.065	
	Chlorophytes	0.009	0.04	-	0.02	0.030	0.070	
	Cyanophytes	0.010	0.02	-	0.01	0.028	0.060	
SAV	Myriophyllum	-	-	-	0.021	0.022	0.060	
	Vallisneria	-	-	-	0.021	0.024	0.055	
	Halodule	-	-	-	0.020	0.022	0.065	
	Thalassia	-	-	-	0.020	0.020	0.058	
Emergents	Distichlis	-	-	-	0.020	0.035	0.010	
	Sagittaria	-	-	-	0.020	0.028	0.010	
	Phragmites	-	-	-	0.003	0.032	0.007	
	Juncus	-	-	-	0.020	0.026	0.010	
	Spartina	-	-	-	0.020	0.031	0.010	

700

TABLE 2 Bioenergetics and Habitat Parameters for CASM MRGO Primary Producer Populations (Continued)

Producer Community	CASM population	Salinity tolerances				Water depth tolerances			
		PSUlt (PSU)	PSUol (PSU)	PSUlt (PSU)	PSUol (PSU)	Dlt (m)	Dol (m)	Dou (m)	Dut (m)
Phytoplankton	Diatoms	-	-	-	-	-	-	-	-
	Chlorophytes	-	-	-	-	-	-	-	-
	Cyanophytes	-	-	-	-	-	-	-	-
Periphyton	Diatoms	-	-	-	-	-	-	-	-
	Chlorophytes	-	-	-	-	-	-	-	-
	Cyanophytes	-	-	-	-	-	-	-	-
SAV	Myriophyllum	0	1	5	10	0.1	0.5	2.5	4.0
	Vallisneria	0	1	7	12	0.1	0.5	1.5	2.0
	Halodule	0	15	37	60	0.1	0.5	3.0	4.0
	Thalassia	0	36	45	60	0.1	0.5	2.5	4.0
Emergents	Distichlis	0	0	0	0	0	0.1	0.5	1.5
	Sagittaria	0	0	0	0	0	0.1	0.5	1.5
	Phragmites	0	5	10	22	0	0.1	0.5	1.5
	Juncus	0	0	0	0	0	0.1	0.5	1.5
	Spartina	0	0	0	0	0	0.1	1.0	2.0

701

TABLE 3 Bioenergetics and Habitat Parameters for CASM MRGO Consumer Populations

CASM Populations	Max Consumption (1/d)	Te_1 (°C)	Te_2 (°C)	Te_3 (°C)	Te_4 (°C)	Rsda (unitless)
Zooplankton	1.500	8	16	34	38	-
Zoobenthos	1.800	8	18	34	38	-
Blue crab – juv	0.687	8, 7[a]	14, **20**	34, **29**	39, **36**	0.175
Brown shrimp - juv	0.738	8, **9**	14, **23**	34, **30**	39, **36**	0.175
White shrimp – juv	0.738	8, 7	14, **21**	34, **30**	38, **36**	0.175
Spotted sea trout – juv	0.287	7, **5**	16, **14**	33, **24**	45, **36**	0.172
Red drum – juv	0.476	8, **5**	16, **11**	32, **16**	40, **22**	0.172
Bay anchovy	0.441	8, **5**	20, **19**	29, **29**	37, **36**	0.163
Gulf menhaden	0.653	8, 7	20, **18**	32, **29**	37, **34**	0.162
Striped mullet	0.225	8, **5**	20, **10**	30, **19**	45, **31**	0.175
Spotted sea trout – adlt	0.142	7, 7	16, **14**	33, **24**	45, **36**	0.140
Red drum – adlt	0.117	6, **5**	10, **11**	34, **16**	40, **22**	0.172
Oyster spat	1.500	10	20	34	39	-
Oysters	1.960	8	20	34	39	0.105
Blue crab – adlt	0.661	8, 7	20, **20**	32, **29**	39, **36**	0.125
Brown shrimp – adlt	0.981	8, **9**	20, **23**	32, **30**	39, **36**	0.105
White shrimp – adlt	0.981	8, 7	20, **21**	34, **30**	39, **36**	0.115
Sheepshead	0.117	5, **8**	10, **17**	30, **28**	35, **33**	0.150
Gulf sturgeon	0.085	5	18	34	40	0.170
Atlantic croaker	0.145	12, **5**	21, **19**	25, **29**	28, **36**	0.140

[a] bold values are revised habitat factors

702

TABLE 3 Bioenergetics and Revised Habitat Parameters for Consumer Populations (Continued)

CASM Populations	Max Respiration (1/d)	Tr_o (°C)	Tr_m (°C)	Egestion (unitless)	Excretion (1/d)	Mortality (1/d)
Zooplankton	0.0500	34	39	0.025	0.06	0.15
Zoobenthos	0.0500	34	39	0.035	0.04	0.10
Blue crab – juv	0.0011	34	39	0.035	0.04	0.10
Brown shrimp - juv	0.0017	34	39	0.035	0.04	0.10
White shrimp – juv	0.0017	34	39	0.035	0.04	0.10
Spotted sea trout – juv	0.0011	34	40	0.158	0.025	0.0016
Red drum – juv	0.0006	34	40	0.128	0.025	0.0016
Bay anchovy	0.0005	34	40	0.104	0.068	0.00084
Gulf menhaden	0.0008	34	39	0.160	0.100	0.002
Striped mullet	0.0002	34	39	0.160	0.100	0.002
Spotted sea trout – adlt	0.0005	34	39	0.020	0.070	0.0003
Red drum – adlt	0.0002	34	39	0.018	0.058	0.0012
Oyster spat	0.0021	34	40	0.035	0.040	0.10
Oysters	0.0165	34	40	0.040	0.050	0.013
Blue crab – adlt	0.0005	34	40	0.040	0.040	0.004
Brown shrimp – adlt	0.0007	34	40	0.060	0.060	0.038
White shrimp – adlt	0.0007	34	40	0.040	0.070	0.00014
Sheepshead	0.0002	34	39	0.035	0.080	0.0007
Gulf sturgeon	0.0001	34	39	0.040	0.080	0.0007
Atlantic croaker	0.0005	34	39	0.000	0.000	0.000

703

TABLE 3 Bioenergetics and Revised Habitat Parameters for Consumer Populations (Continued)

CASM Populations	Dissolved oxygen tolerances (mg/L)				Salinity tolerances (PSU)			
	DOlt	DOol	DOou	DOut	PSUlt	PSUol	PSUou	PSUut
Zooplankton	1.0	6.0	50.0	80.0	0	0	0	0
Zoobenthos	1.0	6.0	50.0	80.0	0	0	0	0
Blue crab – juv	1.0	6.0	50.0	80.0	0, **0.1**	5, **6.1**	25, **14.8**	32, **34.4**
Brown shrimp - juv	1.0	6.0	50.0	80.0	0, **0.1**	3, **6.7**	26, **15.2**	34, **34.4**
White shrimp – juv	1.0	6.0	50.0	80.0	0, **0.5**	3, **7.5**	20, **15.5**	34, **34.4**
Spotted sea trout – juv	1.0	4.0	50.0	80.0	0, **0.5**	3, **6.0**	35, **12.7**	77, **25.2**
Red drum – juv	1.0	4.0	50.0	80.0	0, **4.5**	1, **7.1**	35, **10.7**	50, **17.0**
Bay anchovy	1.0	4.0	50.0	80.0	0, **0.2**	3, **6.1**	20, **13.8**	40, **34.4**
Gulf menhaden	1.0	4.0	50.0	80.0	0, **0.7**	3, **3.8**	20, **10.7**	40, **27.8**
Striped mullet	1.0	4.0	50.0	80.0	0, **1.3**	3, **3.7**	26, **10.4**	32, **17.2**
Spotted sea trout – adlt	2.0	8.0	50.0	80.0	10, **0.5**	20, **6.0**	35, **12.7**	77, **25.2**
Red drum – adlt	2.0	8.0	50.0	80.0	0, **4.5**	20, **7.1**	35, **10.7**	50, **17.0**
Oyster spat	1.0	4.0	50.0	80.0	2.0	10	17	24
Oysters	1.0	4.0	50.0	80.0	2.0	10	17	24
Blue crab – adlt	1.0	4.0	50.0	80.0	0, **0.1**	2, **6.1**	32, **14.8**	40, **34.4**
Brown shrimp – adlt	1.0	4.0	50.0	80.0	0, **0.1**	2, **6.7**	32, **15.2**	40, **34.4**
White shrimp – adlt	1.0	4.0	50.0	80.0	0, **0.5**	2, **7.5**	32, **15.5**	40, **34.4**
Sheepshead	2.0	4.0	50.0	80.0	0, **0.5**	5, **3.9**	10, **10.8**	25, **31.1**
Gulf sturgeon	2.0	4.0	50.0	80.0	0	5	10	25
Atlantic croaker	3.0	8.0	50.0	80.0	0, **0.1**	15, **5.2**	18, **13.2**	36, **34.4**

TABLE 3 Bioenergetics and Revised Habitat Parameters for Consumer Populations (Continued)

CASM Populations	Depth preferences (m)				Spawning rate (1/d)	Spawning temperatures (C)			
	Dlt	Dol	Dou	Dut	PSUlt	STlt	Stol	STou	STut
Zooplankton	-	-	-	-	-	-	-	-	-
Zoobenthos	-	-	-	-	-	-	-	-	-
Blue crab – juv	0.1	1.0	4.0	8.0	-	-	-	-	-
Brown shrimp - juv	0.1	1.0	4.0	18.0	-	-	-	-	-
White shrimp – juv	0.1	1.0	4.0	8.0	-	-	-	-	-
Spotted sea trout – juv	0.5	1.0	4.0	10.0	-	-	-	-	-
Red drum – juv	0.2	1.0	4.0	10.0	-	-	-	-	-
Bay anchovy	-	-	-	-	-	-	-	-	-
Gulf menhaden	0.5	18.0	50.0	90.0	-	-	-	-	-
Striped mullet	0.5	1.0	50.0	90.0	-	-	-	-	-
Spotted sea trout – adlt	0.5	1.0	4.0	5.0	0.05	7	16	33	45
Red drum – adlt	0.5	1.0	4.0	5.0	0.05	6	10	34	40
Oyster spat	0.5	1.0	4.0	12.0	-	-	-	-	-
Oysters	0.5	1.0	4.0	12.0	0.10	8	20	34	39
Blue crab – adlt	0.5	1.0	4.0	10.0	0.20	8	20	32	39
Brown shrimp – adlt	0.5	1.0	48.0	90.0	0.20	8	20	32	39
White shrimp – adlt	0.5	1.0	48.0	90.0	0.20	8	20	34	39
Sheepshead	0.5	1.0	50.0	90.0	-	-	-	-	-
Gulf sturgeon	0	1.0	50.0	90.0	-	-	-	-	-
Atlantic croaker	-	-	-	-	-	-	-	-	-

TABLE 3 Bioenergetics and Habitat Parameters for Consumer Populations (Continued)

CASM Populations	Spawning salinity (PSU)				Spawning/recruitment depth (m)			
	SSlt	SSol	SSou	SSut	SDlt	SDol	SDou	SDut
Zooplankton	-	-	-	-	-	-	-	-
Zoobenthos	-	-	-	-	-	-	-	-
Blue crab – juv	-	-	-	-	0.1	1.0	4.0	8.0
Brown shrimp - juv	-	-	-	-	0.1	1.0	4.0	18.0
White shrimp – juv	-	-	-	-	0.1	1.0	4.0	8.0
Spotted sea trout – juv	-	-	-	-	0.5	1.0	4.0	10.0
Red drum – juv	-	-	-	-	0.2	1.0	4.0	10.0
Bay anchovy	-	-	-	-	-	-	-	-
Gulf menhaden	-	-	-	-	-	-	-	-
Striped mullet	-	-	-	-	-	-	-	-
Spotted sea trout – adlt	10	20	35	77	0.5	1.0	4.0	5.0
Red drum – adlt	0	20	35	50	0.5	1.0	4.0	5.0
Oyster spat	-	-	-	-	-	-	-	-
Oysters	5	8	17	30	0.5	1.0	4.0	12.0
Blue crab – adlt	0	2	32	40	0.5	1.0	4.0	10.0
Brown shrimp – adlt	0	27	32	40	10.0	20.0	50.0	90.0
White shrimp – adlt	0	27	32	40	10.0	20.0	50.0	90.0
Sheepshead	-	-	-	-	-	-	-	-
Gulf sturgeon	-	-	-	-	-	-	-	-
Atlantic croaker	-	-	-	-	-	-	-	-

7006

TABLE 3 Bioenergetics and Habitat Parameters for Consumer Populations (Continued)

CASM Populations	Spawning months		Recruitment months	
	SMi	SMe	RMi	RMe
Zooplankton	-	-	-	-
Zoobenthos	-	-	-	-
Blue crab – juv	-	-	1	12
Brown shrimp – juv	-	-	1	4
White shrimp – juv	-	-	9	12
Spotted sea trout – juv	-	-	1	6
Red drum – juv	-	-	1	6
Bay anchovy	-	-	-	-
Gulf menhaden	-	-	-	-
Striped mullet	-	-	-	-
Spotted sea trout – adlt	3	9	-	-
Red drum – adlt	9	11	-	-
Oyster spat	-	-	1	12
Oysters	1	12	-	-
Blue crab – adlt	2	11	-	-
Brown shrimp – adlt	9	12	-	-
White shrimp – adlt	4	9	-	-
Sheepshead	-	-	-	-
Gulf sturgeon	-	-	-	-
Atlantic croaker	-	-	-	-

TABLE 4 Baseline Simulation of Plant Population Productivity ($gC/m^2/y$)

CASM MRGO	Phytoplankton			Periphyton		
Node	Diatoms	Chlorophytes	Cyanophytes	Diatoms	Chlorophytes	Cyanophytes
MRGO UNO 001	86.8	71.5	200.1	74.0	50.0	30.4
MRGO UNO 002	14.9	37.4	85.8	21.2	23.1	17.9
MRGO UNO 003	123.1	77.6	253.2	93.0	60.6	29.6
MRGO UNO 004	104.0	77.4	186.8	81.3	62.2	37.8
MRGO UNO 005	86.0	75.7	214.0	73.0	57.8	38.4
MRGO UNO 008	82.2	71.9	209.9	64.1	51.5	32.8
MRGO UNO 009	103.7	68.3	108.6	57.7	45.6	28.9
MRGO UNO 013	0.0	14.8	67.1	21.3	25.4	22.3
MRGO UNO 014	54.1	67.0	175.6	61.1	51.4	32.1
MRGO UNO 028	331.2	209.5	356.5	140.1	220.2	70.7
MRGO UNO 073	0.0	5.8	57.8	19.0	23.7	21.3
MRGO UNO 074	0.0	19.4	72.7	23.4	29.7	23.8
MRGO UNO 076	83.1	70.4	139.4	82.3	56.8	31.7
MRGO UNO 077	13.0	38.9	159.9	27.7	27.2	19.6
MRGO UNO 078	26.1	50.7	119.7	46.2	39.9	27.4
MRGO UNO 080	53.8	63.1	172.5	61.4	48.3	30.4
MRGO UNO 016	18.8	70.7	113.7	41.9	45.6	33.2
MRGO UNO 017	23.8	56.4	147.0	42.8	43.5	29.9
MRGO UNO 018	28.8	57.9	155.1	42.7	43.2	30.2
MRGO UNO 027	74.2	73.1	185.3	62.1	46.2	28.7
MRGO UNO 022	416.2	212.5	82.4	185.3	259.9	173.5
MRGO UNO 021	1,287.0	402.9	86.8	199.6	209.5	158.0
MRGO UNO 020	2,963.0	654.7	67.9	200.4	179.6	125.3

TABLE 4 Baseline Simulation of Plant Population Productivity ($gC/m^2/y$) (Continued)

CASM MRGO	Submerged aquatic vegetation (SAV)			
Node	Myriophyllum	Vallisneria	Halodule	Thalassia
MRGO UNO 001	20.1	94.9	0.0	0.0
MRGO UNO 002	0.0	0.0	0.0	0.0
MRGO UNO 003	33.9	171.3	0.0	0.0
MRGO UNO 004	178.2	21.1	0.0	0.0
MRGO UNO 005	208.4	2.3	0.0	0.0
MRGO UNO 008	162.6	0.0	0.0	0.7
MRGO UNO 009	224.4	0.0	0.0	0.0
MRGO UNO 013	0.5	9.5	0.0	0.0
MRGO UNO 014	0.0	0.0	10.3	63.8
MRGO UNO 028	0.0	0.0	20.3	112.4
MRGO UNO 073	0.0	4.7	0.0	0.0
MRGO UNO 074	0.0	0.0	0.0	0.5
MRGO UNO 076	7.9	30.1	2.9	13.7
MRGO UNO 077	0.0	0.7	2.6	16.9
MRGO UNO 078	0.0	0.5	2.5	10.6
MRGO UNO 080	0.0	0.0	9.8	63.3
MRGO UNO 016	0.0	0.0	3.4	33.8
MRGO UNO 017	0.0	0.0	6.2	47.8
MRGO UNO 018	0.0	0.0	7.5	66.8
MRGO UNO 027	0.0	2.0	9.3	53.1
MRGO UNO 022	0.0	0.0	0.0	0.0
MRGO UNO 021	0.0	0.0	0.0	0.0
MRGO UNO 020	0.0	0.0	0.0	0.0

709

TABLE 4 Baseline Simulation of Plant Population Productivity ($gC/m^2/y$) (Continued)

CASM MRGO	Emergent aquatic vegetation				
Node	Distichlis	Sagittaria	Phragmites	Juncus	Spartina
MRGO UNO 001	1,433	2,905	5,133	363	3,199
MRGO UNO 002	1,433	2,905	4,228	363	3,199
MRGO UNO 003	1,433	2,905	6,861	363	3,199
MRGO UNO 004	1,049	2,091	1,100	274	3,199
MRGO UNO 005	951	1,885	1,481	251	3,199
MRGO UNO 008	671	1,308	24,830	183	3,199
MRGO UNO 009	671	1,308	2,580	183	3,199
MRGO UNO 013	1,433	2,905	27,030	363	3,199
MRGO UNO 014	1,433	2,905	757	363	3,199
MRGO UNO 028	1,433	2,905	537	363	3,199
MRGO UNO 073	1,414	2,860	38,770	359	3,142
MRGO UNO 074	1,414	2,860	6,592	359	3,142
MRGO UNO 076	1,433	2,905	6,808	363	3,199
MRGO UNO 077	1,433	2,905	10,440	363	3,199
MRGO UNO 078	1,433	2,905	5,902	363	3,199
MRGO UNO 080	1,433	2,905	757	363	3,199
MRGO UNO 016	1,433	2,905	0	363	3,199
MRGO UNO 017	1,433	2,905	52	363	3,199
MRGO UNO 018	1,433	2,905	105	363	3,199
MRGO UNO 027	1,433	2,905	9,239	363	3,199
MRGO UNO 022	0	0	0	0	0
MRGO UNO 021	0	0	0	0	0
MRGO UNO 020	0	0	0	0	0

TABLE 5 Baseline Simulation of Consumer Population Productivity ($gC/m^2/y$)

CASM MRGO Node	Zoo-plankton	Zoo-benthos	Oyster spat	Oysters	Blue crab - imm	Brown shrimp - imm	White shrimp – imm	Blue crab - adult	Brown shrimp - adult	White shrimp – adult
MRGO UNO 001	109.7	240.3	17.7	164.1	9.3	3.0	5.4	106.0	33.7	95.6
MRGO UNO 002	95.8	81.9	14.3	33.6	5.5	3.7	4.4	305.6	66.0	173.8
MRGO UNO 003	31.9	31.8	2.6	12.5	1.6	0.8	1.4	43.5	12.7	53.3
MRGO UNO 004	27.2	23.4	0.7	4.0	0.2	0.1	0.1	36.7	6.0	42.9
MRGO UNO 005	26.6	22.3	1.4	5.2	0.2	0.1	0.2	42.6	8.9	47.7
MRGO UNO 008	26.0	24.2	34.1	47.4	0.2	0.3	0.2	55.1	17.3	83.2
MRGO UNO 009	24.5	26.5	3.6	16.3	0.0	0.0	0.0	52.5	9.6	64.9
MRGO UNO 013	139.6	633.9	17.0	37.8	87.8	13.5	17.1	39.5	1.3	41.6
MRGO UNO 014	76.0	212.0	66.9	103.3	3.9	2.2	4.4	129.1	43.3	132.9
MRGO UNO 028	73.4	52.2	111.7	169.8	2.0	1.4	2.4	235.0	59.6	150.0
MRGO UNO 073	176.1	460.1	12.3	28.6	100.1	61.1	82.9	233.2	0.2	31.4
MRGO UNO 074	124.8	445.4	74.3	125.4	11.7	9.4	12.0	86.1	6.6	69.6
MRGO UNO 076	76.3	196.8	64.2	121.4	5.8	4.4	6.5	122.4	32.9	115.4
MRGO UNO 077	130.0	300.9	66.1	110.4	7.8	6.0	8.9	128.7	28.5	111.4
MRGO UNO 078	106.1	404.0	94.4	125.8	0.0	0.0	0.0	115.9	31.8	113.4
MRGO UNO 080	74.6	210.8	66.0	101.6	3.9	2.2	4.3	127.1	42.3	131.4
MRGO UNO 016	224.9	238.8	5.5	14.5	1.4	1.2	2.1	68.6	12.6	73.9
MRGO UNO 017	122.8	131.5	46.6	50.7	0.5	0.4	0.7	185.5	38.4	126.4
MRGO UNO 018	124.3	149.4	28.6	40.9	0.9	0.5	1.2	103.3	15.3	90.4
MRGO UNO 027	75.9	186.8	66.9	237.5	7.6	4.6	7.7	131.9	50.9	140.6
MRGO UNO 022	73.9	60.3	0.0	0.0	0.0	0.0	0.0	0.0	4.6	115.3
MRGO UNO 021	293.0	59.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	89.3
MRGO UNO 020	470.3	63.3	0.0	0.0	0.0	0.0	0.0	0.0	4.7	124.9

711

TABLE 5 Baseline Simulation of Consumer Population Productivity ($gC/m^2/y$) (Continued)

CASM MRGO Node	Sea trout juvenile	Sea trout adult	Red drum-juvenile	Red drum – adult	Bay anchovy	Gulf menhaden	Sheeps head	Stripe mullet	Gulf sturgeon	Atlantic croaker
MRGO UNO 001	92.8	44.4	73.5	3.9	14.6	8.4	6.7	9.2	1.8	2.4
MRGO UNO 002	139.8	132.7	59.8	2.1	27.1	18.0	66.0	12.3	1.9	6.6
MRGO UNO 003	50.6	24.6	24.5	1.1	10.9	8.8	10.9	6.3	1.0	3.3
MRGO UNO 004	39.4	0.0	0.0	0.0	9.4	9.7	14.9	6.7	0.8	3.8
MRGO UNO 005	41.9	0.0	0.0	0.0	9.9	10.5	15.0	5.2	0.8	3.8
MRGO UNO 008	89.8	0.0	91.3	0.0	18.2	14.5	48.3	8.7	0.6	6.9
MRGO UNO 009	63.0	0.0	0.0	0.0	10.8	11.7	37.2	10.2	0.8	5.1
MRGO UNO 013	211.1	161.3	131.2	6.0	40.1	13.1	18.5	11.8	0.7	3.6
MRGO UNO 014	121.7	97.6	31.1	2.2	22.2	11.5	39.4	3.3	1.2	6.0
MRGO UNO 028	109.0	86.2	2.0	0.3	21.9	13.8	40.4	1.3	0.8	7.2
MRGO UNO 073	344.6	182.3	102.9	3.8	42.7	13.0	12.9	11.2	1.7	8.4
MRGO UNO 074	175.7	153.9	47.8	2.6	39.4	11.3	25.5	4.6	0.8	4.1
MRGO UNO 076	139.7	91.2	39.7	2.4	30.6	15.6	17.9	5.7	1.0	3.5
MRGO UNO 077	173.4	144.1	72.7	4.7	34.6	15.5	40.6	4.4	0.9	5.5
MRGO UNO 078	169.7	157.9	41.8	2.9	34.8	12.8	43.7	5.8	0.7	5.1
MRGO UNO 080	121.3	95.8	31.1	2.2	22.2	11.4	38.6	3.3	1.2	5.8
MRGO UNO 016	10.4	5.1	0.0	0.0	24.8	5.8	9.9	0.0	0.0	5.1
MRGO UNO 017	58.7	41.2	0.2	0.0	22.1	9.7	27.2	0.1	0.4	4.8
MRGO UNO 018	33.3	16.5	0.0	0.0	17.6	7.5	15.7	0.0	0.1	5.2
MRGO UNO 027	171.8	122.2	132.4	7.1	24.5	13.2	38.8	9.1	1.6	5.5
MRGO UNO 022	0.0	0.0	0.0	0.0	21.5	19.0	69.7	0.0	0.0	25.2
MRGO UNO 021	0.0	0.0	0.0	0.0	27.6	11.1	39.2	0.0	0.0	20.1
MRGO UNO 020	0.0	0.0	0.0	0.0	190.2	209.0	76.9	0.0	0.0	166.2

712

TABLE 6 Simulation of Plant Population Productivity ($gC/m^2/y$) for WQ1

CASM MRGO	Phytoplankton			Periphyton		
Node	Diatoms	Chlorophytes	Cyanophytes	Diatoms	Chlorophytes	Cyanophytes
MRGO UNO 001	87.2	71.2	199.7	73.9	50.1	30.5
MRGO UNO 002	15.3	37.6	82.4	21.0	23.0	17.9
MRGO UNO 003	123.6	77.9	247.5	93.1	60.8	29.9
MRGO UNO 004	106.8	81.4	143.6	81.4	64.3	41.3
MRGO UNO 005	87.8	77.5	178.4	73.0	59.7	41.5
MRGO UNO 008	84.9	75.8	189.5	65.0	53.0	34.6
MRGO UNO 009	103.4	68.7	99.3	57.6	46.2	30.0
MRGO UNO 013	0.0	15.8	66.8	22.5	26.6	23.8
MRGO UNO 014	61.8	72.3	174.9	59.6	49.7	30.2
MRGO UNO 028	340.4	209.6	338.1	149.1	242.1	80.2
MRGO UNO 073	0.0	6.2	60.8	19.1	24.1	21.8
MRGO UNO 074	0.0	16.9	69.8	24.0	29.5	23.5
MRGO UNO 076	85.4	73.8	182.1	84.0	56.3	31.1
MRGO UNO 077	9.6	36.9	173.1	28.6	27.0	19.0
MRGO UNO 078	25.6	48.4	104.6	46.7	40.1	27.6
MRGO UNO 080	60.5	70.2	173.3	59.2	45.8	27.7
MRGO UNO 016	15.2	60.2	127.8	42.2	45.4	31.8
MRGO UNO 017	22.4	53.2	148.3	42.0	42.2	28.0
MRGO UNO 018	25.2	54.4	153.7	42.4	42.7	29.2
MRGO UNO 027	71.8	72.9	189.5	60.3	44.4	27.1
MRGO UNO 022	415.1	213.3	82.4	186.0	260.2	173.6
MRGO UNO 021	1,286.0	402.8	86.8	199.7	209.6	158.1
MRGO UNO 020	2,963.0	655.0	67.9	200.1	178.9	125.1

713

TABLE 6 Simulation of Plant Population Productivity ($gC/m^2/y$) for WQ1 (Continued)

CASM MRGO	Submerged aquatic vegetation (SAV)			
Node	Myriophyllum	Vallisneria	Halodule	Thalassia
MRGO UNO 001	20.1	94.5	0.0	0.0
MRGO UNO 002	0.0	0.0	0.0	0.0
MRGO UNO 003	33.9	172.2	0.0	0.0
MRGO UNO 004	102.0	17.6	0.0	0.0
MRGO UNO 005	151.9	1.9	0.0	0.0
MRGO UNO 008	230.2	0.0	0.0	0.0
MRGO UNO 009	212.4	0.0	0.0	0.0
MRGO UNO 013	1.0	12.2	0.0	0.0
MRGO UNO 014	0.0	0.2	7.8	45.0
MRGO UNO 028	6.9	101.5	7.5	40.6
MRGO UNO 073	0.1	4.7	0.0	0.0
MRGO UNO 074	0.0	6.7	0.0	0.0
MRGO UNO 076	11.2	66.2	0.2	1.3
MRGO UNO 077	0.0	19.9	0.2	6.2
MRGO UNO 078	0.1	12.3	1.0	5.7
MRGO UNO 080	0.1	3.1	6.8	35.0
MRGO UNO 016	0.0	0.0	4.9	27.8
MRGO UNO 017	0.0	0.0	7.3	35.0
MRGO UNO 018	0.0	0.0	9.8	51.6
MRGO UNO 027	2.6	13.3	7.7	26.3
MRGO UNO 022	0.0	0.0	0.0	0.0
MRGO UNO 021	0.0	0.0	0.0	0.0
MRGO UNO 020	0.0	0.0	0.0	0.0

TABLE 6 Simulation of Plant Population Productivity ($gC/m^2/y$) for WQ1 (Continued)

CASM MRGO	Emergent aquatic vegetation				
Node	Distichlis	Sagittaria	Phragmites	Juncus	Spartina
MRGO UNO 001	1,433	2,905	3,965	363	3,199
MRGO UNO 002	1,433	2,905	3,029	363	3,199
MRGO UNO 003	1,433	2,905	4,387	363	3,199
MRGO UNO 004	1,049	2,091	360	274	3,199
MRGO UNO 005	951	1,885	505	251	3,199
MRGO UNO 008	671	1,308	2,859	183	3,199
MRGO UNO 009	671	1,308	443	183	3,199
MRGO UNO 013	1,433	2,905	29,260	363	3,199
MRGO UNO 014	1,433	2,905	3,955	363	3,199
MRGO UNO 028	1,433	2,905	7,568	363	3,199
MRGO UNO 073	1,414	2,860	30,050	359	3,142
MRGO UNO 074	1,414	2,860	16,280	359	3,142
MRGO UNO 076	1,433	2,905	10,740	363	3,199
MRGO UNO 077	1,433	2,905	26,890	363	3,199
MRGO UNO 078	1,433	2,905	12,410	363	3,199
MRGO UNO 080	1,433	2,905	5,931	363	3,199
MRGO UNO 016	1,433	2,905	53	363	3,199
MRGO UNO 017	1,433	2,905	755	363	3,199
MRGO UNO 018	1,433	2,905	774	363	3,199
MRGO UNO 027	1,433	2,905	17,110	363	3,199
MRGO UNO 022	0	0	0	0	0
MRGO UNO 021	0	0	0	0	0
MRGO UNO 020	0	0	0	0	0

TABLE 7 Simulation of Consumer Population Productivity ($gC/m^2/y$) for WQ1

CASM MRGO Node	Zoo-plankton	Zoo-benthos	Oyster spat	Oysters	Blue crab - imm	Brown shrimp - imm	White shrimp – imm	Blue crab - adult	Brown shrimp - adult	White shrimp – adult
MRGO UNO 001	112.4	228.6	14.4	130.4	8.6	2.8	4.9	108.4	32.2	91.1
MRGO UNO 002	95.7	82.5	11.0	27.3	4.5	2.9	3.4	297.2	62.6	166.4
MRGO UNO 003	31.7	32.1	2.0	10.2	1.5	0.7	1.2	42.7	12.0	49.9
MRGO UNO 004	33.3	27.8	0.2	0.9	0.1	0.03	0.01	28.8	4.8	32.8
MRGO UNO 005	31.6	25.2	0.5	2.0	0.1	0.03	0.03	33.6	7.4	38.4
MRGO UNO 008	23.1	19.0	3.7	15.4	0.0	0.04	0.05	43.6	7.1	51.2
MRGO UNO 009	24.2	26.9	0.0	0.0	0.0	0.00	0.00	27.9	4.5	38.2
MRGO UNO 013	141.8	640.8	12.3	28.5	99.9	13.4	17.0	34.8	0.3	38.0
MRGO UNO 014	80.2	196.9	83.0	174.8	5.5	3.4	6.1	151.0	52.6	150.1
MRGO UNO 028	92.8	159.0	132.3	237.4	5.1	3.9	5.7	223.4	87.3	189.1
MRGO UNO 073	161.9	356.3	10.1	25.5	79.2	54.5	75.2	222.6	0.2	29.8
MRGO UNO 074	140.4	601.5	47.2	88.7	22.7	12.7	15.6	66.1	4.4	58.2
MRGO UNO 076	99.1	233.7	21.3	52.4	8.5	7.1	9.6	108.8	43.6	107.7
MRGO UNO 077	179.7	540.4	60.2	101.3	11.7	9.2	13.0	109.2	24.0	98.3
MRGO UNO 078	120.4	504.5	73.2	98.3	0.0	0.0	0.0	94.4	24.9	100.3
MRGO UNO 080	85.5	218.9	81.1	161.3	5.8	3.9	6.5	147.3	51.8	146.8
MRGO UNO 016	150.0	188.4	56.2	78.5	2.5	2.3	3.5	96.0	16.9	86.4
MRGO UNO 017	97.4	213.9	85.3	116.6	1.0	0.8	1.2	183.7	54.2	148.9
MRGO UNO 018	93.1	105.9	50.4	72.3	2.1	1.3	2.5	153.5	23.5	108.8
MRGO UNO 027	93.8	242.7	66.1	184.3	8.9	5.5	8.7	133.2	49.4	133.4
MRGO UNO 022	73.2	60.3	0.0	0.0	0.0	0.0	0.0	0.0	6.2	121.0
MRGO UNO 021	293.2	59.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	88.9
MRGO UNO 020	477.4	63.3	0.0	0.0	0.0	0.0	0.0	0.0	4.1	123.5

716

TABLE 7 Simulation of Consumer Population Productivity ($gC/m^2/y$) for WQ1 (Continued)

CASM MRGO Node	Sea trout juvenile	Sea trout adult	Red drum-juvenile	Red drum – adult	Bay anchovy	Gulf menhaden	Sheeps Head	Stripe mullet	Gulf sturgeon	Atlantic croaker
MRGO UNO 001	87.8	40.0	56.5	2.7	14.2	8.2	5.8	8.8	1.7	2.5
MRGO UNO 002	126.3	119.9	6.2	0.7	25.2	17.5	59.7	11.8	1.9	6.3
MRGO UNO 003	41.6	19.4	14.4	0.8	10.0	7.8	8.0	5.7	0.9	2.9
MRGO UNO 004	18.3	0.0	0.0	0.0	7.9	5.0	6.0	3.0	0.6	3.0
MRGO UNO 005	22.7	0.0	0.0	0.0	8.4	5.8	7.3	2.9	0.6	3.1
MRGO UNO 008	53.5	0.0	0.0	0.0	10.6	11.8	30.4	7.7	0.7	4.8
MRGO UNO 009	24.1	0.0	0.0	0.0	6.8	7.4	11.0	1.1	0.5	3.1
MRGO UNO 013	210.5	156.6	133.5	5.9	39.5	13.2	16.7	12.7	0.7	3.4
MRGO UNO 014	153.7	123.8	59.5	3.7	25.7	13.3	47.6	4.5	1.4	6.3
MRGO UNO 028	167.7	132.9	65.7	3.4	32.9	21.4	60.6	5.7	1.2	7.6
MRGO UNO 073	334.0	175.6	95.7	3.7	41.8	13.0	12.3	11.1	1.7	8.3
MRGO UNO 074	194.6	162.2	79.6	4.3	41.3	12.0	22.1	6.4	0.8	4.1
MRGO UNO 076	130.4	82.3	73.9	3.8	23.6	11.9	12.8	7.5	1.1	3.4
MRGO UNO 077	212.9	168.0	159.6	11.6	35.6	15.6	40.8	7.4	1.0	5.6
MRGO UNO 078	184.2	161.4	74.1	4.4	36.5	13.6	35.6	8.4	0.7	4.6
MRGO UNO 080	157.2	125.8	59.6	3.7	27.6	14.6	50.4	5.0	1.3	6.3
MRGO UNO 016	58.3	38.2	0.0	0.0	28.4	10.2	17.9	0.0	0.4	4.5
MRGO UNO 017	132.2	113.1	26.1	1.9	27.2	12.0	43.9	3.1	0.9	5.8
MRGO UNO 018	80.0	49.8	0.1	0.0	21.0	10.5	24.0	0.3	0.5	4.8
MRGO UNO 027	186.2	122.7	154.8	8.0	28.7	16.2	39.0	10.9	1.2	5.1
MRGO UNO 022	0.0	0.0	0.0	0.0	22.7	22.4	77.6	0.0	0.0	27.4
MRGO UNO 021	0.0	0.0	0.0	0.0	27.5	10.7	38.7	0.0	0.0	19.9
MRGO UNO 020	0.0	0.0	0.0	0.0	185.3	199.3	75.1	0.0	0.0	157.5

TABLE 8 Simulation of Plant Population Productivity ($gC/m^2/y$) for WQ6

CASM MRGO	Phytoplankton			Periphyton		
Node	Diatoms	Chlorophytes	Cyanophytes	Diatoms	Chlorophytes	Cyanophytes
MRGO UNO 001	86.9	70.6	197.3	73.1	49.5	30.3
MRGO UNO 002	16.3	43.3	78.5	23.9	27.4	20.9
MRGO UNO 003	123.0	77.3	243.7	92.5	60.4	30.0
MRGO UNO 004	108.4	84.1	132.6	81.6	65.1	42.1
MRGO UNO 005	88.6	78.8	165.4	72.5	60.0	42.2
MRGO UNO 008	238.4	300.7	242.5	118.2	131.2	58.5
MRGO UNO 009	186.1	134.0	74.7	93.4	86.0	47.7
MRGO UNO 013	0.0	15.9	66.5	22.4	26.7	23.9
MRGO UNO 014	61.8	72.3	174.6	59.0	48.9	29.8
MRGO UNO 028	339.5	209.5	338.8	148.5	240.5	79.7
MRGO UNO 073	0.0	7.3	59.4	19.3	25.0	22.6
MRGO UNO 074	0.0	16.4	69.7	23.7	29.2	23.4
MRGO UNO 076	85.5	73.9	183.4	84.0	56.2	31.0
MRGO UNO 077	9.6	36.8	176.6	28.8	27.2	19.2
MRGO UNO 078	25.6	48.4	103.7	47.5	40.8	28.4
MRGO UNO 080	60.4	70.2	173.7	58.6	45.3	27.4
MRGO UNO 016	14.9	59.9	127.7	42.0	45.3	31.8
MRGO UNO 017	21.7	52.6	148.1	41.5	41.7	27.8
MRGO UNO 018	24.7	54.0	153.8	42.0	42.3	29.0
MRGO UNO 027	69.6	71.6	190.7	59.8	43.9	26.8
MRGO UNO 022	412.7	212.5	82.1	185.5	259.0	172.4
MRGO UNO 021	1,285.0	403.1	86.9	199.6	209.6	158.2
MRGO UNO 020	2,964.0	654.4	67.9	200.1	178.9	125.1

718

TABLE 8 Simulation of Plant Population Productivity ($gC/m^2/y$) for WQ6 (Continued)

CASM MRGO	Submerged aquatic vegetation (SAV)			
Node	Myriophyllum	Vallisneria	Halodule	Thalassia
MRGO UNO 001	18.2	93.7	0.0	0.0
MRGO UNO 002	0.0	0.0	0.0	0.0
MRGO UNO 003	33.3	172.4	0.0	0.0
MRGO UNO 004	75.8	14.6	0.0	0.0
MRGO UNO 005	126.1	1.6	0.0	0.0
MRGO UNO 008	209.4	0.0	0.0	0.0
MRGO UNO 009	87.2	0.0	0.0	0.0
MRGO UNO 013	1.2	12.3	0.0	0.0
MRGO UNO 014	0.0	0.6	7.5	42.6
MRGO UNO 028	7.2	102.7	7.5	39.6
MRGO UNO 073	0.1	5.0	0.0	0.0
MRGO UNO 074	0.0	6.8	0.0	0.0
MRGO UNO 076	12.2	68.1	0.1	1.0
MRGO UNO 077	0.0	23.3	0.2	5.6
MRGO UNO 078	0.1	16.1	0.5	4.1
MRGO UNO 080	0.1	4.2	6.6	33.0
MRGO UNO 016	0.0	0.0	4.9	27.6
MRGO UNO 017	0.0	0.0	7.4	34.5
MRGO UNO 018	0.0	0.0	10.1	50.5
MRGO UNO 027	3.4	14.9	6.6	24.7
MRGO UNO 022	0.0	0.0	0.0	0.0
MRGO UNO 021	0.0	0.0	0.0	0.0
MRGO UNO 020	0.0	0.0	0.0	0.0

719

TABLE 8 Simulation of Plant Population Productivity ($gC/m^2/y$) for WQ6 (Continued)

CASM MRGO	Emergent aquatic vegetation				
Node	Distichlis	Sagittaria	Phragmites	Juncus	Spartina
MRGO UNO 001	1,433	2,905	2,927	363	3,199
MRGO UNO 002	1,433	2,905	1,404	363	3,199
MRGO UNO 003	1,433	2,905	3,394	363	3,199
MRGO UNO 004	1,049	2,091	298	274	3,199
MRGO UNO 005	951	1,885	413	251	3,199
MRGO UNO 008	671	1,308	637	183	3,199
MRGO UNO 009	671	1,308	234	183	3,199
MRGO UNO 013	1,433	2,905	30,040	363	3,199
MRGO UNO 014	1,433	2,905	4,531	363	3,199
MRGO UNO 028	1,433	2,905	7,718	363	3,199
MRGO UNO 073	1,414	2,860	23,190	359	3,142
MRGO UNO 074	1,414	2,860	17,100	359	3,142
MRGO UNO 076	1,433	2,905	10,890	363	3,199
MRGO UNO 077	1,433	2,905	28,090	363	3,199
MRGO UNO 078	1,433	2,905	13,240	363	3,199
MRGO UNO 080	1,433	2,905	6,596	363	3,199
MRGO UNO 016	1,433	2,905	56	363	3,199
MRGO UNO 017	1,433	2,905	855	363	3,199
MRGO UNO 018	1,433	2,905	898	363	3,199
MRGO UNO 027	1,433	2,905	17,760	363	3,199
MRGO UNO 022	0	0	0	0	0
MRGO UNO 021	0	0	0	0	0
MRGO UNO 020	0	0	0	0	0

TABLE 9 Simulation of Consumer Population Productivity ($gC/m^2/y$) for WQ6

CASM MRGO Node	Zoo-plankton	Zoo-benthos	Oyster spat	Oysters	Blue crab - imm	Brown shrimp - imm	White shrimp – imm	Blue crab - adult	Brown shrimp - adult	White shrimp – adult
MRGO UNO 001	115.9	217.7	12.7	110.9	7.9	2.6	4.5	117.7	31.1	89.1
MRGO UNO 002	97.0	84.4	6.5	18.6	3.3	2.1	2.4	274.7	57.6	151.3
MRGO UNO 003	31.6	32.3	1.9	9.2	1.4	0.7	1.1	42.4	11.7	47.3
MRGO UNO 004	36.0	30.5	0.1	0.7	0.1	0.02	0.01	29.1	5.3	28.0
MRGO UNO 005	33.7	26.8	0.4	1.7	0.1	0.02	0.01	32.7	7.4	35.8
MRGO UNO 008	73.1	27.7	0.4	3.9	0.03	0.01	0.00	34.5	5.4	44.5
MRGO UNO 009	38.1	39.5	0.0	0.0	0.00	0.00	0.00	30.2	5.4	39.2
MRGO UNO 013	142.2	640.4	11.6	27.2	101.7	13.4	16.9	34.1	0.2	37.5
MRGO UNO 014	81.1	199.6	83.9	181.2	5.7	3.6	6.3	151.9	53.0	151.2
MRGO UNO 028	93.9	162.1	131.9	238.8	5.2	4.0	5.8	224.6	87.4	189.7
MRGO UNO 073	153.0	246.3	9.3	24.5	62.9	47.0	66.3	227.1	0.2	30.6
MRGO UNO 074	141.8	612.0	45.7	86.4	26.2	12.9	15.8	64.7	4.2	57.5
MRGO UNO 076	99.9	233.1	20.6	52.0	8.5	7.2	9.6	108.2	43.6	107.2
MRGO UNO 077	184.6	557.4	59.2	99.7	11.9	9.2	13.1	108.1	23.6	97.3
MRGO UNO 078	122.1	516.5	67.6	93.5	0.00	0.00	0.00	90.9	24.0	98.1
MRGO UNO 080	87.0	224.5	83.8	167.5	6.0	4.0	6.7	149.8	52.4	149.0
MRGO UNO 016	148.6	187.3	57.0	79.5	2.6	2.3	3.6	96.7	17.0	86.6
MRGO UNO 017	96.9	216.0	85.8	117.3	1.0	0.8	1.3	184.0	54.5	149.3
MRGO UNO 018	92.6	105.2	51.1	73.4	2.2	1.4	2.6	155.3	24.1	109.5
MRGO UNO 027	96.6	248.1	66.2	167.6	8.9	5.6	8.7	131.3	47.9	131.0
MRGO UNO 022	73.0	60.2	0.0	0.0	0.0	0.0	0.0	0.0	6.2	121.3
MRGO UNO 021	292.9	59.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	89.2
MRGO UNO 020	477.2	63.3	0.0	0.0	0.0	0.0	0.0	0.0	4.2	123.7

721

TABLE 9 Simulation of Consumer Population Productivity ($gC/m^2/y$) for WQ6 (Continued)

CASM MRGO Node	Sea trout juvenile	Sea trout adult	Red drum-juvenile	Red drum – adult	Bay anchovy	Gulf menhaden	Sheeps Head	Stripe mullet	Gulf sturgeon	Atlantic croaker
MRGO UNO 001	82.3	35.9	46.2	2.1	13.8	7.8	4.8	8.4	1.7	2.5
MRGO UNO 002	103.2	95.6	0.0	0.0	21.7	15.9	42.3	9.8	1.7	5.5
MRGO UNO 003	36.8	17.1	9.8	0.7	9.5	7.1	6.7	5.4	0.9	2.8
MRGO UNO 004	14.8	0.0	0.0	0.0	8.4	5.1	3.8	2.8	0.6	2.9
MRGO UNO 005	19.1	0.0	0.0	0.0	8.6	5.3	5.9	2.6	0.6	3.0
MRGO UNO 008	33.3	0.0	0.0	0.0	10.0	10.7	18.0	4.5	0.6	4.3
MRGO UNO 009	17.7	0.0	0.0	0.0	7.2	4.6	8.2	0.0	0.5	3.3
MRGO UNO 013	210.3	155.9	137.0	6.0	39.3	13.2	16.4	12.9	0.7	3.4
MRGO UNO 014	157.0	126.7	61.5	3.8	26.2	13.6	48.8	4.6	1.4	6.4
MRGO UNO 028	168.5	132.8	66.2	3.5	32.8	21.3	60.4	5.7	1.2	7.6
MRGO UNO 073	328.2	172.4	97.6	3.8	41.5	13.0	11.6	11.0	1.7	8.0
MRGO UNO 074	196.0	162.5	81.4	4.4	41.5	12.1	21.5	6.5	0.8	4.1
MRGO UNO 076	130.2	81.9	77.2	3.9	23.5	11.9	12.7	7.7	1.1	3.4
MRGO UNO 077	215.5	167.3	172.4	12.4	35.0	15.3	40.5	7.7	1.0	5.6
MRGO UNO 078	185.3	160.9	80.9	4.8	36.6	13.6	32.9	8.7	0.7	4.6
MRGO UNO 080	160.4	128.2	60.2	3.7	28.3	15.0	51.6	5.1	1.3	6.3
MRGO UNO 016	59.2	39.2	0.0	0.0	28.5	10.3	18.0	0.0	0.4	4.5
MRGO UNO 017	135.0	115.2	27.2	1.9	27.4	12.0	44.4	3.2	0.9	5.8
MRGO UNO 018	83.8	52.1	0.1	0.0	21.2	10.7	24.6	0.4	0.5	4.9
MRGO UNO 027	187.7	122.6	155.7	7.8	29.4	16.7	38.8	11.0	1.2	5.0
MRGO UNO 022	0.0	0.0	0.0	0.0	22.7	22.6	78.2	0.0	0.0	27.5
MRGO UNO 021	0.0	0.0	0.0	0.0	27.7	10.9	39.0	0.0	0.0	20.1
MRGO UNO 020	0.0	0.0	0.0	0.0	185.6	199.9	75.3	0.0	0.0	158.0

AQUATICS MODELING

Comprehensive Aquatic Systems Model (CASM

DESCRIPTION OF WORK TO BE PERFORMED

Conduct aquatic analysis, to include modeling, of potential impacts (i.e., risks) posed by a freshwater diversion to fisheries production (i.e., standing crop) within the freshwater area influenced by the diversion. Analysis must incorporate existing literature and data, hydrodynamic and WQ reports, applicable data from other existing diversion (as appropriate) and statistical analysis provided by LDWF.

The Contractor will utilize the Comprehensive Aquatic Systems Model (CASM) and methods to quantify potential impacts (i.e., risks) posed by a freshwater diversion to fisheries production (i.e., standing crop) within the freshwater area of influence.

The purpose of the assessment would be to:

1) Determine impacts of the freshwater diversion to fisheries productivity within the diversion area of influence

2) Determine if fisheries would be displaced and to what extent fisheries would be displaced in the receiving areas of the diversion to inform the NEPA document.

The aquatic assessment model will use the results from the MRGO hydrodynamic modeling effort (e.g., Mike21, FVCOM) to help determine the potential impacts. It is assumed that for each project alternative (including the no-action alternative) the hydrodynamic model will produce time series of current velocities and water elevations for selected locations near the outfall and extending throughout the influence area. Any other water quality parameters (e.g., temperature, dissolved oxygen, salinity, TSS) addressed by the hydrodynamic model will be examined for inclusion in the aquatic ecosystem model.

The aquatic ecosystem model will evaluate the likely impacts at the diversion outfall and to the furthest extent of the freshwater influence area. Impacts are defined as changes in production (e.g., biomass, standing crop) of the modeled species of interest compared to the no-action alternative. To the extent that uncertainties can be identified and quantified in the modeling, the impacts will be developed as probabilities (i.e., risks) of different magnitudes of change in population production. Modeling assumptions, data sources, and parameter estimation will be documented as part of the assessment.

The model will address potential project risks/impacts for approximately 18 species and their life stages selected on the basis of ecological, economical, and recreational importance in coastal LA wetlands (e.g., white and brown shrimp, catfish, large mouth bass and oysters). Impacts on species of interest will be assessed over the project planning time frame (50 y) for the modeled

alternatives, including the no-action alternative. The impacts of the with-project alternatives will be compared to the no-action alternative in assessing incremental effects. The modeled incremental effects on fisheries can then enter into the design of strategies to avoid, minimize, or mitigate these effects.

The aquatic assessment modeling and draft report would be complete no later than March 30, 2010

Louisiana Department of Wildlife and Fisheries

Statistical Analysis of Fisheries

MRGO/Violet Diversion Statistical Analyses Scope of Work

The contractor will collaborate with the USACE in the statistical analyses of fisheries-independent data collected by the Louisiana Department of Wildlife and Fisheries for the region influenced by the MRGO/Violet freshwater diversion projects. This effort is part of a larger project aiming to quantify the potential impacts of the freshwater diversion/s on fisheries production (i.e., standing crop biomass) and finfish-shellfish community structure (e.g., species/trophic guild composition).

The contractor will relate the physical-chemical (i.e., water quality) and habitat (e.g., water flow, elevation) changes caused by the diversion/s to responses in the distribution, abundance and/or biomass of 15 commercially and recreationally important species in the region (e.g., brown and white shrimp, blue crab, oysters, red drum, spotted seatrout), as well as to the overall finfish-shellfish community structure of the region. A suite of statistical methods and models that relate the diversion effects to population and community responses will be constructed and evaluated using all available data, including but not limited to: simple and multiple linear and nonlinear regression, multivariate analysis of variance or multi-response permutation procedures, canonical correspondence analysis, and spatial characterization and correlation of species distributions to fine-scale water quality measurements taken within the region. The multivariate analyses will assess how species composition and/or trophic structure is influenced by diversion-induced fluctuations in habitat and water quality. The regression models will evaluate the functional relationships between the species population responses and water quality changes. Geospatial maps of species distributions and abundance changes will be developed from a geographic information system (GIS) which will illustrate region-wide spatial and temporal shifts in species abundances as a function of diversion-related changes in water quality, flow and elevation.

Results from the modeling and statistical analyses will describe functional relationships among the population dynamics and physical-chemical changes caused by freshwater diversion. These results will then be used to 1) inform the aquatic models for the region (e.g., Comprehensive Aquatic Systems Model (CASM) and EcoPath with EcoSim), 2) provide quantitative estimates for the aquatic model calibration and results comparison, and 3) allow scientists and managers to make predictions regarding the current diversion operation and the effects of alternative operations. Finally, the analyses will help scientists identify important information gaps in the field data. Consequently, the contractor will be able to provide recommendations to managers for sampling efforts that would more effectively monitor diversion impacts to the region.

Consumer Species	REVISED 1/21/2010
eastern oyster	**x with oyster spat**
brown shrimp	X
white shrimp	X
blue crab	X
grass shrimp	**OUT**
spotted seatrout	X
red drum	X
atlantic croaker	**X**
bay anchovy	**X**
sea catfish	
sand seatrout	
striped mullet	**X**
gulf menhaden	**one stage**
southern flounder	
black drum	**OUT**
sheepshead	**X**
largemouth bass	**OUT**
blue catfish	
channel catfish	
redear sunfish	
gulf sturgeon	**X**
gulf killifish	**OUT**
diammond killifish	**OUT**
spot	**OUT**

X	juvenile and adult life stages	(inshore/offshore)

APPENDIX J

MRGO ECOSYSTEM RESTORATION FEASIBILITY STUDY

CHANDELEUR AND BRETON ISLANDS

Prepared for:

URS Group

And

U.S. Army Corps of Engineers
New Orleans District

Prepared by:

Coastal Planning & Engineering, Inc.[1]
2481 NW Boca Raton Blvd, Boca Raton, FL

and

Pontchartrain Institute for Environmental Sciences, University of New Orleans[2]
2000 Lakeshore Drive, New Orleans, LA





Gordon Thomson, P.E.[1]
Michael Miner, Ph.D.[2]
Andrew Wycklendt, M.Sc.[1]
Michelle Rees, M.Sc.[1]
David Swigler, M.Sc.[1]

Recommended Citation: Thomson, G., Miner, M., Wycklendt, A., Rees, M. Swigler, D., 2010. *MRGO Ecosystem Restoration Feasibility Study – Chandeleur and Breton Islands*. Boca Raton, Florida: Coastal Planning & Engineering, Inc. 122p. (Report prepared for USACE under contract to URS)

December 2009
Rev May 2010

MRGO ECOSYSTEM RESTORATION FEASIBILITY STUDY CHANDELEUR AND BRETON ISLANDS

EXECUTIVE SUMMARY

Along the Chandeleur Islands, Louisiana, a net loss of barrier island sand to deepwater, downdrift sinks and offshore dredge disposal sites has resulted in a reduction of total island area from 17.2 mi^2 in 1855 to 1.8 mi^2 in 2005. Increased hurricane intensity and frequency in the northern Gulf of Mexico during the past decade has accelerated this land loss trend, forcing the Chandeleur Islands into a mode of rapid dissection and transgressive submergence (conversion from emergent barrier islands to submerged shoals). Based on extrapolated historical land loss and shoreface retreat rates, the islands will be completely converted to a system of submerged shoals within approximately 25 years. This 50-mile long barrier arc plays a crucial role in: 1) attenuating storm impacts for mainland Louisiana and Mississippi (Stone et al. 2004; 2005), 2) regulating conditions for a 4,650 mi^2 estuary (including salinity gradients, circulation patterns, nutrient retention and distribution, and magnitude of wave and tidal energy; Reyes et al., 2005); 3) supporting a $2.7 billion fisheries industry (Fearnley et al., 2009), and 4) providing unique habitat for threatened and endangered species including nesting sea turtles, brown pelicans, piping plovers, and least terns (Lavoie et al., 2009; Poirrier and Handley 2007).

The Chandeleurs were produced by marine reworking of seaward portions of abandoned Mississippi River delta lobes beginning approximately 1,800 years ago; a process dominated by lateral spit accretion downdrift from a central deltaic headland sediment source. Lateral transport along the Chandeleurs has produced up to a 33-foot thick spit platform deposits and a series of relict recurved spits that today are overlain by back barrier marsh. During island landward retreat (~50 feet/year for 1855-2008), sands from the subsurface relict spit deposits are liberated in the nearshore providing a local sand source to the active littoral system. Where barrier marshes overlie relict deltaic or lagoonal muds instead of relict sandy spits, shorelines are sand-starved and island disintegration rates are highest. During the past 125 years ~400M cubic yards of sand has accumulated in deepwater sinks at the flanks of the barrier island arc; twice as much as deposited in the back barrier. In contrast to popular transgressive barrier island models, no new back barrier marshes have formed during the last century, so that the loss of sediment to flanking sinks has forced the long-term reduction in island area.

The long-term reduction in barrier island sand volume (a trend that was greatly accelerated by Hurricane Katrina) inhibits the islands from maintaining exposure by means of landward transfer of sand by overwash processes and subsequent colonization of overwash deposits by back barrier marsh vegetation. During the past two decades, landward transfer of sand has been limited to post-storm recovery periods and is facilitated by: (1) landward migration of offshore bars that weld to marsh islets, (2) recurved spit formation at hurricane-cut inlets, (3) aeolian processes constructing dunes wind tidal flats, and (4) shoal aggradation and landward migration. In their present state, the islands are sediment-starved and these recovery processes appear to have exhausted most of the available sand supply, limiting further recovery.

This study proposes a barrier island management strategy that aims to replicate the natural processes of island development by: (1) reintroducing sand at updrift back barrier feeder sites, (2) using shoreface retreat to liberate sand from feeder sites into the littoral system for lateral distribution over the long-term, and (3) establishing salt marshes upon back barrier sand placement sites. This comprehensive plan derives from extensive studies on long term geomorphic evolution and short term changes—driven primarily by loss of sand from the barrier system, rapid relative sea level rise, and hurricanes—to provide the barrier system the means to be sustainable for generations.

It is proposed to construct eight shore-perpendicular back-barrier sand reserve feeder sites and a shore parallel beach berm along the Chandeleur Islands. The sand reserve feeder site will vary from approximately 800 to 1,400 feet long (shore-parallel) and 1,800 to 5,500 feet wide (shore perpendicular). The feeder sites will be constructed to an elevation of +2 feet, NAVD resulting in a fill volume of approximately 4.9M cubic yards of sand. The 7-mile long beach berm will be constructed to an elevation of +3 feet, NAVD and be approximately 500 feet wide. The beach berm will contain approximately 3.8M cubic yards of sand.

Five alternatives were considered for Breton Island encompassing a variety of costs and construction concepts.

1. Alternative 1 is a 4-mile long, crescent shaped beach berm with a crest width of approximately 1,000 feet at an elevation of +4 feet, NAVD. A backing marsh is proposed that will have a maximum width of approximately 3,700 feet wide at an elevation of +2 feet, NAVD.
2. Alternative 2 is also 4 miles long but the beach dune is higher than Alternative 1 with a +6 feet, NAVD crest though the dune crest is narrower at 750 feet wide. Alternative 2 has a 500-foot long spit feature at the northwest end. Alternative 2 does not have a marsh.
3. Alternative 3 was designed to minimize pumping distance and thus cost. It includes a 1,000 foot wide platform at +10 feet NAVD at the northern end of the island. The fill then slopes at 1V:300H to the south-southwest.
4. Alternative 4 is similar to Alternative 2 except that a 2,400-foot long terminal groin has been added to the southwest end of the fill. This limits longshore losses from the island and thus provides increased project benefits.
5. Alternative 5 considered filling in portions of the MRGO Channel and Breton Island Pass in order to promote sediment bypassing from Grand Gosier Shoal to Breton Island.

A sediment budget was developed for Breton and Chandeleur Islands that separated losses into longshore, overwash, offshore and losses due to relative sea level rise. The sediment budget was applied through an analytic model to estimate project performance under Future Without Project (FWOP) and Future With Project (FWP) conditions. Project performance was based on the Wetland Value Assessment (WVA) barrier island community methodology (EWG, 2002)

The model suggested that under FWOP conditions, all subaerial acreage will be lost by TY28 along the Chandeleur Islands. It is estimated that FWOP provides 828 Average Annual Habitat Units (AAHUs).

Under FWP conditions on the Chandeleur Islands, subaerial acreage will be completely lost by TY48. It is estimated that FWP will provide 2,292 AAHUs for a net benefit of 1,464 AAHUs. The expected construction cost for the Chandeleur Islands project is $119,568,000, which includes a 25% contingency. The most cost effective borrow source for the Chandeleur Islands alternative is Hewes Point. Table 1 summaries the benefits and cost of the various alternatives.

Table 1. Summary of Alternative Benefits and Costs

Alternative	Fill Volume (cy)	Cost Estimate	Net Benefits (AAHU's)	Cost per AAHU ($/AAHU)
Chandeleur Islands	8,720,000	$119,568,000	1,464	$81,672
Breton Island 1	20,040,000	$178,486,000	195	$915,313
Breton Island 2	9,657,000	$88,450,000	49	$1,807,435
Breton Island 3	7,255,000	$61,038,000	67	$908,645
Breton Island 4	9,382,000	$100,279,000	70	$1,428,307
Breton Island 5	12,321,000	$83,631,000	0	-

No subaerial acreage is estimated to remain at Breton Island by TY0. Since the FWOP condition provides no AAHUs, the total and net benefits for each of the five alternatives are directly dependent on the acreage created during construction. Breton Island Alternative 1 provides subaerial acreage through TY19. Alternative 2 provides subaerial acreage through TY11, Alternative 3 through TY20, and Alternative 4 through TY24. Alternative 5 does not provide subaerial acreage at any time during its project life. The preferred borrow source would be the MRGO Ocean Dredged Material Disposal Site (ODMDS).

The type of benefits provided by reconstructing either the Chandeleur Islands or Breton Island alternatives can be considered identical as they provide similar habitat (supratidal, gulf intertidal, bay intertidal, and subtidal) along barrier island shorelines that are geographically close.

The Chandeleur Islands option is the recommended alternative because it has the lowest cost per AAHU and provides similar habitat benefits as those on Breton Island. Breton Island Alternative 1 is the recommended alternative if restoration at Breton Island is deemed preferable. Alternative 1 is recommended because it provides the greatest number of AAHU's, the cost per AAHU is within 1% of the most cost effective alternative, it provides the greatest volume of fill, and it has the lowest degree of uncertainty of the five Breton Island alternatives. If the high cost of Breton Island Alternative 1 requires another alternative be selected, it is recommended that Alternative 3 be considered. Alternative 3 has the least cost per AAHU of Breton Island alternatives. Alternative 5 is not recommended as it provides no quantifiable benefits.

MRGO ECOSYSTEM RESTORATION
FEASIBILITY STUDY
CHANDELEUR AND BRETON ISLANDS

Table of Contents

1 INTRODUCTION 1
2 AUTHORIZATION 1
3 PURPOSE AND SCOPE 2
4 PROJECT LOCATION 2
5 GEOMORPHIC EVOLUTION 4
5.1 Deltaic Abandonment and Early Island Evolution 4
5.2 Chandeleur Islands Barrier System Morphology and Historical (1855-2005) Evolution 7
5.3 Role of Tidal Inlets 10
5.4 Back Barrier Platform and Submerged Aquatic Vegetation 12
5.5 Spits 13
5.6 Barrier Shoals 16
5.7 The Role of Hurricanes 16
5.8 Sediment Dynamics 19
5.9 Hurricane Katrina Recovery 21
5.10 Implications for Island Management 26
6 HISTORIC DATA 27
6.1 Survey Data 27
6.2 Nourishment History 28
7 SUBSIDENCE AND SEA LEVEL RISE 30
7.1 National Research Council 30
8 SHORELINE CHANGES 32
8.1 Historic Shoreline Changes 36
8.1.1 Historic Gulf Shoreline Changes 36
8.1.2 Historic Bay Shoreline Changes 38
8.2 Recent Shoreline Changes 40
8.2.1 Recent Gulf Shoreline Changes 41
8.2.2 Recent Bay Shoreline Changes 43
8.3 Shoreline Response to Relative Sea Level Rise 45
9 ACTIVE PROFILE HEIGHT 47
10 VOLUME CHANGES 48
11 SEDIMENT BUDGET 52
11.1 Island Composition 53
11.2 Relative Sea Level Rise 56

11.3 Overwash 56
11.4 Longshore Transport 57

12 CONCEPTUAL RESTORATION DESIGN 62
12.1 Chandeleur Islands 62
12.2 Breton Island 66
12.2.1 Breton Island Alternative 1 66
12.2.2 Breton Island Alternative 2 70
12.2.3 Breton Island Alternative 3 72
12.2.4 Breton Island Alternative 4 75
12.2.5 Breton Island Alternative 5 78

13 PROJECT PERFORMANCE 81
13.1 Wetland Value Assessment 81
13.2 Analytic Model of Habitat Acreage Change 87
13.2.1 Longshore Losses 87
13.2.2 Relative Sea Level Rise Losses 87
13.2.3 Overwash 88
13.2.4 Offshore Losses 88
13.3 Other Processes and Assumptions 89
13.4 Chandeleur Islands 89
13.4.1 Chandeleur Islands FWOP 89
13.4.2 Chandeleur Islands FWP 91
13.5 Breton Island 93
13.5.1 Breton Island FWOP 93
13.5.2 Breton Island Alternative 1 94
13.5.3 Breton Island Alternative 2 95
13.5.4 Breton Island Alternative 3 97
13.5.5 Breton Island Alternative 4 99
13.5.6 Breton Island Alternative 5 101

14 BORROW AREAS 102
14.1 Hewes Point Borrow Area 104
14.2 St. Bernard Shoals 104
14.3 MRGO Ocean Dredge Material Disposal Site 104
14.4 South of Breton Island 105

15 CONSTRUCTION COST ESTIMATE 105
15.1 Mobilization Cost 105
15.2 Beach Fill Dredging Unit Costs 107
15.3 Marsh Fill Dredging Unit Costs 108
15.4 Terminal Groin Cost 108
15.5 Other Costs 108
15.6 Cost Estimates 109

16 RISK AND UNCERTAINTY 110
16.1 Hydrodynamic Forces 111
16.2 Relative Sea Level Rise 111
16.3 Planform and Cross-section 112

16.4 Island Composition 112
16.5 Performance Prediction Methodology 113
17 SUMMARY 113
18 RECOMMENDATIONS 114
19 REFERENCES 116

List of Figures

Figure 1. Chandeleur Islands study area with bathymetry 3
Figure 2. Map of the Holocene Mississippi River delta plain. 4
Figure 3. Three-stage model conceived by Penland et al. (1988) for the formation and evolution of transgressive Mississippi River delta barrier islands. 5
Figure 4. Geologic cross-section trending along the northern Chandeleur island arc from the Hewes Point spit platform in the north to Monkey Bayou in the south 6
Figure 5. Map of BICM seafloor change analysis results showing zones of sediment erosion and accretion for 1870-2007.. 8
Figure 6. Conceptual model for transgressive submergence of the Chandeleur Islands. 10
Figure 7. Map showing 1870s bathymetry and island positions for the southernmost Chandeleur Islands. 11
Figure 8. 2007 bathymetric map of the southern Chandeleur Islands 12
Figure 9. Oblique aerial photograph of Monkey Bayou in the southern Chandeleurs. 14
Figure 10. Conceptual model for inlet fill development from lateral spit accretion 14
Figure 11. Oblique 1996 aerial photograph of Hewes Point terminal spit. 15
Figure 12. Bathymetric profiles for three time periods that trend north from the back barrier across Hewes Point and into the inlet north of the Chandeleur Islands. 15
Figure 13. Digital elevation models of bathymetric surfaces for two time periods (1870s – blue; 2006 – red) shown in the same space 16
Figure 14. Northern island area and trend lines for the two time periods 1855 to 1996 and 1989 to 2005 differentiated based on storm impact frequency at the Chandeleur Islands.. 18
Figure 15. Average island area change associated with storm impacts for the southern Chandeleur Islands 19
Figure 16. Locations along the Chandeleur Islands where longshore transport calculations were performed by Georgiou and Schindler (2009) and Potential net longshore transport as a function of differing forcings based on long term 1985 to 2006 wind records 20
Figure 17. Time series of oblique aerial photographs facing west that demonstrate the impacts of Katrina and the continued shoreline erosion for 1.5 years after storm impact 22
Figure 18. Oblique aerial photograph view to the north of the sand-rich northern Chandeleur islands 23
Figure 19. Dunes accreting around Roseau cane and black mangroves in the northern Chandeleur Islands. 24
Figure 20. Shell dominated beaches of the southern Chandeleur islands. 25

Figure 21. Bathymetric and Topographic Map....29
Figure 22. Sea Level Rise Estimates following USACE Guidance....31
Figure 23. Linearized Relative Sea Level Rise Estimates....32
Figure 24. Chandeleur Islands Shoreline Location Map (1855 to 2004)....34
Figure 25. Breton Island Shoreline Location Map....35
Figure 26. Historic Gulf Shoreline Changes along the Chandeleur Islands....37
Figure 27. Historic Gulf Shoreline Changes along Breton Island....38
Figure 28. Historic Bay Shoreline Changes along the Chandeleur Islands....39
Figure 29. Historic Bay Shoreline Changes along Breton Island....40
Figure 30. Recent Gulf Shoreline Changes along the Chandeleur Islands....42
Figure 31. Recent Gulf Shoreline Changes along Breton Island....43
Figure 32. Recent Bay Shoreline Changes along the Chandeleur Islands....44
Figure 33. Recent Bay Shoreline Changes along Breton Island....45
Figure 34. Impact of Sea Level Rise on Shoreline Recession....46
Figure 35. Profile Comparison along USGS Transect N-30....48
Figure 36. Longshore Sediment Transport Curve for the Chandeleur Islands (1996 to 2004)....58
Figure 37. Longshore Sediment Transport Curve for Breton Island (1996 to 2004)....59
Figure 38. Chandeleur Islands Sediment Budget for the 1996 to 2004 Time Period....60
Figure 39. Breton Island Sediment Budget for the 1996 to 2004 Time Period....61
Figure 40. Location of Berm and Back Barrier Feeder Sites for Chandeleur and Breton Islands....63
Figure 41. Cross-section of Berm and Back-Barrier Berm Reserve Feeder Site for Chandeleur Islands....64
Figure 42. Marsh Settlement Curves....65
Figure 43. Location of Berm and Back Barrier Feeder Sites for the various Breton Island Alternatives....67
Figure 44. Cross-Section of Beach and Backing Marsh for Breton Island....68
Figure 45. Equilibrium Beach Profile for Breton Island....70
Figure 46: Cross-Section of Breton Island Alternatives 2 and 4....71
Figure 47: Cross-Section of Beach for Alternative 3 from east to west....73
Figure 48: Cross-Section of Beach for Alternative 3 from north to south....74
Figure 49. Fillet Growth due to Terminal Groin....77
Figure 50. Breton Island and Breton Pass Bathymetry Plot and Bathymetric Change Comparison within the MRGO....80
Figure 51. WVA Boundary for Chandeleur Islands....82
Figure 52. WVA Boundary for Breton Island....83
Figure 53. Borrow Area Location Map....103

List of Tables

Table 1. Summary of Alternative Benefits and Costs....iii
Table 2. Sediment erosion/accretion volumetric change results for geomorphic zones presented in Figure 5....9
Table 3. Summary of Available Survey and Shoreline Data....27
Table 4. Summary of Nourishment History along Breton Island....28

Table 5. Relative Sea Level Rise Summary....32
Table 6. Historic Shoreline Changes along the Chandeleur Islands....36
Table 7. Historic Shoreline Changes along Breton Island....36
Table 8. Recent (1996-2004) Shoreline Changes along the Chandeleur Islands and Breton Island....41
Table 9. Shoreline Response to Relative Sea Level Rise....47
Table 10. Volume Changes along the Chandeleur Islands....50
Table 11. Volume Changes along Breton Island....52
Table 12. Shoreline Changes Resulting from MRGO Beneficial Disposal....52
Table 13. Sediment Budget along the Chandeleur Islands (1996-2004)....54
Table 14. Sediment Budget along Breton Island (1996-2004)....56
Table 15. Habitat Description (after Williams and Sweeney, 2005)....84
Table 16. Planform Performance Projection for Chandeleur Islands FWOP....90
Table 17. Barrier Island WVA Benefits for Chandeleur Islands FWOP....91
Table 18. Planform Performance Projection for Chandeleur Islands FWP....92
Table 19. Barrier Island WVA Benefits for Chandeleur Islands FWP....93
Table 20. Planform Performance Projection for Breton Island FWOP....93
Table 21. Barrier Island WVA Benefits for Breton Island FWOP....94
Table 22. Planform Performance Projection for Breton Island Alternative 1....94
Table 23. Barrier Island WVA Benefits for Breton Island Alternative 1....95
Table 24. Planform Performance Projection for Breton Island Alternative 2....96
Table 25. Barrier Island WVA Benefits for Breton Island Alternative 2....97
Table 26. Planform Performance Projection for Breton Island Alternative 3....98
Table 27. Barrier Island WVA Benefits for Breton Island Alternative 3....99
Table 28. Planform Performance Projection for Breton Island Alternative 4....100
Table 29. Barrier Island WVA Benefits for Breton Island Alternative 4....101
Table 30. Planform Performance Projection for Breton Island Alternative 5....102
Table 31. Barrier Island WVA Benefits for Breton Island Alternative 5....102
Table 32. Summary of Borrow Area Grain Size, Silt Content and Volumes....102
Table 33. Hopper Dredge Mobilization Cost Estimate....106
Table 34. Cutterhead Dredge Mobilization Cost Estimate....106
Table 35. Beach Fill Unit Cost Summary using a $3.75 Marine Diesel Price....107
Table 36. Beach Fill Unit Cost Summary for Breton Island Alternatives....107
Table 37. Construction Cost Estimate for the Alternative 4 Terminal Groin....108
Table 38. Construction Cost Estimate for the Chandeleur Islands Alternative....109
Table 39. Construction Cost Estimate for the Breton Island Alternative 1....109
Table 40. Construction Cost Estimate for the Breton Island Alternative 2....109
Table 41. Construction Cost Estimate for the Breton Island Alternative 3....110
Table 42. Construction Cost Estimate for the Breton Island Alternative 4....110
Table 43. Construction Cost Estimate for the Breton Island Alternative 5....110

List of Appendices

Appendix A	Analytic Model and WVA Acreages
Appendix B	Unit Cost Estimates
Appendix C	SBEACH Modeling

1 INTRODUCTION

The Mississippi River Gulf Outlet (MRGO) Ecosystem Restoration Plan is being developed by the U.S. Army Corps of Engineers (USACE), New Orleans District as a supplement to the MRGO Deep-Draft De-Authorization Report. The USACE is conducting a Feasibility Study that will result in a comprehensive ecosystem restoration plan to restore the Lake Borgne ecosystem and areas affected by the MRGO channel. This restoration plan is being developed in accordance with Section 7013 of the Water Resources Development Act (WRDA) of 2007. It is fully funded by the Federal government. The purpose of the study is to address systematic ecosystem restoration with consideration of measures to reduce or prevent damages from storm surge.

This report is designed to synthesize earlier findings and provide a basis for planning and designing a management scheme for the Chandeleur Islands and Breton Island associated with the MRGO Ecosystem Restoration Plan and Feasibility Study. The intent is to present a background summary of the morphology and physical processes governing the evolution of the Chandeleur and Breton Islands, which is then applied to develop a barrier island management plan. The restoration plan is designed to employ the physical processes that led to the initial development of the islands by reintroducing sand that has been lost to downdrift, deepwater sinks back into the central portion of the islands for natural reintroduction to the littoral system during island retreat. In this way, the natural processes of island development will be mimicked so that spits will laterally accrete to close inlets, expand emergent back barrier marsh area, and increase dune elevations.

Much of this background report is based on findings presented in *Sand Resources, Regional Geology, and Coastal Processes of the Chandeleur Islands Coastal System — an Evaluation of the Resilience of the Breton National Wildlife Refuge* (Lavoie, 2009), a study conducted by the U.S. Geological Survey (USGS) and the University of New Orleans-Pontchartrain Institute for Environmental Sciences (UNO-PIES) and funded by the U.S. Fish and Wildlife Service. A significant component of this synthesis also includes data collected under the Barrier Island Comprehensive Monitoring program (BICM), a Louisiana Coastal Area Science and Technology Program (LCA S&T)-funded study implemented by the Louisiana Office of Coastal Protection and Restoration (OCPR) and conducted by UNO-PIES and USGS. Subsequent to these two efforts additional data included in this report was collected under an ongoing study by UNO-PIES and USGS funded through the USGS Northern Gulf of Mexico Ecosystem Change and Hazard Susceptibility Project (NGOM).

This report discusses plans, benefits and costs for ecosystem restoration along the Chandeleur Islands and Breton Island as part of the larger MRGO Ecosystem Restoration Plan.

2 AUTHORIZATION

The restoration plan is being developed in accordance with Section 7013 of WRDA 2007. Coastal Planning & Engineering, Inc (CPE) conducted the work in this report under a contract with URS Corporation, which has a direct contract with USACE, New Orleans District

(W912P8-09-D-0007). Pontchartrain Institute for Environmental Sciences was a sub-consultant to CPE.

3 PURPOSE AND SCOPE

This report provides technical information and an engineering assessment of the existing conditions at the Chandeleur Islands and Breton Island. The report will be used to support the Feasibility Report of the Mississippi River Gulf Outlet (MRGO) Ecosystem Restoration Plan. Project benefits are evaluated over a 50-year period using the Wetlands Value Assessment (WVA) methodology. No additional data was collected as part of this work. This study evaluates historic shoreline retreat rates, sediment patterns and geomorphic evolution to develop a sediment budget that accounts for losses due to longshore transport, relative sea level rise, silt release and overwash. The sediment budget in association with cross-shore modeling is used to predict project performance.

4 PROJECT LOCATION

The Chandeleur Islands are composed of an 50-mile long arcuate-shaped barrier island chain located in southeast Louisiana on the north-central coast of the Gulf of Mexico and are separated from the Louisiana mainland wetlands by the ~15-25 mile wide Breton and Chandeleur Sound where depths average 10 to 15 feet. They are the oldest transgressive barrier island arc in the Mississippi River delta plain system. The island chain is composed of the northern island arc that extends from Hewes Point in the north to Monkey Bayou in the south, a series of ephemeral barrier islands (Curlew and Grand Gosier) south of Monkey Bayou, and Breton Island, the southernmost island in the chain (Figure 1). These islands are extremely dynamic, but in their present state they are characterized by a relatively sand-rich northern section (north of Redfish Point) and a sand-starved southern section that extends south to Breton Island.

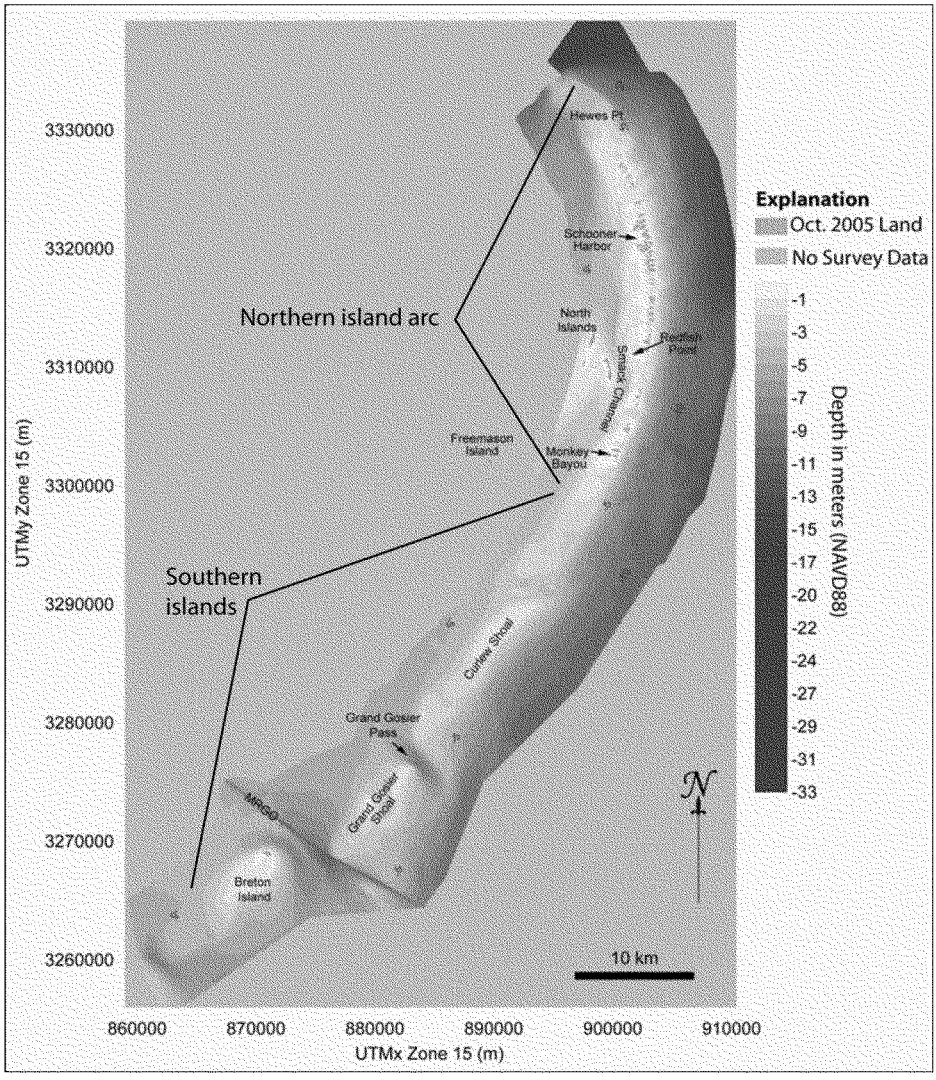


Figure 1. Chandeleur Islands study area with bathymetry collected in 2006-2007 and island area from October 2005 (post-Hurricane Katrina). For this report, the island chain is divided into two major units: the northern island arc and the southern islands. Other geographic locations that are discussed throughout the text are noted on this map. Shoreline data from Martinez et al. (2009) and bathymetry from Miner et al. (2009c). Map modified from Miner et al. (2009d).

5 GEOMORPHIC EVOLUTION

5.1 Deltaic Abandonment and Early Island Evolution

The Mississippi River Delta Plain is the product of deposition by multiple, spatially and temporally offset, deltaic depocenters fed by distributary systems of the lower Mississippi River drainage basin (Russell, 1936; Fisk, 1944). Chronological alterations in the location of these depocenters arise from upstream avulsions of the Mississippi River and its distributaries. With each avulsion event, a new distributary network and attendant delta complex is formed. In total, the Holocene delta plain consists of six delta complexes: Maringouin (7,500 - 5,000 yrs BP), Teche (5,500 – 3,800 yrs BP), St. Bernard (4,000 – 1,800 yrs BP), Lafourche (2,500 – 400 yrs BP), Balize (1,000 yrs BP – present), and Atchafalaya (400 yrs BP – present) (Kolb and Van Lopik, 1958; Frazier, 1967; Coleman, 1988; Penland et al., 1988; Roberts, 1997) (Figure 2). Names, location, and chronology for delta complexes are derived from Frazier (1967), Penland et al. (1988), Törnqvist et al. (1996), Roberts (1997), and Kulp et al. (2005a). Each delta complex consists of smaller scale delta lobes. Products of this cyclic process of delta lobe progradation and subsequent abandonment are the transgressive components of the delta plain that include barrier island/tidal inlet systems, inner-shelf sand shoals, tidal channels, and interdistributary bays (Roberts, 1997).

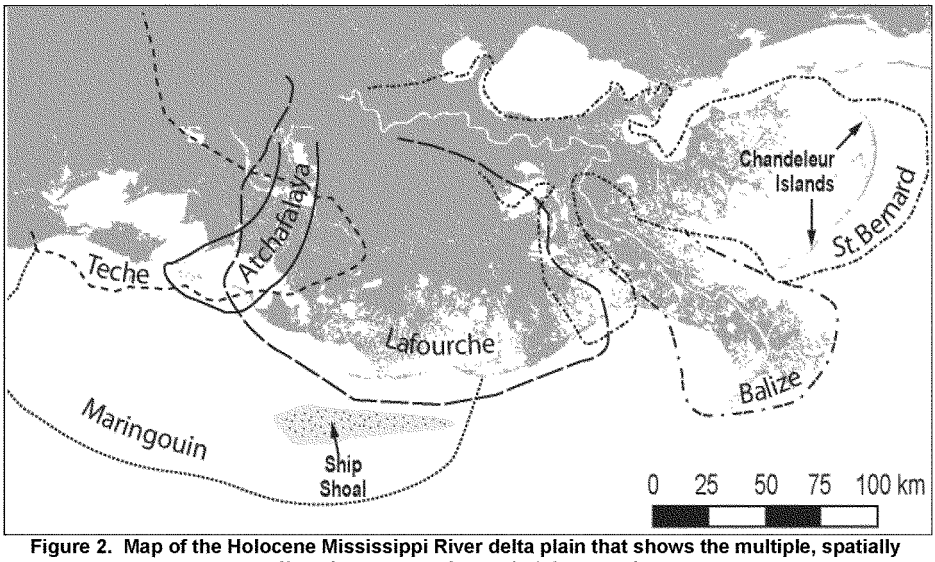


Figure 2. Map of the Holocene Mississippi River delta plain that shows the multiple, spatially offset depocenters for each delta complex.

Subsequent to deltaic abandonment, previously active delta lobes become erosional headlands, and subsidence and marine reworking results in the landward migration of the shoreline. Sediment comprising the headland is reworked laterally by waves and storm impacts to form barrier islands, and eventually inner-shelf shoals (Kwon, 1969; Penland et al., 1988). A three-

stage conceptual model depicting the evolution from deltaic abandonment to barrier island formation to inner-shelf shoal formation was conceived by Penland et al. (1988; Figure 3). During Stage 1, the abandoned deltaic headland is reworked to form an erosional headland with flanking barrier islands. Submergence and interior wetland erosion due to RSLR and decreased fluvial sediment supply leads to mainland detachment and formation of a Stage 2 transgressive barrier island arc. In Stage 3, continued RSLR results in transgressive submergence of the island arc to form an inner-shelf barrier shoal (Penland et al., 1988).

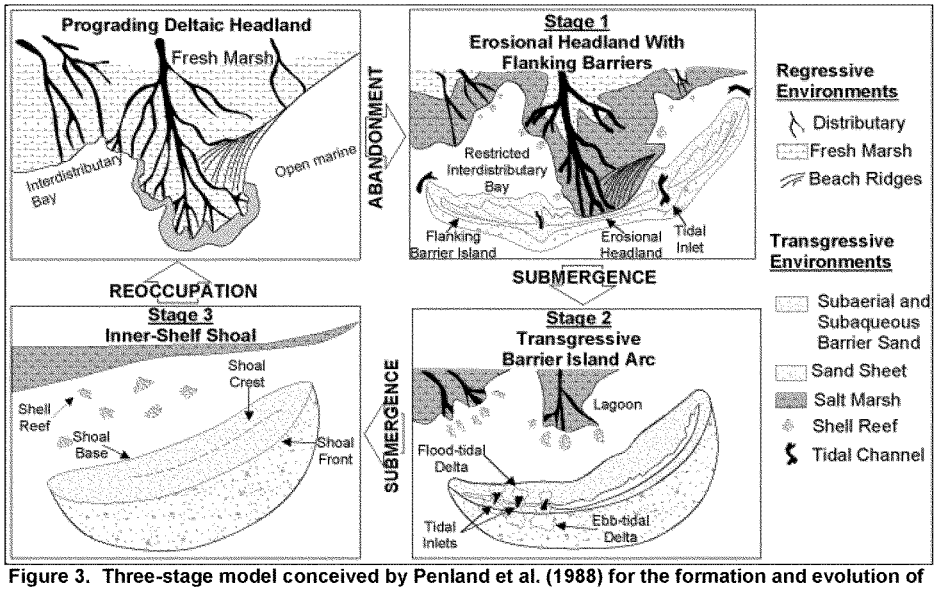


Figure 3. Three-stage model conceived by Penland et al. (1988) for the formation and evolution of transgressive Mississippi River delta barrier islands. From Kulp et al. (2005b) modified from Penland et al. (1988).

The Chandeleur Islands represent a Stage 2 barrier island arc, the product of abandonment and reworking of the St. Bernard delta complex (Frazier 1967; Penland et al., 1988). The most recent distributary active in the region is associated with Bayou La Loutre and was abandoned by fluvial processes approximately 1,800 yrs BP (Frazier, 1967; Rogers et al., 2009). Shoreline development and barrier geometry are controlled by orientation of the abandoned deltaic headland relative to the dominant wave approach. Wave-induced lateral transport is the most significant factor in the development of a Louisiana barrier coastline (Penland and Boyd, 1985) and produces sand-rich flanking barrier islands. Because the transgressive shoreline is naturally isolated from the sediment load of the Mississippi River, there is a finite supply of sand for natural island maintenance. In earlier stages of barrier development a significant sand source is derived from erosion of deltaic deposits by waves. Once the deltaic sediment source has been completely reworked, or has subsided below effective wave base (~23 feet for the Chandeleur Islands; Penland and Boyd, 1985), the barrier and lagoonal deposits are continually recycled at the shoreface during retreat; which for a period of time allows the barrier system to maintain its

exposure during relative sea level rise (RSLR). Much of this sand recycling during shoreface retreat is not in the form of hurricane overwash deposits that eventually become exposed at the shoreface (although this is a significant component), but by recycling of relict recurved spit and large terminal spit deposits (Section 5.5) at the shoreface. Figure 4 is a stratigraphic cross section demonstrating the relationship between these sandy lateral accretion deposits that underlie the northern half of the Chandeleur Islands from Redfish Point, north to Hewes Point and the mud-rich deltaic deposits that underlie the southern half of the islands in the vicinity of Monkey Bayou.

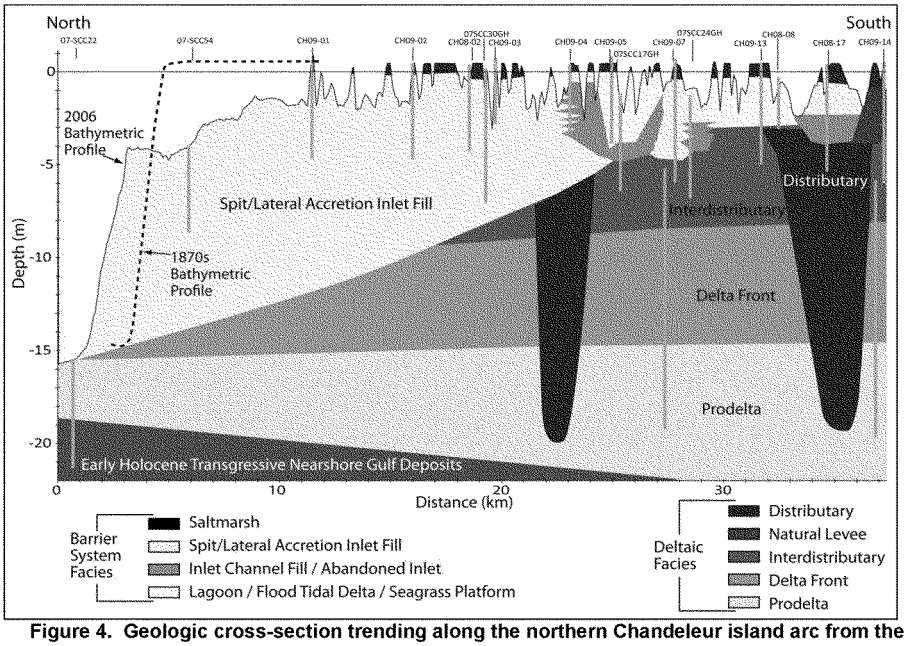


Figure 4. Geologic cross-section trending along the northern Chandeleur island arc from the Hewes Point spit platform in the north to Monkey Bayou in the south (see Figure 1). Bathymetric profiles from Miner et al. (2009c). Subsurface data from unpublished UNO-PIES and USGS vibracores and high-resolution shallow seismic profiles and USACE (1958).

Note in Figure 4 that the salt marsh north of Redfish Point (location of core CH-09-07) is underlain by thick, sandy spit and lateral accretion inlet fill deposits whereas salt marsh south of this location is underlain by muddy relict deltaic and lagoonal deposits. This cross-section demonstrates in profile view the importance of lateral sediment transport in the development and ultimately, the demise of Louisiana transgressive barrier islands. Also note that the dashed line representing the 1870s position of the Hewes Point spit relative to the 2006 bathymetric profile. Approximately 170M cubic yards (130 x 10^6 m^3) of sand has accumulated north of Hewes Point since 1870s (see Figure 4 and Table 1).

5.2 Chandeleur Islands Barrier System Morphology and Historical (1855-2005) Evolution

The historical evolution is documented in seafloor change analysis conducted by Miner et al, 2009c, d). Detailed accounts of the historical shoreline change and seafloor changes along the Chandeleur Islands can be found in Martinez et al. (2009); Fearnley et al., (2009a, b); and Miner et al. (2009c, d). What follows is a summary of those reports with a focus on long term sediment dynamics and shoreface evolution that provide an important background and basis for island management designs herein.

Shoreline retreat rates average ~50 feet/year for 1855-2008 (Martinez et al., 2009). However, these retreat rates are not accompanied by conservation of sand in a landward direction, landward translation of the barrier island, or formation of new back barrier marsh. Instead, lateral transport to the flanks of the island arc (north of Hewes Point and South of Breton Island) continues to be the dominant trend driving island evolution during the historical record (1855-present). The results from the BICM historical seafloor change analysis (Miner et al., 2009c) are presented in Figure 5. Numbered polygons delineate zones for which sediment volumetric change data are presented in Table 2. Note the widespread erosion along the shoreface fronting the island arc and depositional sinks at the flanks of the island arc. These results demonstrate that during the past 125 years approximately 392M cubic yards (300 x 10^6 m^3) of sand has accumulated in deepwater sinks at the flanks of the barrier island arc; twice as much as deposited in the back barrier. This net loss of sediment to flanking sinks has resulted in island area reduction from 17.2 mi^2 in 1855 to 1.8mi^2 in 2005 (Fearnley et al., 2009; Miner et al., 2009d).

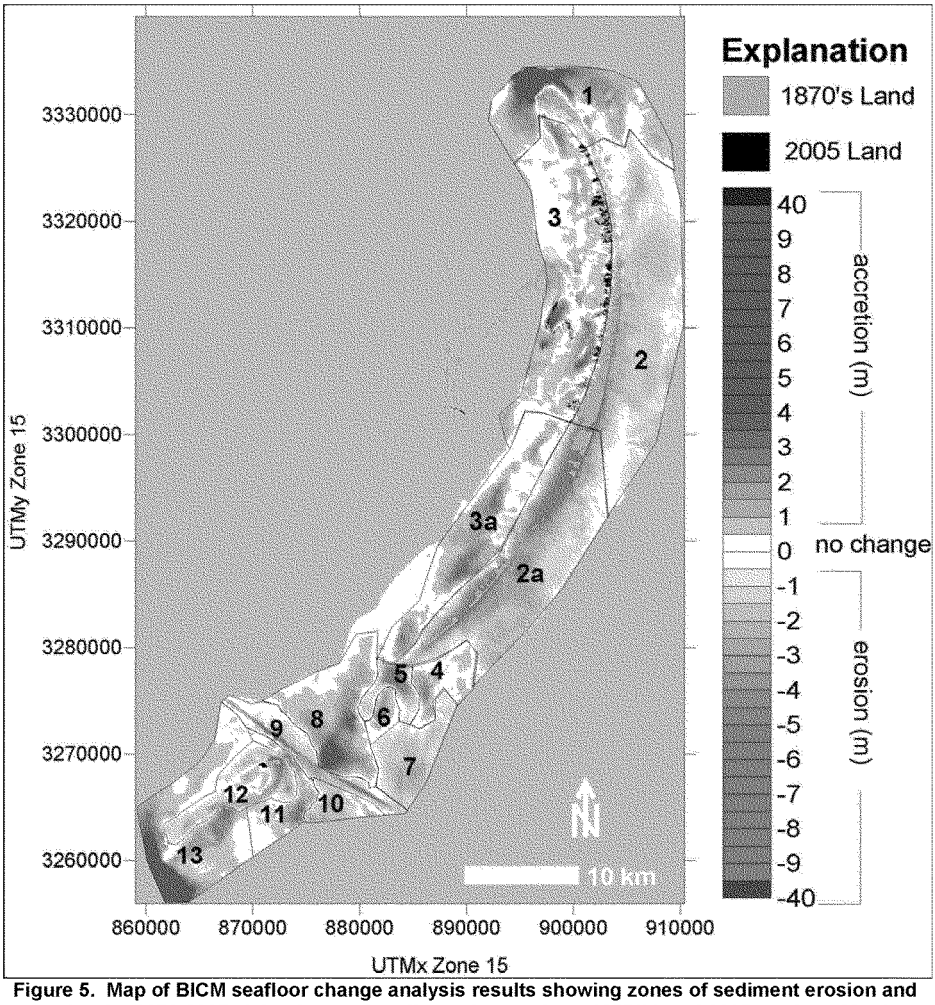


Figure 5. Map of BICM seafloor change analysis results showing zones of sediment erosion and accretion for 1870-2007. Island area shoreline polygons from 1855/69 and 2005 are from Martinez et al. (2009). Bathymetry and shoreline change analysis from Miner et al. (2009c). Map reproduced from Miner et al. (2009d).

Table 2. Sediment erosion/accretion volumetric change results for geomorphic zones presented in Figure 5.

Zone	Accretion ($x10^6$ m^3)	Erosion ($x10^6$ m^3)	Net Vol ($x10^6$ m^3)	Area ($x10^6$ m^2)	Net vol Error +/- ($x10^6$ m^3)	Dz min	Dz max
1. Hewes Point/ North Inlet	147.03	-18.26	128.77	91.67	25.67	-4.28	10.82
2. Northern Chandeleur Shoreface	4.68	-289.98	-285.29	212.19	59.41	-8.06	1.5
3. Northern Chandeleur Backbarrier	110.61	-26.50	84.11	166.76	46.69	-3.68	5.88
2a. Southern Chandeleur Shoreface	1.49	-406.63	-405.14	163.52	45.78	-8.89	1.70
3a. Southern Chandeleur Backbarrier	80.19	-4.72	75.47	84.92	23.78	-2.32	3.30
4. Updrift Curlew Pass Ebb Delta	14.30	-1.62	12.68	24.78	6.94	-1.20	2.85
5. Curlew Pass Inlet Scour	0.66	-34.27	-33.61	18.93	5.30	-7.20	1.40
6. Downdrift Curlew Pass Ebb Delta	7.74	-0.35	7.39	9.33	2.61	-0.64	2.82
7. Grand Gosier Shoreface	0.29	-56.29	-55.99	40.61	11.37	-3.43	0.81
8. Updrift MRGO	91.20	-0.16	91.04	70.41	19.71	-1.00	4.67
9. MRGO	0.10	-52.18	-52.08	25.34	7.10	-8.54	1.91
10. Downdrift MRGO shoreface	1.72	-21.35	-19.62	15.88	4.45	-3.43	1.85
11. Breton Pass Ebb delta and inlet fill	20.17	-0.13	20.04	20.69	5.79	-1.18	3.23
12. Breton Island Nearshore/Backbarrier	3.45	-51.03	-47.58	39.49	11.06	-7.95	1.33
13. Downdrift Breton Island	176.46	-0.10	176.35	74.98	2.10	-0.59	12.18
TOTAL	**660.09**	**-963.57**	**-303.47**	**1,059.49**	**296.66**		

Notes: Dz min = largest magnitude of vertical erosion within each polygon; Dz max = greatest magnitude of vertical accretion within each polygon. Data from Miner et al. (2009c). Reproduced from Miner et al. (2009d).

Results from the previous studies capture a transition from relatively sediment rich barriers (1855 -1922) that build new land in the back barrier by overwash, flood tidal delta, and recurved spit formation to sediment starved barriers that no longer build new back barrier land and begin to thin in place (1922 - 2005). Once the thinning has reached the point where no back barrier marsh exists, the barriers cross the transgressive submergence threshold becoming mobile sand bodies that migrate landward through a cycle encompassed by storm destruction followed by emergence landward of their former positions during calm weather.

The threshold crossing from barrier island to submerged shoal is characterized by: (1) sand lost to flanks decreases barrier sand supply restricting new back barrier marsh development, (2) continued loss to flanks forces barrier thinning and segmentation with fragmented marsh islands serving as spit nucleation sites, and (3) gulf shoreline and back barrier shoreline meet resulting in sandy ephemeral barrier islands/shoals that are destroyed by storms but reemerge during calm weather landward of their pre-storm location (Figure 6). It is not until this final stage of disintegration that cross-shore sand distribution becomes an efficient enough process to translate the barrier sand body landward during shoreface retreat.

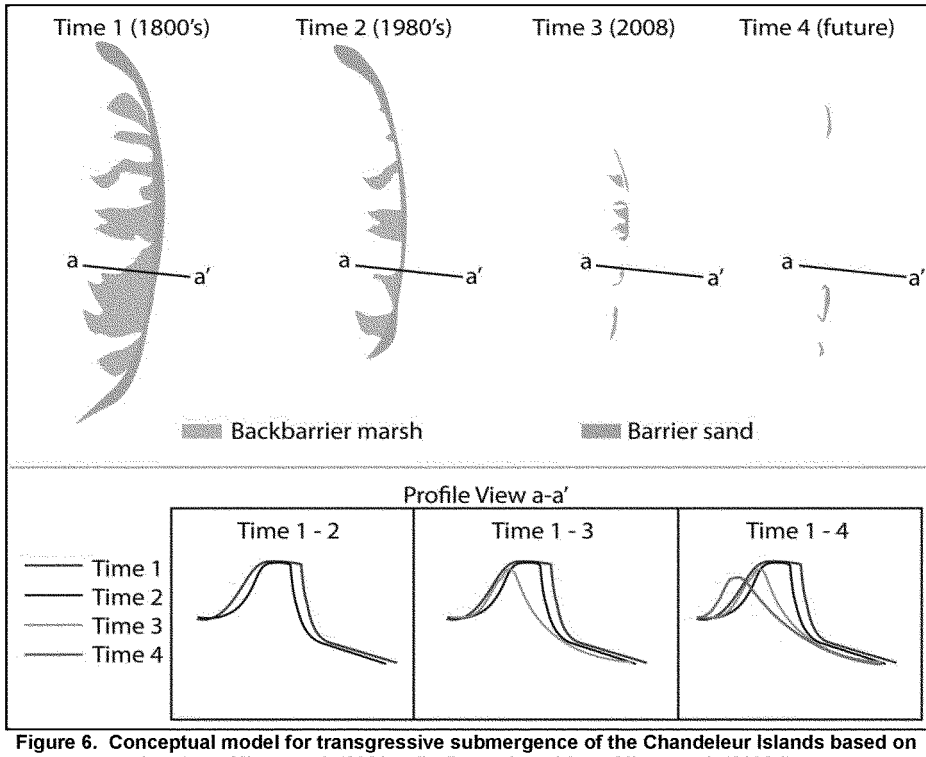


Figure 6. Conceptual model for transgressive submergence of the Chandeleur Islands based on data from Miner et al. (2009c, d). Reproduced from Miner et al. (2009d).

5.3 Role of Tidal Inlets

A tidal inlet is a shore-perpendicular channel along a barrier shoreline that connects the gulf with bays, lagoons, marsh, and tidal creeks (Brown, 1928; Escoffier, 1940; Davis and FitzGerald, 2004). Tidal currents maintain the inlet channel by flushing of sediment that is transported alongshore by waves (Brown, 1928; Escoffier, 1940). There are four large tidal inlets responsible for the majority of tidal exchange between the Gulf of Mexico and the Chandeleur/Breton Sound and numerous (>60) ephemeral hurricane-cut inlets along the northern island arc.

The major tidal inlets in the Chandeleur Islands system are the channels that flank the terminal spits of the barrier arc and include the inlet north of Hewes Point and an inlet that is south of Breton Island (Figure 1). Current measurements and numerical modeling shows that these two flanking channels are responsible for the majority of tidal flow into and out of Chandeleur and Breton Sounds (Hart and Murray, 1978). North Inlet extends from the back barrier and curves around Hewes Point where maximum channel depths are >50 feet. Lateral spit accretion towards the north at Hewes Point has forced a northerly migration of this inlet.

The inlet at the southern extent of the Chandeleur Islands located south of Breton Island has migrated south and undergone considerable infilling. Observations during surveying and subsequent aerial reconnaissance flights confirm strong tidal currents flowing through this broad channel.

The MRGO intersects the Chandeleur Islands just north of Breton Island and was cut through the existing tidal inlet of Breton Island Pass. Although the natural inlet configuration was downdrift-offset (the inlet channel was oriented to the south in an alongshore direction), the MRGO trends perpendicular to the shoreline. The MRGO construction did not result in the abandonment of the natural channel in favor of the engineered one, and both channels remained open. The MRGO required frequent maintenance dredging to remove sand before being decommissioned in 2008. Strong tidal currents flow through MRGO because it is a major conduit for tidal exchange for much of the Lake Pontchartrain Basin. The increased tidal prism and strong ebb tidal currents result in seaward transport of sand to distal ebb shoals that would have otherwise bypassed the inlet (Figure 7 and Figure 8).

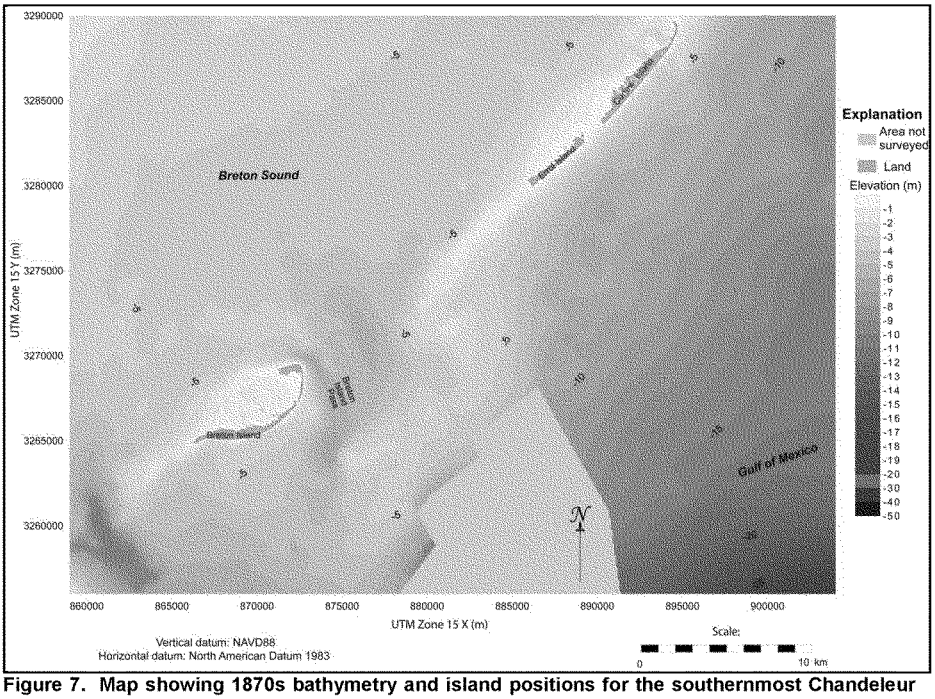


Figure 7. Map showing 1870s bathymetry and island positions for the southernmost Chandeleur Islands. Bathymetry from Miner et al. (2009c).

Note in Figure 7 Breton Island Pass' downdrift-offset, two-channel inlet morphology and offshore ebb tidal delta that becomes the site of the MRGO navigation channel. Prior to MRGO construction, sand that transported alongshore could bypass this inlet via the ebb tidal delta.

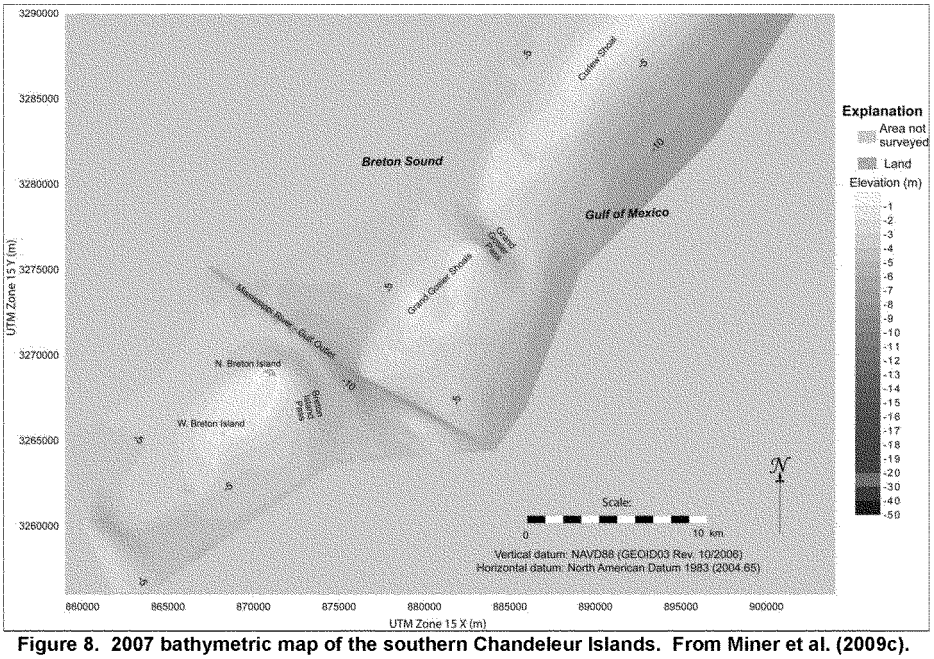


Figure 8. 2007 bathymetric map of the southern Chandeleur Islands. From Miner et al. (2009c).

Grand Gosier Pass is a natural tidal inlet located between Curlew and Grand Gosier Shoals that trends perpendicular to Curlew and Grand Gosier Shoals. This inlet was not present in the 1870s bathymetry, but by 2007 had scoured to a depth of > 30 feet. The date of inlet formation is not known, but the inlet is denoted on navigational charts dating to the 1950s (McBride et al. 1992). An ebb tidal delta has developed here as indicated by a seaward excursion of the 10-foot contour offshore of Curlew Shoal since the 1870s.

Numerous ephemeral hurricane-cut inlets along the barrier chain have historically been active for several years after a storm impact and then fill in to form a continuous barrier shoreline along the northern arc during extended periods of calm weather (Kahn, 1986). Since Hurricane Katrina, more than 60 hurricane cut tidal inlets have remained open. Based on the 2006 bathymetric surveys, widths range from ~ 250 to 10,000 feet and maximum depths exceed 10 feet.

5.4 Back Barrier Platform and Submerged Aquatic Vegetation

The northern island arc (north of Monkey Bayou) is backed by a broad (maximum width ~ 1.5 miles), sandy platform that averages ~3 to 6 feet in depth (Miner et al., 2009c) and is blanketed by submerged aquatic vegetation (SAV) (Porrier and Handley, 2006; Bethel and Martinez, 2008). Storm-generated flood tidal deltas have formed landward of deeper hurricane-cut inlets. The back barrier platform is intersected by channels that were scoured during storms. Coastal

SAV meadows are a rapidly declining critical habitat for juvenile aquatic species, sea turtles, Florida Manatee, and wintering migratory waterfowl in the northern Gulf of Mexico (Byron and Heck, 2006; Poirrier and Handley, 2006; Michot, et al 2008). Besides habitat, these seagrass meadows provide important physical benefits to the stability of the Chandeleur Islands by baffling water flow, reducing wave energy and current velocity (Koch et al., 2006; Chen et al., 2007). This process results in back barrier sediment trapping (vertical accretion) and protection of back barrier marsh shorelines form wave attack in Chandeleur Sound. The latter is important at the Chandeleurs because of the large fetch distance across Chandeleur Sound, especially during the passage of winter cold fronts. These seagrass beds are amazingly resistant to hurricanes and recover rapidly after storms when destroyed; however, the occurrence and distribution of seagrass at the Chandeleur Islands is directly related to the presence of a fronting barrier island (Poirier and Handley, 2006; Bethel and Martinez, 2008). The island dissection and rapid land loss associated with Hurricane Katrina has resulted in decreased suitable conditions for the seagrass colonization (Bethel and Martinez, 2008).

5.5 Spits

A spit is a sandy ridge attached to land at one end and terminating in open water at the other (Evans, 1942). Spits are built by lateral accretion of sand due to wave-induced transport. Spits accrete laterally over the subaqueous spit platform, which progrades ahead of the subaerial spit. Seasonal variations in wave approach and the refraction of waves bending around the spit end often form a hook-shaped recurved spit that extends into the back barrier (Figure 9). Lateral accretion of a terminal spit (at the end of a barrier island) usually results in development of a thick sand body because the leading edge of the prograding spit fills a relatively deep inlet channel (Figure 10; Hoyt and Henry, 1967). Hewes Point is the terminal spit system at the northern end of the Chandeleur Islands (Figure 11) and is prograding, due to northerly longshore transport, into the marginal deltaic basin that flanks the St. Bernard delta complex.

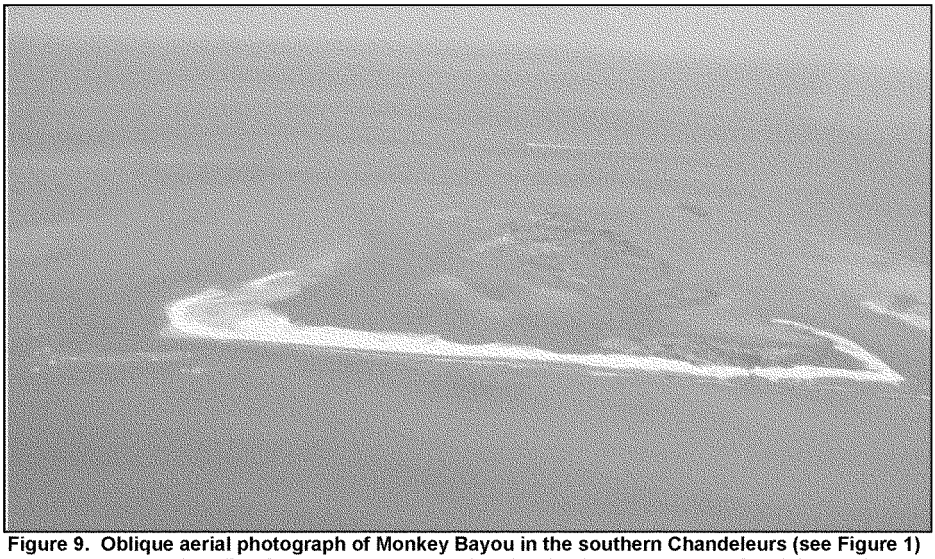


Figure 9. Oblique aerial photograph of Monkey Bayou in the southern Chandeleurs (see Figure 1) taken 10 May 2009. View is to the west with Gulf of Mexico in the foreground and Chandeleur Sound in the background. Note the recurved spits that extend into the back barrier and attach to the marsh island and shell berm shoreline.

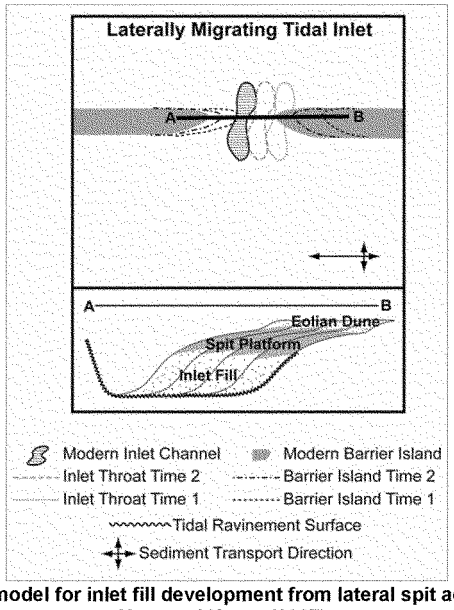


Figure 10. Conceptual model for inlet fill development from lateral spit accretion. Modified from Hoyt and Henry (1967).

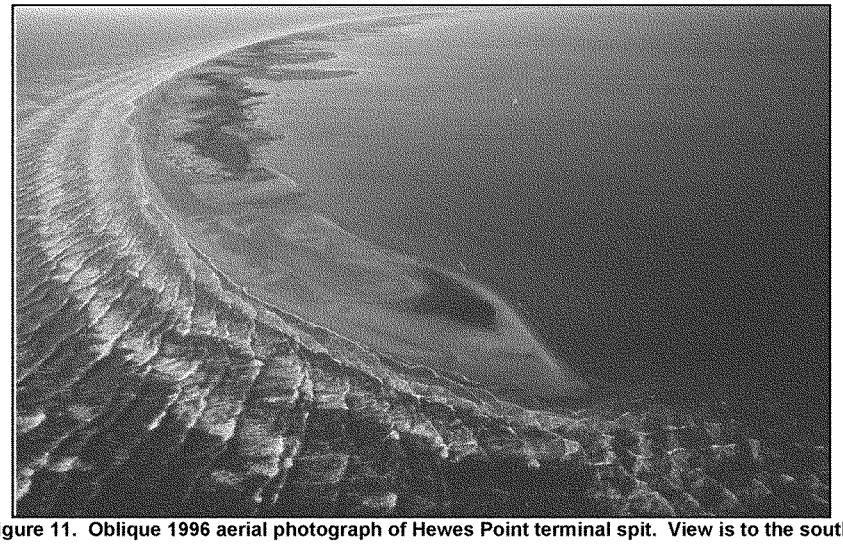


Figure 11. Oblique 1996 aerial photograph of Hewes Point terminal spit. View is to the south. Note the landward protruding back barrier marsh lobes that represent former spit locations. Also note the wave refraction pattern that is responsible for development of the recurved morphology. Photo from National Geographic.

Figure 12 shows the northward progradation of the Hewes Point terminal spit through a series of bathymetric profiles over time. Figure 13 uses a digital elevation model to show the accretion of sediment over time with a three-dimensional perspective.

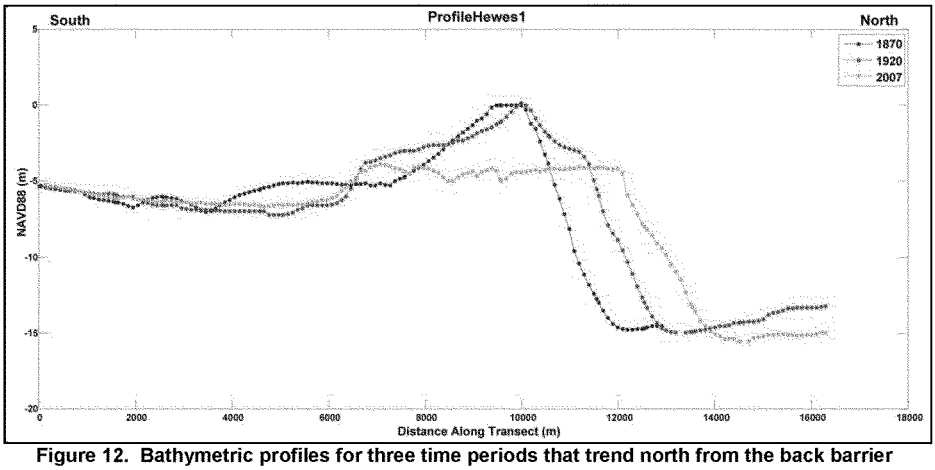


Figure 12. Bathymetric profiles for three time periods that trend north from the back barrier across Hewes Point and into the inlet north of the Chandeleur Islands. Bathymetry from Miner et al. (2009c, d).

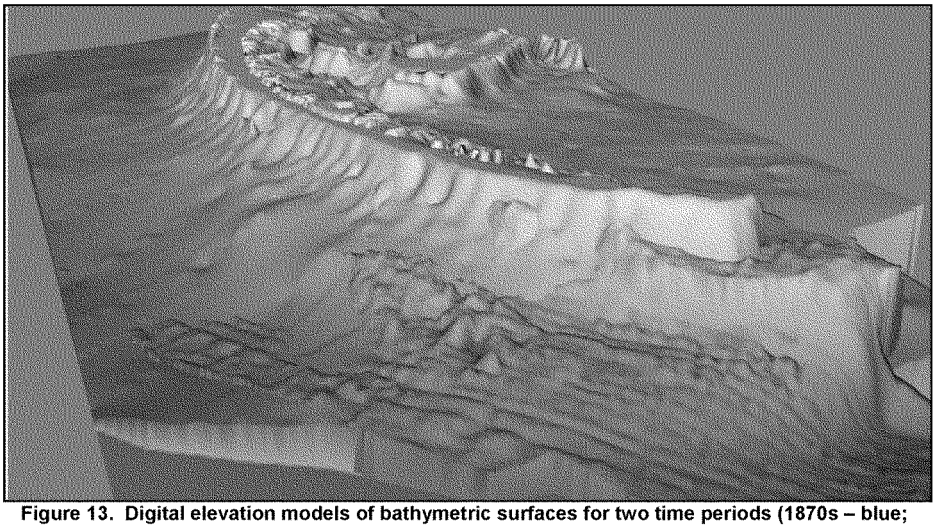


Figure 13. Digital elevation models of bathymetric surfaces for two time periods (1870s – blue; 2006 – red) shown in the same space. View is to the south. Note the large zone of accretion north of Hewes Point where the shoreface has also prograded in an offshore direction. Also note the landward migration of the barrier shoreline. Data from Miner et al. (2009c).

The scale of this terminal spit accretionary process is important because it demonstrates how an abandoned deltaic headland is reworked by marine processes to form Stage 1 flanking barriers, and eventually a Stage 2 barrier island arc (Figure 3; Penland et al., 1988). Lateral spit accretion remains an important process throughout Stage 2, as shown by the lateral accretion of Hewes Point in a northerly direction (Penland et al., 1988); this concept forms the basis for the development of the restoration plan proposed herein.

5.6 Barrier Shoals

The barrier shoals that occur along the Chandeleur Islands are present in the southern portion south of Monkey Bayou and include Curlew and Grand Gosier Shoals (formerly Curlew Island and Grand Gosier Islands). These are actually ephemeral barrier islands that are destroyed during storms and reemerge during extended fair weather periods (Otvos, 1981; Penland and Boyd, 1985; Fearnley et al., 2009; Miner et al., 2009d). Recent increased storm frequency and a decrease in sediment supply has inhibited island emergence since Hurricane Katrina (Fearnley et al., 2009). The same factors leading to submergence and inhibiting reemergence have also forced other historically more stable portions of the Chandeleur Islands into ephemeral island/shoal mode. It is predicted that this coastal behavior will eventually be characteristic of the entire island arc as it is converted to an inner shelf shoal through transgressive submergence.

5.7 The Role of Hurricanes

It has been suggested that the long-term evolution of the Chandeleur Islands and their fate are governed by tropical cyclone impacts, which result in a long-term net land loss driven by

insufficient post-storm recovery leading to the islands' conversion to an inner shelf shoal through transgressive submergence (Kahn 1980; Kahn and Roberts 1982; Penland et al. 1983; 1988; Suter et al. 1988). McBride et al. (1992) proposed that the Chandeleur Islands would remain supratidal until the year 2360 on the basis of projected shoreline change and linear regression analysis of island area changes between 1855 and 1989. However, these predictions did not account for the increase in northern Gulf of Mexico storm frequency and intensity that ensued in the decade following their analysis (Fearnley et al., 2009a).

Recent increased storminess associated with the impacts of Hurricanes Georges, Ivan, and Katrina during the past decade is unprecedented for the Chandeleur Islands during the historic record (Fearnley et al., 2009a). These multiple, closely spaced (temporally) storm impacts culminated with Hurricane Katrina completely inundating the islands, removing >90% of the sand, exposing back barrier marsh along the gulf shoreline to wave attack (Miner et al., 2009d), and reducing total island area by ~50% (Fearnley et al., 2009a). These recent hurricane impacts have raised new questions regarding lifespan and sustainability of the Chandeleur Islands; especially their ability to recover from future storms.

Recently, Fearnley et al. (2009a, b) investigated the role of storm frequency, intensity, and track on island evolution for the time period spanning from 1855 to 2005, with the goal of forecasting the transition from islands to shoals based on historical island area changes. For the northern island arc, the average rate of island shoreline retreat was ~40 feet/year between 1922 and 2004 with retreat rates increasing to >159 feet/year after storm impacts. The impact of Hurricanes Ivan and Katrina along the northern Chandeleur Islands were extreme erosional events and the average amount of linear shoreline erosion for the two storms combined (-660 feet/year) was unprecedented throughout the rest of the analysis time period (1855 to 2004). A linear regression analysis of island area change demonstrate a land loss rate of 40 acres/year (0.16 km^2/yr) between 1922 and 1996 and a land loss rate of 250 acres/year (-1.01 km^2/yr) between 1996 and 2005 (Fearnley et al 2005; Figure 14). By projecting trends calculated from the linear regression analysis of island area change through time, the expected date of the northern Chandeleur Islands' conversion to an inner shelf shoal falls between 2013 and 2037 (Fearnley et al., 2009a, b; Figure 14). The earlier date is based on a projected storm frequency consistent with that of the past decade, whereas the later date represents a projected low storm recurrence interval similar to that for the period from 1922 to 1996.

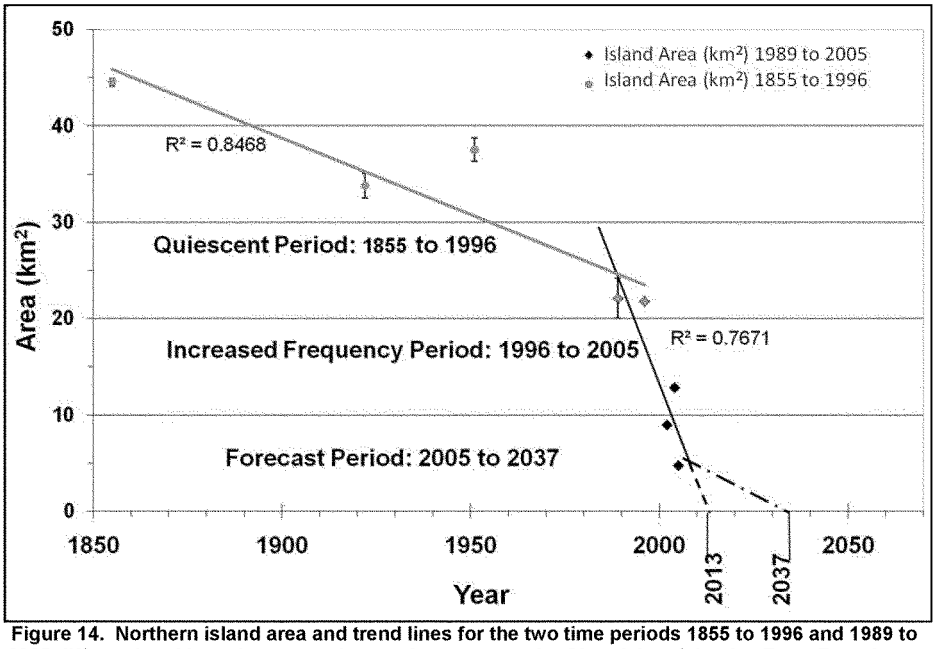


Figure 14. Northern island area and trend lines for the two time periods 1855 to 1996 and 1989 to 2005 differentiated based on storm impact frequency at the Chandeleur Islands. From Fearnley et al. (2009 a, b).

Note the drastic increase in island area loss rates associated with the increased storm frequency period in Figure 14. The dashed projection of the 1989 to 2005 trend predicts transgressive submergence could occur as early as 2013 if storm frequency observed over the past decade persists. The dash-dot-dash line represents the trajectory of the islands in their current state under low frequency storm conditions such as existed during the 1855 to 1996 time period, indicating a transgressive submergence date of 2037.

The southern Chandeleur Islands (Figure 1) encompass a different storm impact response and mode of recovery than the northern Chandeleur Islands. Like the northern barrier arc, the southern Chandeleur Islands are characterized by shoreface retreat; however, major storm impacts result in almost complete island destruction and conversion to inner shelf shoals (Breton Island is an exception to this trend). During extended periods of calm weather following storm impacts, new islands reemerge along this sector (Fearnley et al., 2009a, b; Miner et al, 2009d). During long term periods (>100 yrs) the rate of shoreline retreat along the southern islands was approximately 50 feet/year for the time period from 1869 to 1996 and island area decreased from 19 mi^2 to 0.7 mi^2 between the years 1869 to 2005 (Fearnley et al., 2009a, b).

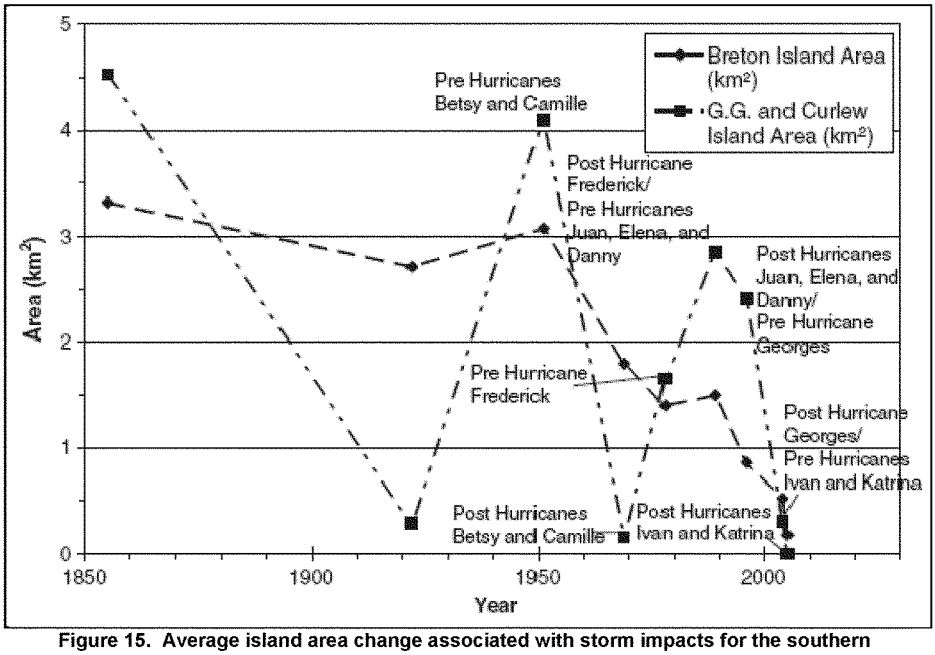


Figure 15. Average island area change associated with storm impacts for the southern Chandeleur Islands. From Fearnley et al. (2009).

Note the dynamic nature of Curlew and Grand Gosier Islands through time. These islands are almost completely destroyed during storms and reemerge landward of their former locations during extensive periods of calm weather. This coastal behavior is predicted to encompass the entire island chain once back barrier marshes have eroded (2013 to 2037 based on Figure 14 and Fearnley et al., 2009a). Note that Curlew Island and Grand Gosier Island remain submerged as shoals today (Fall 2009).

5.8 Sediment Dynamics

With regard to longshore sediment transport, the arcuate barrier island trend is characterized by a bidirectional system, with material moving from the central arc to the flanks (Figure 16; Georgiou and Schindler, 2009). Seasonal variations in wind dominance cause an imbalance in transport gradients through time forcing higher rates of transport potential in a northward direction (Georgiou and Schindler 2009). Significant wave heights along the northern portion of the barrier have a peak of 1.5 feet based on a 25-year hourly average with significant wave heights in excess of 3.3 feet occurring ~4% of the year and >6.6-foot waves having a return period of less than 1% (Georgiou and Schindler, 2009). Net longshore transport rates north of the nodal point (Figure 16) are directed northward with rates increasing away from the nodal point toward the flaks reaching values > 144,000 cubic yards/year (110,000 m^3/yr) (Georgiou and Schindler, 2009). Transport rates south of the nodal point are generally directed to the south

with potential rates reaching ~150,000 cubic yards/year (115,000 m^3/yr) (Georgiou and Schindler, 2009).

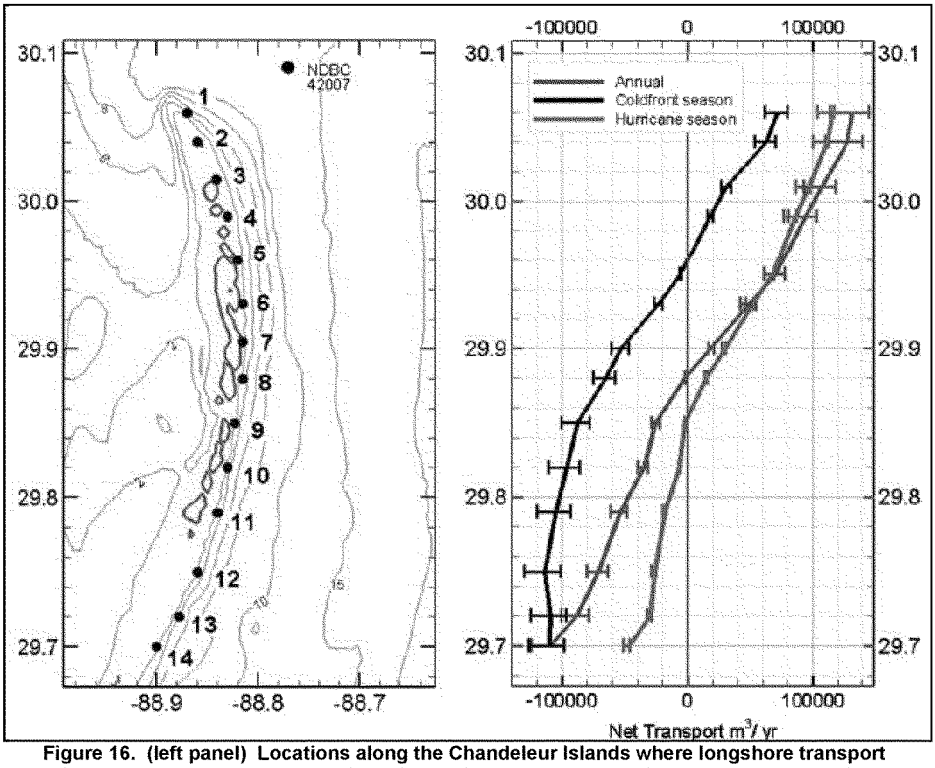


Figure 16. (left panel) Locations along the Chandeleur Islands where longshore transport calculations were performed by Georgiou and Schindler (2009). (right panel) Potential net longshore transport as a function of differing forcings based on long term 1985 to 2006 wind records measured at NDBC buoy 42007: blue line – long term annual average, black line – seasonal averaging during the cold-front season, red line – hurricane season. Note that the two panels are aligned to show trends along the island shoreline. Values that plot to the left of zero on the right panel indicate a net transport potential to the south, and those that plot to the right of zero indicate net transport potential to the north. From Georgiou and Schindler (2009).

Under non-storm conditions, significant sediment transport is restricted to the upper shoreface, landward of the 16-foot isobath (Penland and Boyd, 1981), however recent studies along Louisiana barrier islands demonstrate that storm-associated seafloor scour and transport occurs at depths >50 feet (Miner et al., 2009a; 2009b; Allison et al., 2007). It is important to note that the predicted rates of longshore sediment transport discussed above are an order of magnitude lower than the rates of deposition at the island flanks inferred from the sediment volumetric change analysis discussed in Section 5.2 (~1 x 10^5 cubic yards/year for versus ~1 x 10^6 cubic yards/year; Figure 16 and Table 2, respectively). Georgiou and Schindler (2009) stated that no field measurements on longshore sand transport rates were available and absolute transport rates

were not the focus of the study. Recent observational and numerical modeling studies suggest that storm wave-induced currents play a major role in sediment transport within the lower shoreface zone and inner continental shelf off of Louisiana coast (Jaffe et al., 1997; Teague et al., 2006; Miner et al., 2009a; Georgiou and Schindler, 2009b).

5.9 Hurricane Katrina Recovery

Hurricane Katrina segmented the island arc into multiple small marsh islets separated by wide hurricane-cut tidal passes. More than 90% of sand comprising the barriers was removed, exposing back barrier marshes to wave attack. During the following year, >50% of the length of the northern Chandeleur Islands shoreline continued to erode. However, during year two of recovery, marsh islands served as nucleation sites for sand accumulation along the northern arc, north of Redfish Point. Early stages of recovery along this sector were marked by sand and shell recurved spit formation at hurricane-cut tidal passes followed by onshore bar migration and welding; a process that resulted in the closure of some inlets (Figure 17). Prior to the 2008 Hurricanes, elevation along the northern section began to increase as aeolian processes constructed dune fields in the wind shadow of black mangroves and roseau cane thickets (Figure 18). Contrastingly, recovery along the southern segment of the northern arc (between Redfish Point and Monkey Bayou) was not characterized by sandy shoreline development and closing of inlets. Here, marsh islands fronted by a shell berm continue to undergo rapid shoreline retreat (>650 feet/year, locally; Figure 20). Where marsh islands were absent prior to Katrina's impact (south of Monkey Bayou to Grand Gosier Islands), the sandy barriers underwent transgressive submergence. These southern shoals persisted for 2 years after Katrina's impact, but began to emerge as narrow, ephemeral barrier islands until they were once again destroyed by Hurricanes Gustav and Ike.

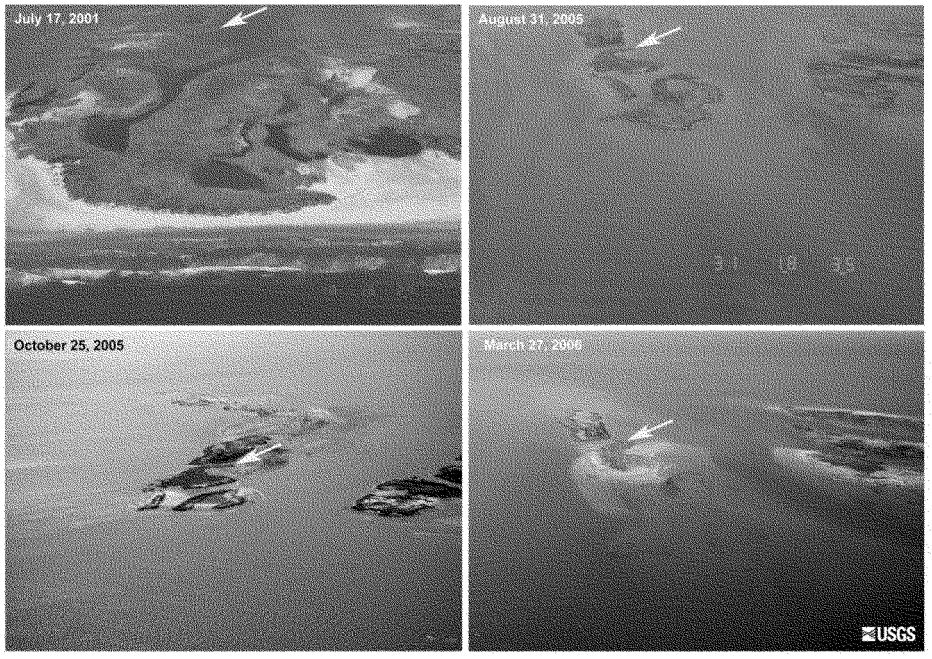


Figure 17. Time series of oblique aerial photographs facing west that demonstrate the impacts of Katrina and the continued shoreline erosion for 1.5 years after storm impact. Yellow arrow is in a fixed geographic location in each photo. Images courtesy of Abby Sallenger, USGS.

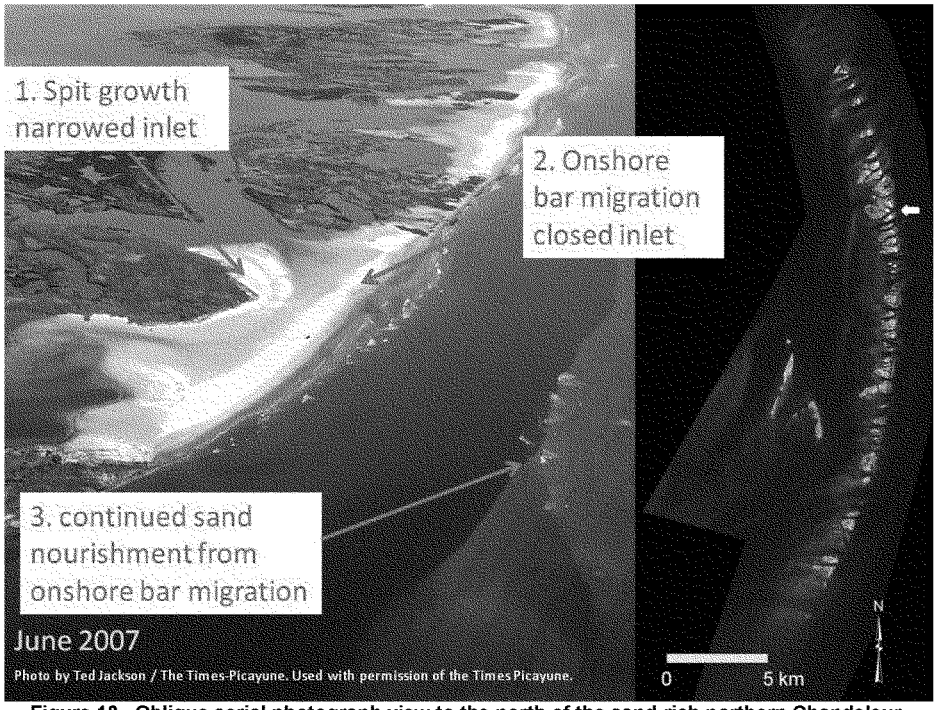


Figure 18. Oblique aerial photograph view to the north of the sand-rich northern Chandeleur islands. Arrow in right panel shows the location of the photo. Note the closure of hurricane cut passes and landward sand movement during year 2 of post-storm recovery. Subsurface sand deposits are excavated during shoreface retreat, liberating sand reserves for spit, beach, and dune construction.

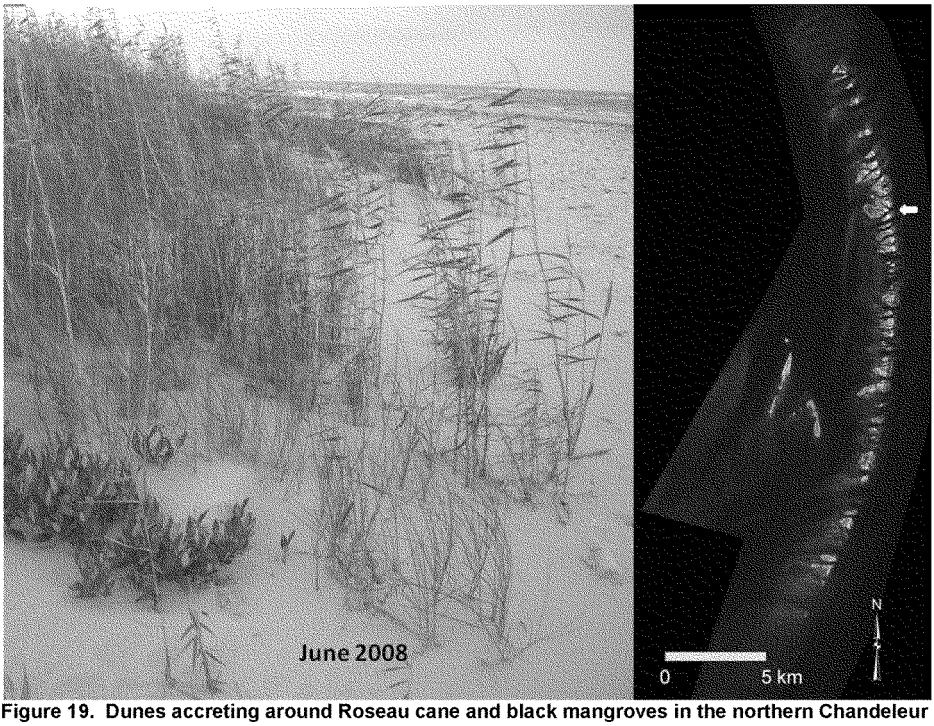


Figure 19. Dunes accreting around Roseau cane and black mangroves in the northern Chandeleur Islands. Photo is 1 year after Figure 20. Note the deflated beach surface that sourced the sand for dune construction.

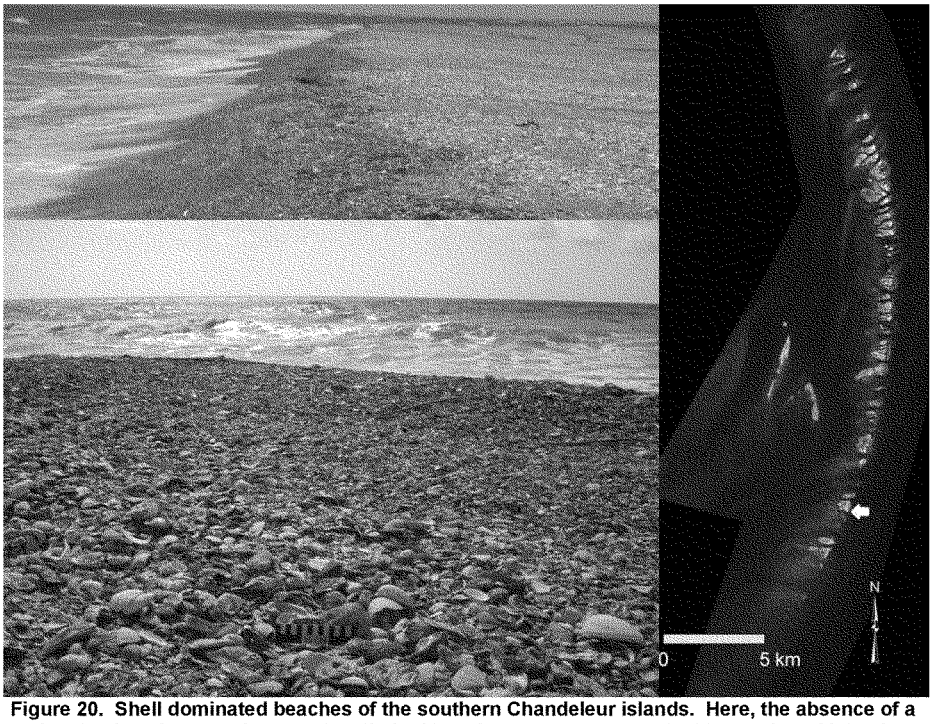


Figure 20. Shell dominated beaches of the southern Chandeleur islands. Here, the absence of a local subsurface sand source has limited beach recovery and resulted in continued island dissection.

An understanding what governs the disparity in recovery behavior between the northern and southern sections of the island arc is important for predicting long-term island sustainability and development of a long-term island management plan. In order to address this, UNO-PIES and USGS conducted a subsurface investigation along the island arc. Results demonstrate that recovery is controlled by the relative abundance of local subsurface sand supply; the marsh islands along the northern sand-rich sector are underlain by thick (up to ~33 feet) relict spit platform and lateral accretion inlet fill deposits, whereas the section south of Redfish Point is underlain by muddy lagoonal and deltaic deposits (Figure 4). Therefore, as the shoreline retreats landward (a process that is greatly accelerated during post-storm recovery phases; Fearnley et al., 2009), relict sandy spit deposits underlying the back barrier marsh in the north are liberated at the shoreface and introduced to the littoral system. In the south, local sand supply is limited, inhibiting rapid recovery. This disparity in sand distribution along the island arc is a consequence of long term lateral accretion away from the original, centralized deltaic sand source in the vicinity of Monkey Bayou. Over the past several centuries the deltaic sand source has been exhausted leaving a sand-starved zone of islands between Redfish Point and Monkey Bayou and relatively sand-rich zones north of Redfish Point. Ultimately, in the north, the sand is lost from the barrier island littoral system to a deepwater sink north of Hewes Point. South of Monkey Bayou, and extending beyond Breton Island exists a similar sand-rich trend, however

with the exception of Breton Island, there are no marshy islands for sand to accumulate subaerially resulting in rapidly retreating ephemeral barriers of Curlew and Grand Gosier Island Shoals and a deepwater sand sink south of Breton Island similar to Hewes Point. These downdrift sand reservoirs provide a unique, quasi-renewable resource for nourishing the updrift barrier system as will be discussed in the following section.

5.10 Implications for Island Management

The long-term diminished sediment supply, location of sediment sinks, and storm recovery processes documented in Miner et al. (2009a, b), Fearnley et al., (2009 a, b), and Georgiou and Schindler (2009 a, b) provide an understanding of the mechanism that drives barrier island arc transgressive submergence and the natural sediment dispersal processes at work that prolong submergence. Based on this newly developed understanding of how the islands naturally sequester sediment that is introduced to the littoral system during shoreface retreat and respond to a rapid introduction of new sediment, efficient barrier management strategies can be developed.

The dominance of lateral transport over cross-shore transport is important. Sand is not being removed and deposited offshore in thin sand sheets as proposed by previous works, instead, sand is being concentrated as thick sediment bodies at the flanks of the island arc. These downdrift sand reservoirs lie outside of the littoral system and provide a resource for nourishing the updrift barrier system (i.e., the central arc).

Restoration goals should mimic the natural processes that encompass early stages of barrier island evolution including lateral transport to the flanks from a centralized sand source that will ultimately enhance the island's ability to naturally build back barrier marsh, dunes, and a continuous sandy shoreline. Gulf shoreline erosion is inevitable, however, island integrity can be maintained and enhanced during retreat with strategic sand placement if:

1) Nourishment sand recovered from deepwater sinks at the flanks of the island arc is reintroduced to the barrier sand budget at a centralized location based on longshore sediment transport predictions from Georgiou and Schindler (2009, Figure 16).

2) Distribution of naturally occurring hurricane-cut passes is maintained as storm surge/overwash pathways. These natural high energy environments should be avoided as sand placement areas except where they have widened to the point where islands have been converted to shoals.

3) Sand is placed at a centralized location along the island arc where it will naturally disperse to the flanks. Hurricane cut inlets will heal by spit accretion and bar welding processes. These processes will increase sand in the littoral system and will nourish the beach, providing material for aeolian dune building, resulting in increased island elevation and storm protection.

4) Sand reserves are strategically placed in the back barrier as vegetated shore perpendicular platforms upon which the island can migrate across. These will also serve to reintroduce sand into the littoral system as the island migrates.

5) An initial sand infusion to the littoral system along the central barrier arc fronting the back barrier sand reserves, in the form of nearshore bars and beach, as well as area specific restoration can simultaneously be placed.

6 HISTORIC DATA

6.1 Survey Data

This report is intended as an initial evaluation of project feasibility so additional data collection was not part of the scope of work. Bathymetric, topographic, and shoreline data were obtained from the following five sources: USGS Coastal Erosion and Wetland Change in Louisiana, USGS National Assessment of Shoreline Change, USGS Atlas of Shoreline Changes, NOAA Coastal Services Center LIDAR, and the University of New Orleans. Table 3 summarizes the available survey and shoreline data used in this report.

Table 3. Summary of Available Survey and Shoreline Data

Date	Data Type	Source/Description
June 2007	Topography (LIDAR)	BICM LIDAR Survey
September 2006	Topography (LIDAR)	
March 2006	Topography (LIDAR)	
September 2005	Topography (LIDAR)	NOAA LIDAR Survey
September 1998	Topography (LIDAR)	NOAA LIDAR Survey
2007/2006, 1920, 1880	Bathymetry Grid	BICM
2005, 2004, 1999, 1996, 1989, 1978, 1969, 1951, 1922, 1855	Shoreline	BICM
1989, 1978, 1951, 1922, 1869, 1855	Shoreline Change	USGS Atlas of Shoreline Changes
1973-1978, 1922-1934, 1855-1887	Shoreline	USGS National Assessment of Shoreline Change
1999, 1855	Shoreline	USGS Coastal Erosion and Wetland Change in Louisiana
1951	Topography Grid	USGS Digital Elevation Models
2006-2007	Bathymetry Grid	USGS

LIDAR data provides the most comprehensive data set for topography. Five LIDAR sets are available to evaluate topographic changes. However, the lack of water clarity restricts LIDAR from providing bathymetric data.

Barrier Island Comprehensive Monitoring (BICM) data was collected in 2006 and 2007 but provides only hydrographic data. The 2006 LIDAR data and 2006/2007 BICM data have been compiled to provide the bathymetric and topographic map shown in Figure 21.

6.2 Nourishment History

The Chandeleur Islands and Breton Island are located within the Breton National Wildlife Refuge. Beneficial disposal of dredged material occurred on and close to Breton Island between 1993 and 2005 (Creef, 2009). A summary of the nourishment history along Breton Island is provided in Table 4.

Table 4. Summary of Nourishment History along Breton Island

Year	Placement Location	Volume (cy)
1993	Northeast Sacrificial Berm	1,600,000
1999	Northeast Sacrificial Berm	3,800,000
1999	Northeast Rim Breaches	1,101,100
2001	Northeast Rim Breaches	1,942,408
2005	Northeast Rim Breaches	4,073,720

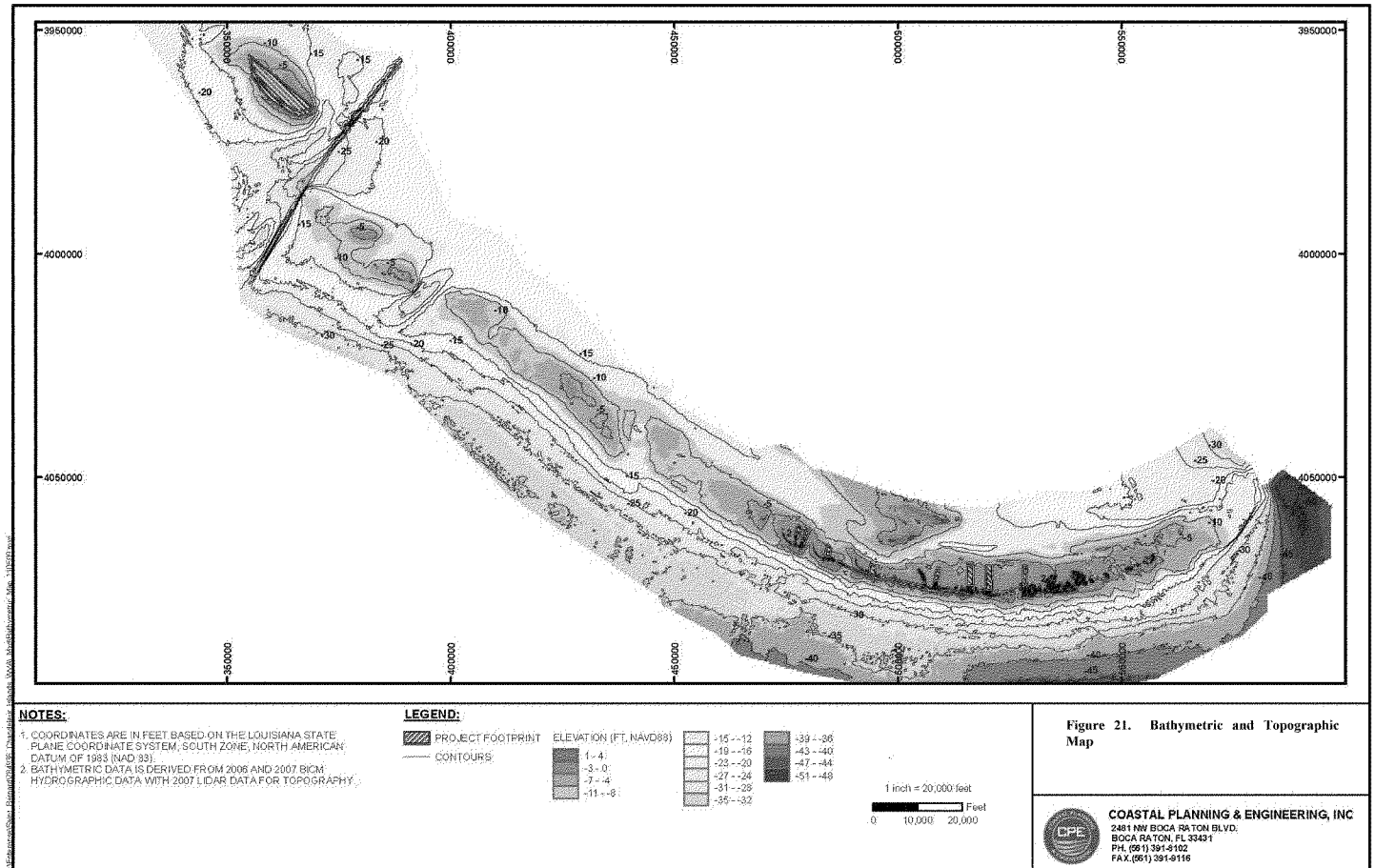


Figure 21. Bathymetric and Topographic Map

COASTAL PLANNING & ENGINEERING, INC
2481 NW BOCA RATON BLVD.
BOCA RATON, FL 33431
PH. (561) 391-8102
FAX.(561) 391-9116

7 SUBSIDENCE AND SEA LEVEL RISE

A primary factor governing land loss along the Louisiana shoreline is relative sea level rise. Relative sea level rise consists of two components (NRC, 1987) as follows:

1. Eustatic sea level change. Eustatic sea level change is defined as the global change in oceanic water level relative to a fixed vertical datum (ie. NAVD).

2. Subsidence. Subsidence is defined as the local change in land elevation relative to a fixed vertical datum (ie. NAVD).

Along the Louisiana coast the land elevation is decreasing while the mean sea level elevation is increasing, resulting in significant land loss.

7.1 National Research Council

Relative sea level rise can be estimated using tidal records and the National Research Council (NRC) methodology. For a tidal record to be sufficient for this purpose it must be at least 37 years long, which is twice the length of the 18.6 year lunar nodal tide cycle. The rate of relative sea level rise along the Chandeleur Islands is 0.0164 feet/year (Miner, 2009a).

The NRC (1995) developed a numerical relationship (Equation 1) for estimating the total relative sea level rise for any location, given a known rate of subsidence, as follows:

$$E(t) = (0.0039 + M)t + Bt^2 \qquad \text{[Equation 1]}$$

where:

E = relative sea level change between 1986 and year t in feet
M = subsidence in feet/year
B = acceleration in the rate of eustatic sea level change in feet/year^2
t = years after 1986

The NRC committee recommended sea level rise projections be updated every decade to incorporate additional data. Equation 1 was derived at a time when the global mean sea level change was approximately 0.0039 feet/year. The current estimate of global mean sea level change is 0.0056 feet/year (IPCC, 2007). Therefore, Equation 1 was modified, as shown in Equation 2, to include the most recent estimate of global mean sea level change (USACE, 2009).

$$E(t) = (0.0056 + M)t + Bt^2 \qquad \text{[Equation 2]}$$

Subsidence was calculated by comparing the local rate of relative sea level rise with the global rate of mean sea level change. It was assumed that the local sea level change rate is equal to the global mean sea level change rate and was constant over the analysis period. Therefore, the local subsidence rate was obtained by subtracting the global mean sea level change rate from the local rate of relative sea level rise (0.0164 – 0.0056 = 0.0108 feet/year).

The USACE (2009) suggests using baseline (low), intermediate, and high sea level changes when planning, engineering, and designing coastal projects. Baseline sea level changes assume that sea level rises at the historic rate with no acceleration (B = 0 feet/year^2). Intermediate sea level changes employ an acceleration term that results in a eustatic sea level rise of 1.64 feet (0.5 meters) by the year 2100 (NRC Curve 1, B = 7.74x10^{-5} feet/year^2). The acceleration term used to model high sea level changes results in a eustatic sea level rise of 4.92 feet (1.5 meters) by the year 2100 (NRC Curve 3, B = 3.30x10^{-4} feet/year^2). Figure 22 shows a schematic of sea level change expected over the 50 year project evaluation period.

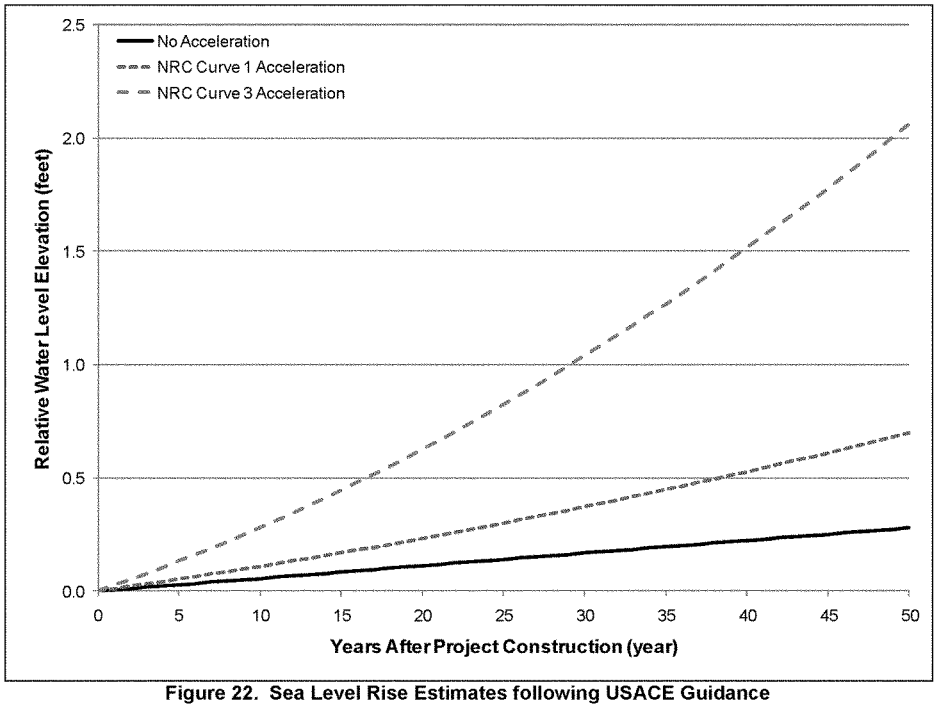


Figure 22. Sea Level Rise Estimates following USACE Guidance

Average relative sea level rise rates are used in this report to decompose historic shoreline change data and estimate future project performance. Over the 50-year project evaluation period (2015 to 2065) the rate of relative sea level rise is projected to increase; however, the rate of relative sea level rise can be treated as a constant over the 50-year project evaluation period. The constant rate of relative sea level rise was obtained by linearizing the sea level rise projections over the project evaluation period. The rate of relative sea level rise at the beginning and end of the project evaluation period and the average rate of relative sea level rise for low (baseline), intermediate, and high sea level changes are provided in Table 5 and are shown graphically in Figure 23.

Table 5. Relative Sea Level Rise Summary

Sea Level Rise Acceleration	Relative Sea Level Rise (ft/yr)		
	TY0 (2015)	TY50 (2065)	Applied
Low (Baseline)	0.0164	0.0164	0.0164
Intermediate	0.0209	0.0286	0.0248
High	0.0355	0.0685	0.0520

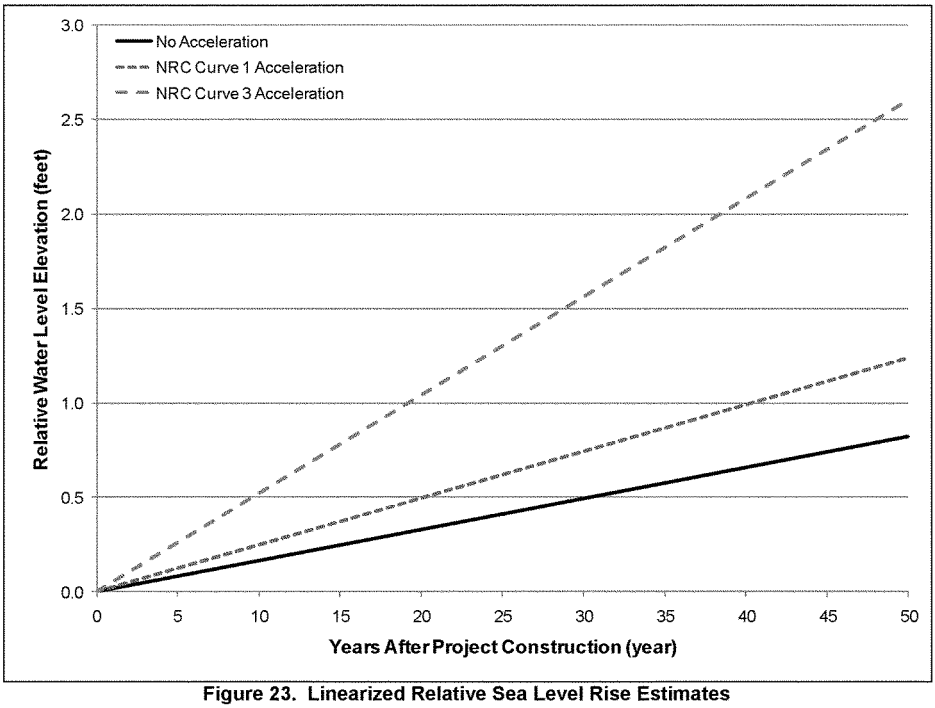


Figure 23. Linearized Relative Sea Level Rise Estimates

Project performance and benefit assessments in this report assumed the low RSLR value, per direction from the USACE Study Manager, Sandra Stiles. This report presents a first screening of alternatives. If either the Chandeleur Islands or Breton Island is selected for further evaluation, then the project will be reevaluated using the medium and high RSLR rates.

8 SHORELINE CHANGES

The long-term (1855-2002) average rate of gulf shoreline recession along the entire Chandeleur Islands barrier shoreline, stretching 58.2 miles between Plaquemines Parish and St. Bernard

Parish, is approximately -45 feet/year. Recent analyses suggest that gulf shoreline recession is accelerating along the Chandeleur Islands, given the -69 feet/year short-term (1988-2002) erosion rate (Penland et al, 2002).

Shoreline changes were extracted along USGS transects identified in the Louisiana Barrier Island Erosion Study – Atlas of Shoreline Changes in Louisiana from 1853 to 1989 (Williams et al, 1992). Williams et al (1992) presented two transect sets for analyzing gulf and bay shoreline changes. The historic shoreline change analysis, presented in Section 1.1, utilized the gulf transects when describing gulf shoreline changes and bay transects when describing bay shoreline changes. The recent shoreline change analysis, presented in Section 8.2, used only the gulf transect lines, shown in Figure 24 (Chandeleur Islands) and Figure 25 (Breton Island), when describing both gulf and bay shoreline changes.

LEGEND:
1855 BOM SHORELINE
1922 BOM SHORELINE
1951 BOM SHORELINE
1978 BOM SHORELINE
1988 BOM SHORELINE
1996 BOM SHORELINE
2004 BOM SHORELINE
NOTES:
1. OCTOBER 28/29, 2008 AERIAL PHOTOGRAPHY DOWNLOADED FROM www.tecost.gov, FLOWN BY PHOTO SCIENCE, INC.
2. BOM SHORELINES OBTAINED FROM THE UNIVERSITY OF NEW ORLEANS.
N 526,000
N 494,000
N 462,000
E 4,054,000
N 598,000
GULF OF MEXICO
GRAPHIC SCALE IN FT
0 4000 8000
Figure 24. Chandeleur Islands Shoreline Location Map (1855 to 2004)
COASTAL PLANNING & ENGINEERING, INC.
2481 N.W. BOCA RATON BOULEVARD
BOCA RATON, FLORIDA 33431
PH. (561) 391-9102
FAX (561) 391-9116
www.CoastalPlanning.com

Figure 25. Breton Island Shoreline Location Map

8.1 Historic Shoreline Changes

Historic shoreline change data were obtained from the Louisiana Barrier Island Erosion Study – Atlas of Shoreline Changes in Louisiana from 1853 to 1989 (Williams et al, 1992). The historic shorelines used in the historic shoreline change analysis are presented graphically in Figure 24 (Chandeleur Islands) and Figure 25 (Breton Island). Gulfside and bayside shoreline changes presented in Williams et al (1992) were annualized for comparison purposes, with a statistical description of the data provided in Table 6 (Chandeleur Islands) and Table 7 (Breton Island). A negative gulf shoreline change indicates shoreline recession and movement to the west-northwest while a positive gulf shoreline change indicates shoreline advance and movement to the east-southeast. A positive bay shoreline change indicates movement to the west-northwest while a negative bay shoreline change indicates shoreline recession and movement to the east-southeast.

Table 6. Historic Shoreline Changes along the Chandeleur Islands

Time Period	Shoreline Change (feet/year)					
	Gulf			Bay		
	Average	Minimum	Maximum	Average	Minimum	Maximum
1855-1922	-18	19	-49	7	-31	67
1922-1951	-18	10	-52	18	-28	124
1951-1978	-34	-2	-177	11	-20	164
1978-1989	-38	-11	-85	16	-16	143

Table 7. Historic Shoreline Changes along Breton Island

Time Period	Shoreline Change (feet/year)					
	Gulf			Bay		
	Average	Minimum	Maximum	Average	Minimum	Maximum
1869-1922	-24	-2	-43	19	-9	52
1922-1951	-13	34	-40	8	-22	26
1951-1978	-21	21	-56	-18	-97	15
1978-1989	-13	12	-73	-4	-11	17

8.1.1 Historic Gulf Shoreline Changes

Gulf shoreline recession along the Chandeleur Islands was greatest near the southern extent and decreased towards the north. Between 1855 and 1989 the gulf shoreline receded west at an average rate of -21 feet/year, with a minimum and maximum recession rate of -1 feet/year and -58 feet/year, respectively. The greatest shoreline recession rate was experienced between 1978 and 1989, with an average recession rate of -38 feet/year. The smallest shoreline recession rate was experienced between 1855 and 1922 and between 1922 and 1951, with the shoreline receding at an average rate of -18 feet/year. Shoreline recession between 1951 and 1978 averaged -34 feet/year. Figure 26 provides a graphic representation of annualized historic gulf shoreline changes along the Chandeleur Islands.

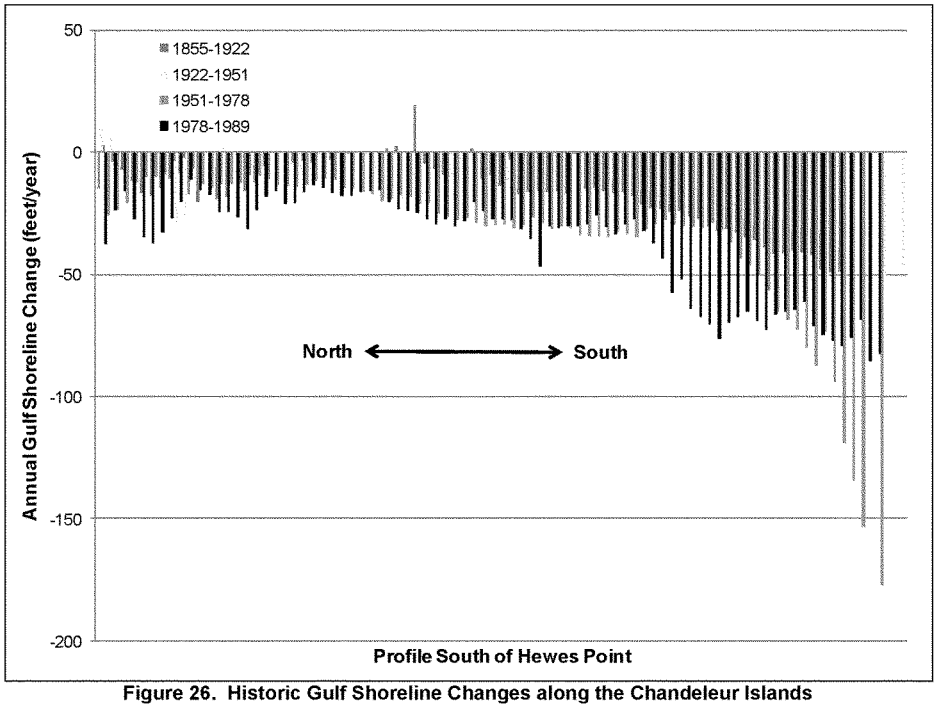


Figure 26. Historic Gulf Shoreline Changes along the Chandeleur Islands

Gulf shoreline recession along Breton Island was greatest near the northeastern extent of the island and decreased towards the southwest. Between 1869 and 1989 the gulf shoreline receded northwest at an average rate of -19 feet/year, with a minimum and maximum recession rate of 19 feet/year (advance) and -30 feet/year, respectively. The greatest shoreline recession rate was experienced between 1869 and 1922, with an average recession rate of -24 feet/year. The smallest shoreline recession rate was experienced between 1922 and 1951 and between 1978 and 1989, with the shoreline receding at an average rate of -13 feet/year. Shoreline recession between 1951 and 1978 averaged -21 feet/year. Figure 27 provides a graphic representation of annualized historic gulf shoreline changes along Breton Island.

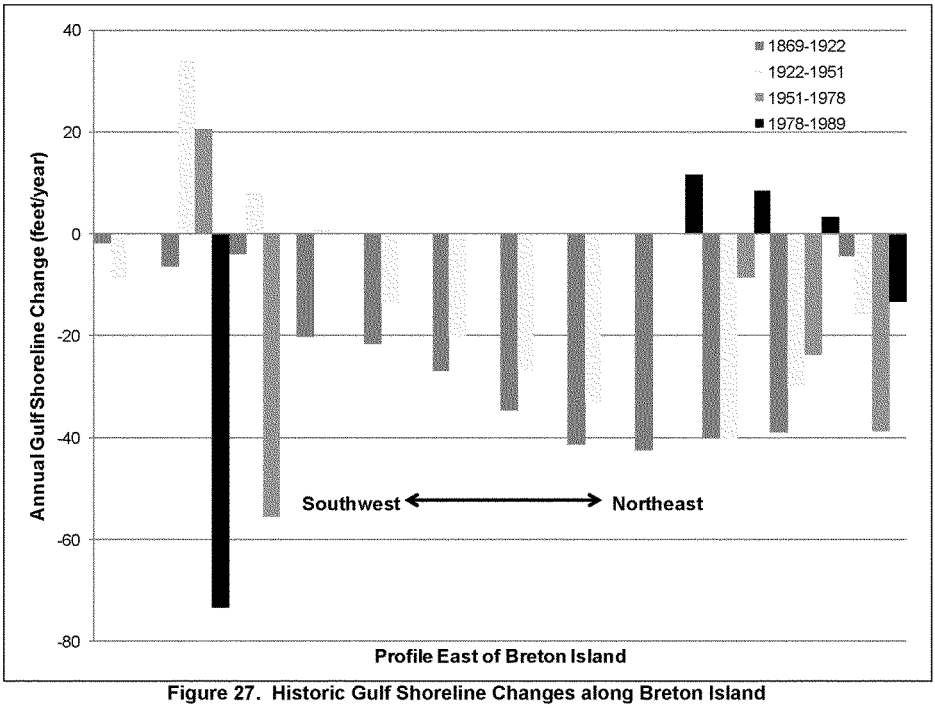


Figure 27. Historic Gulf Shoreline Changes along Breton Island

8.1.2 Historic Bay Shoreline Changes

Bay shoreline migration along the Chandeleur Islands was highly variable. Between 1855 and 1989 the bay shoreline migrated west at an average rate of 10 feet/year, with a minimum and maximum migration rate of -6 feet/year (recession) and 49 feet/year, respectively. The greatest shoreline migration rate was experienced between 1922 and 1951, with an average migration rate of 18 feet/year. The smallest shoreline migration rate was experienced between 1855 and 1922, with the shoreline migrating at an average rate of 7 feet/year. Shoreline migration between 1951 and 1978 averaged 11 feet/year while shoreline migration between 1978 and 1989 averaged 16 feet/year. Figure 28 provides a graphic representation of annualized historic bay shoreline changes along the Chandeleur Islands.

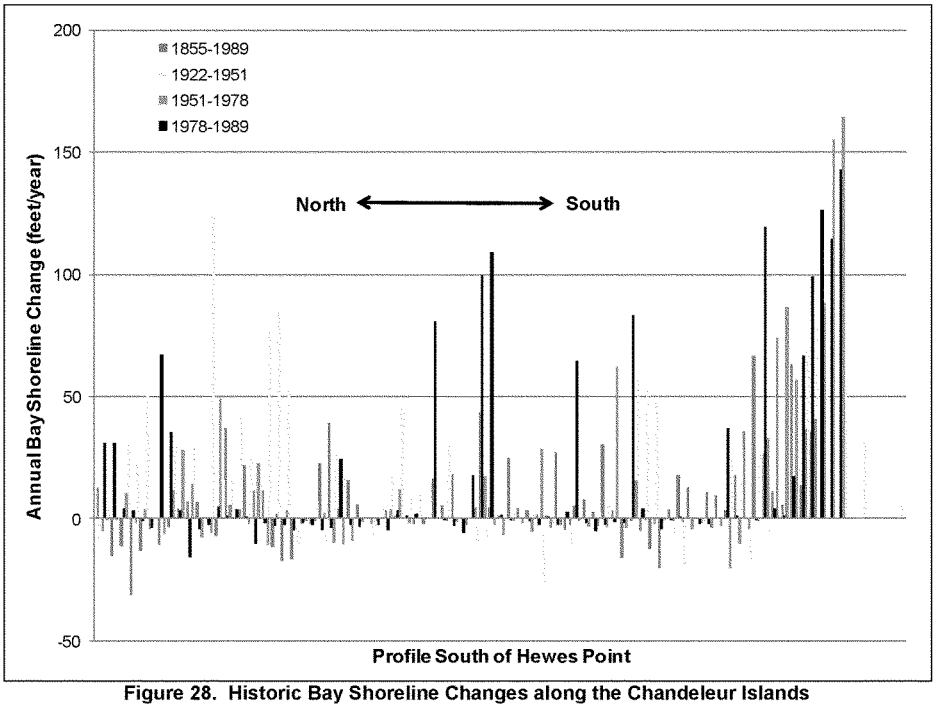


Figure 28. Historic Bay Shoreline Changes along the Chandeleur Islands

Bay shoreline migration along Breton Island was greatest near the northeastern extent of the island and decreased towards the southwest. Between 1869 and 1989 the bay shoreline migrated northwest at an average rate of 13 feet/year, with a minimum and maximum migration rate of -25 feet/year (recession) and 33 feet/year, respectively. The greatest shoreline migration rate was experienced between 1869 and 1922, with an average migration rate of 19 feet/year. The smallest shoreline migration rate was experienced between 1951 and 1978, with the shoreline migrating at an average rate of -18 feet/year (recession). Shoreline migration between 1922 and 1951 averaged 8 feet/year while shoreline migration between 1978 and 1989 averaged -4 feet/year (recession). Figure 29 provides a graphic representation of annualized historic bay shoreline changes along Breton Island.

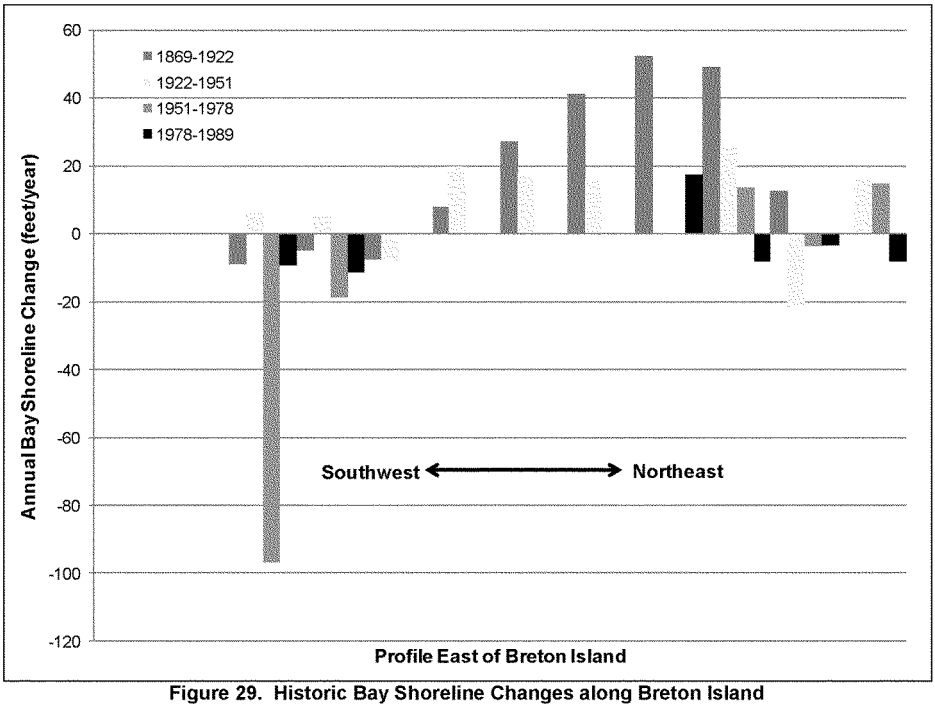


Figure 29. Historic Bay Shoreline Changes along Breton Island

8.2 Recent Shoreline Changes

Recent shorelines were obtained from the Louisiana Barrier Island Comprehensive Monitoring Program (BICM). Shorelines compiled under the BICM program were derived from a number of sources, including National Oceanic and Atmospheric Administration (NOAA)/National Ocean Service (NOS) topographic sheets (T-sheets), U.S. Geological Survey digital orthophoto quarter quads (DOQQ's), Color Infrared (CIR) aerial photography, and Digital Globe QuickBird satellite imagery (Martinez et al, 2009). Shoreline locations, defined by the high-water line, were obtained using image processing algorithms, spatial models, and aerial photograph interpretation techniques. The following shorelines were generated under the BICM program for the Chandeleur Islands: 1855, 1922, 1951, 1996, 2004, and 2005.

Recent shoreline changes were obtained using the 1996 and 2004 BICM shorelines. These shorelines were chosen because they best represent present and project shoreline locations, orientations, and changes along the entirety of the Chandeleur Islands barrier shoreline. The 2005 shoreline was not used in this analysis because island breaching and overwash, as a result of Hurricanes Katrina and Rita. The segmentation of the island chain prohibited a shoreline change analysis along the entire Chandeleur Islands. An attempt was made to extract shorelines from the LIDAR data sets described in Section 6; however, LIDAR data collected after hurricanes Katrina and Rita produced a highly segmented shoreline and LIDAR data collected

prior to hurricanes Katrina and Rita did not include the westernmost extent of the bay shoreline along the Chandeleur Islands.

The shorelines used in the recent shoreline change analysis (1996 and 2004) are presented graphically in Figure 24 (Chandeleur Islands) and Figure 25 (Breton Island). Gulfside and bayside shoreline changes were calculated along USGS transects, shown in Figure 24 and Figure 25, and were then annualized for comparison purposes. A summary of the recent shoreline change data is provided in Table 8. A negative gulf shoreline change indicates shoreline recession and movement to the west-northwest while a positive gulf shoreline change indicates shoreline advance and movement to the east-southeast. A positive bay shoreline change indicates shoreline advance and movement to the west-northwest while a negative bay shoreline change indicates shoreline recession and movement to the east-southeast.

Table 8. Recent (1996-2004) Shoreline Changes along the Chandeleur Islands and Breton Island

	Shoreline Change (feet/year)					
	Gulf			Bay		
Location	Average	Minimum	Maximum	Average	Minimum	Maximum
North Islands	-58	14	-223	14	-198	227
Breton Island	-41	25	-65	19	-41	109

8.2.1 Recent Gulf Shoreline Changes

Gulf shoreline recession along the Chandeleur Islands was greatest near the southern extent and decreased towards the north. Between 1996 and 2004 the gulf shoreline receded west at an average rate of -58 feet/year, with a minimum and maximum recession rate of 14 feet/year (advance) and -223 feet/year, respectively. Figure 30 provides a graphic representation of annualized recent gulf shoreline changes along the Chandeleur Islands.

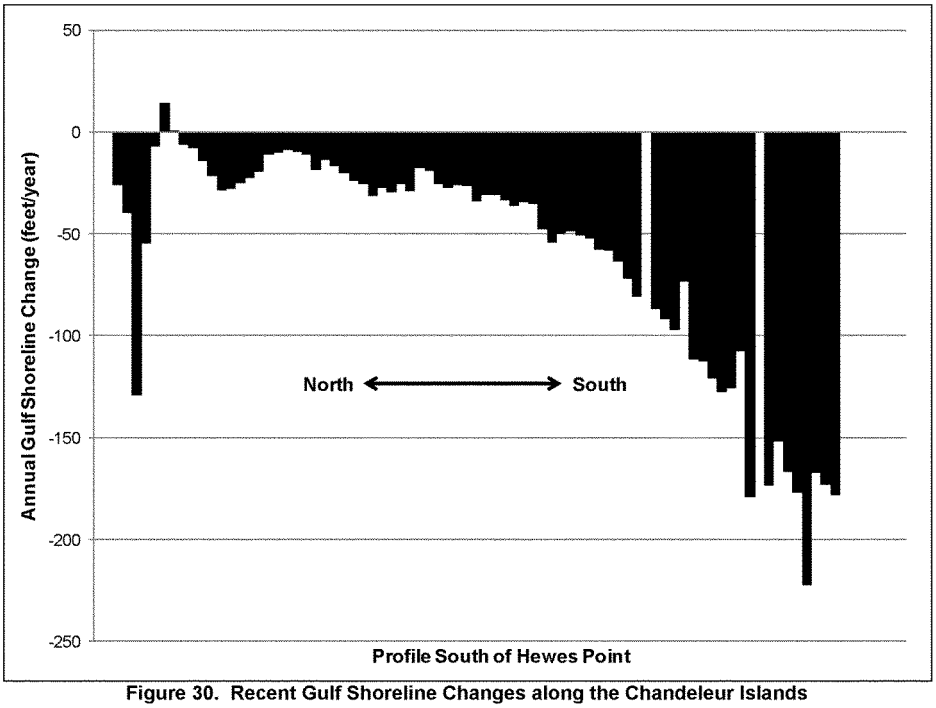


Figure 30. Recent Gulf Shoreline Changes along the Chandeleur Islands

Gulf shoreline recession along Breton Island was greatest near the northeastern extent of the island and decreased towards the southwest. Between 1996 and 2004 the gulf shoreline receded northwest at an average rate of -41 feet/year, with a minimum and maximum recession rate of 25 feet/year (advance) and -65 feet/year, respectively. Figure 31 provides a graphic representation of annualized recent gulf shoreline changes along Breton Island.

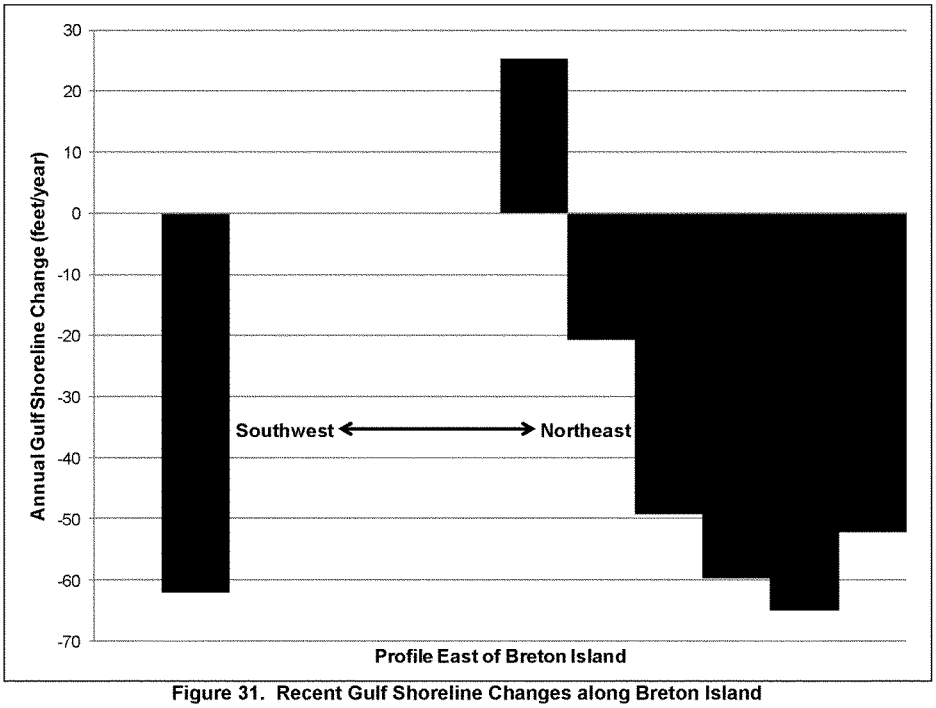


Figure 31. Recent Gulf Shoreline Changes along Breton Island

8.2.2 Recent Bay Shoreline Changes

Bay shoreline migration along the Chandeleur Islands was greatest near the southern extent and decreased towards the north. Between 1996 and 2004 the bay shoreline migrated west at an average rate of 14 feet/year, with a minimum and maximum migration rate of -198 feet/year (recession) and 227 feet/year, respectively. Figure 32 provides a graphic representation of annualized recent bay shoreline changes along the Chandeleur Islands.

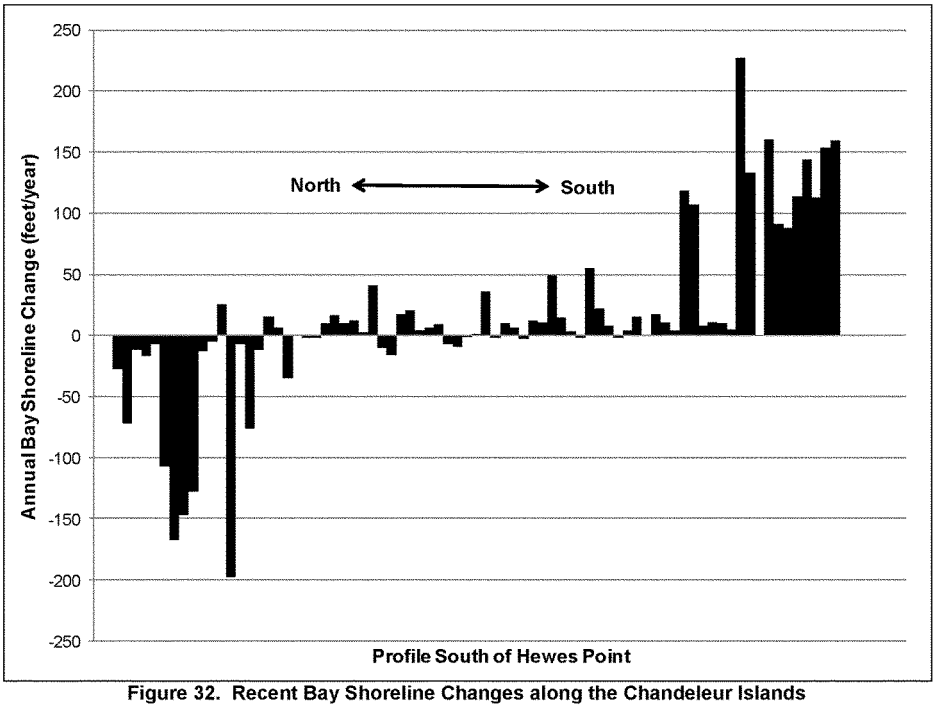


Figure 32. Recent Bay Shoreline Changes along the Chandeleur Islands

Bay shoreline migration along Breton Island was greatest near the northeastern extent of the island and decreased towards the southwest. Between 1996 and 2004 the bay shoreline migrated northwest at an average rate of 19 feet/year, with a minimum and maximum migration rate of -41 feet/year (recession) and 109 feet/year, respectively. Figure 33 provides a graphic representation of annualized historic bay shoreline changes along Breton Island.

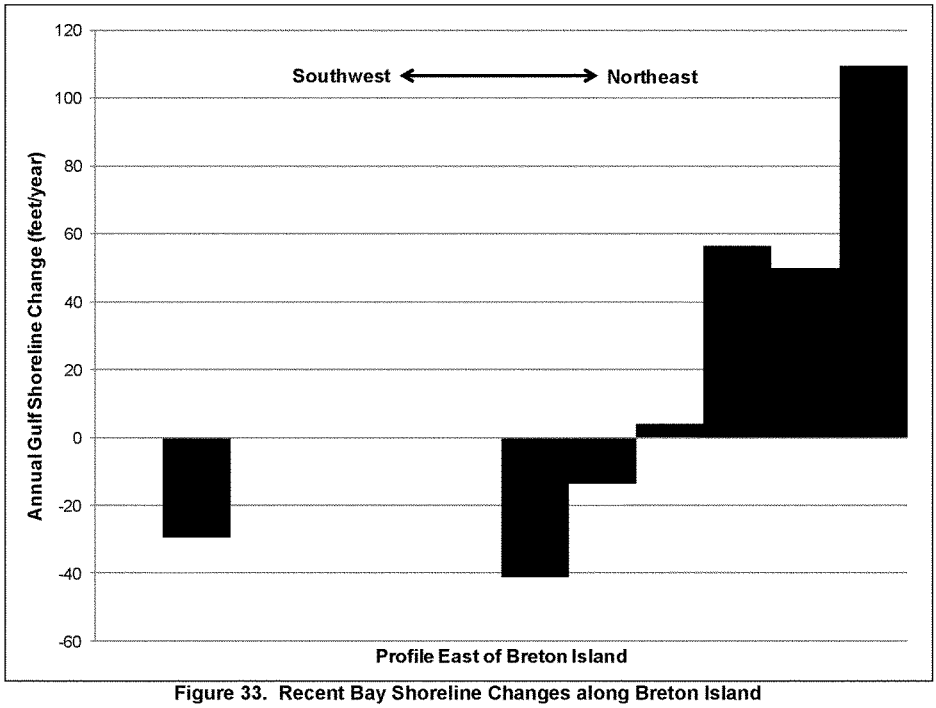


Figure 33. Recent Bay Shoreline Changes along Breton Island

8.3 Shoreline Response to Relative Sea Level Rise

Bruun (1982) showed that beach profiles should adjust to increased water elevation with a recession of the shoreline and a deposition of sand in the offshore area (Figure 34). Shoreline recession due to relative sea level rise for a sand only system can be estimated using Bruun's (1982) rule (Equation 3).

$$x = rb/(h-d) \qquad \text{[Equation 3]}$$

where:

x = shoreline recession (feet)
r = relative sea level rise (feet)
b = distance from the berm crest to the depth of closure (feet)
h = berm elevation (feet, NAVD)
d = depth of closure elevation (feet, NAVD)

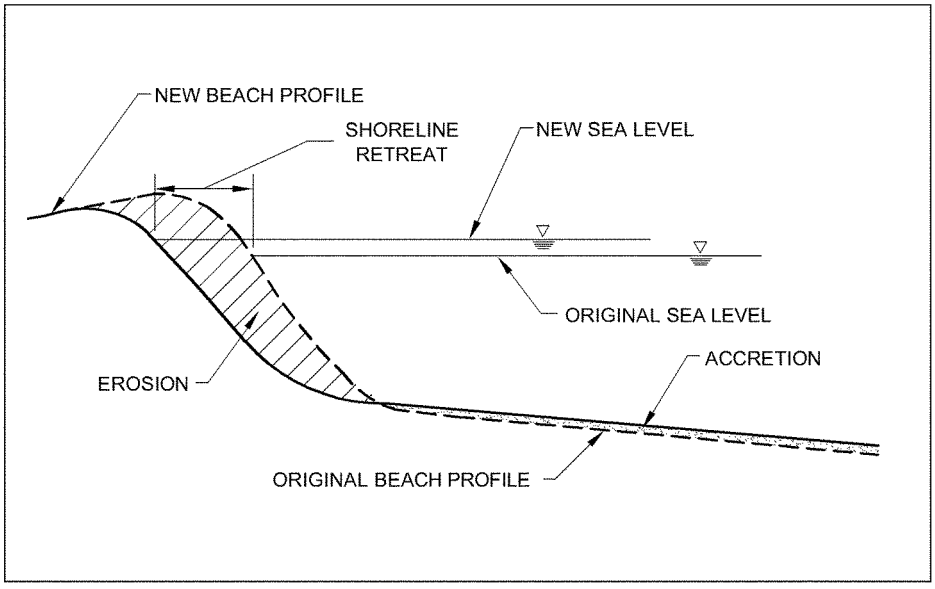


Figure 34. Impact of Sea Level Rise on Shoreline Recession

The berm elevation, depth of closure, and distance from the berm to the depth of closure were all determined by inspecting profiles generated using BICM bathymetric data. Bathymetric data was collected offshore of the Chandeleur Islands in 1880, 1920, and 2006 while bathymetric data was collected offshore of Breton Island in 1870, 1920, and 2007. Profiles were extracted along the USGS transects shown in Figure 24 and Figure 25. Comparison of recent and historic profiles suggests that the average nearshore slope is 1V:580H along the Chandeleur Islands and 1V:560H along Breton Island. Since the nearshore slopes calculated along Breton Island and the Chandeleur Islands are similar, it was decided to use an average nearshore slope when calculating shoreline response to relative sea level rise. The average nearshore slope for applied Breton Island and the Chandeleur Islands is 1V:580H. A detailed discussion of the closure depth and berm elevation is provided in Section 9.

Shoreline response to relative sea level rise was calculated for the three relative sea level rise rates discussed in Section 7. Presently, it is estimated that the shoreline along the Chandeleur Islands and Breton Island is receding approximately 9.5 feet annually due to the effect of relative sea level rise. This response to relative sea level rise is expected to increase during the project evaluation period as sea level rise is accelerating. Shoreline recession due to relative sea level rise could be anywhere between 14.4 feet/year and 30.2 feet/year depending on how quickly sea level rise accelerates. A summary of shoreline recession rates due to varying levels of sea level rise acceleration, as discussed in Section 7, is provided in Table 9.

Table 9. Shoreline Response to Relative Sea Level Rise

Sea Level Rise Acceleration	Relative Sea Level Rise (ft/yr)	Shoreline Retreat due to Relative Sea Level Rise (ft/yr)
Low (Baseline)	0.0164	9.5
Intermediate	0.0248	14.4
High	0.0520	30.2

9 ACTIVE PROFILE HEIGHT

Volume changes can be calculated by multiplying the shoreline change by the active profile height and the longshore distance between profiles. Typically the active profile extends from the berm crest to the depth of closure, where the depth of closure is defined as the depth at which there is no net cross-shore movement of sediment. In Louisiana, the barrier islands are low lying and are frequently overtopped. The resultant overwash of sediment deposited on the backing marsh platform is what maintains island elevation and helps rebuild the migrating dune (Campbell, 2005). The volume above the marsh remains relatively constant due to overwash, whereas the true volume change occurs between the top of the marsh and the depth of closure. Therefore, the marsh elevation can be considered to be the top of the active profile and the depth of closure can be considered to be the bottom of the active profile when calculating volume changes.

Observation of historic shorelines along the Chandeleur Islands and Breton Island shows that these barrier islands are migrating west-northwest while becoming narrower. This landward migration occurs when sediment is washed over the island and is deposited in the backing bay. Over time sediment deposited in the backing bay builds up and eventually emerges to become new marsh. Therefore, the true volume change is the volume change along the gulf face less the volume change along the bay face.

The gulf and bay depth of closure were both determined by examining historic cross-shore profiles along the Chandeleur Islands and Breton Island. Profiles were extracted from the 1922 and 2006/2007 BICM bathymetry along the USGS transects shown in Figure 24 and Figure 25. The profiles were inspected to determine the closure elevation on the gulf and bay sides of the barrier islands. Figure 35 is an example profile showing both the gulf and bay depth of closure. The gulf and bay depth of closure were determined for all profiles. An average depth of closure was then calculated to facilitate a volume change estimate along the gulf and bay shore faces. The average gulf and bay closure depths along the Chandeleur Islands were calculated to be -34 feet, NAVD and -16 feet, NAVD, respectively. The average gulf and bay closure depths along Breton Island were calculated to be -22 feet, NAVD and -17 feet, NAVD, respectively.

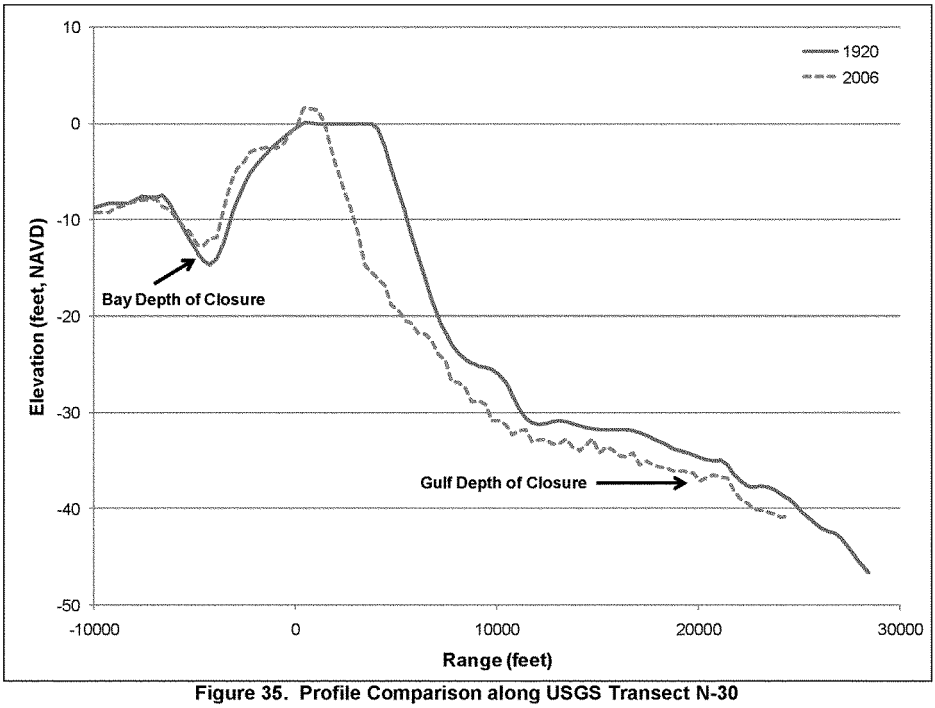


Figure 35. Profile Comparison along USGS Transect N-30

10 VOLUME CHANGES

Profile data is normally used to calculate volume change estimates in project areas. However, recent profile comparison data was not available (the only comparison could have been 1920 to 2007 and Section 5.7 discussed why a post MRGO data set should be used to evaluate recent changes). LIDAR data is available but it only captures subaerial changes in the profile. Consequently, it was not possible to directly calculate volumes based on survey data. Shoreline data are available and allowed for a greater number of comparison points along the island chain. Therefore, it was decided to base volumetric change estimates on the shoreline change data.

Shoreline based volumetric changes can be approximated by multiplying the shoreline change by the active profile height and the alongshore distance between profiles (USACE, 2001). As described in Dean (2002), volume changes for a stabilized coast are proportional to changes in the shoreline location. However, barrier islands, such as the Chandeleur and Breton Islands, have the tendency to migrate landward due to the effects of significant storms and relative sea level rise. Significant storms simultaneously erode the shoreline and wash sediment over the island and into the backing bay causing the island to roll over. Therefore, the total volume change for a migrating barrier island should be the gulf side volume change less the bay side volume change. This theory assumes that the island form remains the same (in terms of dune

elevation, dune width, and marsh elevation; i.e. the volume above the marsh remains constant) and the only parameter changing is the width of the barrier island.

Volumetric changes along the Chandeleur and Breton Islands were calculated using the shoreline change data presented in Section 8.2 and the active profile heights discussed in Section 9. A negative volume change indicates a volumetric loss (erosion) while a positive volume change indicates a volumetric gain (accretion). The volume changes along the Chandeleur Islands and Breton Island are presented in Table 10 and Table 11, respectively. The total volume change along the North Chandeleur Islands is -7,812,000 cubic yards/year while the total volume change along Breton Island is -1,248,000 cubic yards/year.

Table 10. Volume Changes along the Chandeleur Islands

		Gulf Side Change			Bay Side Change		
Station	Cell Width (ft)	Shoreline Change (ft/yr)	Active Profile Height (ft)	Volume Change (cy/yr)	Shoreline Change (ft/yr)	Active Profile Height (ft)	Volume Change (cy/yr)
N-1	1,335	-	35.2	-	-	17.5	-
N-2	2,665	-	35.2	-	-	17.5	-
N-3	1,903	-	35.2	-	-	17.5	-
N-4	1,485	-	35.2	-	-	17.5	-
N-5	1,662	-	35.2	-	-	17.5	-
N-6	1,339	-	35.2	-	-	17.5	-
N-7	1,720	-	35.2	-	-	17.5	-
N-8	1,519	-178.2	35.2	-352,416	159.3	17.5	156,463
N-9	1,028	-173.1	35.2	-231,679	154.2	17.5	102,556
N-10	1,681	-167.5	35.2	-366,499	112.8	17.5	122,637
N-11	1,980	-222.5	35.2	-573,585	144.2	17.5	184,690
N-12	1,609	-177.4	35.2	-371,602	113.2	17.5	117,861
N-13	1,379	-166.8	35.2	-299,532	87.9	17.5	78,392
N-14	1,525	-151.9	35.2	-301,460	91.1	17.5	89,852
N-15	1,525	-173.5	35.2	-344,433	160.0	17.5	157,792
N-16	1,592	-	35.2	-	-	17.5	-
N-17	1,650	-178.9	35.2	-384,501	133.2	17.5	142,241
N-18	1,647	-107.6	35.2	-230,635	226.7	17.5	241,570
N-19	1,477	-126.0	35.2	-242,164	4.9	17.5	4,710
N-20	1,414	-127.8	35.2	-235,202	9.9	17.5	9,088
N-21	1,654	-120.7	35.2	-259,857	10.4	17.5	11,082
N-22	1,588	-112.3	35.2	-232,039	8.3	17.5	8,567
N-23	1,483	-111.5	35.2	-215,252	106.8	17.5	102,400
N-24	1,522	-73.6	35.2	-145,849	118.1	17.5	116,213
N-25	1,580	-96.9	35.2	-199,353	4.2	17.5	4,337
N-26	1,554	-91.5	35.2	-185,111	10.6	17.5	10,640
N-27	1,551	-86.9	35.2	-175,490	16.9	17.5	16,988
N-28	1,516	-	35.2	-	-	17.5	-
N-29	1,433	-80.9	35.2	-151,050	15.2	17.5	14,054
N-30	1,545	-71.9	35.2	-144,605	3.8	17.5	3,782
N-31	1,560	-63.7	35.2	-129,275	-1.6	17.5	-1,567
N-32	1,472	-58.2	35.2	-111,482	8.2	17.5	7,794
N-33	1,566	-57.8	35.2	-117,877	22.4	17.5	22,693
N-34	1,608	-52.3	35.2	-109,408	55.4	17.5	57,612
N-35	1,525	-50.8	35.2	-100,866	-2.0	17.5	-1,944
N-36	1,488	-48.6	35.2	-94,211	3.2	17.5	3,033
N-37	1,598	-49.8	35.2	-103,576	15.0	17.5	15,515
N-38	1,461	-54.0	35.2	-102,818	49.5	17.5	46,788
N-39	1,449	-47.8	35.2	-90,189	10.8	17.5	10,099
N-40	1,690	-35.5	35.2	-78,209	12.4	17.5	13,504
N-41	1,480	-34.5	35.2	-66,403	-2.4	17.5	-2,270
N-42	1,317	-36.4	35.2	-62,407	6.4	17.5	5,472
N-43	1,434	-33.6	35.2	-62,794	10.1	17.5	9,338

N-44	1,505	-31.0	35.2	-60,848	-1.7	17.5	-1,650
N-45	1,474	-30.8	35.2	-58,995	36.2	17.5	34,522
N-46	1,494	-34.0	35.2	-66,043	1.8	17.5	1,722
N-47	1,478	-26.3	35.2	-50,548	-0.2	17.5	-191
N-48	1,390	-26.1	35.2	-47,155	-9.4	17.5	-8,416
N-49	1,449	-27.6	35.2	-52,024	-6.6	17.5	-6,232
N-50	1,477	-25.6	35.2	-49,218	8.6	17.5	8,192
N-51	1,516	-19.0	35.2	-37,587	6.2	17.5	6,102
N-52	1,493	-17.6	35.2	-34,172	3.9	17.5	3,799
N-53	1,474	-29.1	35.2	-55,759	20.3	17.5	19,387
N-54	1,485	-25.3	35.2	-48,869	16.9	17.5	16,190
N-55	1,347	-29.6	35.2	-51,843	-15.9	17.5	-13,850
N-56	1,372	-27.7	35.2	-49,435	-10.2	17.5	-9,032
N-57	1,419	-31.4	35.2	-57,989	40.8	17.5	37,425
N-58	1,436	-25.4	35.2	-47,552	2.1	17.5	1,950
N-59	1,400	-23.8	35.2	-43,402	12.2	17.5	11,081
N-60	1,531	-20.1	35.2	-40,036	9.4	17.5	9,354
N-61	1,657	-16.5	35.2	-35,675	16.1	17.5	17,283
N-62	1,516	-13.8	35.2	-27,177	9.8	17.5	9,619
N-63	1,402	-18.8	35.2	-34,320	-1.7	17.5	-1,585
N-64	1,383	-11.2	35.2	-20,116	-1.6	17.5	-1,459
N-65	1,446	-9.6	35.2	-18,056	0.8	17.5	764
N-66	1,527	-8.6	35.2	-17,173	-35.1	17.5	-34,624
N-67	1,531	-10.1	35.2	-20,217	6.1	17.5	6,040
N-68	1,658	-11.4	35.2	-24,659	15.7	17.5	16,884
N-69	1,621	-19.3	35.2	-40,829	-12.1	17.5	-12,677
N-70	1,442	-22.7	35.2	-42,543	-75.6	17.5	-70,582
N-71	1,529	-25.2	35.2	-50,107	-7.1	17.5	-7,005
N-72	1,479	-28.1	35.2	-54,153	-198.1	17.5	-189,516
N-73	1,469	-28.3	35.2	-54,124	25.1	17.5	23,881
N-74	1,607	-21.5	35.2	-44,948	-4.9	17.5	-5,121
N-75	1,879	-14.3	35.2	-34,969	-12.4	17.5	-15,051
N-76	1,577	-7.7	35.2	-15,817	-127.4	17.5	-129,991
N-77	1,278	-6.0	35.2	-10,036	-146.9	17.5	-121,447
N-78	1,494	0.6	35.2	1,087	-167.5	17.5	-161,829
N-79	1,719	13.8	35.2	30,873	-107.3	17.5	-119,340
N-80	1,932	-7.4	35.2	-18,586	-6.4	17.5	-8,006
N-81	1,844	-54.7	35.2	-131,205	-16.8	17.5	-20,030
N-82	1,798	-129.2	35.2	-302,347	-12.0	17.5	-14,001
N-83	1,861	-40.1	35.2	-97,097	-72.1	17.5	-86,737
N-84	1,828	-26.2	35.2	-62,341	-27.0	17.5	-31,958
N-85	1,403	-	35.2	-	-	17.5	-
N-86	507	-	35.2	-	-	17.5	-
Total	132,335			-8,847,839			1,035,844

Table 11. Volume Changes along Breton Island

Station	Cell Width (ft)	Gulf Side Change: Shoreline Change (ft/yr)	Gulf Side Change: Active Profile Height (ft)	Gulf Side Change: Volume Change (cy/yr)	Bay Side Change: Shoreline Change (ft/yr)	Bay Side Change: Active Profile Height (ft)	Bay Side Change: Volume Change (cy/yr)
S-1	1,845	-	23.3	-	-	18.1	-
S-2	3,966	-62.1	23.3	-211,943	-29.5	18.1	-78,316
S-3	3,783	-	23.3	-	-	18.1	-
S-4	2,525	-	23.3	-	-	18.1	-
S-5	1,771	-	23.3	-	-	18.1	-
S-6	1,609	-	23.3	-	-	18.1	-
S-7	1,289	-117.4	23.3	-130,281	-41.3	18.1	-35,668
S-8	1,167	-178.3	23.3	-179,193	-13.6	18.1	-10,634
S-9	1,144	-209.8	23.3	-206,747	3.8	18.1	2,915
S-10	904	-225.1	23.3	-175,332	56.4	18.1	34,189
S-11	667	-370.6	23.3	-212,721	49.8	18.1	22,238
S-12	327	-322.8	23.3	-90,877	109.3	18.1	23,939
Total	20,996			-1,207,094			-41,337

The Mississippi River Gulf Outlet (MRGO) was a federally authorized and maintained deep draft navigable waterway between 1965 and 2009. As described in Section 6.2, spoil dredged from the MRGO has been beneficially disposed of on and close to Breton Island during maintenance dredging operations. In order to determine natural shoreline movement from shoreline change due to beneficial material disposal, the benefit of these disposal projects was included in the volumetric calculations. Table 12 provides a summary of the disposal volumes and locations of maintenance dredging operations between 1996 and 2004.

Table 12. Shoreline Changes Resulting from MRGO Beneficial Disposal

Station	Beneficial Disposal Volume (cy) 1999	Beneficial Disposal Volume (cy) 2001	Resultant Shoreline Gain (ft) 1999	Resultant Shoreline Gain (ft) 2001
S-7	1,266,667	-	1,142	-
S-8	1,266,667	-	1,260	-
S-9	1,266,667	-	1,285	-
S-10	253,600	777,243	326	998
S-11	626,000	777,243	1,091	1,354
S-12	221,500	387,922	787	1,378

11 SEDIMENT BUDGET

A sediment budget was developed to describe the movement of sediment into, out of, and within the project areas. The sediment budget was developed by decomposing the volumetric change, described in the previous section, into component parts. This section discusses the separation of the volume change into offshore losses associated with island composition, losses due to relative sea level rise, overwash, and longshore transport.

11.1 Island Composition

The Chandeleur Islands and Breton Island are composed of sand, silt, and clay. A distinction must be made within a sediment budget to account for the difference in material. It is assumed that sand will remain within the confines of the system whereas when silt and clay are exposed to direct wave attack, they are suspended in the water column and can be transported out of the system.

The sediment budget assumes that silt and clay exposed along the shoreline face are placed in suspension and transported offshore, while the sand fraction remains behind. The sand component is then transported alongshore or overwashes the island. Therefore, volume changes must be reduced by the percent silt and clay to obtain the sand volume changes. Campbell (2005) suggested that marsh samples should be taken to estimate the silt content in the island as the beach face is transient and does not represent the composition of the island.

Fifteen vibracore samples were taken from the Chandeleur Islands in July 2009. The core samples were collected along the western edge of the Chandeleur Islands. The average core depth was approximately 15.5 feet, with minimum and maximum core depths of 8.2 feet and 21.9 feet, respectively. It was determined that on average the island is composed of approximately 32% silt/clay and 68% sand. Therefore, the total volumetric loss was multiplied by 32% to determine the volume of silts and clay lost offshore from each profile line. The volume lost offshore along the Chandeleur Islands was estimated at 2,841,536 cubic yards/year, as shown in Table 13. The volume lost offshore along Breton Island was estimated at 386,270 cubic yards/year, as shown in Table 14. Note that where the gulf shoreline advanced there is no volumetric gain of silt.

Table 13. Sediment Budget along the Chandeleur Islands (1996-2004)

Station	Total Volume Lost From Gulf Face (cy/yr)	Volume Lost Offshore (Silt Loss) (cy/yr)	Volume Lost to RSLR (cy/yr)	Overwash Volume (cy/yr)	Net Longshore Sand Volume Change (cy/yr)	Longshore Transport Rate (cy/yr)
N-1	-	-	-	-	-	-1,037,484
N-2	-	-	-	-	-	-1,037,484
N-3	-	-	-	-	-	-1,037,484
N-4	-	-	-	-	-	-1,037,484
N-5	-	-	-	-	-	-1,037,484
N-6	-	-	-	-	-	-1,037,484
N-7	-	-	-	-	-	-1,037,484
N-8	352,416	112,773	18,811	156,463	64,369	-1,037,484
N-9	231,679	74,137	12,736	102,556	42,250	-973,115
N-10	366,499	117,280	20,819	122,637	105,764	-930,865
N-11	573,585	183,547	24,519	184,690	180,828	-825,101
N-12	371,602	118,913	19,927	117,861	114,902	-644,272
N-13	299,532	95,850	17,080	78,392	108,210	-529,370
N-14	301,460	96,467	18,884	89,852	96,257	-421,161
N-15	344,433	110,218	18,882	157,792	57,540	-324,904
N-16	-	-	-	-	-	-267,364
N-17	384,501	123,040	20,441	142,241	98,778	-267,364
N-18	230,635	73,803	20,400	241,570	-105,138	-168,586
N-19	242,164	77,492	18,291	4,710	141,671	-273,724
N-20	235,202	75,265	17,507	9,088	133,342	-132,052
N-21	259,857	83,154	20,482	11,082	145,138	1,289
N-22	232,039	74,253	19,662	8,567	129,558	146,428
N-23	215,252	68,881	18,364	102,400	25,607	275,986
N-24	145,849	46,672	18,847	116,213	-35,883	301,594
N-25	199,353	63,793	19,564	4,337	111,660	265,711
N-26	185,111	59,236	19,247	10,640	95,989	377,370
N-27	175,490	56,157	19,215	16,988	83,130	473,359
N-28	-	-	-	-	-	556,489
N-29	151,050	48,336	17,754	14,054	70,905	556,489
N-30	144,605	46,274	19,141	3,782	75,409	627,395
N-31	129,275	41,368	19,319	0	68,588	702,804
N-32	111,482	35,674	18,231	7,794	49,783	771,391
N-33	117,877	37,721	19,391	22,693	38,073	821,175
N-34	109,408	35,011	19,920	57,612	-3,134	859,247
N-35	100,866	32,277	18,887	0	49,702	856,113
N-36	94,211	30,147	18,426	3,033	42,605	905,815
N-37	103,576	33,144	19,790	15,515	35,127	948,420
N-38	102,818	32,902	18,101	46,788	5,028	983,547
N-39	90,189	28,860	17,945	10,099	33,284	988,575
N-40	78,209	25,027	20,932	13,504	18,746	1,021,859
N-41	66,403	21,249	18,335	0	26,819	1,040,605
N-42	62,407	19,970	16,311	5,472	20,654	1,067,424
N-43	62,794	20,094	17,754	9,338	15,608	1,088,078
N-44	60,848	19,471	18,644	0	22,732	1,103,686

N-45	58,995	18,878	18,251	34,522	-12,657	1,126,418
N-46	66,043	21,134	18,503	1,722	24,684	1,113,761
N-47	50,548	16,175	18,299	0	16,073	1,138,446
N-48	47,155	15,090	17,220	0	14,846	1,154,519
N-49	52,024	16,648	17,951	0	17,426	1,169,365
N-50	49,218	15,750	18,297	8,192	6,980	1,186,791
N-51	37,587	12,028	18,777	6,102	680	1,193,771
N-52	34,172	10,935	18,490	3,799	948	1,194,451
N-53	55,759	17,843	18,259	19,387	270	1,195,399
N-54	48,869	15,638	18,393	16,190	-1,352	1,195,669
N-55	51,843	16,590	16,684	0	18,569	1,194,317
N-56	49,435	15,819	16,988	0	16,627	1,212,886
N-57	57,989	18,557	17,574	37,425	-15,567	1,229,513
N-58	47,552	15,217	17,779	1,950	12,606	1,213,947
N-59	43,402	13,889	17,344	11,081	1,088	1,226,553
N-60	40,036	12,811	18,960	9,354	-1,089	1,227,641
N-61	35,675	11,416	20,525	17,283	-13,549	1,226,551
N-62	27,177	8,697	18,770	9,619	-9,908	1,213,003
N-63	34,320	10,982	17,370	0	5,968	1,203,094
N-64	20,116	6,437	17,124	0	-3,446	1,209,062
N-65	18,056	5,778	17,911	764	-6,396	1,205,617
N-66	17,173	5,495	18,907	0	-7,229	1,199,221
N-67	20,217	6,470	18,966	6,040	-11,258	1,191,992
N-68	24,659	7,891	20,539	16,884	-20,656	1,180,734
N-69	40,829	13,065	20,077	0	7,687	1,160,078
N-70	42,543	13,614	17,865	0	11,065	1,167,765
N-71	50,107	16,034	18,937	0	15,136	1,178,830
N-72	54,153	17,329	18,315	0	18,509	1,193,966
N-73	54,124	17,320	18,189	23,881	-5,265	1,212,474
N-74	44,948	14,383	19,902	0	10,663	1,207,209
N-75	34,969	11,190	23,269	0	510	1,217,872
N-76	15,817	5,061	19,533	0	-8,778	1,218,382
N-77	10,036	3,211	15,832	0	-9,008	1,209,604
N-78	-1,087	0	18,504	0	-19,591	1,200,596
N-79	-30,873	0	21,287	0	-52,160	1,181,005
N-80	18,586	5,948	23,931	0	-11,293	1,128,845
N-81	131,205	41,986	22,833	0	66,387	1,117,553
N-82	302,347	96,751	22,265	0	183,331	1,183,939
N-83	97,097	31,071	23,046	0	42,980	1,367,270
N-84	62,341	19,949	22,642	0	19,750	1,410,250
N-85	-	-	-	-	-	1,430,000
N-86	-	-	-	-	-	1,430,000
Total	8,847,839	2,841,536	1,426,865	2,111,954	2,467,484	

Table 14. Sediment Budget along Breton Island (1996-2004)

Station	Total Volume Lost From Gulf Face (cy/yr)	Volume Lost Offshore (Silt Loss) (cy/yr)	Volume Lost to RSLR (cy/yr)	Overwash Volume (cy/yr)	Net Longshore Sand Volume Change (cy/yr)	Longshore Transport Rate (cy/yr)
S-1	-	-	-	-	-	-310,011
S-2	211,943	67,822	32,492	0	111,629	-310,011
S-3	-	-	-	-	-	-198,382
S-4	-	-	-	-	-	-198,382
S-5	-	-	-	-	-	-198,382
S-6	-	-	-	-	-	-198,382
S-7	130,281	41,690	10,556	0	78,035	-198,382
S-8	179,193	57,342	9,561	0	112,290	-120,347
S-9	206,747	66,159	9,375	2,915	128,298	-8,057
S-10	175,332	56,106	7,408	34,189	77,629	120,240
S-11	212,721	68,071	5,460	22,238	116,952	197,869
S-12	90,877	29,081	2,679	23,939	35,179	314,821
Total	1,207,094	386,270	77,531	83,282	660,011	

11.2 Relative Sea Level Rise

A portion of the shoreline recession is due to the island maintaining its elevation while relative sea level rise processes are occurring. Shoreline recession due to relative sea level rise does not result in a net volume change in the cross-shore profile but simply a redistribution of the sediment across the profile (Figure 34). The volume change calculated from shoreline recession must therefore be reduced to account for relative sea level rise prior to calculating the volume change used to develop the sand longshore transport rate. The shoreline retreat due to relative sea level rise was estimated to be 9.5 feet/year (Section 8.3). This was multiplied by the cell width and active profile height to determine the volumetric loss due to relative sea level rise. The volumetric loss due to relative sea level rise along the Chandeleur Islands was approximately 1,426,865 cubic yards/year (Table 13). The volumetric loss due to relative sea level rise along Breton Island was approximately 77,531 cubic yards/year (Table 14).

11.3 Overwash

The average crest elevation along the Chandeleur Islands and Breton Island is low at approximately 2 feet, NAVD. As a result, sediment is transported over the island by waves during storm events. This is the primary mechanism for island rollover. The landward movement of sediment conserves sediment within the system despite the landward shift of the shoreline. Therefore, the volume change, calculated from shoreline change, must be reduced to account for the conservation of the sediment within the system. The overwash volume was estimated using island migration rates and the bay active profile, which extends from the marsh platform to the bottom of the backing bay (bay depth of closure). The overwash volume along the Chandeleur Islands was estimated at 2,112,000 cubic yards/year, as shown in Table 13. The overwash volume along Breton Island was estimated at 83,300 cubic yards/year, as shown in Table 14. Note that where the bay shoreline retreated there is no volumetric loss of overwash.

11.4 Longshore Transport

This section discusses the longshore transport rate for the Chandeleur Islands and Breton Island. An annualized sediment budget was developed using shoreline changes, active profile heights, island composition percentages, and relative sea level rise rates.

The conservation of sand principle was used to estimate the volume of sand transported in a longshore direction. The conservation of sand equation allows for the longshore transport to be estimated using Equation 4.

$$LT_{out} = \Delta V_{total} - V_{offshore} - V_{RSLR} - V_{overwash} + LT_{in} \qquad \text{[Equation 4]}$$

where:

LT_{out} = Longshore transport out of the reach
ΔV_{total} = Volume change calculated based on shoreline change
$V_{offshore}$ = Offshore (silt) volume loss
V_{RSLR} = Volume change associated with relative sea level rise
$V_{overwash}$= Volume of overwash
LT_{in} = Longshore transport into the reach from an adjacent cell

The various components of volume change along the Chandeleur Islands and Breton Island between 1996 and 2004 are summarized in Table 13 and Table 14, respectively. From this a volume change within each cell due to longshore transport was calculated. If the net longshore sand volume change is greater than zero then net sediment transport was out of the cell, while a negative value indicates that net sediment transport was into the cell. However, a positive or negative value for volume change due to longshore transport does not indicate the direction of longshore transport. The net longshore transport rate along the barrier island is determined by integrating these volumes in a longshore direction (Equation 4).

A starting point for the longshore transport integration must be identified. An area of zero net sediment transport (a nodal point) is the typical point at which to start such a summation because it is easier to identify an area of no net sediment transport than estimate the longshore transport at a given point. The nodal point is often located at the location with the greatest sand volume change. The greatest sand volume change along the Chandeleur Islands between 1996 and 2004 occurred near profile N-21 (located 100,201 feet south of Hewes Point). Therefore, profile N-21 was chosen as the nodal point along the Chandeleur Islands. The greatest sand volume change along Breton Island between 1996 and 2004 occurred near profile S-9 (located 17,954 feet northeast of the southwestern extent of Breton Island). Therefore, profile S-9 was chosen as the nodal point along Breton Island. Plots of the longshore sediment transport curve for the Chandeleur Islands and Breton Island are shown in Figure 36 and Figure 37, respectively.

Georgiou and Schindler (2009) suggested that the nodal point for sediment transport was closer to N-30, which is located approximately 2.5 miles north of N-21. They determined the nodal point by modeling potential sediment transport based on wave data.

Ellis and Stone (2006) suggested that the nodal point was located at approximately N-29. They also determined the nodal point based on wave modeling using 5 monochromatic wave cases.

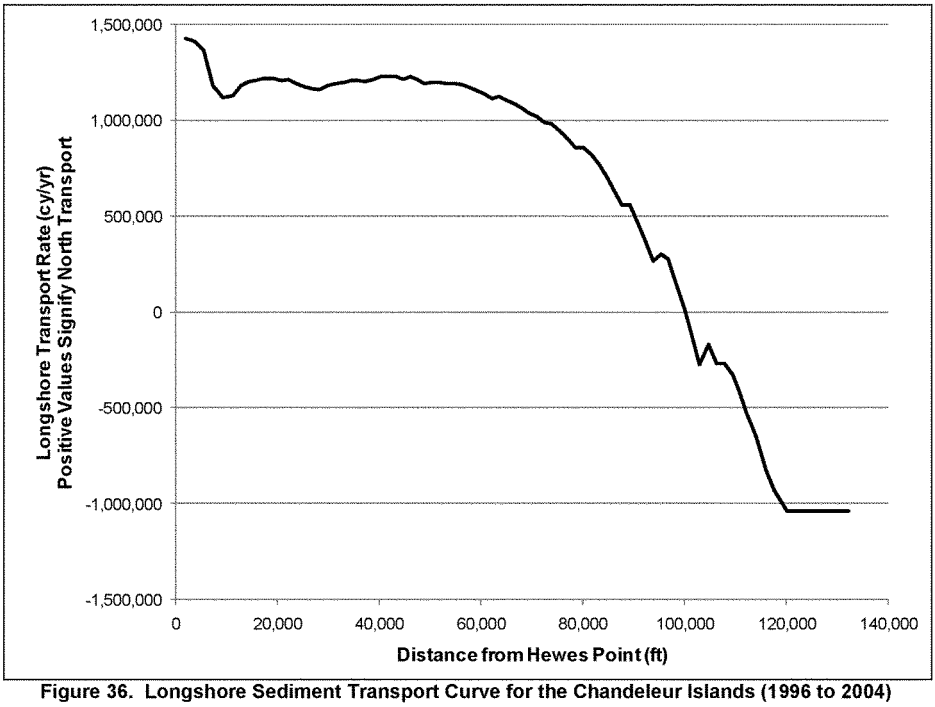


Figure 36. Longshore Sediment Transport Curve for the Chandeleur Islands (1996 to 2004)

The longshore transport curve generated for the Chandeleur Islands, shown in Figure 36, was verified using volume change estimates near Hewes Point. Analysis of BICM bathymetric data presented by Miner (2009, a) suggests that approximately 168,423,791 ± 33,574,891 cubic yards of material has accreted at Hewes Point between the 1870 and 2007. This suggests an annual accretion rate of 1,229,371 ± 245,072 cubic yards/year. The longshore transport curve generated for the North Chandeleur Islands suggests that approximately 1,218,000 cubic yards/year of sand is transported into Hewes Point, located near Profile N-75 (approximately 19,120 feet from the northern extent of Hewes Point), which verifies the analysis. Furthermore, inspection of historic shorelines suggest that the island chain is rotating around a point located somewhere along the southern half of the Chandeleur Islands, which corresponds with the nodal point further verifying the analysis.

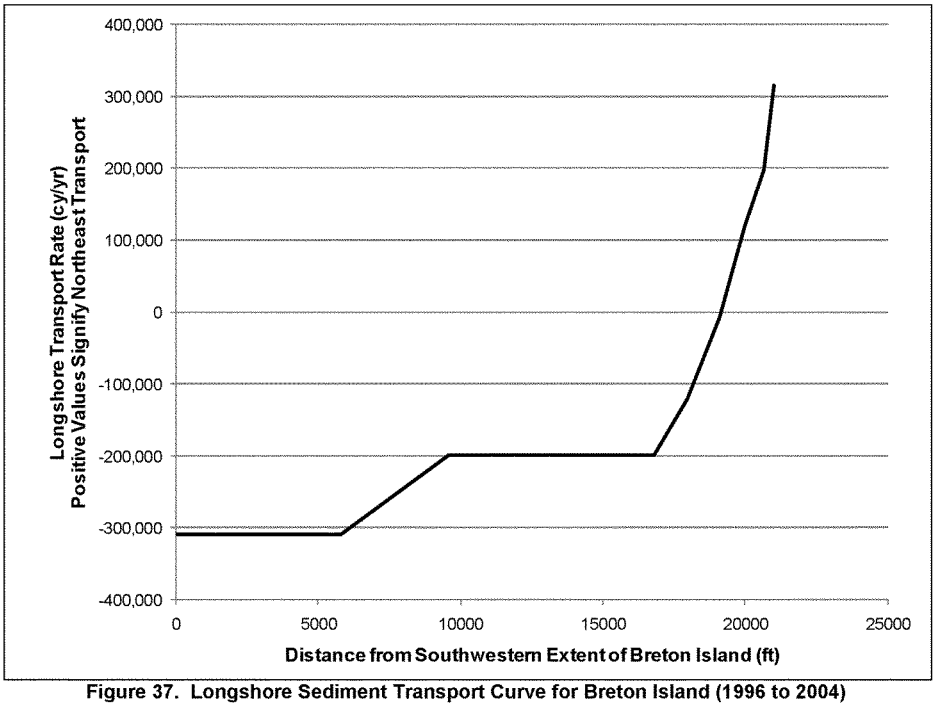


Figure 37. Longshore Sediment Transport Curve for Breton Island (1996 to 2004)

The slope of the longshore transport curve indicates whether erosion or accretion is occurring and the severity of this erosion or accretion. The steeper the slope of the longshore transport curve, the greater the associated erosion or accretion. Therefore, the longshore transport curve suggests that erosion is occurring along the entire project length. The severity of the erosion along the Chandeleur Islands increases towards the southern extent of the island chain. The severity of erosion along Breton Island increases towards the northeastern extent of the island.

The development of the longshore transport curve allows for the prediction of sediment transport under a nourished with project condition. The longshore transport rate can be applied to alternatives that are similar to the island conditions between 1996 and 2004. A summary of the various components of the sediment budget for the Chandeleur Islands and Breton Island are provided in Figure 38 and Figure 39, respectively.

LEGEND:
LONGSHORE TRANSPORT (CY/YR)
OVERWASH (CY/YR)
OFFSHORE LOSS (CY/YR)
RSLR LOSS (CY/YR)
NOTES:
1. THIS SEDIMENT BUDGET WAS DEVELOPED USING SHORELINE BASED VOLUMETRIC CHANGES BETWEEN 1996 AND 2004.
2. DATE OF PROJECT AREA PHOTOGRAPH: OCTOBER 28-29, 2008 PROVIDED BY PHOTO SCIENCE, INC.
NEW HARBOR ISLANDS
1,037,000
2,112,000
1,427,000
2,842,000
1,430,000
GULF OF MEXICO
N 494,000
N 526,000
N 462,000
N 558,000
E 1,054,000
GRAPHIC SCALE IN FT
0 4000 8000
Figure 38. Chandeleur Islands Sediment Budget for the 1996 to 2004 Time Period
COASTAL PLANNING & ENGINEERING, INC.
2481 N.W. BOCA RATON BOULEVARD
BOCA RATON, FLORIDA 33431
PH. (561) 391-9102
FAX (561) 391-9116
www.CoastalPlanning.com
P:\Louisiana\7840\26 Chandeleur WMA\CAD\Figures\Sediment Budget-Shorelines.dwg - Nov 09 2009 @ 1:04pm - cstrasse

Figure 39. Breton Island Sediment Budget for the 1996 to 2004 Time Period

12 CONCEPTUAL RESTORATION DESIGN

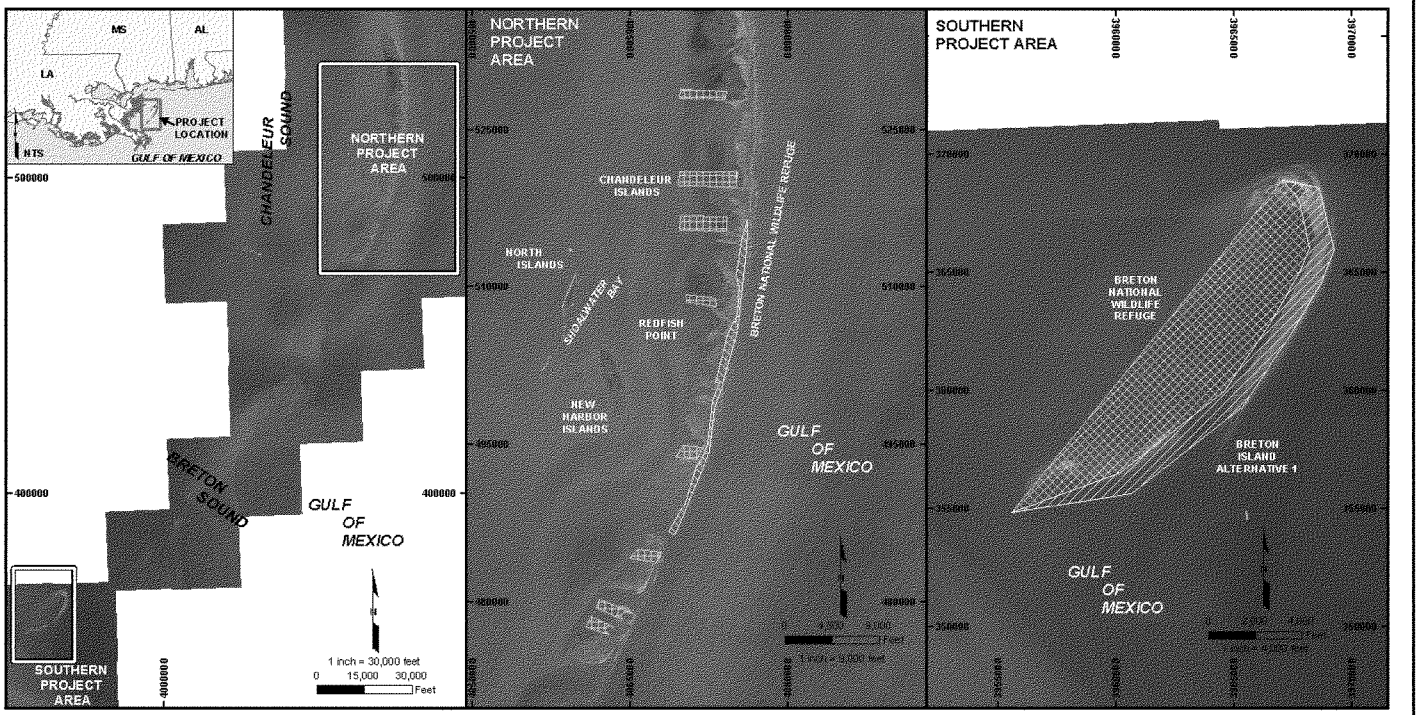
On the basis of findings from the recent framework geology, geomorphic evolution, and physical process studies by USGS, UNO-PIES, and OCPR that are summarized in the preceding sections, a conceptual design and fill template for the Chandeleur Islands was developed. This restoration design is unique with regard to other Louisiana barrier island projects because the goal is to construct a morphodynamic restoration project that utilizes the physical processes (shoreface retreat and lateral sand distribution to the flanks) to replicate the early stages of island evolution and lateral expansion for extensive period of time. By mining sand lost to the deepwater sinks at the island flanks and replacing it in a centralized location along the island arc, the same physical processes that are currently forcing the island toward submergence will be the mechanism for its reconstruction in a regime of increased sand supply. This "turning back the clock" to an early Stage 2 (see Figure 3) barrier island arc will allow for the island to maintain exposure during retreat, even in the face of increased sea-level rise rates. The proposed design is broken down into two sections that are prioritized based on predicted effectiveness and longevity: (1) Chandeleur Islands, and (2) Breton Island

12.1 Chandeleur Islands

The Chandeleur Islands have been defined as extending from Hewes Point to Monkey Bayou and includes constructing shore-perpendicular back barrier sand reserve feeder sites. Segmented clay berms will be constructed to contain the sand during hydraulic placement, prevent dispersal during storms, and provide stability to the island chain. After construction the surface of these will be planted with salt marsh vegetation. Additionally, a shore-parallel beach berm within the center of the Chandeleur Islands is proposed. In areas where islands are segmented by hurricane-cut channels, this sandy berm will be backed by a segmented clay berm.

The goal of the back barrier feeder sites is to augment and expand the role that natural relict spit deposits that underlie the marshes north of Redfish Point play in providing a long-term sand source for barrier shoreline maintenance by natural processes. As the shoreline migrates landward this sand will be liberated and introduced to the littoral system for distribution and redeposition as recurved spits, beach berms, dunes and wind tidal flats in a similar manner that characterized the post Hurricane Recovery along the northern island arc (see Figure 18 and Figure 19). The initial infusion zone and backing cohesive berm will provide a pathway for sediment transported alongshore and inhibit the loss of sand to deepwater back barrier sinks in that area.

The proposed design along the Chandeleur Islands includes a shore-parallel beach berm and eight shore-perpendicular back-barrier sand reserve feeder sites (Figure 40). The seven mile long beach berm will be constructed to an elevation of +3 feet, NAVD and be approximately 500 feet wide. The berm will be constructed on top of the existing island following the contour of the gulf shoreline. As the berm will be constructed on top of the existing island and will not be contained with a clay dike, a side slope of 1V:30H is proposed.



NOTES:

1. COORDINATES ARE IN FEET BASED ON THE LOUISIANA STATE PLANE COORDINATE SYSTEM, SOUTH ZONE, NORTH AMERICAN DATUM OF 1983 (NAD 83).
2. OCTOBER 28-29, 2008 AERIAL PHOTOGRAPHY DOWNLOADED FROM WWW.LACOAST.GOV, FLOWN BY PHOTO SCIENCE, INC.

LEGEND:

- BRETON ISLAND DUNE CREST
- BRETON ISLAND MARSH PLATFORM
- CHANDELEUR ISLAND DUNE CREST
- SAND FEEDER BERM

Figure 40. Location of Berm and Back Barrier Feeder Sites for Chandeleur and Breton Islands

COASTAL PLANNING & ENGINEERING, INC
2481 NW BOCA RATON BLVD.
BOCA RATON, FL 33431
PH. (561) 391-8102
FAX (561) 391-9116

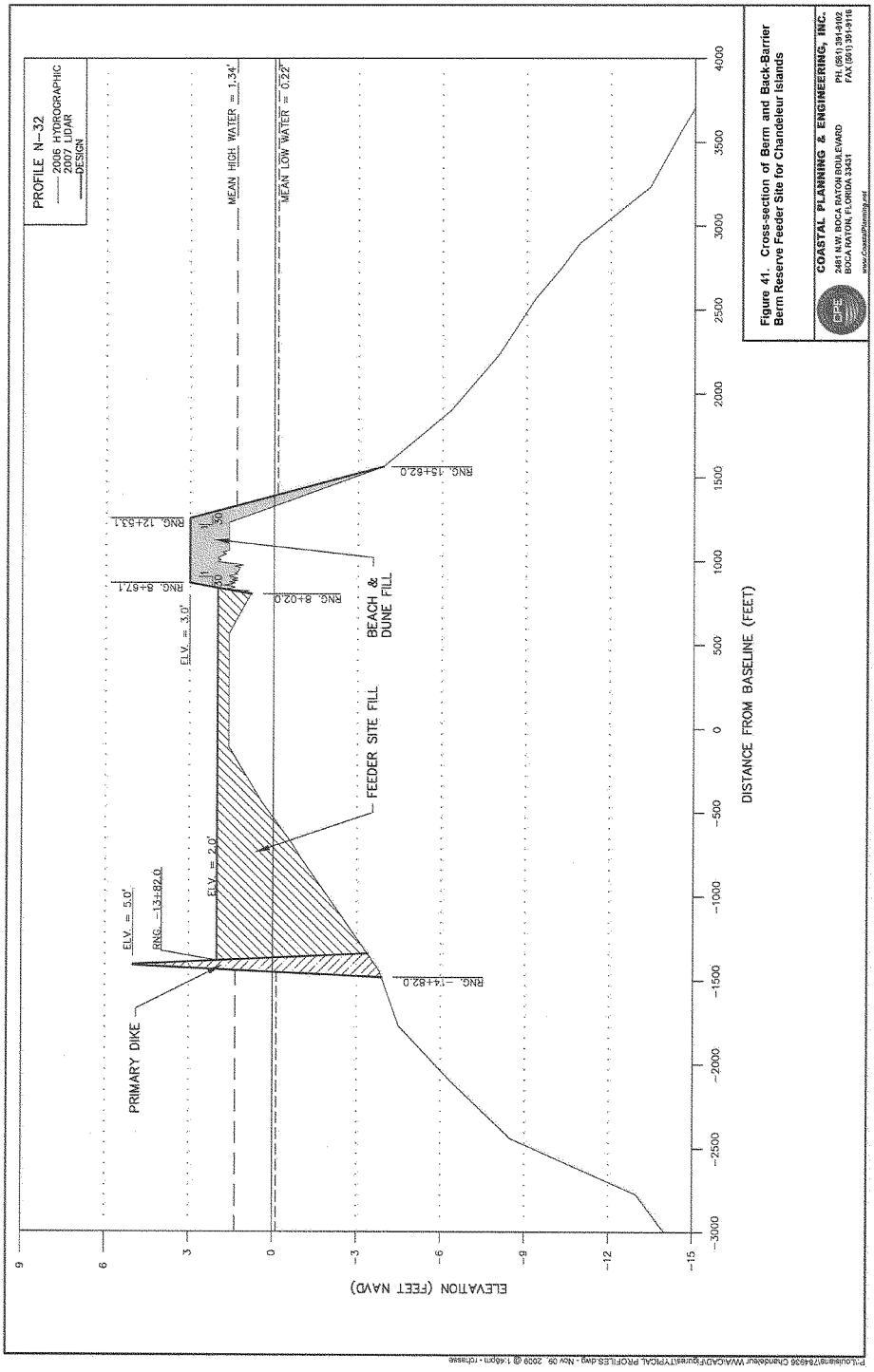


Figure 41. Cross-section of Berm and Back-Barrier Berm Reserve Feeder Site for Chandeleur Islands

COASTAL PLANNING & ENGINEERING, INC.
2481 NW. BOCA RATON BOULEVARD
BOCA RATON, FLORIDA 33431
PH. (561) 391-9102
FAX. (561) 391-9116
www.CoastalPlanning.com

P:\Louisiana\726536 Chandeleur\MXD\CAD\Surveys\TYPICAL PROFILES.dwg - Nov 09, 2009 @ 1:46pm - rdriesse

The shore-perpendicular sand feeder sites will be constructed to an elevation of +2 feet, NAVD and be approximately 6,000 feet long and 1,200 feet wide. The elevation of the feeder sites was based on existing island elevations of the back bay sections and estimated using the 2007 LIDAR survey. The 2007 LIDAR provides elevations above 0 feet, NAVD that are considered valid. Most of the back bay area visible in the 2008 aerial images is between 0 and +2 feet, NAVD (Figure 40). The present mean high water and mean low water elevations are +1.34 and -0.22 feet, NAVD, respectively, suggesting that the back bay is inundated during most of the tidal cycle.

One element of the feeder site design is to optimize performance. One goal is to maximize the time period that the platform has an elevation in the bay intertidal zone for environmental function. The bay intertidal zone, as defined for the Wetland Value Assessment model (WVA), is between 0.0 and +2.0 feet, NAVD. Figure 42 shows the expected settlement of the feeder site.

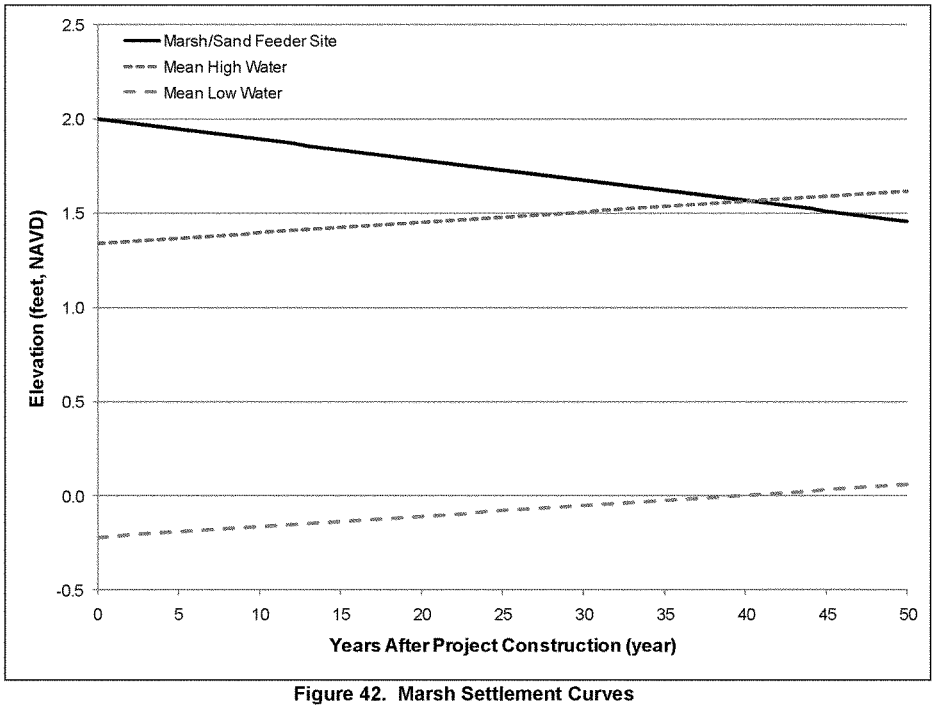


Figure 42. Marsh Settlement Curves

The feeder sites will be contained with a silt/clay dike. A primary dike with an elevation of +5 feet, NAVD and side slopes of 1V:8H are proposed along the extents of the marsh fill not bordered by beach fill. Geotechnical analyses of dike stability for previously constructed projects suggest that a freeboard of 3 feet with 1V:4H slopes would be stable during construction. A flatter dike slope is proposed for constructability purposes and will increase the

safety factor. Furthermore, the high sand content and shallow water depths in the project areas suggest that these dimensions should be sufficient for dike stability.

The back-barrier sand feeder sites will be planted with salt marsh vegetation following construction.

The proposed feeder sites along the Chandeleur Islands contain approximately 4,910,000 cubic yards of fill while the berm contains 3,810,000 cubic yards. Thus, the total volume of fill required to construct the Chandeleur Islands alternative is 8,720,000 cubic yards. This volume was calculated by comparing the construction template to the 2006/2007 BICM data and then assuming 0.0108 feet/year of subsidence under the project footprint between 2007 and 2014. Losses from the island were ignored as it was assumed that the footprint could be relocated at the time of construction and the berm located on the highest ground remaining.

The footprint of the sand feeder sites along the Chandeleur Islands range from 42.2 acres to 172.5 acres, with a total footprint area of 647.7 acres.

12.2 Breton Island

Five Alternatives were evaluated for Breton Island. These are discussed in the next sub-chapters and shown in Figure 43.

12.2.1 Breton Island Alternative 1

Alternative 1 for Breton Island consists of a beach berm that extends the entire length of the island combined with a backing marsh platform (Figure 43). The four mile long beach berm will be constructed to an elevation of +4 feet, NAVD and be approximately 1,000 feet wide. This elevation is 2 feet lower than typical construction elevations for Louisiana barrier islands. However, the lower berm elevation combined with wider dune widths are similar to dune dimensions historically observed along Louisiana barrier islands. The lower dune reduces the fill volume and thus construction cost. No steps (berm platforms) are proposed in the construction template. Additional working of the fill can increase the cost of construction and does not provide any added benefits compared to a single slope. Regardless of the constructed template, the material will be reworked into a natural profile by wave and wind action. A cross-section proposed for Alternative 1 is shown in Figure 44.

It is projected that Breton Island will exist only as a shoal at the time of construction in 2014 (see Section 13.5.1). The berm and marsh have been located to minimize construction fill volumes. A side slope of 1V:45H is proposed as some of the material will be placed below 0 feet, NAVD. Thus a flatter slope to minimize construction losses is proposed. This is the same slope as that proposed for the Holly Beach Sand Management Project, (CPE, 2003), which had a similar grain size and silt content.

The backing marsh platform will be constructed to an elevation of +2 feet, NAVD and be approximately 3,000 feet wide on average. The fine-grained marsh platform will be planted with salt marsh vegetation following construction.

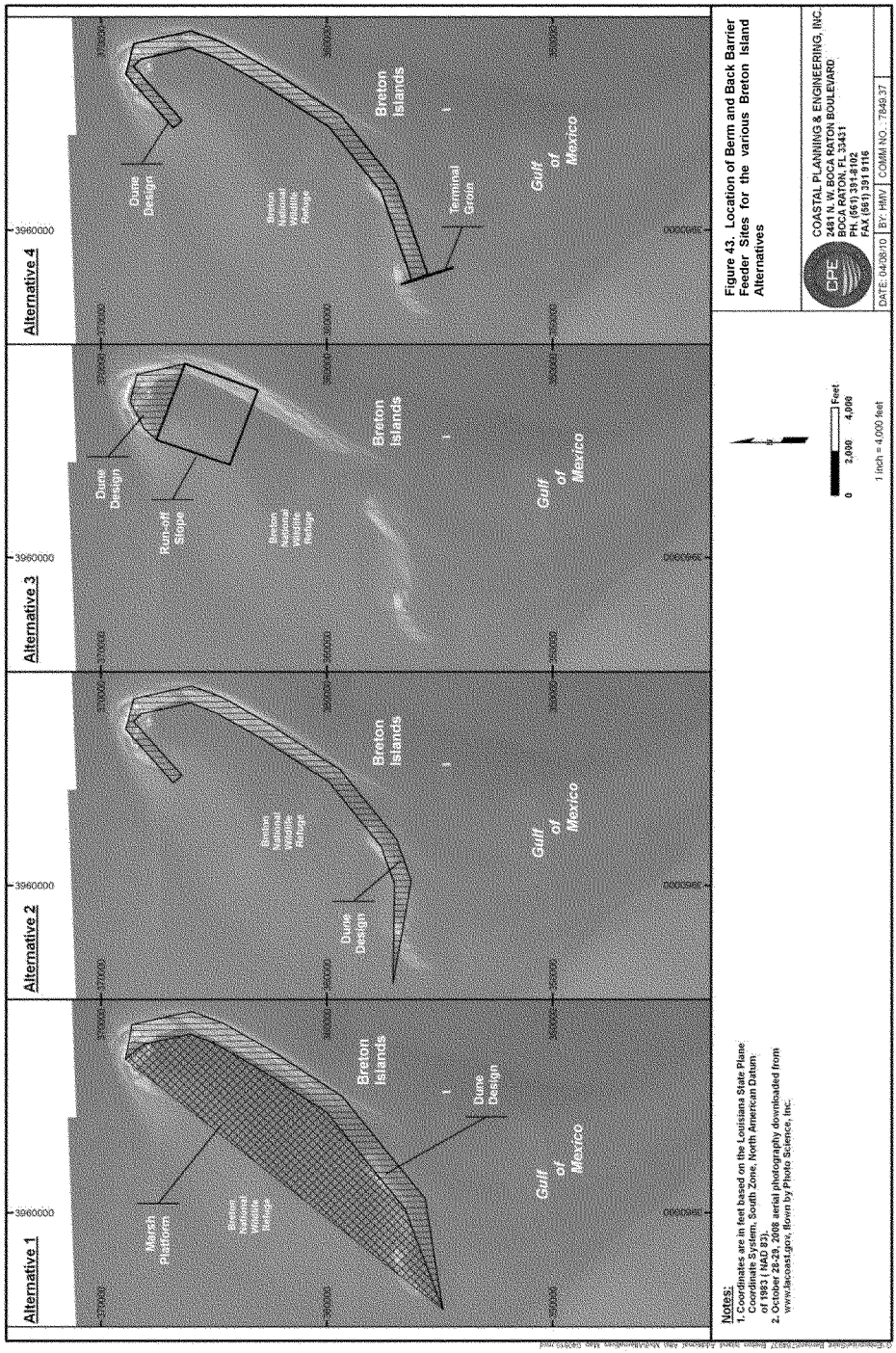


Figure 43. Location of Berm and Back Barrier Feeder Sites for the various Breton Island Alternatives

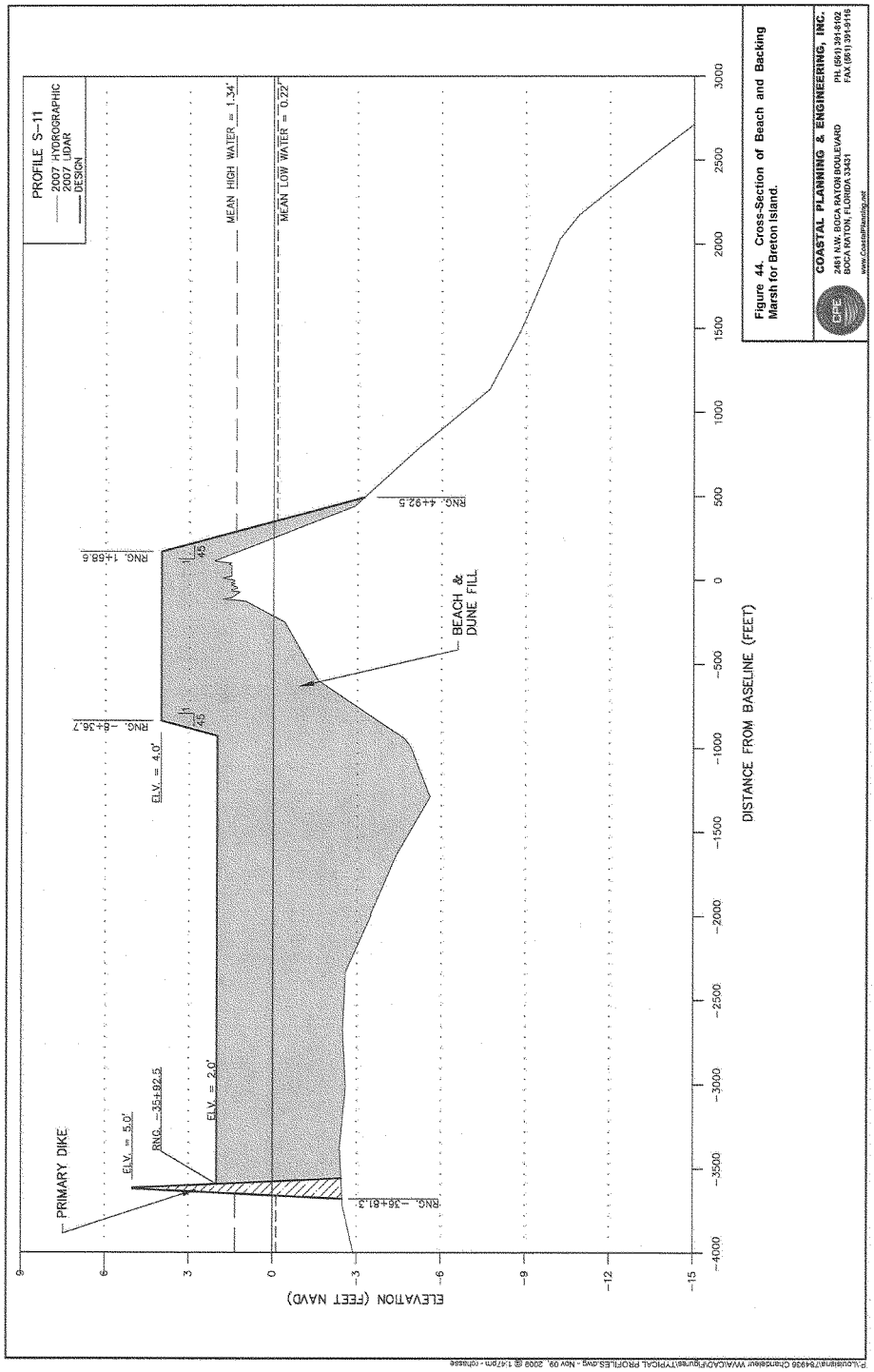


Figure 44. Cross-Section of Beach and Backing Marsh for Breton Island.

COASTAL PLANNING & ENGINEERING, INC.
2481 N.W. BOCA RATON BOULEVARD
BOCA RATON, FLORIDA 33431
PH. (561) 391-8102
FAX (561) 391-9116
www.CoastalPlanning.net

It is expected that the constructed Breton Island beach template will readjust to an equilibrium beach profile in the year following construction. The Chandeleur Islands beach template is not expected to readjust as the beach template will be constructed on top of the existing dune with only small portions of the template extending below mean high water. The equilibration process assumes that there is only cross-shore redistribution of sediment and the sand volume is conserved. Below mean high water the profile is anticipated to approximate Dean's (1987) equilibrium beach profile of the form described in Equation 5. Above mean high water the seaward dune crest is expected to translate such that the sand volume is conserved.

$$y = Ax^{2/3} \qquad \text{[Equation 5]}$$

where:

y = depth below mean high water (ft)
A = 0.1071 ($ft^{1/3}$) (Dean's empirically derived coefficient for 0.12 mm grain size)
x = distance from mean high water (ft)

The constructed beach slope along Breton Island is 1V:45H from the dune crest to the construction toe of fill. For a 1V:45H offshore slope, it is anticipated that the mean high water shoreline will retreat due to profile equilibration as the offshore slope of the construction template is slightly steeper than the slope of Dean's (1987) equilibrium beach profile for the MRGO Ocean Dredged Material Disposal Site (ODMDS) borrow area sand.. The 2007 profile, construction template, and equilibrium beach profile at Station S-11 are shown in Figure 45. Assuming that volume is conserved during the equilibration process, the seaward dune crest is expected to translate approximately 11 feet landward if the MRGO ODMDS borrow area is used.

The footprint of the proposed project is 1,635 acres. It will require approximately 20,040,000 cubic yards to construct the proposed project at Breton Island. As with the Chandeleur Islands alternative (and all other Breton Island alternatives, the construction volume was calculated based on a comparison of the construction template with the BICM 2006/2007 bathymetric data and then accounting for 7 years of subsidence within the project footprint between the BICM survey and the time of construction (2014).

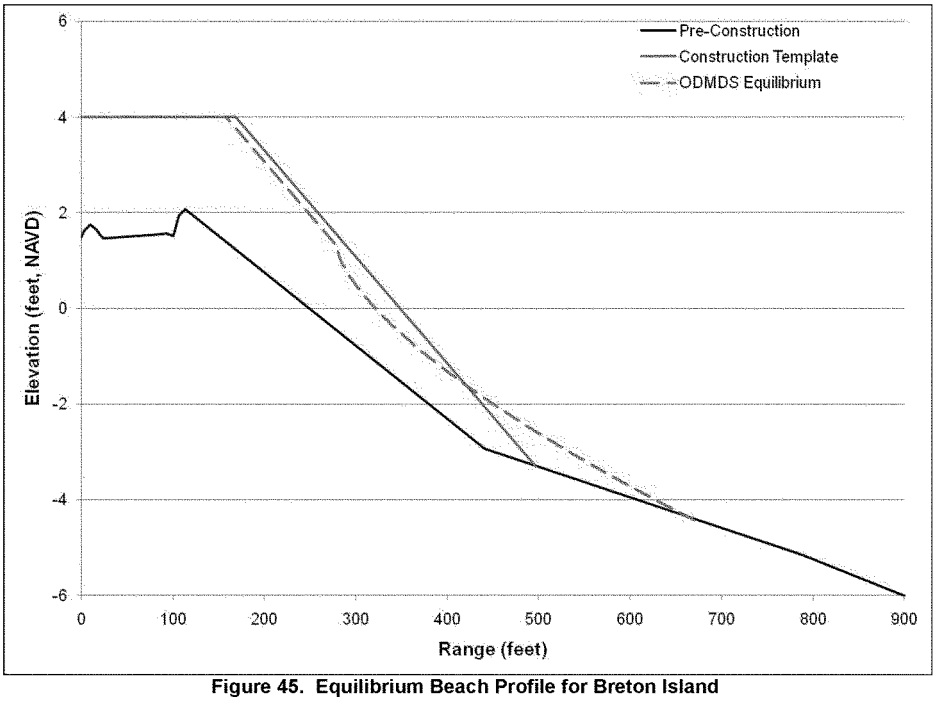


Figure 45. Equilibrium Beach Profile for Breton Island

12.2.2 Breton Island Alternative 2

Alternative 2 for Breton Island consists of a beach berm that extends the entire length of the island (Figure 43), similar to Alternative 1. The four mile long beach berm will be constructed to an elevation of +6 feet, NAVD and be approximately 750 feet wide. This elevation is 2 feet higher than Alternative 1, but typical of construction elevations for Louisiana barrier islands. Since a back barrier marsh is not proposed for this alternative, a higher dune crest is necessary to reduce the frequency of overtopping and thus material transported landward into back bay areas during overwash events. The southwest portion of the dune is curved further to the west compared to Alternative 1 in order to position the dune crest on top of the existing subaerial landmasses. This will reduce the volume of material required to construct the dune and position it so that material transported landward during overwash events will be deposited in shallower water depths and increase the stability to the barrier island system. No steps (berm platforms) are proposed in the construction template. Additional working of the fill can increase the cost of construction and does not provide any added benefits compared to a single slope. Regardless of the constructed template, the material will be reworked into a natural profile by wave and wind action. A cross-section of the proposed Alternative 2 is shown in Figure 46.

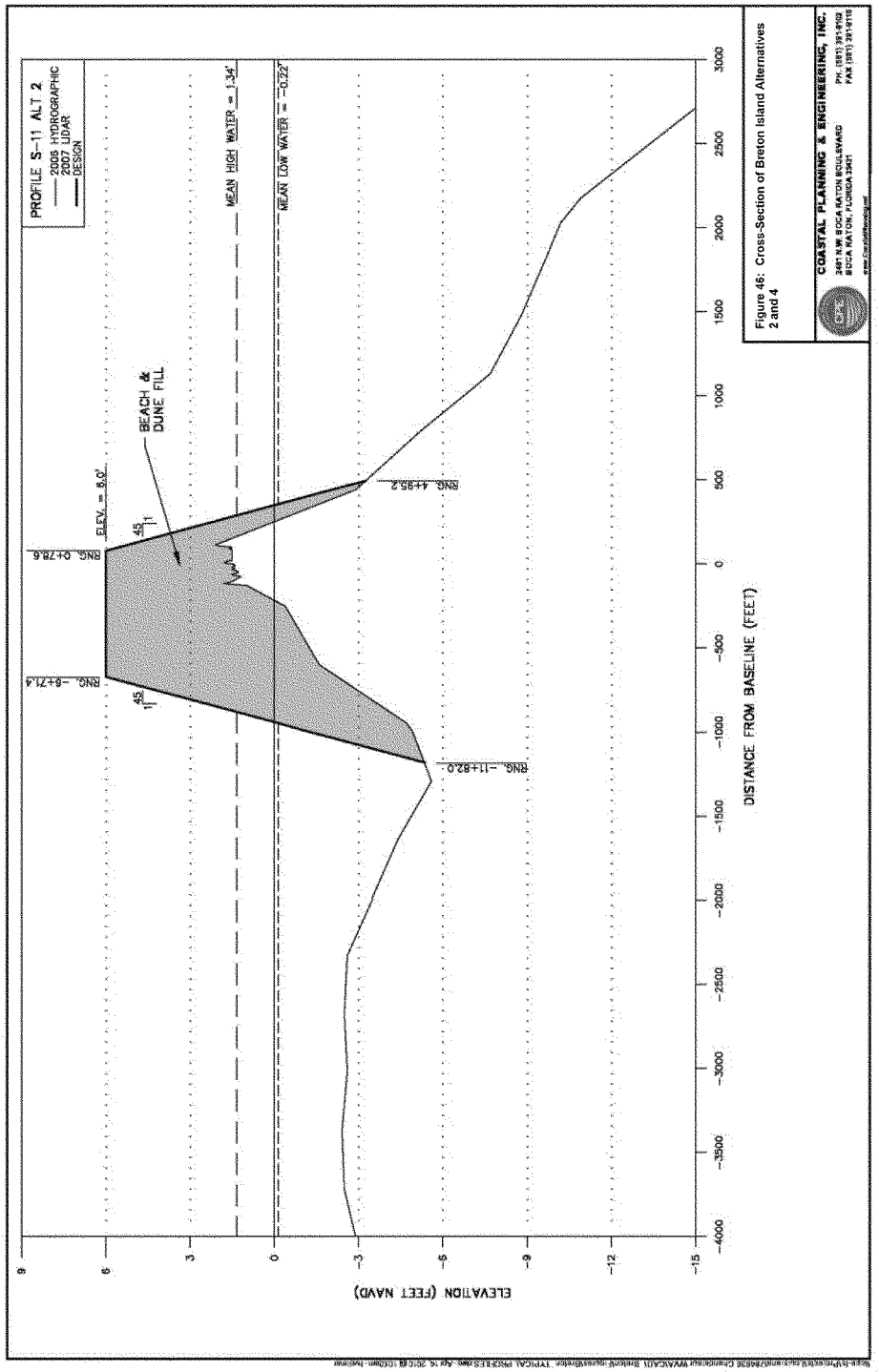


Figure 46: Cross-Section of Breton Island Alternatives 2 and 4

Included in Alternative 2, is an extension of the dune to the west around the northern end of the island. A spit feature has been indentified in aerial photographs and observed to occur by natural processes over a significant period of time. The dune template is continued around the northern extent of the project area and then approximately 500 feet southwest along the existing spit. By placing material in the area of the spit, sediment will be introduced to existing spit feature and reworked by the natural processes to armor and fortify the island along the northwest boundary of the project area. The spit provides protection to the bay shoreline of Breton Island from the wave energy generated in the large open water bay to the northwest. By reducing the wave energy directly impacting the bay shoreline, which has a higher silt content compared to the gulf shoreline, the erosion rate along the bay shoreline would be reduced and help to increase the longevity of the project. It is projected that Breton Island will exist only as a shoal at the time of construction in 2014 (see Section 13.5.1). The berm has been located to minimize construction fill volumes. A side slope of 1V:45H is proposed as some of the material will be placed below 0 feet, NAVD. Thus a flatter slope to minimize construction losses is proposed. This is the same slope as that proposed for the Holly Beach Sand Management Project, (CPE, 2003), which had a similar grain size and silt content.

The constructed beach template will readjust to an equilibrium beach profile in the year following construction. The gulf beach face will translate landward approximately 8 feet due to the same processes described for Breton Island Alternative 1, which assumes a Dean's equilibrium profile and that the ODMDS borrow area sand (~0.12 mm) is used. The landward translation is less for Alternative 2 than Alternative 1, because the dune crest for Alternative 2 is higher, which provides greater volume to redistribute per foot and thus requires less recession.

It will require approximately 9,657,000 cubic yards to construct the proposed project at Breton Island for Alternative 2. The footprint of the proposed project is 892 acres.

12.2.3 Breton Island Alternative 3

Breton Island Alternative 3 has a fundamentally different design basis than Alternatives 1 and 2. Alternative 3 was designed to minimize cost by limiting pumping distance while constructing a higher island to limit losses due to overwash. The design includes a 3,700 foot wide platform at +10 feet, NAVD, with slopes of 1V:45H along the north, east, and west sides (Figure 46) and a run-off slope of 1V:300H along the south side (Figure 47). The 1V:300H slope was based on uncontained construction slopes observed during the Chaland Headland and East Grand Terre barrier island restoration projects.

By constructing the platform at a higher elevation, the frequency of overtopping will be reduced and the transport of the sediment landward into the open water bay areas would be minimized. The platform would be subject to dispersion through the cross shore and longshore processes, which will result in sand deposition along the gulf beach face and should slow loss of silts.

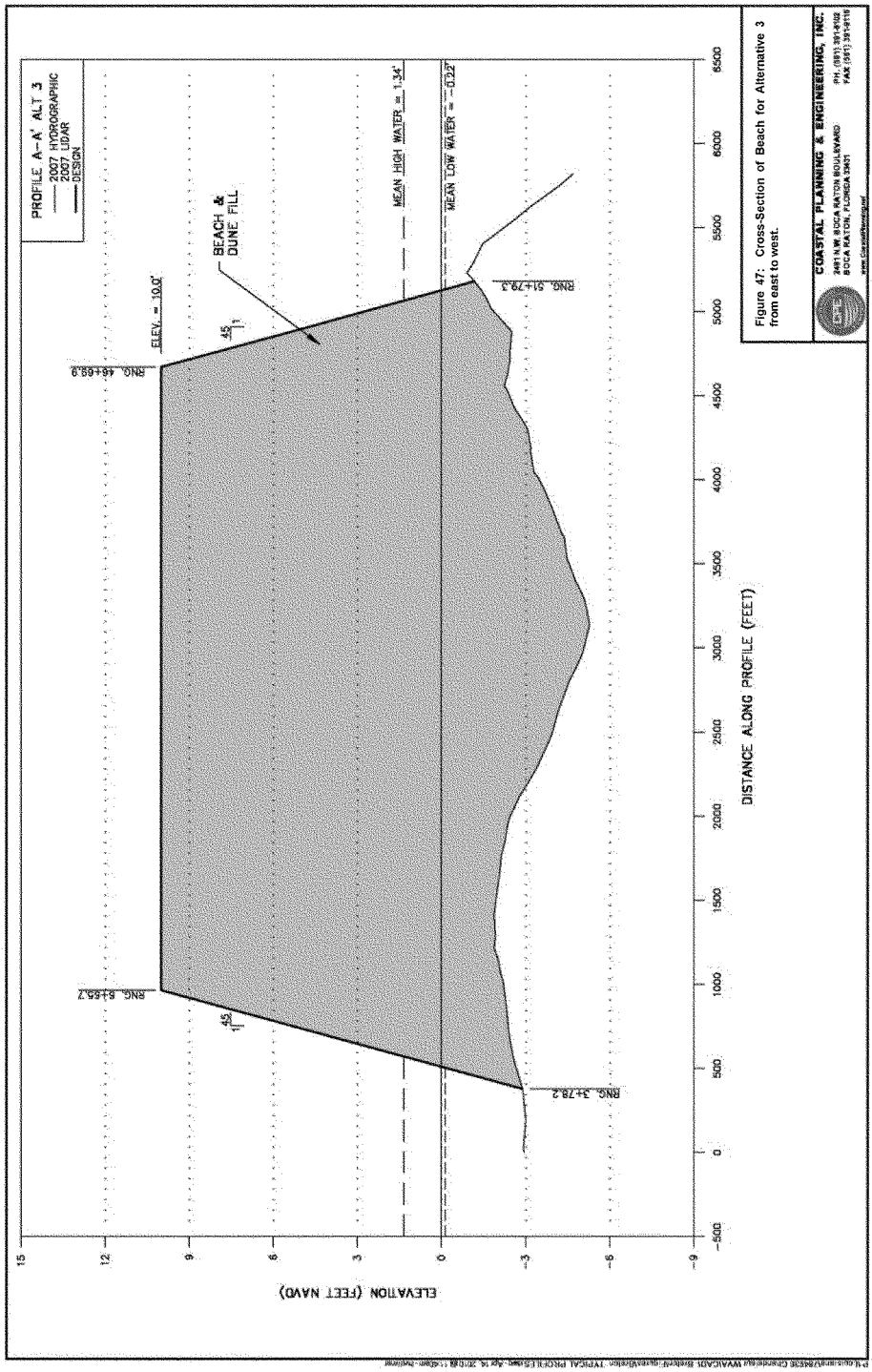


Figure 47: Cross-Section of Beach for Alternative 3 from east to west.

COASTAL PLANNING & ENGINEERING, INC.
2481 N.W. BOCA RATON BOULEVARD
BOCA RATON, FLORIDA 33431
PH: (561) 391-9102
FAX: (561) 391-9116

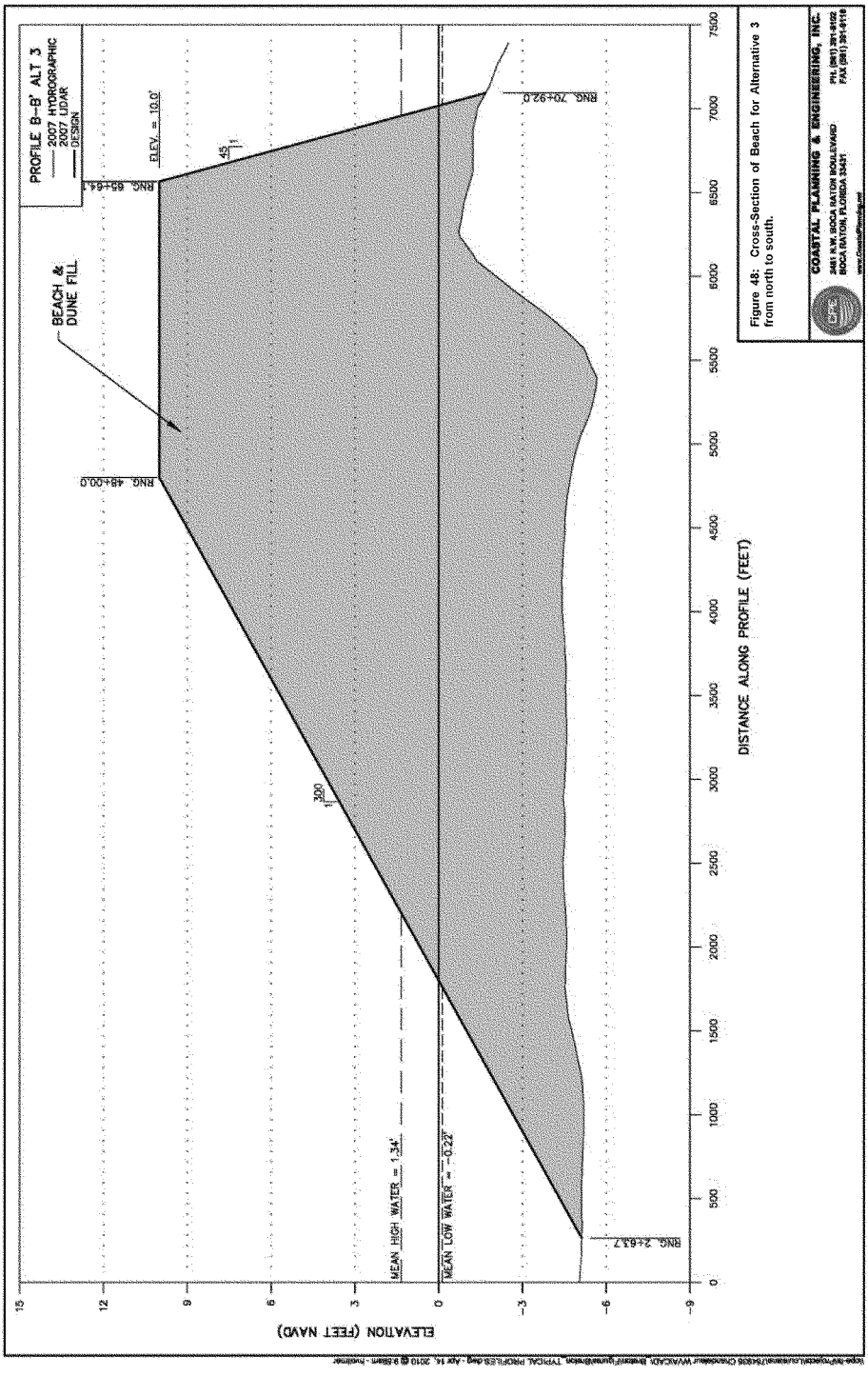


Figure 48: Cross-Section of Beach for Alternative 3 from north to south.

COASTAL PLANNING & ENGINEERING, INC.
3481 N.W. BOCA RATON BOULEVARD
BOCA RATON, FLORIDA 33431
PH. (561) 391-9102
FAX (561) 391-9116

A slope of 1V:300H was observed in front of the discharge pipe at the Chaland Headland and East Grand Terre Restoration Projects. The intent is to let the material flow down this slope with only side containment and without extending the shore pipe. By not extending the shore pipe, friction losses within the pipe will be avoided (offsetting the loss due to initially pumping the material to a higher elevation) and production rates should remain higher. This should minimize the unit cost for the beach fill.

It is not expected that constructed beach template will readjust to an equilibrium beach profile in the year following construction given the ODMDS borrow area sand is used. The platform will be constructed on top of the existing subaerial landmasses thus reducing the water depth that the template extends below MHW. As a result, the landward translation of the constructed beach template due to the steeper construction slope compared to Dean's equilibrium profile is not expected.

It will require approximately 7,255,000 cubic yards to construct the proposed project at Breton Island for Alternative 3. The footprint of the proposed project is 616 acres.

12.2.4 Breton Island Alternative 4

12.2.4.1 Beach Fill Design

Alternative 4 for Breton Island has a similar footprint to Alternative 2 except that a terminal groin has been added to the southern end of the project. To accommodate the terminal groin, the tapered section at the southern end of Alternative 2 has been removed. The groin will help to contain the placed fill and reduce the volume of material lost to the south due to longshore sediment transport. In addition, material transported in the longshore direction will accrete at the groin forming a fillet.

As with Alternative 2, the berm crest will be constructed to an elevation of +6 feet, NAVD and will be approximately 750 feet wide. There is no backing marsh in Alternative 4. A cross-section proposed for Alternative 4 is shown in Figure 46.

It is projected that Breton Island will exist only as a shoal at the time of construction in 2014 (see Section 13.5.1). The berm has been located to minimize construction fill volumes. A side slope of 1V:45H is proposed as some of the material will be placed below 0 feet, NAVD. Thus a flatter slope to minimize construction losses is proposed. This is the same slope as that proposed for the Holly Beach Sand Management Project, (CPE, 2003), which had a similar grain size and silt content.

It is expected that the constructed beach template will readjust to an equilibrium beach profile in the year following construction. It is expected that the gulf beach face will translate landward approximately 8 feet due to the same processes described for Breton Island Alternative 2.

It will require approximately 9,382,000 cubic yards to construct the proposed project at Breton Island for Alternative 4. The footprint of the proposed project is 834 acres.

12.2.4.2 Terminal Structure Design

The longshore loss of sediment to the southwest is approximated to be 310,000 cubic yards/year (Figure 39). A terminal structure was proposed for Alternative 4 to minimize this loss of sediment from the project area. A terminal groin can be considered because there are no downdrift areas that could be negatively impacted due to an interruption of sediment supply.

The terminal groin will trap sediment transported alongshore due to the waves arriving at an angle to the shoreline. As this sand starts to build against the structure and the shoreline advances seaward forming a fillet, the incident wave angle decreases due to reorientation of the shoreline, which reduces the longshore transport. Assuming that the terminal groin is long enough and that there is sufficient sediment, the shoreline will reorient itself to minimize longshore transport by becoming perpendicular to the incident wave angle.

WIS data from Station 139 located in the Gulf of Mexico southeast of the project area was used to estimate the average incident wave direction. Offshore waves were projected from the offshore buoy location to the constructed shoreline up to the point of breaking. Due to sheltering by the Mississippi Delta a swell window from 50° to 150° was applied to isolate waves that could impact the project area. Assuming basic linear theory, shoaling, refraction and a wave height and direction relative to the shoreline at breaking was determined. These values were then applied within the CERC expression (USACE, 2002) to estimate the bulk sediment transport rate with respect to each wave condition. The sediment transport rates were averaged allowing a weighted average breaking wave height and direction to be determined based on their potential longshore transport rates. (This method incorporates the effect of wave height rather than just averaging the wave direction and accounts for larger waves arriving from a given direction.) It was determined that the approximate average breaking wave angle to the constructed shoreline was 6.8°. Therefore, the fillet should have to store sufficient sand to reduce the shoreline angle by 6.8°.

The shape of the shoreline due to the structure was determined using Walton and Chiu's (1979) analytic solution. Walton and Chiu's method is based on the formula in Equation 6:

$$\frac{Y}{2tan\alpha_o\sqrt{Kt}} = \frac{1}{\sqrt{\pi}} exp\left(\frac{-x^2}{2\sqrt{Kt}}\right) - \left(\frac{x}{2\sqrt{Kt}}\right) erfc\left(\frac{x}{2\sqrt{Kt}}\right) \qquad \textbf{[Equation 6]}$$

where:

Y = Shoreline change excluding background erosion
$K = 2\ C_1\ H_b^{2.5} / d$
$C_1 = CSPM' (g/0.78)^{0.5} / (16\ (G_s\text{-}1)(1\text{-}p))$
X = the distance alongshore
α_o = Initial wave angle at breaking depth = 6.8°
t = time
H_b = Breaking wave height = 1.5 ft
d = Berm Elevation - Depth of Closure Elevation = 28 feet
G_s = Specific gravity of beach sediment solids, $G_s \sim 2.65$.

p = Porosity of beach sediments, p~0.4.
CSPM' = Empirical constant usually known as "K1".

The value of CSPM' was evaluated using the USACE (1989) longshore transport equation. A net littoral transport rate of 280,000 cubic yards/year to the southwest was used based on the longshore transport rates developed in Section 11.4 and assuming that there was a 10% loss of sediment through the structure. Using this procedure, CSPM' = 0.91.

A structure that only maintains the beach fill construction template would be approximately 1,800 feet long (measured along the +2 feet, NAVD contour). It was determined that an additional 600 feet should be added to the structure in order to facilitate growth of the fillet, which helps to reduce longshore sediment transport by altering the shoreline angle.

Figure 49 shows the expected growth of the fillet assuming that sufficient sediment is available updrift and that the background retreat rate is only 10 feet/year due to relative sea level rise. Shoreline retreat due to offshore loss of silt is neglected in this initial part of the analysis.

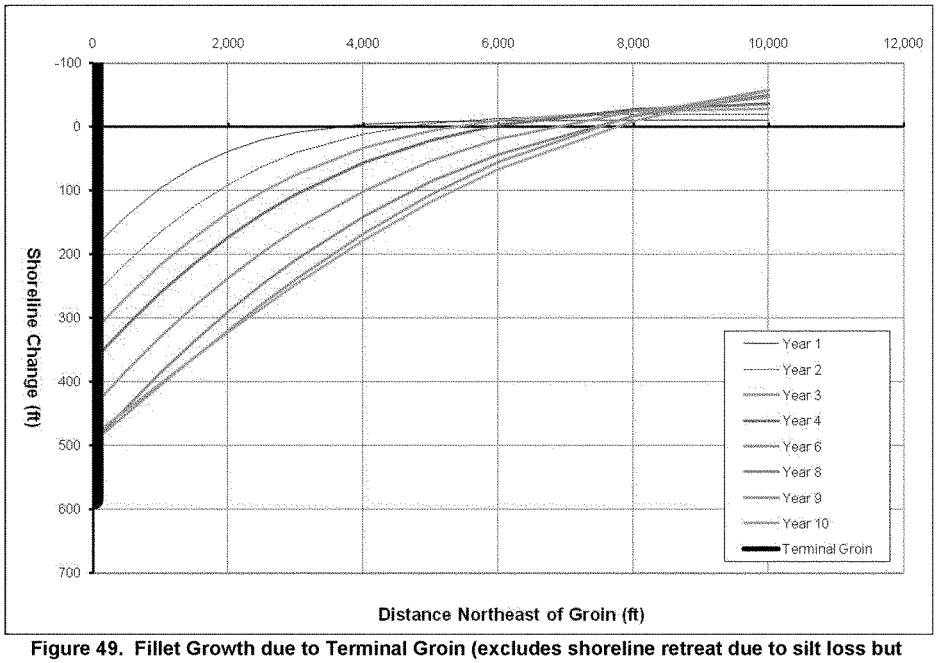


Figure 49. Fillet Growth due to Terminal Groin (excludes shoreline retreat due to silt loss but includes loss due to RSLR).

Walton and Chiu's method does not account for the complexity of Louisiana's coastal system where silt losses play a major role in shoreline retreat. A shoreline advance in Louisiana due to longshore transport infers accretion of sand from the berm crest down to the depth of closure. This effectively limits any further loss of fines by armoring the erosive face with sand.

However, updrift of the fillet, silt losses are still occurring and the shoreline is retreating more quickly. Therefore, the reorientation of the shoreline is expected to occur much more quickly than within a sand only, low retreat rate, environment.

Including the additional 600 feet gulfward to allow for growth of the fillet extends the structure length to 2,400 feet. The breakwater is tapered longitudinally to follow the equilibrium beach profile of the fillet assuming that it extends approximately 300 feet along the length of the groin. The structure will have a crest elevation of +6 feet, NAVD and side slopes of 1V:2H. A 6-foot crest elevation was chosen as the SBEACH modeling (Appendix C) suggested that the typical post-storm profile elevation is +4 feet, NAVD, and the constructed dune would be constructed to +6 feet, NAVD. Ideally, the structure should be higher than the expected profile elevation to reduce losses over the structure and as high as the constructed dune elevation for ease of construction.

The armor stone size was developed using Hudson's Equation (USACE, 2000) and assuming that granite with a minimum density of 160 pcf would be used. The worst case scenario is when the breaking wave crest is at the same elevation as the structure crest. Applying these values and a damage coefficient of 2 within Hudson's equation, gives a median stone weight of 6.1 tons and a nominal stone diameter of 4.2 feet. As the structure is between 1 and 3 armor stones high, the entire groin will be constructed with armor stone rather than trying to place a core layer and then a secondary cover layer. To allow armor stone placement directly on top of the foundation, it is proposed to use a marine mattress foundation.

The exclusive use of armor stone will result in some loss of sediment through the structure. The potential for losses due to longshore transport in the first few years, it was assumed that losses through the structure would be approximately 30,000 cubic yards/year.

The terminal groin will require approximately 63,170 tons of armor stone and 102,000 square feet of marine mattress.

12.2.5 Breton Island Alternative 5

The fifth alternative considered for Breton Island is to restore the natural sediment transport across Breton Island Pass. The goal is that sediment within Grand Gosier Shoal would cross Breton Island Pass and help maintain Breton Island. As discussed in Section 5.3, the MRGO channel shares Breton Island Pass with the natural inlet and strong ebb tidal currents resulted in seaward transport of sand to the distal ebb shoals. However, the distal ebb shoals are located approximately 4 miles offshore of Breton Island and are now been abandoned (no longer bypassing material to the shoreline). Any sediment transport around the ebb shoal would not result in sediment being supplied to Breton Island because water depths between the abandoned ebb shoal and Breton Island range up to -26 feet, NAVD. This is deeper than the depth of closure and thus onshore movement of this sediment is not anticipated. Therefore, a new bypassing pathway (ebb shoal) would need to be created between Grand Gosier Shoal and Breton Island.

Creating a new sediment pathway would require infilling portions of the MRGO channel so that it would not continue to act as a sediment sink. Comparison of BICM survey data collected in June 2006 and a channel survey conducted by the USACE in December 2008 provided an initial assessment of the extent and location of infilling of the existing channel (Figure 50). This figure shows that infilling is occurring along almost the entire channel length though a specific bypassing location could not be identified.

It is estimated that it will require 1.4M cubic yards of sediment to fill the MRGO in the area proposed, which is located between the main mass of Grand Gosier Shoal and Breton Island. This area is approximately 2 miles long. An additional 10.9M cubic yards of sand would be required to fill the natural inlet and water depths below -22 feet NAVD located to the south of the MRGO in order to promote sediment bypassing.

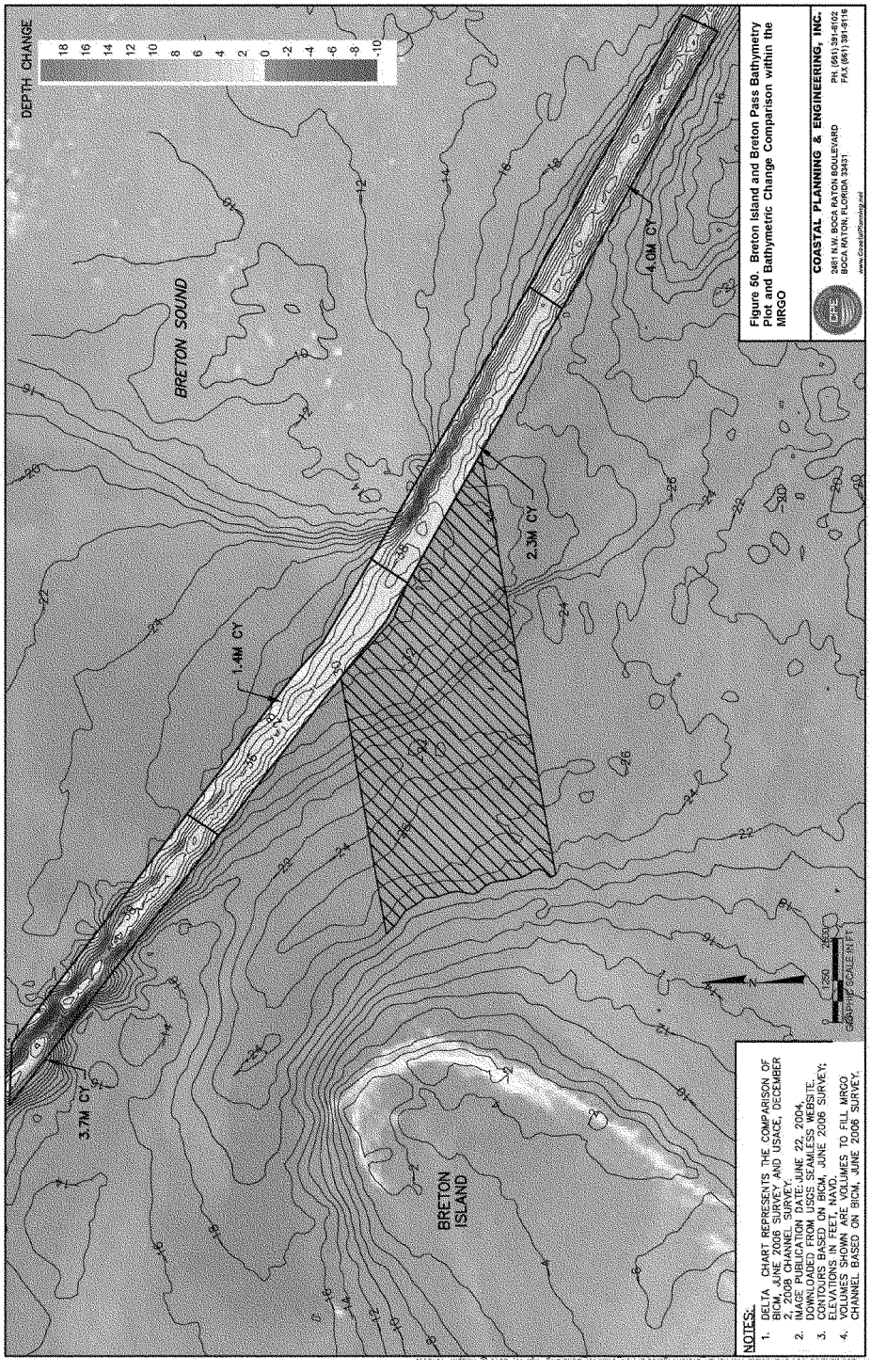


Figure 50. Breton Island and Breton Pass Bathymetry Plot and Bathymetric Change Comparison within the MRGO

COASTAL PLANNING & ENGINEERING, INC.
2481 N.W. BOCA RATON BOULEVARD
BOCA RATON, FLORIDA 33431
PH: (561) 391-8102
FAX: (561) 391-9116
www.CoastalPlanning.net

13 PROJECT PERFORMANCE

13.1 Wetland Value Assessment

Louisiana restoration projects are typically evaluated using the Wetland Value Assessment model. The Chandeleur Islands and Breton Island benefits were calculated using the Barrier Island Community Model in accordance with guidelines prepared by William and Sweeney (2005) and the Environmental Working Group (2002 and 2007). Given that the same methodology is applied for both Chandeleur and Breton Islands, the existing island habitat is similar, and their proximity, the benefits provided by either island can be considered equivalent.

The first step in the analysis is to define the boundaries of the WVA. The project boundary used for the Chandeleur Islands WVA calculations is shown in Figure 51. The project boundaries were defined based on the 2006/2007 BICM bathymetry contours and an estimated seagrass boundary. The north and south boundaries were terminated at the nearest channel to the sand feeder sites. The landward boundary is defined by the extent of seagrass growth, and is open water area. The seaward boundary is defined by intertidal elevations (i.e., the 0-foot contour).

The project boundary used for the Breton Island alternatives WVA calculations is shown in Figure 52. The project boundaries were defined based on the 2006/2007 BICM bathymetry contours and the most expansive construction toes of fill to encompass all five of the alternatives. Natural boundaries such existing landmass were not used because it is expected that there will not be existing acreage applicable to the WVA analysis at the time of construction. As a result, all acreages analyzed in the WVA calculations were created during construction.

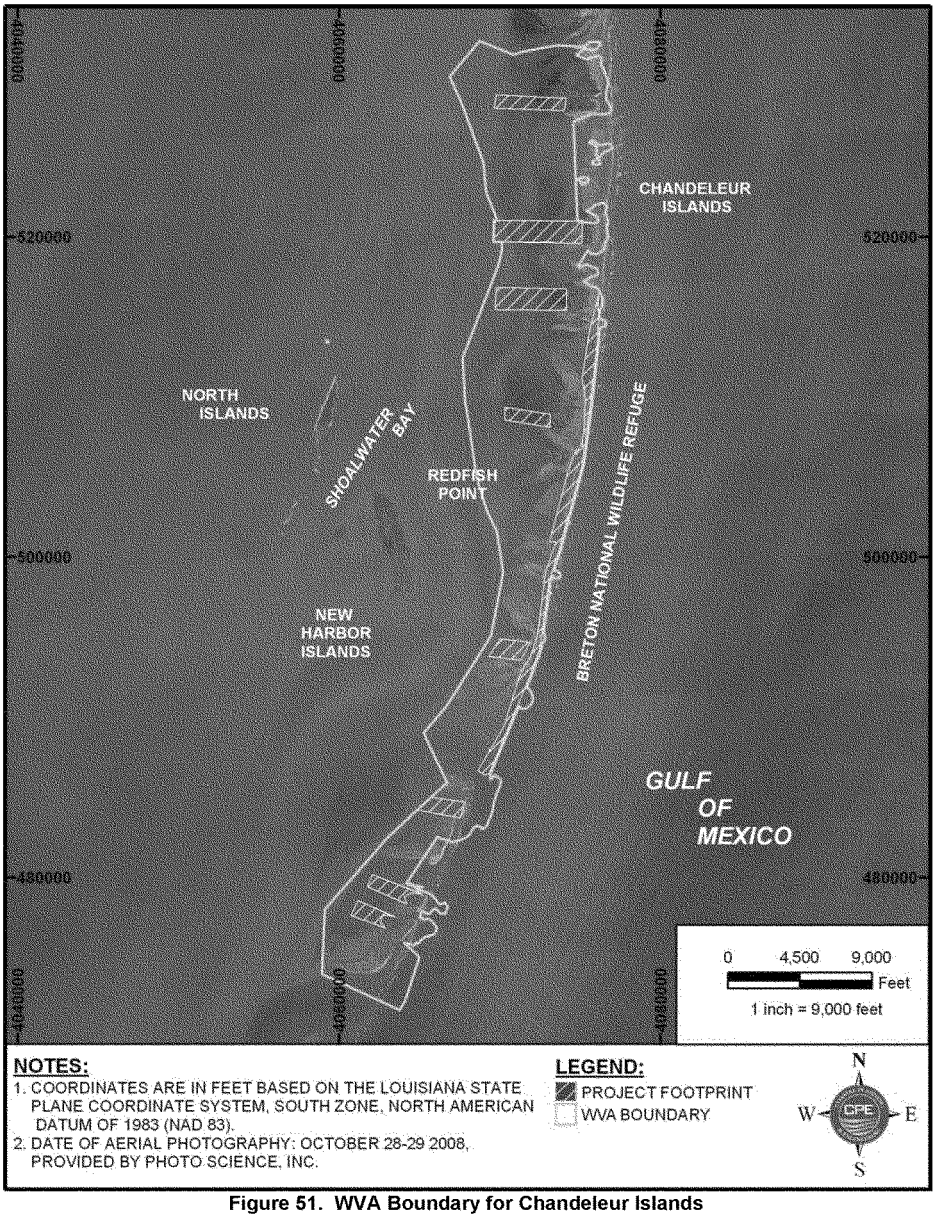


Figure 51. WVA Boundary for Chandeleur Islands

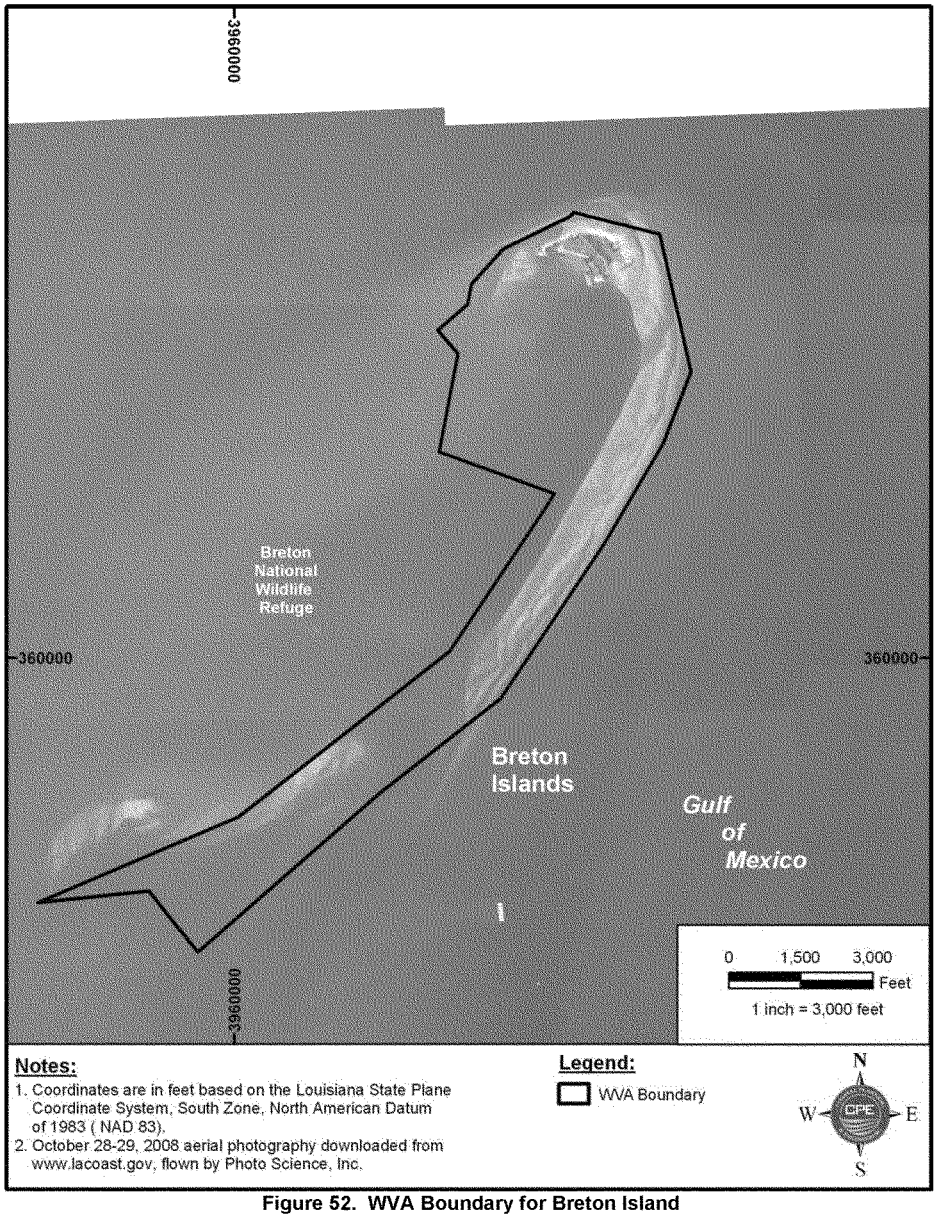


Figure 52. WVA Boundary for Breton Island

The barrier island model does not include areas of deep water (<-1.5 feet, NAVD). However, open water areas that contain seagrass beds surrounding the Chandeleur Islands are beneficial to the island's habitat. The barrier island model has been supplemented with an open water component to include the benefits of aquatic growth for the Chandeleur Islands only. A modified AAHU calculation has applied per guidance provided by Catherine Breaux of the USFWS (2009).

The delineation between gulf and bay intertidal and subtidal zones was determined using 2007 aerial images and contours. Gulf and bay intertidal area were mainly divided by the vegetation line, or where the island is impacted by gulf or bay wave action. Areas converted to deep water on the gulf side are not included in the calculation. Though the effective boundary shrinks due to subsidence and erosion, any acreage within the initial domain (encompassed by the boundary in Figure 51) is evaluated at each target year.

Once the boundaries of the WVA are defined, the next step is to determine the response of the future without-project (FWOP) and future with-project (FWP) scenarios with respect to various habitat elevations. For each target year (TY), open water (bayside), subtidal (bayside), intertidal (gulf and bay sides), supratidal, and dune acreages are required for the FWOP and FWP conditions. The range of various habitat elevations and associated descriptions are defined in Table 15.

Table 15. Habitat Description (after Williams and Sweeney, 2005)

Habitat	Description
Dune	≥ +5 feet, NAVD 88 The portions of the dune platform anticipated to be within the elevation range.
Supratidal	≥ +2 feet to ≤+4.9 feet, NAVD 88 Beach berms and portions of the fore and back slope of the dune within elevation the elevation range. Also includes primary retention/ containment dikes for the period anticipated to remain in the elevation range. Generally includes major portion of the marsh platform until the time dewatering and consolidation reduce the elevation to intertidal.
Gulf Intertidal	≥ 0 feet to ≤ +1.9 feet, NAVD 88 Gulf side beach slope / shallow open water.
Bay Intertidal	≥ 0 feet to ≤ +1.9 feet, NAVD 88 Bayside elevations including vegetated wetlands, flats and bayside open water areas.
Subtidal	0.0 to -1.5 feet, NAVD 88 or 1,000 feet bayward of the 0.0 feet contour Shallow Open water bayside area only.

FWOP values are based on survey data from 2006/07, as this is the latest date for which survey data was available, and are then eroded forward to approximate 2014 conditions, which are considered the TY0 (pre-construction) conditions.

Acreage values at the various target years are developed from an analytic model based on average predicted shoreline retreat rates, elevation change rates, and overwash. These are discussed in the sub-sections following the discussion of the WVA methodology.

WVA acreages calculated for each target year of the project life are multiplied by a Habitat Suitability Index (HSI) to yield Habitat Units (HUs). There are separate equations to calculate HSI for the barrier headland portion of the project and the emergent saline marsh component.

The barrier island model was developed to determine the sustainability of barrier island habitat to provide resting, foraging, breeding, and nursery habitat to a diverse assemblage of fish and wildlife species. Each model variable (V_x) is used to obtain a corresponding suitability index (SI) ranging from 0.0 – 1.0 from the Suitability Index graphs (Environmental Working Group, 2002). These suitability indices are then used to calculate the habitat suitability index (HSI). Equation 6 shows how the HSI is calculated for a given target year for the barrier island model.

$$HSI = 0.14(SIV_1) + 0.14(SIV_2) + 0.17(SIV_3) + 0.20\ (SIV_4) + 0.10(SIV_5) + 0.15(SIV_6) + 0.10(SIV_7) \quad \text{[Equation 7]}$$

where:

HSI = Habitat Suitability Index
SIV_1 = Suitability index for percent of the subaerial area that is classified as dune habitat,
SIV_2 = Suitability index for percent of subaerial area that is classified as supratidal habitat,
SIV_3 = Suitability index for percent of the subaerial area that is classified as intertidal habitat,
SIV_4 = Suitability index for percent of vegetative cover of dune, supratidal and intertidal habitats,
SIV_5 = Suitability index for percent vegetative cover by woody species,
SIV_6 = Suitability index for edge and interspersion,
SIV_7 = Suitability index for beach/surf zone features, and

Calculations of the suitability index for percent dune (SIV_1), percent supratidal (SIV_2), and percent intertidal (SIV_3) acreage are based on the output from the analytical model. There is no dune present in with or without project conditions, so the SIV_1 value will remain the same for every scenario (0.1).

A list of vegetative cover species used in determining SIV_4 and SIV_5 can be found in the WVA methodology (Environmental Work Group, 2002). Percent vegetative cover is typically determined based on historic aerials and ground truthing. Future vegetative cover and woody coverage will be based on estimates made for other barrier island projects with post-construction vegetative plantings.

Edge and interspersion (SIV_6) is determined by comparing the project area to sample illustrations given in the model methodology. Each class (1-5) depicts the combination of intertidal, subaerial habitat and intra-island aquatic habitats (i.e., ponds, lagoons, tidal creeks, etc.).

Optimal aquatic organism access exists when all of the study area is accessible and the access points are entirely open and unobstructed. However, high access may indicate island degradation. Additional details are provided by the Environmental Working Group (2007).

For beach/surf zone features (SIV_7), it is assumed that a natural beach/surf zone profile provides optimal habitat conditions for fish and wildlife. Man-made structures such as breakwaters, containment dikes, and shoreline protection reduce the suitability of the zone. The classes range from a natural beach (Class 1) to where a seawall or no emergent habitat exists (Class 5). The WVA methodology (Environmental Work Group, 2002) provides examples of various beach/surf zone features and how they are classified in order to determine the suitability index.

Coastal SAV meadows are a rapidly declining critical habitat for juvenile aquatic species, sea turtles, Florida Manatee, and wintering migratory waterfowl in the northern Gulf of Mexico (Byron and Heck, 2006; Poirrier and Handley, 2006; Michot, et al 2008). Aside from their important role in providing habitat, these seagrass meadows provide essential physical benefits to the stability of the Chandeleur Islands by reducing wave energy and current velocity due to the baffling effects of the seagrass. This process results in back barrier sediment trapping (vertical accretion) and protection of back barrier marsh shorelines form wave attack in Chandeleur Sound. The latter is important at the Chandeleur Islands because of the large fetch distance across Chandeleur Sound, especially during the passage of winter cold fronts. These seagrass beds are amazingly resistant to hurricanes and recover rapidly after storms when destroyed; however, the occurrence and distribution of seagrass at the Chandeleur Islands is directly related to the presence of a fronting barrier island (Poirier and Handley, 2006; Bethel and Martinez, 2008). The island dissection and rapid land loss associated with Hurricane Katrina has resulted in decreased suitable conditions for the seagrass decolonization (Bethel and Martinez, 2008). Vegetation also provides food and cover for a variety of fish and wildlife species.

Given the factors discussed above, the barrier island model assessing Chandeleur Islands was altered to include open water area. Because of the importance of seagrass beds to the Chandeleur Islands the HET agreed to add the variable V_8 cover of submerged aquatic vegetation (SAV). The variable SIV_2 from the marsh model was incorporated into the barrier island HSI calculation to include effects of SAV. The variables from the barrier island calculation were adjusted to give V_8 a weight of 10%. The modified HSI calculation used to evaluate the Chandeleur Islands is as follows:

$$HSI = 0.13(V_1) + 0.13(V_2) + 0.16(V_3) + 0.19(V_4) + 0.08\ (V_5) + \ldots$$
$$0.13(V_6) + 0.08(V_7) + 0.1(V_8) \qquad \text{[Equation 8]}$$

where:

SIV_8 = Suitability index for percent open water area covered by aquatic vegetation.

For submerged aquatic vegetative cover (SIV_8), optimal conditions are 100% cover with a linear increase starting at 0.1 for no SAV.

The HUs are annualized and averaged over the project life to determine the Average Annual Habitat Units (AAHUs). The AAHUs for future with and without project conditions are compared to determine the benefit attributable to the project in terms of quality and quantity.

13.2 Analytic Model of Habitat Acreage Change

An analytic model was developed that estimated the acreages of various habitat elevations for each alternative. The quantities and the model results for the FWOP and FWP alternatives are shown in Appendix B. A similar analytic model was applied on other Louisiana shoreline restoration projects including the Barataria Basin Barrier Shoreline Restoration Project, Shell Island component (Thomson, et al., 2008) and West Belle Pass Barrier Headland Restoration Project (TE-52) (Thomson, et al., 2009).

A summary of the key elements of the analytic model is included in the paragraphs below.

13.2.1 Longshore Losses

The fill volume required to counteract the effects of longshore transport was calculated using the longshore transport rates discussed in Section 11.4. Variations in the longshore transport rate are expected to be similar to those observed between 1996 and 2004 as the constructed shoreline is parallel to the analyzed shoreline. Transport at the north end of the project area along the Chandeleur Islands was estimated to be approximately 1,210,000 cubic yards/year to the north while longshore transport at the southern end of the project area was estimated at 325,000 cubic yards to the north at the southern end of the project area. Therefore, the total volumetric loss due to longshore transport was estimated at 1,535,000 cubic yards/year. Given an active profile height of 35 feet and future without project length of 12.3 miles, the average shoreline recession rate due to longshore loss was estimated at 18.3 feet/year. Under future with project conditions, the project length is slightly longer though the active profile height and sediment loss remains the same. This results in the FWP condition having a smaller average shoreline loss of 11.2 feet/year.

A similar analysis was performed at Breton Island. The FWOP shoreline retreat was 142 feet/year based on a net longshore transport loss of 513,000 cubic yards/year. The FWP loss was 36 feet/year based on a net longshore loss of 625,000 cubic yards. The reason for FWP having a lower shoreline recession than FWOP despite having a larger longshore transport loss is because that loss is averaged over a longer shoreline length (4 miles for FWP compared to 0.8 miles for FWOP).

13.2.2 Relative Sea Level Rise Losses

A portion of the shoreline recession is due to relative sea level rise. Shoreline recession due to relative sea level rise does not result in a net volume change in the cross-shore profile but simply a redistribution of the sediment across the profile (Figure 34). This does result in a loss of acreage and must therefore be accounted for within the project performance and benefits analysis.

The post-construction beach is expected to have a beach profile that is similar to the pre-construction beach as the grain size and percent silt in the placed fill is expected to be similar to that observed on the existing islands. Therefore, the existing shoreline recession rates due to relative sea level rise can be used when calculating advanced fill requirements. The advanced fill volume required to counteract the effects of baseline relative sea level rise along the Chandeleur Islands project area is approximately 435,000 cubic yards/year. This requires an average annual shoreline recession of almost 10 feet/year along both project areas under FWOP and FWP conditions.

13.2.3 Overwash

Analysis of recent shoreline changes, as discussed in Section 8, suggests that the dune will migrate landward due to overwash. The backing marsh helps maintain island elevation and provides a platform for the dune when rolling over. Sediment deposited on the backing marsh during overwash events provides additional elevation and volume for the dune when rolling over. SBEACH modeling was used to estimate the extent of overwash under FWOP and FWP conditions.

It was estimated that the shoreline face receded 11 feet/year due to overwash. This loss was applied to the highest remaining elevation (ie supratidal first and then gulf intertidal).

However, this loss results in acreage gain in other areas of the project boundary. There is a gain in supratidal acreage due to overwash as bay intertidal is converted to supratidal. This was estimated at both project areas to be approximately 34 feet/year based on the migration of the westernmost 2-foot contour from SBEACH. The return probability of the 1, 2, 3, 4, 5, 10, 15, 20, 50, and 100 year storms along with the overwash distances were used to determine the annual overwash distance at the 2-foot contour.

Overwash also results in the growth of the back bay. This growth can also occur due to sediment transport through the breaches but this was ignored in favor of simplification of the overwash process accounting for both processes. This growth was measured at 14 feet/year for the Chandeleur Islands (see Section 8.2.2).

13.2.4 Offshore Losses

As the islands erode, the mixed sediment body of the island becomes exposed. As discussed previously, the silt and clay are released into the water column and are considered to be transported out of the project area while the sand is transported via longshore and overwash processes.

To calculate losses due to release of silt, the total shoreline retreat rate due to longshore, overwash and relative sea level rise processes are summed and the offshore loss is then considered an additional 32% of that sum. The 32% is based on the percentage of silt and clay within the islands based on vibracore samples.

The offshore losses were held constant for FWOP and FWP conditions because the fill being added is a cap and does not extend the full face of the islands. This is considered a retreat design (USACE, 2004). Under a retreat design, the percentage of silt/clay in the island that erodes with shoreline retreat is unchanged because the erosional face of the island is unchanged.

13.3 Other Processes and Assumptions

Other processes and assumptions in the analytic habitat acreage change model include:

1. Subsidence results in conversion of one habitat type to another (bay intertidal to bay subtidal).

2. The SAV acreage decreases proportionally to the bay intertidal acreage for the Chandeleur Islands. Therefore, when all bay intertidal acreage is lost, it is assumed that all of the SAV will not survive. This is based on waves being able to impact the beds from the gulf side with only bay subtidal remaining.

3. Baseline numbers for vegetative and woody cover are based on best professional judgment of those with experience and knowledge of the island chain and an over flight (Nov 3, 2009). It was assumed that dune, supratidal, and intertidal habitats would be planted. It is recommend dune plantings include sea oats, bitter panicum, beach morning glory (if available), and Roseau (use source material for better survivability in saline conditions).

4. Existing conditions for submerged aquatic vegetative cover are based on cover of sea grass beds in 2005 post hurricane Katrina.

5. Beach/surf zone is Class 1 throughout the project life for both project areas as long as subaerial habitat exists.

13.4 Chandeleur Islands

13.4.1 Chandeleur Islands FWOP

Starting acreages were obtained from 2007 BICM bathymetry and LIDAR data. The acreages were then projected forward to the TY1 Post-Construction (2015) by incorporating 8 years of habitat acreage change. The total loss due to shoreline recession is 58.5 feet/yr. Table 16 summarizes the planform project performance for each of the habitat areas. Appendix A contains the analytic model acreage calculations.

Table 16. Planform Performance Projection for Chandeleur Islands FWOP

Target Year	Habitat (acres)						Total
	Dune	Supratidal	Gulf Intertidal	Bay Intertidal	Bay Subtidal	SAV Area	
TY0 Pre-Con	0	0	365	765	367	5,239	6,736
TY1 Post-Con	0	0	338	755	367	5,170	6,631
TY3	0	0	285	735	368	5,031	6,419
TY5	0	0	231	715	370	4,892	6,208
TY10	0	0	97	665	373	4,543	5,680
TY14	0	0	0	615	376	4,195	5,186
TY15	0	0	0	570	377	3,886	4,834
TY20	0	0	0	345	381	2,344	3,071
TY25	0	0	0	120	386	807	1,313
TY28	0	0	0	0	393	0	393
TY30	0	0	0	0	317	0	317
TY31	0	0	0	0	279	0	279
TY39	0	0	0	0	0	0	0
TY50	0	0	0	0	0	0	0

The Chandeleur Islands were estimated to have 50% vegetative cover from TY0 through TY3. Vegetative cover was then decreased to 0% at TY28, when the island is projected to have no remaining subaerial acreage.

There is very little woody vegetative cover on the existing islands; therefore woody cover is at 0.5% for TY0 but 0% from TY1 and on.

Percent of submerged aquatic vegetation covering open water area remains at 41% through TY28 until the back bay is unprotected from gulf wave action and the percentage reduces to 0%.

Interspersion is 100% Class 4 through TY28. With the loss of all subaerial acreage, interspersion is switched to Class 5.

The FWOP conditions for the Chandeleur Islands provide 828 AAHUs. The individual HSI calculations for the various years and habitat areas are included in Appendix A while Table 17 summarizes the overall AAHU calculation.

Table 17. Barrier Island WVA Benefits for Chandeleur Islands FWOP

Target Year	Acres	x HSI	Total HUs	Cumulative HUs
0	6736	0.383	2577	0
1	6631	0.379	2513	2545
3	6419	0.379	2433	4946
5	6208	0.360	2238	4669
10	5680	0.343	1948	10456
14	5186	0.325	1687	7263
15	4834	0.308	1487	1586
20	3071	0.299	917	5998
25	1313	0.242	317	3003
28	393	0.172	68	545
30	317	0.172	55	122
31	279	0.172	48	51
39	0	0.172	0	192
50	0	0.172	0	0
Average Annual Habitat Units				828

13.4.2 Chandeleur Islands FWP

TY1 Post-Construction combines the remaining acreage that was projected forward from 2007 overlaid with the constructed project. It was assumed that construction would account for losses during the year of construction.

Table 18 shows the performance of the various habitat types over the 50-yer project evaluation period. Note that supratidal acreage is completely lost by TY13. Gulf intertidal habitat is lost by TY24 though it is difficult to define the difference between gulf and bay intertidal without a dune. Therefore, it is preferable to state that intertidal acreage is lost by TY48. Submerged aquatic vegetation is therefore also considered lost in TY48.

Since the berm is constructed on both existing island and open water areas, two overwash values were used to include overwash of the berm in each respective area. Overwash of the berm that is backed by existing island will result in the conversion of supratidal to intertidal acreage. Overwash of the berm where is it constructed on open water will result in a loss of supratidal acreage. When supratidal acreage is lost, it is assumed that overwash will resume at the same rate as FWOP conditions. The existing islands that were not constructed upon are overwashed at the same rate as the FWOP conditions.

Vegetative cover percentages are based on the Shell Island project. In TY1, 50% of the existing island, 10% of the constructed supratidal acreage, and 25% of the constructed intertidal acres are planted. This leads to a vegetative cover percentage of 52% in TY1. Vegetative cover increases with growth on the island so that in TY3 the vegetative cover is anticipated to be 60%. In TY5

the cover is 69% before reaching a maximum cover of 70% in TY10 through TY15. The cover percentage then decreases until all cover is lost in TY48.

Table 18. Planform Performance Projection for Chandeleur Islands FWP

Target Year	Habitat (acres)						Total
	Dune	Supratidal	Gulf Intertidal	Bay Intertidal	Bay Subtidal	SAV Area	
TY0 Pre-Con	0	0	365	765	367	5,239	6,736
TY1 Post-Con	0	374	231	1,392	344	4,869	7,211
TY3	0	301	258	1,327	345	4,672	6,903
TY5	0	228	285	1,261	346	4,474	6,594
TY10	0	45	352	1,097	348	3,975	5,817
TY13	0	0	297	1,070	349	3,885	5,602
TY15	0	0	225	1,066	350	3,869	5,510
TY20	0	0	43	1,057	353	3,829	5,282
TY24	0	0	0	1,022	354	3,738	5,114
TY25	0	0	0	979	355	3,581	4,914
TY30	0	0	0	765	357	2,792	3,914
TY40	0	0	0	337	362	1,219	1,918
TY48	0	0	0	0	361	0	361
TY50	0	0	0	0	358	0	358

Woody vegetation is planted during construction so that percent woody vegetation is 5% in TY1 and increases to 10% in TY5 with additional planting and natural recruitment. Woody vegetation was assumed to remain constant at 10% from TY5 through TY20 before decreasing to 0% at TY48, the point at which all subaerial acreage is lost.

Interspersion was based on the initial construction project length. The shore parallel length of the constructed project was approximately 58% of the WVA boundary length. The 42% of the shoreline that did not have a constructed feature was assumed to be Class 4. At TY1, the 58% of the shoreline with a constructed feature was assumed to be Class 3. At Ty3, it was assumed that the constructed areas would be Class 1. Over time, the Class 1 acreage was reduced to Class 2 and then Class 3 interspersion. By TY40, all of the project area was assumed to be Class 4 and at TY50, it was assumed that the project area was Class 5 because there was no subaerial acreage remaining.

Submerged aquatic vegetation provides benefit through to TY48 when all intertidal acreage is lost. As stated previously, SAV acreage was assumed to be proportional to the subaerial acreage. The percent of submerged aquatic vegetation was estimated to start at 41% but increased to 90% by TY5 due to the benefit of sheltering provided by with project conditions. The percent SAV then decreased to 0% between TY5 and TY48.

The FWP condition for the Chandeleur Islands provides 2,292 AAHUs, and 1,464 net AAHUs, as shown in Table 19.

Table 19. Barrier Island WVA Benefits for Chandeleur Islands FWP

Target Year	Acres	x HSI	Total HUs	Cumulative HUs
0	6736	0.383	2,577	0
1	7211	0.653	4,706	3,620
3	6903	0.704	4,859	9,571
5	6594	0.717	4,729	9,589
10	5817	0.598	3,481	20,446
13	5602	0.564	3,158	9,954
15	5510	0.557	3,067	6,224
20	5282	0.547	2,890	14,891
24	5114	0.523	2,676	11,130
25	4914	0.509	2,501	2,588
30	3914	0.471	1,843	10,829
40	1918	0.406	778	12,888
48	361	0.172	62	2,875
50	358	0.000	0	62
FWP Average Annual Habitat Units				2,292
FWOP Average Annual Habitat Units				828
Net Average Annual Habitat Units				1,464

13.5 Breton Island

13.5.1 Breton Island FWOP

Starting acreages were obtained from 2007 BICM bathymetry and LIDAR data. The acreages were then projected forward to the TY1 Post-Construction (2015) by incorporating 8 years of habitat acreage change. Table 20 summarizes the planform project performance for each of the habitat areas. Appendix A contains the analytic model acreage calculations.

Table 20. Planform Performance Projection for Breton Island FWOP

Target Year	Habitat (acres)					Total
	Dune	Supratidal	Gulf Intertidal	Bay Intertidal	Bay Subtidal	
TY0 Pre-Con	0	0	0	0	0	0
TY1 Post-Con	0	0	0	0	0	0
TY50	0	0	0	0	0	0

It is estimated that the remaining acreage at Breton Island will be lost in approximately 3 to 4 years. Therefore, there is no FWOP acreage and there are no AAHU's provided by Breton Island under FWOP conditions (Table 21).

Table 21. Barrier Island WVA Benefits for Breton Island FWOP

Target Year	Acres	x HSI	Total HUs	Cumulative HUs
0	0	0.190	0	0
1	0	0.190	0	0
50	0	0.190	0	0
FWOP Average Annual Habitat Units				0

13.5.2 Breton Island Alternative 1

Given that there are no FWOP acreage by 2014, TY0 has no project acreage. Thus, the project creates all of the project acreage in TY1 (Table 22). However, loss rates and overtopping of the island results in the loss of supratidal and gulf intertidal acreage by TY9. The loss of gulf intertidal acreage is slightly misleading as gulf intertidal and bay intertidal acreage are functionally similar, given that they are constructed from the same material. Intertidal acreage is expected to remain through TY19. Due to limited overwash from bay intertidal to bay subtidal, complete loss of bay subtidal also occurs in TY19.

Table 22. Planform Performance Projection for Breton Island Alternative 1

Target Year	Habitat (acres)					Total
	Dune	Supratidal	Gulf Intertidal	Bay Intertidal	Bay Subtidal	
TY0 Pre-Con	0	0	0	0	0	0
TY1 Post-Con	0	517	49	1066	3	1634
TY3	0	373	49	1027	3	1453
TY5	0	230	49	988	4	1271
TY8	0	14	49	930	5	998
TY9	0	0	0	902	6	907
TY10	0	0	0	811	6	817
TY15	0	0	0	355	8	363
TY19	0	0	0	0	0	0
TY50	0	0	0	0	0	0

Vegetative cover is similar to the Chandeleur Islands percentages at the start of the project. In TY1, 10% of supratidal and 25% of intertidal acreage has vegetative cover resulting in a net of 21%. It then increases to 80% by TY8 and returns to 0% by TY19 when there is no subaerial acreage remaining.

Woody cover is the same as the Chandeleur Islands. It is assumed that there will be some woody vegetation plated during construction giving a TY1 woody cover of 5%. Natural recruitment increases woody cover to 10% in TY5. This percentage holds through TY8 before percent woody cover decreases to 0% in TY 19 when there is no remaining subaerial acreage.

Edge and interspersion is 100% Class 3 in TY1, 100% Class 1 in TY3. Edge and interspersion then deteriorates going through varying percentages of Class 2, Class 3, and Class 4 before becoming Class 5 in TY19 with the loss of all subaerial acreage.

The FWP conditions for Breton Island Alternative 1 provide 195 AAHUs (Table 23).

Table 23. Barrier Island WVA Benefits for Breton Island Alternative 1

Target Year	Acres	x HSI	Total HUs	Cumulative HUs
0	0	0.190	0	0
1	1635	0.647	1058	405
3	1452	0.785	1140	2207
5	1271	0.787	1000	2140
8	998	0.581	580	2342
9	908	0.517	469	524
10	817	0.499	408	438
15	363	0.451	164	1410
19	0	0.190	0	264
50	0	0.235	0	0
FWP Average Annual Habitat Units				195
FWOP Average Annual Habitat Units				0
Net Average Annual Habitat Units				195

13.5.3 Breton Island Alternative 2

Given that there are no FWOP acreage by 2014, TY0 has no project acreage. Thus, the project creates all of the project acreage in TY1 (Table 24).

Loss rates of the island results in the loss of dune acreage by TY7. Major lowering of the island also occurs in TY7 due to the decreased dune width and the 10-year storm conditions, causing the remaining dune acreage to be overwashed and lowered to supratidal acreage. After the island is lowered to supratidal elevation, it is estimated to suffer an annual shoreline loss due to overwash. Due to the lack of a backing marsh platform and limited amount of bay intertidal and subtidal acreage placed during project construction, overwashing of the island results in a net loss of acreage to the deep open water behind the project area. The intertidal and subtidal acreage are expected to remain through TY13.

Table 24. Planform Performance Projection for Breton Island Alternative 2

Target Year	Habitat (acres)					
	Dune	Supratidal	Gulf Intertidal	Bay Intertidal	Bay Subtidal	Total
TY0 Pre-Con	0	0	0	0	0	0
TY1 Post-Con	400	141	43	52	39	674
TY2	343	141	43	52	39	617
TY5	171	141	43	52	39	445
TY7	0	219	43	52	39	353
TY10	0	23	43	52	39	156
TY11	0	0	0	52	39	90
TY12	0	0	0	0	32	32
TY13	0	0	0	0	0	0
TY50	0	0	0	0	0	0

Vegetative cover is similar to the Chandeleur Islands percentages at the start of the project. In TY1, 10% of supratidal and 25% of intertidal acreage has vegetative cover resulting in a net of 7%. It then increases to 80% by TY10 and returns to 0% by TY12 when there is no subaerial acreage remaining.

Woody cover is the same as the Chandeleur Islands. It is assumed that there will be some woody vegetation plated during construction giving a TY1 woody cover of 5%. Natural recruitment increases woody cover to 10% in TY5. This percentage holds through TY10 before percent woody cover decreases to 0% in TY 12 when there is no remaining subaerial acreage.

Edge and interspersion is 100% Class 3 in TY2, 100% Class 1 in TY5. Edge and interspersion then deteriorates going through varying percentages of Class 2 and Class 3 before becoming Class 5 in TY12 with the loss of all subaerial acreage.

Alternative 2 erodes more quickly than Alternative 1 due to the narrower dune and lack of backing marsh to accumulate overwashed sediments.

The FWP conditions for Breton Island Alternative 2 provide 49 AAHUs (Table 25).

Table 25. Barrier Island WVA Benefits for Breton Island Alternative 2

Target Year	Acres	x HSI	Total HUs	Cumulative HUs
0	0	0.190	0	0
1	674	0.379	255	107
2	617	0.513	316	287
5	445	0.647	288	918
7	353	0.633	223	511
10	156	0.751	117	523
11	90	0.481	43	77
12	32	0.190	6	22
13	0	0.190	0	3
50	0	0.190	0	0
FWP Average Annual Habitat Units				49
FWOP Average Annual Habitat Units				0
Net Average Annual Habitat Units				49

13.5.4 Breton Island Alternative 3

Alternative 3 consists of the +10 ft, NAVD platform placed at the northern end of Breton Island. Given that there are no FWOP acreage by 2014, TY0 has no project acreage. Thus, the project creates all of the project acreage in TY1 (Table 26).

Loss rates of the island results in the loss of dune acreage by TY13. The island resists overwash better than the other alternatives due to the high elevation and width of the dune. Some overwash is incorporated due to overwash on the runoff slope section. Given the varying elevation of the runoff slope, overwash is incorporated starting in TY1. Once the dune is lost due to shoreline recession, the entire island will behave similarly to Alternative 1, having a low elevation fronting dune backed by a lower marsh area. Complete loss of all acreage occurs in TY20.

Table 26. Planform Performance Projection for Breton Island Alternative 3

Target Year	Habitat (acres)					
	Dune	Supratidal	Gulf Intertidal	Bay Intertidal	Bay Subtidal	Total
TY0 Pre-Con	0	0	0	0	0	0
TY1 Post-Con	271	108	15	61	46	501
TY2	247	107	15	61	46	477
TY5	176	103	15	61	46	402
TY10	58	97	15	61	46	277
TY13	0	81	15	58	46	200
TY15	0	33	15	47	46	142
TY18	0	0	3	47	46	97
TY19	0	0	0	29	46	76
TY20	0	0	0	8	46	55
TY21	0	0	0	0	30	31
TY22	0	0	0	0	0	0
TY50	0	0	0	0	0	0

Vegetative cover is similar to the Chandeleur Islands percentages at the start of the project. In TY1, 10% of supratidal and 25% of intertidal acreage has vegetative cover resulting in a net of 7%. It then increases to 80% by TY13 and returns to 0% by TY18 when there is no subaerial acreage remaining.

Woody cover is the same as the Chandeleur Islands. It is assumed that there will be some woody vegetation plated during construction giving a TY1 woody cover of 5%. Natural recruitment increases woody cover to 10% in TY5. This percentage holds through TY10 before percent woody cover decreases gradually to 0% in TY 21 when there is no remaining subaerial acreage.

Edge and interspersion is 100% Class 3 in TY2, 100% Class 1 in TY5. Edge and interspersion then deteriorates going through varying percentages of Class 2, Class 3, and Class 4 before becoming Class 5 in TY21 with the loss of all subaerial acreage.

The Alternative 3 conditions for Breton Island provide 67 AAHUs (Table 27).

Table 27. Barrier Island WVA Benefits for Breton Island Alternative 3

Target Year	Acres	x HSI	Total HUs	Cumulative HUs
0	0	0.175	0	0
1	501	0.380	190	78
2	477	0.515	246	219
5	402	0.633	255	755
10	277	0.757	210	1173
13	200	0.780	156	549
15	142	0.789	112	268
18	97	0.481	47	231
19	76	0.454	35	40
20	55	0.415	23	29
21	31	0.190	6	13
22	0	0.190	0	3
50	0	0.190	0	0
FWP Average Annual Habitat Units				67
FWOP Average Annual Habitat Units				0
Net Average Annual Habitat Units				67

13.5.5 Breton Island Alternative 4

Alternative 4 consists of a 750-foot wide dune platform at an elevation of +6.0 feet, NAVD with a terminal groin at the southwest end of the fill area. Given that there are no FWOP acreage by 2014, TY0 has no project acreage. Thus, the project creates all of the project acreage in TY1 (Table 28).

The performance analysis for Breton Island Alternative 4 was broken into two parts in order to better account for the effect of the groin. The first section extends 11,800 feet from the north of the island through to the central portion. It was analyzed similarly to Alternative 2 except that the project length was shorter. The second section extends 7,000 feet north from the terminal groin. The length of the shoreline was based on the updrift limit of the fillet after approximately 7 years. Given an average annual recession rate of 116 feet/year, the shoreline has retreated through the dune width and therefore it was assumed that there would be limited additional sand to grow the fillet.

The size of the fillet was estimated in order to develop the required length of the terminal groin, as described in Section 12.2.4.2. Shoreline retreat due to relative sea level rise and overwash was incorporated as described for the other alternatives. However, the growth of the fillet with sand fundamentally alters the silt loss rate. In year 1, it was assumed that silt losses would occur as with Alternative 2, at approximately 72 feet/year over the full 7,000 feet of the analysis length. In year 2, this loss was eliminated over the 4,000 feet where the fillet had grown (predicted using Walton and Chiu's method). The remaining 3,000 feet were assumed to have suffered a silt loss of 72 feet/year. This calculation was continued each year with a longer fillet and shorter silt loss section until TY7. Between TY7 and TY20, it was assumed that there would

be no offshore silt losses as the full profile had been armored with sand. After TY20, the retreat due to relative sea level rise and overwash re-exposes the silt core and offshore silt losses restart.

Once the silt losses restart in this section of Alternative 4, intertidal and subaerial acreage is lost more quickly and Breton Island with no subaerial acreage remaining by TY24. Table 28 summarizes the total acreage for both sections of Alternative 4.

Table 28. Planform Performance Projection for Breton Island Alternative 4

Target Year	Habitat (acres)					
	Dune	Supratidal	Gulf Intertidal	Bay Intertidal	Bay Subtidal	Total
TY0 Pre-Con	0	0	0	0	0	0
TY1 Post-Con	401	63	50	51	42	608
TY2	352	69	50	51	42	565
TY5	239	83	50	51	42	467
TY7	0	278	50	51	42	422
TY10	0	163	29	51	42	287
TY11	0	153	22	22	42	241
TY12	0	142	22	14	16	195
TY13	0	132	22	14	14	183
TY20	0	59	22	14	14	109
TY22	0	15	22	14	14	65
TY23	0	0	16	14	14	45
TY24	0	0	0	4	14	19
TY25	0	0	0	0	1	1
TY26	0	0	0	0	0	0
TY50	0	0	0	0	0	0

This scenario is very complex and it is recommended that if Alternative 4 is carried forward for final design that three dimensional numerical modeling, including mixed sediment tracking, be considered to optimize the groin length and beach fill layout.

Vegetative cover is similar to the Chandeleur Islands percentages at the start of the project. In TY1, 10% of supratidal and 25% of intertidal acreage has vegetative cover resulting in a net of 6%. It then increases to 65% by TY10 and returns to 0% by TY25 when there is no subaerial acreage remaining.

Woody cover is the same as the Chandeleur Island. It is assumed that there will be some woody vegetation plated during construction giving a TY1 woody cover of 5%. Natural recruitment increases woody cover to 10% in TY5. This percentage holds through TY10 before percent woody cover decreases to 0% in TY 23 when there is no remaining subaerial acreage.

Edge and interspersion is 100% Class 5 in TY1, 100% Class 1 in TY5. Edge and interspersion then deteriorates going through varying percentages of Class 2, Class 3, and Class 4 before becoming Class 5 in TY25 with the loss of all subaerial acreage.

The FWP conditions for Breton Island Alternative 4 provide 70 AAHUs (Table 29).

Table 29. Barrier Island WVA Benefits for Breton Island Alternative 4

Target Year	Acres	x HSI	Total HUs	Cumulative HUs
0	0	0.190	0	0
1	608	0.322	196	85
2	565	0.462	261	229
5	467	0.621	290	834
7	422	0.633	267	557
10	287	0.656	188	684
11	241	0.589	142	165
12	195	0.530	103	122
13	183	0.522	96	99
20	109	0.598	65	569
22	65	0.757	49	117
23	45	0.417	19	33
24	19	0.415	8	13
25	1	0.190	0	3
26	0	0.190	0	0
50	0	0.190	0	0
FWP Average Annual Habitat Units				70
FWOP Average Annual Habitat Units				0
Net Average Annual Habitat Units				70

13.5.6 Breton Island Alternative 5

As shown in Section 13.5.1, it is not anticipated that Breton Island will have any emergent acreage remaining at the time of construction. Since Alternative 5 does not place any material to a subaerial elevation, benefits for Alternative 5 are based on the onshore movement of sediment.

Once Breton Island Pass and the MRGO are filled to depths shallower than -22 feet, NAVD, it will require several years for the material contained within the Grand Gosier Shoal to cross Breton Inlet and feed Breton Island (probably better described as Breton Shoal). Given that the sediment at Grand Gosier Shoal has not reformed as an emergent land mass, it is not expected that this material will cross Breton Island Pass and reform Breton Shoal into an emergent land mass either (Table 30). Therefore, no project benefits are anticipated from Alternative 5 (Table 31).

Table 30. Planform Performance Projection for Breton Island Alternative 5

Target Year	Habitat (acres)					Total
	Dune	Supratidal	Gulf Intertidal	Bay Intertidal	Bay Subtidal	
TY0 Pre-Con	0	0	0	0	0	0
TY1 Post-Con	0	0	0	0	0	0
TY50	0	0	0	0	0	0

Table 31. Barrier Island WVA Benefits for Breton Island Alternative 5

Target Year	Acres	x HSI	Total HUs	Cumulative HUs
0	0	0.190	0	0
1	0	0.190	0	0
50	0	0.190	0	0
FWP Average Annual Habitat Units				0
FWOP Average Annual Habitat Units				0
Net Average Annual Habitat Units				0

14 BORROW AREAS

Three areas were identified as potential sources of fill for the construction of the Chandeleur Islands and Breton Island ecosystem restoration projects: Hewes Point, Saint Bernard Shoals, and the MRGO Ocean Dredged Material Disposal Site (ODMDS) (Figure 53). A summary of the borrow area characteristics is provided in Table 32.

Table 32. Summary of Borrow Area Grain Size, Silt Content and Volumes

Borrow Area	Mean Grain Size (mm)	Percent Silt (%)	Beach Fill Volume (M cy)	Pump Distance (miles)	
				Chandeleur	Breton
Hewes Point	0.15-0.18	10	500	12	42
St. Bernard Shoals	0.13-0.21	10	251	18	34
MRGO ODMDS	0.10-0.15	<25%	>50	30	8

The impact of the Deepwater Horizon oil spill has not been considered in the development of this report. It is likely that additional measures both on the beach and in the borrow areas may be required to minimize, reduce or avoid environmental impacts from dredging and discharge operations. It was assumed that any additional requirements would be similar regardless of the borrow area so that there will be no advantage to using one borrow area over another. Additional investigations may reveal greater impacts to one borrow area compared to another but that information is not available at this time.

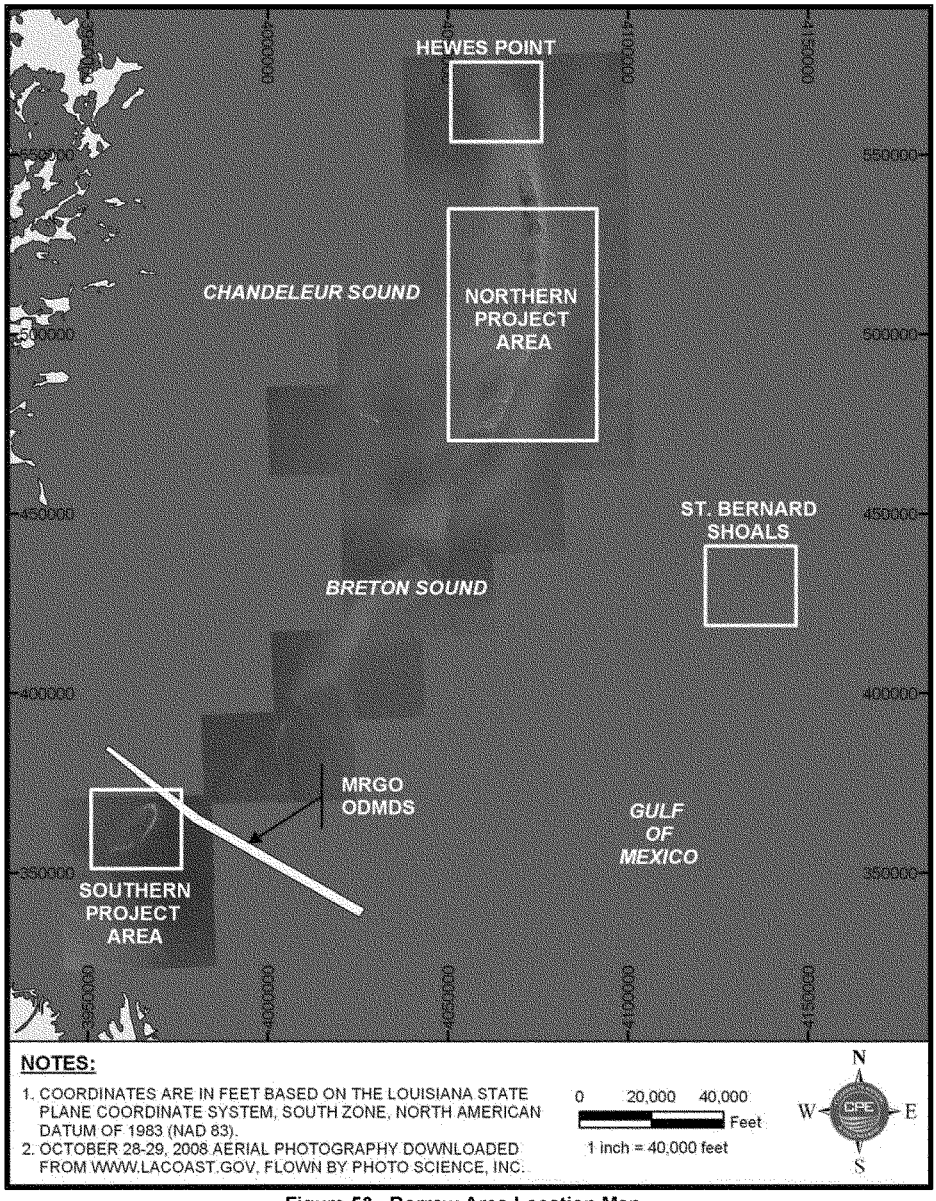


Figure 53. Borrow Area Location Map

14.1 Hewes Point Borrow Area

The Hewes Point borrow area, which is located at the northernmost end of the Chandeleur Island Chain, is approximately 12 miles north of the center of the Chandeleur Islands project site and 42 miles north-northeast of the center of the Breton Island project site. The Hewes Point borrow site consists of approximately 500M cubic yards of sand that was sourced from updrift erosion of the Chandeleur Islands (Twichell et al., 2009). This sand body lies in water depths that range from 9 to 45 feet with an average depth of approximately 15 feet, covers an area of approximately 2,500 acres and maximum sand thickness is approximately 30 feet in the northernmost section (Twichell et al., 2009; unpublished USGS and UNO-PIES vibracore and shallow seismic data). Based on seafloor change analysis, during the past 125 years this area has been the site of 170M cubic yards of sediment accretion (Miner et al., 2009a, b). These deposits consist of relatively clean sand (~90% sand) with a mean grain size diameter of 0.15 to 0.18 mm based on the top 3 feet from vibracores sampled in 2007 (Flocks et al., 2009a). Because this deposit was sourced from erosion of the barriers it is highly compatible with the existing beach sand. Moreover, mining at this site should have minimal if any negative impacts with regard to the littoral sediment budget because this sand is sequestered at the terminus of the littoral system and there are no downdrift barrier islands that will be affected.

14.2 St. Bernard Shoals

The St. Bernard Shoals are located approximately 18 miles southeast of the center of the Chandeleur Islands project site and 34 miles northeast of the center of the Breton Island project site. The St. Bernard Shoals consist of a group of discrete sand bodies ranging in size from 12 to 11,000 acres. They are low-relief sand bodies about 10 to 12 feet thick within a larger inner shelf sand body. Each shoal is approximately 3 to 4 miles wide and aligned with a northward trend (Kulp et al., 2005a). Within the St. Bernard Shoals there are two distinct shoal fields, the southernmost shoal field lies in 50 to 65 feet of water and a smaller field located 3 miles northwest of the larger field is in 45 feet of water (Rogers et al., 2009).

The southern shoal field contains 251M cubic yards of sand and comprises nearly 96% of the total volume of sand in St. Bernard Shoals (Pope et al., 1993; Rogers et al. 2009a, b). The individual sand bodies are typically composed of 3 to 13 feet thick, massive, very well-sorted to well sorted (sorting coefficient of 0.27 – 0.66) moderate yellowish brown fine sand (~0.13 to 0.21 mm mean grain size; Rogers et al., 2009a, b).

14.3 MRGO Ocean Dredge Material Disposal Site

The MRGO ODMDS is located offshore of Breton Island Pass located between Mile Marker -4 and MM -9.38. Approximately 118M cubic yards of sediment was placed here during the construction and maintenance of MRGO between the 1960s and 2004. The exact volume of available sand, its grain size and silt content are unknown though it is anticipated based on disposal volume that more than 50M cubic yards should be available to reconstruct Breton Island. While exact grain size and percent silt quantities are unknown, previous projects using sands dredged in the vicinity of Breton Island suggest that the sand is beach compatible with a

manageable (<25%) silt content. Grain sizes are expected to be in the 0.10 to 0.15mm range based on discussions with Weeks Marine and Ed Creef (USACE).

It should also be noted that the MRGO dissects the Breton Island Pass ebb tidal delta, a large, sand body that could also be a potential resource. This ebb tidal delta is important for inlet sediment bypassing at Breton Island Pass and nourishing adjacent barrier islands, a process that should not be interrupted by dredging. However, the adjustment of the shoal in response to the deep MRGO channel cut and associated tidal currents could have resulted in seaward progradation of this sand body leaving a "stagnant" distal ebb tidal delta that does not play a role in facilitating alongshore sand transport. If that were the case, then a viable sand resource may flank the seaward extent of the MRGO bar channel. A detailed study on the hydrodynamics of this system, the morphology of the ebb delta and dredge placement site, and subsurface investigation is needed to accurately assess the viability of this as a sand resource. The impacts of mining to the sediment transport system and how MRGO has responded (possible shoaling) to the cessation of maintenance dredging activity should also be studied prior to use of the source.

14.4 South of Breton Island

The southernmost terminal spit of the Chandeleur Island system lies south of Breton Island that is filling a large inlet between Breton Island and the Modern Mississippi Delta by lateral accretion. No subsurface data exists for this location but seafloor change analysis results demonstrate that this area has undergone significant accretion during the past 125 years approximately 235M cubic yards; similar to the processes described for the development of the Hewes Point sand body in the north. More data is needed to assess the potential as a viable sand resource target but this deposit is approximately 6 miles from the Breton Island project area.

15 CONSTRUCTION COST ESTIMATE

This section discusses the development of the construction cost estimates. The construction cost estimates are based on costs for similar barrier island projects, specifically the West Belle Pass Barrier Headland Restoration project. The West Bell Pass cost estimate (Thomson et al, 2009) was used as a baseline when developing the cost estimates for the various alternatives.

Cost estimates were developed for the Chandeleur Islands project area using the Hewes Point (cutterhead and hopper dredges) and St. Bernard Shoals (hopper dredge) borrow areas. The cost estimates developed for the Breton Island project area used the Hewes Point (hopper dredge), St. Bernard Shoals (hopper dredge), and the MRGO disposal site (cutterhead dredge). The cost spreadsheets used to develop dredging costs are included in Appendix B.

15.1 Mobilization Cost

Mobilization and demobilization expenses include the cost to prepare and transport all equipment to and from the job site. This includes towing the dredge and transporting other support vessels, transporting and installing submerged pipeline, and bringing personnel and land based equipment to the job site.

Hewes Point is located 21 miles from the furthest sand fill area. While it is possible to construct the project using a cutterhead dredge, it is more likely that a hopper dredge will be used. It is likely that dredging of St. Bernard Shoals would also require a hopper dredge given the distance from the borrow area to the project site, depth of water, and exposure of the borrow area to large waves. The -25-foot contour is located approximately 1.2 miles offshore, which is close enough that a hopper dredge hooked up to a pump-out station could unload and still pump alongshore. The pump-out station would have to be moved every 4 to 5 miles. Therefore, the hopper dredge will have to relocate the pump-out station approximately 6 times to construct the project.

The estimated mobilization cost when using a hopper dredge for the Chandeleur Islands project is $4,325,000 (Table 33). The mobilization cost for a hopper to construct the Breton Island project will be similar as the hopper dredge can use the MRGO to access the project site.

Table 33. Hopper Dredge Mobilization Cost Estimate

Item	Unit	Unit Price	Quantity	Total Price
Dredge	LS	$750,000	1	$750,000
Booster	LS	$275,000	1	$275,000
Pipeline	mile	$500,000	4	$2,000,000
Relocation	LS	$200,000	6	$1,200,000
Quarters Barge	LS	$100,000	1	$100,000
			Subtotal	**$4,325,000**

The Breton Island project could be constructed using either a hopper dredge taking material from St. Bernard Shoal or a 30" cutterhead for dredging the MRGO ODMDS borrow area. The maximum pumping distance would be approximately 10 miles (4 miles along the ODMDS and 4 miles along Breton Island). However, the large volume of material that has been disposed of and the potential to dredge the "stagnant" distal ebb shoal suggests that not all of the ODMDS length would need to be dredged. Therefore, a cost estimate has been developed based on a line length of 8 miles. The mobilization cost when using a 30" cutterhead dredge for the Breton Island project is $5,125,000.

Table 34. Cutterhead Dredge Mobilization Cost Estimate

Item	Unit	Unit Price	Quantity	Total Price
Dredge	LS	$750,000	1	$750,000
Booster	LS	$275,000	1	$275,000
Pipeline	mile	$500,000	8	$4,000,000
Quarters Barge	LS	$100,000	1	$100,000
			Subtotal	**$5,125,000**

Mobilization costs are difficult to predict because there are several variables involved. The biggest cost is the transport of pipeline to the project. This is dependent upon where the Contractor has their pipe at the time the project is due to be constructed. Obviously, the more scattered and further away the pipe, the higher the mobilization cost.

15.2 Beach Fill Dredging Unit Costs

The dredging unit cost was developed using the USACE cost estimating spreadsheets. A summary of all beach fill dredging unit costs is provided in Table 35. The lowest cost solutions are highlighted in this table. The most cost effective method ($9.50/cy) to construct the Chandeleur Islands alternative is to use a hopper dredge and material from Hewes Point. The most cost effective method to construct Breton Island Alternative 1 is using a cutterhead dredge to mine the ODMDS. This is expected to cost $6.75/cy (2009 dollars).

Table 35. Beach Fill Unit Cost Summary using a $3.75 Marine Diesel Price

Project Area	Borrow Area	Dredge	Unit Cost
Chandeleur Islands	Hewes Point	Cutterhead	$22.50
Chandeleur Islands	Hewes Point	Hopper	$9.50
Chandeleur Islands	St. Bernard Shoals	Hopper	$12.50
Breton Island	MRGO ODMDS	Cutterhead	$6.75
Breton Island	St. Bernard Shoals	Hopper	$21.50
Breton Island	Hewes Point	Hopper	$24.75

Once it was determined that dredging the ODMDS with a cutterhead dredge was the most economical method to construct Breton Island Alternative 1, the unit cost to dredge the other Breton Island alternatives was estimated. Table 36 summarizes the beach fill unit costs for the various Breton Island alternatives.

Table 36. Beach Fill Unit Cost Summary for Breton Island Alternatives

Project Area	Borrow Area	Dredge	Unit Cost
Alternative #1	MRGO ODMDS	Cutterhead	$6.75
Alternative #2	MRGO ODMDS	Cutterhead	$6.75
Alternative #3	MRGO ODMDS	Cutterhead	$6.00
Alternative #4	MRGO ODMDS	Cutterhead	$6.75
Alternative #5	MRGO ODMDS	Cutterhead	$5.00

These cost estimates are highly dependent on the workload of the dredge fleet at the time of bidding and the estimate provided is based on the existing fleet capabilities and workload. The cost estimate spreadsheets are included in Appendix B but a summary of some critical parameters are discussed here.

It was assumed that either a 30" cutterhead dredge or a medium sized hopper dredge would be used to construct the beach, marsh, and sand reserve feeder sites. The non-pay loss was assumed to be 15% based on the measured non-pay loss at Holly Beach, where the sediment size and silt content were similar. Downtime was assumed to be 30%. This value is based on the observed downtime at Chaland Headland. Downtime at Holly Beach was higher (approximately 64%) but included the passage of two hurricanes and recurring issues with the submerged line).

A fuel price of $3.75/gallon was used within the USACE spreadsheets, based on the peak price of marine diesel in August 2008. Current (December 2009) marine diesel prices are approximately $2.75/gallon. Unit costs within the USACE spreadsheets are sensitive to marine

diesel prices. For example the cost for hopper dredging Hewes Point would be $8.75/cy if marine diesel was $2.75/gallon while the unit cost for a cutterhead at Breton would be $6.00/cy.

The spreadsheet estimates were quasi-calibrated to recent construction bid amounts (specifically East Grand Terre, BA-30, and Pass La Mer to Grand Bayou, BA-35). However, the unit costs shown here represent an opinion and are subject to market forces, such as the availability of equipment, the increasing cost of fuel, etc.

15.3 Marsh Fill Dredging Unit Costs

The unit cost of the marsh and the sand reserve feeder site fill was assumed to be the same as the beach fill unit cost. Both the Chandeleur Islands and Breton Island Alternative 1 projects will be constructing a backing platform to catch washover deposits; however, the project description states that these platforms will be constructed using fine grained sands.

15.4 Terminal Groin Cost

The cost of the terminal groin proposed for Alternative 4 was estimated to cost approximately $12,965,000. The cost of the structure would be significant to the overall project cost, but the groin would reduce the volume of beach fill material required by eliminating the tapered portion of the dune proposed in Alternative 2. The itemized cost of the groin is shown in Table 37. The unit cost for the individual items deemed necessary to construct the groin were acquired from past rip-rap shoreline protection projects for Louisiana inland areas. The costs were adjusted based on the assumption that construction in exposed gulf locations would require greater resources and risks to the contractor.

Table 37. Construction Cost Estimate for the Alternative 4 Terminal Groin

Description	Quantity	Type	Unit Price	Amount
Mob/Demobilization	1	LS	$400,000	$400,000
Marine Mattress	101,993	S.F.	$35	$3,569,748
Armor Stone	63,170	Tons	$100	$6,317,000
Surveys	1	LS	$75,000	$75,000
Groin Markers	2	Each	$5,000	$10,000
Subtotal (rounded)				**$10,372,000**
25% Contingency (rounded)				**$2,593,000**
Total Project Cost (rounded)				**$12,965,000**

15.5 Other Costs

Costs for primary dikes and pre and post construction surveys were based on costs for similar projects that have been bid recently (East Grand Terre Island Restoration (BA-30) and Pass Chaland to Grand Bayou Pass (BA-35) projects).

15.6 Cost Estimates

Cost estimates for the Chandeleur and Breton Island projects are provided in Table 38 through Table 43. A 25% contingency has been applied, which is standard at this preliminary design phase.

Table 38. Construction Cost Estimate for the Chandeleur Islands Alternative

Description	Quantity	Type	Unit Price	Amount
Mob/Demobilization	1	LS	$4,325,000	$4,325,000
Beach Fill	3,810,000	CY	$9.50	$36,195,000
Marsh Fill	4,910,000	CY	$9.50	$46,645,000
Primary Dikes	73,000	LF	$108.00	$7,884,000
Pre-Construction Survey	1	LS	$330,000	$330,000
As-Built Survey	1	LS	$275,000	$275,000
Subtotal (rounded)				**$95,654,000**
25% Contingency (rounded)				**$23,914,000**
Total Project Cost (rounded)				**$119,568,000**

Table 39. Construction Cost Estimate for the Breton Island Alternative 1

Description	Quantity	Type	Unit Price	Amount
Mob/Demobilization	1	LS	$5,125,000	$5,125,000
Beach Fill	8,550,000	CY	$6.75	$57,712,500
Marsh Fill	11,490,000	CY	$6.75	$77,557,500
Primary Dikes	18,000	LF	$108.00	$1,944,000
Pre-Construction Survey	1	LS	$250,000	$250,000
As-Built Survey	1	LS	$200,000	$200,000
Subtotal (rounded)				**$142,789,000**
25% Contingency (rounded)				**$35,697,000**
Total Project Cost (rounded)				**$178,486,000**

Table 40. Construction Cost Estimate for the Breton Island Alternative 2

Description	Quantity	Type	Unit Price	Amount
Mob/Demobilization	1	LS	$5,125,000	$5,125,000
Beach Fill	9,657,000	CY	$6.75	$65,184,750
Pre-Construction Survey	1	LS	$250,000	$250,000
As-Built Survey	1	LS	$200,000	$200,000
Subtotal (rounded)				**$70,759,750**
25% Contingency (rounded)				**$17,690,000**
Total Project Cost (rounded)				**$88,450,000**

Table 41. Construction Cost Estimate for the Breton Island Alternative 3

Description	Quantity	Type	Unit Price	Amount
Mob/Demobilization	1	LS	$5,125,000	$4,850,000
Beach Fill	7,255,000	CY	$6.00	$43,530,000
Pre-Construction Survey	1	LS	$250,000	$250,000
As-Built Survey	1	LS	$200,000	$200,000
Subtotal (rounded)				**$48,830,000**
25% Contingency (rounded)				**$12,208,000**
Total Project Cost (rounded)				**$61,038,000**

Table 42. Construction Cost Estimate for the Breton Island Alternative 4

Description	Quantity	Type	Unit Price	Amount
Mob/Demobilization	1	LS	$5,125,000	$5,125,000
Beach Fill	9,382,000	CY	$6.75	$63,328,500
Terminal Groin	1	LS	$11,319,000	$11,319,000
Pre-Construction Survey	1	LS	$250,000	$250,000
As-Built Survey	1	LS	$200,000	$200,000
Subtotal (rounded)				**$80,222,500**
25% Contingency (rounded)				**$20,056,000**
Total Project Cost (rounded)				**$100,279,000**

Table 43. Construction Cost Estimate for the Breton Island Alternative 5

Description	Quantity	Type	Unit Price	Amount
Mob/Demobilization	1	LS	$5,125,000	$4,850,000
Offshore Fill	12,321,000	CY	$5.00	$61,605,000
Pre-Construction Survey	1	LS	$250,000	$250,000
As-Built Survey	1	LS	$200,000	$200,000
Subtotal (rounded)				**$66,905,000**
25% Contingency (rounded)				**$16,726,000**
Total Project Cost (rounded)				**$83,631,000**

16 RISK AND UNCERTAINTY

Louisiana's barrier islands are subject to a variety of natural elements that affect their behavior. These elements include waves, winds, tidal currents, storm surge, subsidence, sea level rise, planform, cross-section, geotechnical properties, vegetation, etc. This section discusses the risk and uncertainty associated with the project design and performance projections due to these elements. The design process requires assumptions and simplifications and the influence of these will be discussed.

16.1 Hydrodynamic Forces

As with any coastal engineering design, the primary source of risk and uncertainty with project design and projected performance is the variability associated with the frequency, duration and severity of storm events. The project design process considers the response of the islands due to average conditions as well as the impact from storm events.

By examining shoreline changes over longer periods of times (decades to centuries) the impact of large storm events can be included in project performance by extrapolation. Longer shoreline histories could have been used (as shown in Section 8) but the analysis also showed an increase in the rate of shoreline recession over time. Therefore, applying more recent shoreline changes in the analyses provides a more conservative result. As discussed in Sections 8, 10, and 11, the project design was based on shoreline changes between 1996 and 2004. Hurricane Katrina was specifically excluded from the analysis because, as described in Section 8, the last available shoreline data exhibited several breaches and recovery/closure of some these breaches is evident in the review of aerial photographs following collection of this data set. The available data post-Katrina data was negatively skewed so 2004 data was used in this analysis.

Impacts to FWP conditions from low frequency storm events (10 years or greater) were included by cross-shore modeling with SBEACH. It was assumed that the 10-year storm event would occur by TY7 (the point at which there is a 50% chance that this storm has impacted the project area) and the impact of other, less frequent, storms was also included. More frequent storm events are inherently included because the sediment budget was developed from wave conditions experienced during an 8-year time period.

The uncertainty of project performance is a function of the frequency of large storm. Several low frequency storm events would result in the project not meeting the performance projections and vice versa. However, FWOP and FWP conditions have been developed using the same data set. Therefore, a comparison of project performance effectively eliminates the inherent uncertainty though the absolute result does not.

16.2 Relative Sea Level Rise

The project design assumed the lowest level of sea level rise (Section 7). Higher rates of sea level rise would result in decreased project performance, and vice versa. Again, this uncertainty is eliminated when comparing alternatives but remains when considering the absolute AAHU value.

Subsidence rates in the project area were estimated by Miner (2009a). Subsidence rates were assumed to be constant both over the historic analysis period as well as over the project design life. Subsidence was also assumed to be constant spatially along the project life, which may not accurate. Lastly, it was assumed that subsidence due to the weight of the beach fill was accounted for using Bruun's rule. However, subsidence may be higher than the estimated rate due to localized loading of the substrate by the weight of the project fill. This would affect the absolute performance but have less of an impact when comparing alternatives. Due to the greater load provided by alternatives with greater height and thus weight, there is greater

uncertainty associated with higher alternatives such as Breton Island Alternative 3 than lower alternatives such as the Chandeleur Island alternative.

16.3 Planform and Cross-section

Louisiana's islands exhibit a history of breaching, rollover, and reformation. This increases the difficulty, and hence the risk, in predicting project performance. Generally, long (shore parallel), low and narrow islands are more prone to breaching than higher wider islands. Low islands are overtopped more frequently and typically have less sand available to naturally close a breach. Longer barrier islands have a greater probability that a breach will remain open because the new inlet can capture part of the tidal prism and thus remain open.

When evaluating alternatives, the planform of the alternative should be considered when evaluating the risk associated with the design. Since Breton Island Alternative 3 has the lowest length to width ratio, along with the highest dune elevation, it is the least likely alternative to breach. Therefore, the risk and uncertainty in this design from a breaching perspective is low. Breton Island Alternative 1 has a wide backing marsh, which helps to limit the likelihood of breaching though it also has the lowest crest elevation. Breton Island Alternatives 2 and 4 have a similar length to Alternative 1 but do not have a backing marsh and thus have a higher risk of breaching. The Chandeleur Island feeder sites are located between breaches and finger shaped (long in the shore perpendicular direction but narrow in the shore parallel direction) so are less susceptible to breaching. The berm section of the Chandeleur Island design is exactly the opposite (long in the shore parallel direction but narrow in the shore perpendicular direction) so is more susceptible to breaching. The feeder sites are intended to provide sediment if breaching occurs in the berm and thus reduces the likelihood of a breach remaining open.

The project design and performance projections included overwash estimates modeled using SBEACH. A sensitivity analysis for overwash estimates of Shell Island (Thomson et al, 2008) suggested that the SBEACH model was most sensitive to the landward surf zone depth and transport rate coefficient and least sensitive to the maximum slope prior to avalanching and the slope dependent coefficient.

Another uncertainty within the development of the performance projections is the active profile height. Specifically, the depth of closure is an integral element of the design process. Historic profile data was available upon which these estimates were based. This helps to reduce the uncertainty with respect to the height of the eroding face. However, the project design is sensitive to the active profile height and adds uncertainty to the project design.

16.4 Island Composition

Much of the project design is based on the sediment budget. One of the largest uncertainties within the sediment budget is the offshore loss of silt, which is based on the silt content of the island. Section 11.1 discusses how vibracores were used to estimate the silt content. These cores did not extend to the depth of closure and if the material beneath the core is mostly silt, or the cores happened to be collected in a sandier area, the silt content may be underestimated and the actual offshore loss of material may be higher than that applied in the design. Vibracores

were not available for Breton Island and thus the cores along Chandeleur Island were assumed to be indicative of the composition of Breton Island. This may not be an accurate assessment and increases the uncertainty of the Breton Island design compared to the Chandeleur Islands design.

Under estimating the silt composition of the islands would result in an overestimate of the existing longshore transport. This in turn would result in greater expected loss of sandy material from the island due to longshore transport and thus lower benefits under FWP conditions. Incorrectly estimating the longshore loss would affect a comparison of Alternatives 2 and 4, since lower longshore transport rates would decrease the benefit of constructing a terminal groin.

An under estimate of silt content would also under estimate the benefit of armoring the shoreline with sand (Breton Island alternatives). Sand should decrease the release of silt and thus maintain the shoreline location during average wave conditions (Campbell, 2005). This would decrease the absolute benefit presented in this report though the Chandeleur Islands option would be less affected than the Breton Island alternatives because less sand is expected to be released to the beach face.

The sediment budget is sensitive to changes in island composition. A sensitivity analysis was performed to demonstrate the effect of island composition on shoreline retreat rates. Increasing the silt composition of the island from 32% to 50% decreases the southerly longshore transport from 300,000 cubic yards/year to 100,000 cubic yards/year on Breton Island. This decreased the shoreline loss rate from 35 feet/year to 17 feet/year for Breton Island Alternative 1.

16.5 Performance Prediction Methodology

Performance projections under FWP and FWP were developed using an analytic model as described in the report and shown in Appendix A. Many simplifying assumptions were made that increase the risk and uncertainty of the design. The model assumes that the profile (extending from the dune crest to the depth of closure) maintains a constant shape. While mostly true over longer time periods, over shorter time periods, this assumption may not be accurate. In this case, steepening of the profile and hence less shoreline retreat could occur due to the introduction of sand along the upper face. The sand profile is more stable than the sand/silt base and thus the offshore profile erodes steepening the profile.

17 SUMMARY

Chandeleur and Breton Islands will continue to deteriorate without a restoration project. It is projected that Breton Island will have no remaining subaerial acreage within approximately 5 years (even prior to TY0) while there will be no subaerial acreage left at the Chandeleur Islands by TY28.

It is proposed to construct eight shore-perpendicular back-barrier sand reserve feeder sites and a shore parallel beach berm along the Chandeleur Islands. The feeder sites will require 4.91M cubic yards of sand while the beach berm has a fill volume of approximately 3.8M cubic yards of sand. The most cost effective sand source that can be used to build the proposed design is

Hewes Point. The expected construction cost for the Chandeleur Islands project is $119,568,000, which includes a 25% contingency.

Five alternatives were developed for Breton Island. Alternative 1 included a 4-mile long, +4 feet, NAVD dune with a backing marsh. Alternative 2 had a similar dune footprint as Alternative 1 except that the dune has a proposed elevation of +6-foot, NAVD and there is no backing marsh. Alternative 3 proposes a 1,000-foot diameter, +10 feet, NAVD dune at the north end of the island with a 1V:300H slope on the southern side. Alternative 4 is similar to Alternative 2 except that a 2,400-foot long terminal groin is located at the southern end of the island instead of a beach fill taper. Alternative 5 considers filling a portion of the MRGO and Breton Pass Inlet to facilitate better bypassing of sand from Grand Gosier Shoal to Breton Island.

Project performance was based on the WVA methodology and the barrier island community model. The model suggested that under FWOP conditions, all subaerial acreage will be lost by TY28 along Chandeleur Island. It is estimated that FWOP provides 828 Average Annual Habitat Units (AAHUs). Under FWP conditions, subaerial acreage will be completely lost by TY48. It is estimated that FWP will provide 2,292 AAHUs for a net benefit of 1,464 AAHUs.

No subaerial acreage is estimated to remain at Breton Island by TY0. The five alternatives provide a variety of costs and performance projections. The FWP conditions will provide subaerial acreage anywhere from 11 years to 24 years. Since the FWOP condition provides no AAHUs, the total and net benefits for the Breton Island alternative are due to the fill placed during construction.

The benefits provided by Chandeleur Islands and Breton Island can be considered identical as they provide the same type of habitat (supratidal, gulf intertidal, bay intertidal, and subtidal) along a barrier island shoreline.

18 RECOMMENDATIONS

Following discussions with the Habitat Evaluation Team (HET), the preferred alternative is the Chandeleur Islands alternative. This alternative provides the greatest number of AAHU's at the lowest cost per AAHU (Table 1). The type of benefits provided by restoring the Chandeleur Islands can be considered identical to those provided by reconstructing Breton Island. The risk associated with predicting the performance of restoring the Chandeleur Islands is lower than for any of the Breton Island Alternatives. It is recommended that this alternative be constructed using material dredged from Hewes Point.

Alternative 1 is the preferred restoration option for Breton Island. This alternative provides the greatest number of acres at construction and the greatest number of AAHUs on Breton Island. It is the second most cost effective alternative for Breton Island though the cost effectiveness is within 1% of the most cost effective alternative on Breton Island (Alternative 3). Alternative 1 follows the typical design of Louisiana barrier islands with respect to berm crest elevation and construction of a backing marsh. It is recommended that this alternative be constructed using material dredged from the MRGO ODMDS.

Alternative 3 is the second preferred option at Breton Island. This alternative is the most cost effective solution (lowest cost per AAHU) of the Breton Island alternatives. It also has the lowest overall cost. Alternative 3 provides the widest range of habitat conditions because it is constructed to an elevation of +10 feet, NAVD and then has a long slope on the southern side providing a range of habitat elevations. It is recommended that this alternative be constructed using material dredged from the MRGO ODMDS.

Alternative 2 is the third preferred alternative. Alternative 4 is more cost effective and provides a greater number of AAHUs than Alternative 2 but there is greater uncertainty associated with the design and project performance of Alternative 4 compared to Alternative 2.

Alternative 4 was the most complex alternative to evaluate and has the greatest amount of uncertainty within the design. While the optimization and performance projections for each alternative would benefit from numerical modeling, it is strongly recommended that numerical modeling be performed if Alternative 4 is carried forward.

It is not recommended that Alternative 5 be considered further. It is not anticipated that Alternative 5 will provide any measurable benefits to Breton Island.

19 REFERENCES

Allison, M.A., Dellapenna, T.M., Goni, M.A., and Sheremet, A., 2007, Impact of Hurricanes Katrina and Lili on the Inner Shelf of the Mississippi-Atchafalaya Delta *in* Proceedings, Coastal Sediments 07, New Orleans, American Society of Civil Engineers, p. 882-887.

Bethel, M. and Martinez, L., 2008, Assessment of Seagrass Critical Habitat in Response to Dramatic Shoreline Change Resulting from the 2005 Hurricane Season for the Chandeleur Islands (abs.): Geological Society of America, 2008 Annual Meeting, Abstracts and Programs, v. 40, no. 6, p. 486.

Brown, E. I., 1928, Inlets on Sandy Coasts: Proceedings of the American Society of Civil Engineers, v. 54, no. 4, p. 505-553.

Bruun, P., 1982. Sea-Level Rise as a Cause of Shoreline Erosion. *Journal of Waterways and Harbor Division*, ASCE, Vol 88, No WW1.

Byron, D. and Heck, K.L., Jr., 2006, Hurricane Effects on Seagrass Along Alabama's Gulf Coast: Estuaries and Coasts, v. 29, no. 6a, p. 939-942.

Campbell, T. (2005). Development of a Conceptual Morphosedimentary Model for Design of Coastal Restoration Projects along the Louisiana Coast. *Journal of Coastal Research*. S.I. No. 44, pp. 234-244. The Coastal Education and Research Foundation, West Palm Beach, FL and Louisiana Department of Natural Resources, Baton Rouge, LA.

Coastal Planning & Engineering, Inc. 2003a. Holly *Beach Project Completion Report*. Coastal Planning & Engineering, Inc., Boca Raton, Florida. (Prepared for Louisiana Department of Natural Resources).

Coastal Planning & Engineering, Inc., 2003b. *Chaland Headland and Pelican Island Barrier Shoreline Restoration (BA-38): 30% Design Report*. Report submitted to Tetra Tech for the NOAA National Marine Fisheries Service. Coastal Planning & Engineering, Inc. Boca Raton FL.

Coastal Planning & Engineering, Inc., 2005. *East and West Island Restoration Project (BA-30): 95% Design Report*. Report submitted to Louisiana Department of Natural Resources. Coastal Planning & Engineering, Inc. Boca Raton FL.

Chen, S., Sanford, L.P., Koch, E.W., Shi, F., and North, E.W., 2007, A Nearshore Model to Investigate the Effects of Seagrass Bed Geometry on Wave Attenuation and Suspended Sediment Transport: Estuaries and Coasts, v. 30, no. 2, p. 296- 310.

Coleman, J. M., 1988, Dynamic Changes and Processes in the Mississippi River Delta: Geological Society of America Bulletin, v. 100, p. 999 – 1015.

Creef, E. 2009. "Beneficial Use of Dredged Material Disposal History: Mississippi River-Gulf Outlet, LA: Breton Island: FY 1993-2005." USACE, New Orleans District.

Davis, R. A., Jr. and FitzGerald, D. M., 2004, Beaches and Coasts: Blackwell, Oxford, UK, 419 p.

Dean, R., 1977. Equilibrium Beach Profiles: U.S. Atlantic and Gulf Coasts. Ocean Engineering Technical Report No. 12, Department of Civil Engineering and College of Marine Studies, University of Delaware.

Dean, R., 1987. Coastal Sediment Processes: Toward Engineering Solutions. Proceedings, Coastal Sediments, ASCE, pp. 1-24.

Dean, R., 2002. Beach Nourishment, Theory and Practice. Advanced Series on Ocean Engineering, Vol. 18. World Scientific Press.

Environmental Working Group. (2002) *Coastal Wetlands Planning, Protection and Restoration Act: Wetland Value Assessment Methodology: Barrier Island Community Model.* 20 Pgs. US Fish and Wildlife Service, Lafayette, Louisiana.

Escoffier, F. F., 1940, The Stability of Tidal Inlets: Shore and Beach, v. 8, no. 4, p. 114-115.

Evans, O. F., 1942, The Origin of Spits, Bars, and Related Structures: Journal of Geology, v. 50, p. 846 – 863.

Fearnley, S., Miner, M.D., Kulp, M.A., Bohling, C., and Penland, S., 2009a, Hurricane impact and recovery shoreline change analysis of the Chandeleur Islands, Louisiana, USA: 1855 to 2005: *Geo-Marine Letters*, v. 29, no. 5-6.

Fearnley, S., Bohling, C., Miner, M., Martinez, L., Kulp, M., and Penland, S., 2009b, Hurricane impact and recovery shoreline change analysis and historic island configuration (Age of Discovery): 1700's to 2005, *in* Lavoie, D., ed., Sand resources, regional geology, and coastal processes of the Chandeleur Island coastal system – An evaluation of the resilience of the Breton National Wildlife Refuge: U.S. Geological Survey Scientific Information Report *in press*.

Fisk, H. N., 1944, Geological Investigation of the Alluvial Valley of the Lower Mississippi River: U. S. Army Corps of Engineers, Mississippi River Commission, Vicksburg, Mississippi, 78 p.

Flocks, J., Twichell, D., Sanford, J., Pendleton, E., and Baldwin, W., 2009, Sediment Sampling Analysis to Define Quality of Sand Resources, *in* Lavoie, D., ed., Sand resources, regional geology, and coastal processes of the Chandeleur Island coastal system – An evaluation of the resilience of the Breton National Wildlife Refuge: U.S. Geological Survey Scientific Information Report *in press*.

Flocks, J., M. Miner, D. Twichell, D. Lavoie, and J. Kindinger, 2009. Evolution and Preservation Potential of Fluvial and Transgressive Deposits on the Louisiana Inner Shelf: Understanding Depositional Processes to Support Coastal Management. Geo-Marr Lett.

Frazier, D. E., 1967, Recent Deltaic Deposits of the Mississippi River: Their Development and Chronology: Gulf Coast Association of Geological Societies Transactions, v. 17, p. 287 – 315.

Georgiou, I.Y. and Schindler, J.K., 2009, Wave Forecasting and Longshore Sediment Transport Gradients along a Transgressive Barrier Island: Chandeleur Islands, Louisiana: *Geo-Marine Letters*, v. 29, no. 5-6.

Hart, W. E. and Murray, S. P., 1978, Energy Balance and Wind Effects in a Shallow Sound: Journal of Geophysical Research, v. 83, p. 4097-4106.

Hoyt, J. H. and Henry, V. J., Jr., 1967, Influence of Island Migration on Barrier-Island Sedimentation: Geological Society of America Bulletin, v. 78, p. 77 –86.

Intergovernmental Panel on Climate Change, 2007. Climate Change 2007: The Physical Science Basis. Chapter 5 Observations: Oceanic Climate Change and Sea Level.

Jaffe, B. E., List, J. H., and Sallenger, A. H., Jr., 1997, Massive Sediment Bypassing on the Lower Shoreface of a Wide Tidal Inlet – Cat Island Pass, Louisiana: Marine Geology, v. 136, p. 131 –149.

Kahn, J. H., 1986, Geomorphic Recovery of the Chandeleur Islands, Louisiana after a Major Hurricane: Journal of Coastal Research, v. 2, no. 3, p.337 – 344.

Kahn, J.H. and Roberts, H., 1982, Variations in Storm Response along a Microtidal Transgressive Barrier-Island Arc: Sedimentary Geology, v. 33, p. 129-146.

Koch, E.W., Sanford, L.P, Chen, S., Shafer, D.J., and Smith, J.M., 2006, Waves in Seagrass Systems: Review and Technical Recommendations: U.S. Army Corps of Engineers, Engineer Research and Development Center, Technical Report no. ERDC TR-06-15, 81 p.

Kolb, C. R. and Van Lopik, J. R., 1958, Geology of the Mississippi River Deltaic Plain, Southeastern Louisiana: Vicksburg, Mississippi, U. S. Army Corps of Engineers Waterways Experiment Station, Technical Report no. 3-483, 120 p.

Kulp, M. A., FitzGerald, D. M., and Penland, S., 2005a, Sand-rich Lithosomes of the Holocene Mississippi River Delta Plain, in Liviu, G. and Bhattacharya, J. P. (eds.), River deltas; Concepts, Models, and Examples: Society for Sedimentary Geology (SEPM), Special Publication, v. 83, p. 279 – 293.

Kulp, M.; Penland, S.; Williams, S.J.; Jenkins, C.; Flocks, J., and Kindinger, J., 2005b. Geological Framework and Sediment Resources for Restoration of the Louisiana Coastal Zone. *In*: Finkl, C.W. and Khalil, S. (eds.), *Journal of Coastal Research*, Special Issue no 44, Saving

America's Wetland: Strategies for Restoration of Louisiana's Coastal Wetlands and Barrier Islands, 56-71.

Kwon, H. J., 1969, Barrier Islands of the Northern Gulf of Mexico Coast: Sediment Source and Development: Louisiana State University Press, Coastal Studies Series no. 25, 51 p.

Lavoie, D., 2009. Sand resources, regional geology, and coastal processes of the Chandeleur Island coastal system – An evaluation of the resilience of the Breton National Wildlife Refuge: U.S. Geological Survey Scientific Information Report *in press*.

Martinez, L., S. O'Brien, M. Tethel, S. Penland, and M. Kulp, 2009. Louisiana Barrier Island Comprehensive Monitoring Program (BICM) Volume 2: Shoreline Changes and Barrier Island Land Loss 1800's-2005. University of New Orleans, Pontchartrain Institute for Environmental Sciences, New Orleans.

Martinez, L., Penland, S., Fearnley, S., O'Brien, S. Bethel, M., and Guarisco, P., 2009, Louisiana Barrier Island Comprehensive Monitoring Program (BICM), Vol. 2, Shoreline Change Analysis: 1800s to 2005: University of New Orleans, Pontchartrain Institute for Environmental Sciences Technical Report.

McBride, R. A., Penland, S., Hiland, M. W., Williams, S. J., Westphal, K. A., Jaffe, B. E., and Sallenger, A. H., Jr., 1992, Analysis of Barrier Shoreline Change in Louisiana from 1853 to 1989, in Williams, S. J., Penland, S., and Sallenger, A. H., (eds.) Louisiana Barrier Island Erosion Study, Atlas of Shoreline Changes in Louisiana from 1853 to 1989: Reston, Virginia, U.S. Geological Survey and Louisiana State University, Miscellaneous Investigations Series I-2150-A, p. 36 –97.

Michot, T.C., Woodin, M.C., and Nault, A.J., 2008, Food Habits of Redheads (*Athya Americana*) Wintering in Seagrass Beds of Coastal Louisiana and Texas, USA: Acta Zoologica Academiae Scientarum Hungaricaie, v. 54, sup. 1, p. 239-250.

Miner, M.D., Kulp, M., Flocks, J., Twichell, D., Penland, S., Martinez, L., Motti, J., Weathers, DeWitt, N., Reynolds, B.J., Baldwin, W., Danforth, B., Worley, C., Bergeron, E., Ferina, N., McCarty, P., Brown, M. and Torres, J., 2009a, Louisiana Barrier Island Comprehensive Monitoring Program, Volume 3: South-Central Louisiana and Northern Chandeleur Islands, Bathymetry and Historical Seafloor Change 1873- 2006, Part 1: Methods and Error Analysis for Bathymetry, University of New Orleans - Pontchartrain Institute for Environmental Sciences and US Geological Survey, Submitted to Louisiana Department of Natural Resources, 44 p.

Miner, M.D., Kulp, M.A., Weathers, H.D., and Flocks, J., 2009b, Historical (1870-2007) seafloor evolution and sediment dynamics along the Chandeleur Islands, *in* Lavoie, D., ed., Sand resources, regional geology, and coastal processes of the Chandeleur Island coastal system – An evaluation of the resilience of the Breton National Wildlife Refuge: U.S. Geological Survey Scientific Information Report *in press*.

Miner, M.D., Kulp, M.A., FitzGerald, D.M., and Georgiou, I.Y., 2009c, Hurricane-associated ebb-tidal delta sediment dynamics: *Geology*, v. 37, no. 9, p. 851-854.

Miner, M.D., Kulp, M.A., FitzGerald, D.M., Flocks, J.G., and Weathers, H.D., 2009d, Delta lobe degradation and hurricane impacts governing large scale coastal behavior, south-central Louisiana, USA: *Geo-Marine Letters*, v. 29, no. 5-6.

National Oceanographic and Atmospheric Administration, 2009. WAVEWATCH III Model Data Access, http://polar.ncep.noaa.gov/waves/download.shtml?.

National Research Council (1987) "Responding to Changes in Sea Level: Engineering Implications." National Academy Press, Washington, D.C., 148 pp.

National Research Council, 1995. *Beach Nourishment and Protection.* National Research Council, Washington.

Otvos, E.G., 1981, Barrier Island Formation through Nearshore Aggradation—Stratigraphic and Field Evidence: Marine Geology, v. 43, p. 195-243.

Penland, S. and Boyd, R., 1981, Shoreline changes on the Louisiana barrier coast: IEEE Oceans, v. 81, p. 209-219.

Penland, S. and Boyd, R., 1985, Transgressive Depositional Environments of the Mississippi River Delta Plain: A Guide to the Barrier Islands, Shoals, and Beaches in Louisiana, Louisiana State Geological Survey Guidebook Series, no. 3, Baton Rouge, Louisiana: Louisiana Geological Survey, p.

Penland, S, Suter, J., and Moslow, T., 1983, Generation of Inner Shelf Sand Bodies by Erosional Shoreface Retreat and Sea Level Rise Processes: Eos, Transactions of the American Geophysical Union, v. 64, p. 1065-1066.

Penland, S., Boyd, R., and Suter, J.R., 1988, Transgressive Depositional Systems of the Mississippi Delta Plain: Model for Barrier Shoreline and Shelf Sand Development: Journal of Sedimentary Petrology, v. 58, p. 932 –949.

Penland, S., P. Connor, Jr. and A. Beall, 2002. Changes in Louisiana's shoreline: 1855-2002. Louisiana Coastal Area Ecosystem Restoration Study, Appendix D – Louisiana Gulf Shoreline Restoration Report, pp. D41-D93.

Poirrier, M.A. and Handley, L.R., 2006, Chandeleur Islands, in: Handley, L., Altsman, D., and Demay, R. (eds.), Seagrass Status and Trends in the Northern Gulf of Mexico: 1940-2002: USGS Scientific Investigation Report 2006-5278, p. 62-71.

Pope, D., Connor, P., Jr., and Penland, S., 1993, Stratigraphical Assessment of the Mineral Aggregate Resources in the St Bernard Shoal, Offshore, Louisiana: US Minerals Management Service Professional Paper.

Reyes, E., Georgiou, I.Y., Reed, D.J., and McCorquodale, J.A., 2005, Using Models to Evaluate the Effects of Barrier Islands on Estuarine Hydrodynamics and Habitats: A Numerical Experiment: Journal of Coastal Research, SI 44, p. 176-185.

Roberts, H. H., 1997, Dynamic Changes of the Holocene Mississippi River Delta Plain: The Delta Cycle: Journal of Coastal Research, v. 13, no. 3, p. 605 –627.

Rogers, B., Kulp, M.A., and Miner, M.D., 2009a, Late Holocene shelf sand body development from reworked relict distributary channel deposits exposed on the shelf, St. Bernard Shoals, Northern Gulf of Mexico, USA: *Geo-Marine Letters*, v. 29, no. 5-6.

Rogers, B., Kulp, M.A., and Miner, M.D., 2009b, The St. Bernard Shoals: and Outer Continental Shelf Sedimentary Deposit Suitable for Sandy Barrier Islands Renourishment, *in* Lavoie, D., ed., Sand resources, regional geology, and coastal processes of the Chandeleur Island coastal system – An evaluation of the resilience of the Breton National Wildlife Refuge: U.S. Geological Survey Scientific Information Report *in press*.

Stone, G.W, and Orford, J., 2004, Storms and their Significance in Coastal Morpho-Sedimentary Dynamics: Marine Geology, v. 210, p. 1-5.

Stone, G.W., Zhang, X., and Sheremet, A., 2005, The Role of Barrier Islands, Muddy Shelf, and Reefs in Mitigating the Wave Field Along Coastal Louisiana, *in* Finkl, C.W., and Khalil, S., eds., Saving America's Wetland: Strategies for Restoration of Louisiana's Coastal Wetlands and Barrier Islands: Journal of Coastal Research, Special Issue 44, p. 40-55.

Suter, J., Penland, S., Williams, S.J., and Kindinger, J., 1988, Stratigraphic Evolution of the Chandeleur Islands, Louisiana: Gulf Coast Association of Geological Societies Transactions v. 72, p. 1124-1125.

Teague, W.J., Jaroz, E., Keen, T.R., Wang, D.W., and Hulbert, M.S., 2006, Bottom Scour Observed under Hurricane Ivan: Geophysical Research Letters, v. 33, L07607.

Thomson, G.G., Campbell, T.J., Grabowski, V., and Kendrick, B., 2008. *Barataria Basin Barrier Shoreline Restoration Feasibility Report, Appendix C, Shell Island, Plaquemines Parish, Louisiana.* Boca Raton, Florida: Coastal Planning & Engineering. Report prepared for Louisiana Department of Natural Resources.

Thomson, G., Wycklendt, A., and Rees, M., 2009. *West Belle Pass Barrier Headland Restoration Project (TE-52) - 30% Design Report.* Boca Raton, Florida: Coastal Planning & Engineering, Inc. 158p. Report prepared for the Louisiana Office of Coastal Protection and Restoration.

Twichell, D.; Pendleton, E.; Baldwin, W. and Flocks, J., 2009. Subsurface control on seafloor erosional processes offshore of the Chandeleur Islands, Louisiana. Geo-Marine Letters (Published online in July 2009).

U.S. Army Corps of Engineers, 1958, Geological Investigation of the Mississippi River-Gulf Outlet Channel: Miscellaneous Paper No. 3-259, U.S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi, 22 p., 11 plates.

U.S. Army Corps of Engineers, 2001. Coastal Engineering Manual, Engineer Manual 1110-2-1100, U.S. Army Corps of Engineers, Washington, DC (6 Volumes).

U.S. Army Corps of Engineers, 2003. Coastal and Hydraulics Laboratory Wave Information Studies, http://frf.usace.army.mil/wis/.

U.S. Army Corps of Engineers, 2009. Mississippi River Gulf Outlet Ecosystem Restoration Plan Feasibility Study, http://www.mrgo.gov.

U.S. Army Corps of Engineers, 2009. Water Resource Policies and Authorities Incorporating Sea-Level Change Considerations in Civil Works Programs. EC 1165-2-211.

Walton, T.L. & Chiu, T.Y. (1979). "A Review of Analytical Techniques to Solve the Sand Transport Equation and Some Simplified Solutions", *Coastal Structures '79*, ASCE, Vol 2, pp 809-837.

Williams, S., S. Penland and A. Sallenger, 1992. Louisiana Barrier Island Erosion Study, Atlas of Shoreline Changes in Louisiana from 1853 to 1989, U.S. Geological Survey. Series I-2150-A.

MRGO ECOSYSTEM RESTORATION FEASIBILITY STUDY (W912P8-09-D-0007)

APPENDIX A

ACREAGE AND WVA ANALYSIS

Chandeleur Islands

Table 1. Chandeleur Islands - Future Without Project Acreage Summary

Target Year	Habitat (acres)						Total
	Dune	Supratidal	Gulf Intertidal	Bay Intertidal	Bay Subtidal	SAV Area	
TY0 Pre-Con	0	0	365	765	367	5,239	6,736
TY1 Post-Con	0	0	338	755	367	5,170	6,631
TY3	0	0	285	735	368	5,031	6,419
TY5	0	0	231	715	370	4,892	6,208
TY10	0	0	97	665	373	4,543	5,680
TY14	0	0	0	615	376	4,195	5,186
TY15	0	0	0	570	377	3,886	4,834
TY20	0	0	0	345	381	2,344	3,071
TY25	0	0	0	120	386	807	1,313
TY28	0	0	0	0	393	0	393
TY30	0	0	0	0	317	0	317
TY31	0	0	0	0	279	0	279
TY39	0	0	0	0	0	0	0
TY50	0	0	0	0	0	0	0

Table 2. Chandeleur Islands - Future Without Project Summary of Acreage Benefits

Target Year	Acres	x HSI	Total HUs	Cumulative HUs
0	6736	0.383	2577	0
1	6631	0.379	2513	2545
3	6419	0.379	2433	4946
5	6208	0.360	2238	4669
10	5680	0.343	1948	10456
14	5186	0.325	1687	7263
15	4834	0.308	1487	1586
20	3071	0.299	917	5998
25	1313	0.242	317	3003
28	393	0.172	68	545
30	317	0.172	55	122
31	279	0.172	48	51
39	0	0.172	0	192
50	0	0.172	0	0
Average Annual Habitat Units				828

Table 3. Chandeleur Islands - Future Without Project – Acreage Calculations

Input	Value	Units	Process	Dune	Supratidal	Gulf Intertidal	Bay Intertidal	Bay Subtidal	SAV Area	Total
2007				**0**	**177**	**376**	**835**	**364**	**5,726**	**7,477**
Years passed	7									
Years left of supratidal acreage	6.6									
Gulf Intertidal Length	32,162	ft								
Supratidal Length	32,162	ft								
Total island length loss	330	ft/yr								
Shoreline recession: Longshore Loss	18.3	ft/yr	Loss due to longshore transport		-3,874,799	-234,836				
Shoreline recession: Overwash	11.2	ft/yr	Loss due to Overwash		-2,377,317	-144,080	2,521,397			
Shoreline recession: RSLR	9.5	ft/yr	Loss due to RSLR		-2,019,834	-122,414				
Shoreline Recession: Silt Loss	19.5		Offshore losses		-4,144,070	-251,156				
RSLR	0.0164	ft/yr								
Overwash distance from SBEACH	34	ft/yr	Overwash into back bay		7,217,045	437,397	-7,654,442			
Gulf Intertidal Perimeter	32,162	ft								
Bay Intertidal Perimeter	27,444	ft	Subsidence out of bay intertidal				-557,180	557,180		
Bay Subtidal Perimeter	31,123	ft	Subsidence out of bay subtidal					-420,469	420,469	
Open Water Perimeter	58,538	ft	Subsidence out of SAV Area						-790,854	
Gulf Intertidal Slope 1V:	580									
Bay Subtidal Slope 1V:	386	H								
Subsidence	-0.005	ft/yr								
Open Water Length	58,538	ft								
Bay Subtidal Length	31,123	ft								
Bay Intertidal Length	27,444	ft	SAV loss due to bay intertidal loss						-20,850,041	
Bay Change Rate	13.8	ft/yr	Bay gain from gulf loss (overwash)		-2,499,593	-151,491	2,651,084			
TY0 Pre Construction (2014)			**Total Acres in TY0**	**0**	**0**	**365**	**765**	**367**	**5,239**	**6,736**

Input	Value	Units	Process	Dune	Supratidal	Gulf Intertidal	Bay Intertidal	Bay Subtidal	SAV Area	Total
TY1										
Years passed	1									
Years left of gulf intertidal acreage	1									
Gulf Intertidal Length	32,162	ft								
Supratidal Length	29,522	ft								
Total island length loss	330	ft/yr								
Shoreline recession: Longshore Loss	18	ft/yr	Loss due to longshore transport			-587,091				
Shoreline recession: Overwash	11	ft/yr	Loss due to Overwash			-360,200	360,200			
Shoreline recession: RSLR	10	ft/yr	Loss due to RSLR			-306,035				
Shoreline Recession: Silt Loss	20		Offshore losses			-627,889				
RSLR	0.0164	ft/yr								
Overwash distance from SBEACH	34	ft/yr	Conversion of GI to BI from overwash			1,093,492	-1,093,492			
Gulf Intertidal Perimeter	32,162	ft								
Bay Intertidal Perimeter	24,804	ft	Subsidence out of bay intertidal				-71,940	71,940		
Bay Subtidal Perimeter	27,444	ft	Subsidence out of bay subtidal					-52,967	52,967	
Open Water Perimeter	58,538	ft	Subsidence out of SAV Area						-112,979	
Gulf Intertidal Slope 1V:	580	H								
Bay Subtidal Slope 1V:	386	H								
Subsidence	-0.005	ft/yr								
Open Water Length	58,538									
Bay Subtidal Length	31,123	ft								
Bay Intertidal Length	27,444	ft	SAV loss due to bay intertidal loss						-2,921,305	
Bay Change Rate	14	ft/yr	Bay gain from gulf loss (overwash)			-378,726	378,726			
TY1			**Total Acres in TY1**	**0**	**0**	**338**	**755**	**367**	**5,170**	**6,631**

Input	Value	Units	Process	Dune	Supratidal	Gulf Intertidal	Bay Intertidal	Bay Subtidal	SAV Area	Total
TY3										
Years passed	2									
Years left of supratidal acreage	2									
Gulf Intertidal Length	32,162	ft								
Supratidal Length	28,862	ft								
Total island length loss	330	ft/yr								
Shoreline recession: Longshore Loss	18	ft/yr	Loss due to longshore transport			-1,174,181				
Shoreline recession: Overwash	11	ft/yr	Loss due to Overwash			-720,399	720,399			
Shoreline recession: RSLR	10	ft/yr	Loss due to RSLR			-612,071				
Shoreline Recession: Silt Loss	20		Offshore losses			-1,255,779				
RSLR	0.0164	ft/yr								
Overwash distance from SBEACH	34	ft/yr	Overwash into back bay			2,186,983	-2,186,983			
Gulf Intertidal Perimeter	32,162	ft								
Bay Intertidal Perimeter	27,444	ft	Subsidence out of bay intertidal				-159,194	159,194		
Bay Subtidal Perimeter	26,778	ft	Subsidence out of bay subtidal					-103,364	103,364	
Open Water Perimeter	58,538	ft	Subsidence out of SAV Area						-225,958	
Gulf Intertidal Slope 1V:	580									
Bay Subtidal Slope 1V:	386	H								
Subsidence	-0.005	ft/yr								
Open Water Length	58,538									
Bay Subtidal Length	31,123	ft								
Bay Intertidal Length	27,444	ft	SAV loss due to bay intertidal loss						-5,945,917	
Bay Change Rate	14	ft/yr	Bay gain from gulf loss (overwash)			-757,453	757,453			
TY3			**Total Acres in TY3**	**0**	**0**	**285**	**735**	**368**	**5,031**	**6,419**

Input	Value	Units	Process	Dune	Supratidal	Gulf Intertidal	Bay Intertidal	Bay Subtidal	SAV Area	Total
TY5										
Years passed	2									
Years left of gulf intertidal acreage	2									
Gulf Intertidal Length	32,162	ft								
Supratidal Length	28,202	ft								
Total island length loss	330	ft/yr								
Shoreline recession: Longshore Loss	18	ft/yr	Loss due to longshore transport			-1,174,181				
Shoreline recession: Overwash	11	ft/yr	Loss due to Overwash			-720,399	720,399			
Shoreline recession: RSLR	10	ft/yr	Loss due to RSLR			-612,071				
Shoreline Recession: Silt Loss	20		Offshore losses			-1,255,779				
RSLR	0.0164	ft/yr								
Overwash distance from SBEACH	34	ft/yr	Overwash into back bay			2,186,983	-2,186,983			
Gulf Intertidal Perimeter	32,162	ft								
Bay Intertidal Perimeter	27,444	ft	Subsidence out of bay intertidal				-159,194	159,194		
Bay Subtidal Perimeter	26,112	ft	Subsidence out of bay subtidal					-100,794	100,794	
Open Water Perimeter	58,538	ft	Subsidence out of SAV Area						-225,958	
Gulf Intertidal Slope 1V:	580									
Bay Subtidal Slope 1V:	386	H								
Subsidence	-0.005	ft/yr								
Open Water Length	58,538									
Bay Subtidal Length	31,123	ft								
Bay Intertidal Length	27,444	ft	SAV loss due to bay intertidal loss						-5,942,593	
Bay Change Rate	14	ft/yr	Bay gain from gulf loss (overwash)			-757,453	757,453			
TY5			**Total Acres in TY5**	**0**	**0**	**231**	**715**	**370**	**4,892**	**6,208**

Input	Value	Units	Process	Dune	Supratidal	Gulf Intertidal	Bay Intertidal	Bay Subtidal	SAV Area	Total
TY10										
Years passed	5									
Years left of gulf intertidal acreage	5									
Gulf Intertidal Length	32,162	ft								
Supratidal Length	26,552	ft								
Total island length loss	330	ft/yr								
Shoreline recession: Longshore Loss	18	ft/yr	Loss due to longshore transport			-2,935,453				
Shoreline recession: Overwash	11	ft/yr	Loss due to Overwash			-1,800,998	1,800,998			
Shoreline recession: RSLR	10	ft/yr	Loss due to RSLR			-1,530,177				
Shoreline Recession: Silt Loss	20		Offshore losses			-3,139,447				
RSLR	0.0164	ft/yr								
Overwash distance from SBEACH	34	ft/yr	Overwash into back bay			5,467,459	-5,467,459			
Gulf Intertidal Perimeter	32,162	ft								
Bay Intertidal Perimeter	27,444	ft	Subsidence out of bay intertidal				-397,986	397,986		
Bay Subtidal Perimeter	24,448	ft	Subsidence out of bay subtidal					-235,922	235,922	
Open Water Perimeter	58,538	ft	Subsidence out of SAV Area						-564,896	
Gulf Intertidal Slope 1V:	580									
Bay Subtidal Slope 1V:	386	H								
Subsidence	-0.005	ft/yr								
Open Water Length	58,538									
Bay Subtidal Length	31,123	ft								
Bay Intertidal Length	27,444	ft	SAV loss due to bay intertidal loss						-14,847,761	
Bay Change Rate	14	ft/yr	Bay gain from gulf loss (overwash)			-1,893,631	1,893,631			
TY10			**Total Acres in TY10**	**0**	**0**	**97**	**665**	**373**	**4,543**	**5,680**

Input	Value	Units	Process	Dune	Supratidal	Gulf Intertidal	Bay Intertidal	Bay Subtidal	SAV Area	Total
TY14										
Years passed	4									
Years left of gulf intertidal acreage	3.8									
Gulf Intertidal Length	32,162	ft								
Supratidal Length	26,882	ft								
Total island length loss	330	ft/yr								
Shoreline recession: Longshore Loss	18	ft/yr	Loss due to longshore transport			-2,230,945	-117,418			
Shoreline recession: Overwash	11	ft/yr	Loss due to Overwash			-1,368,758	1,296,718			
Shoreline recession: RSLR	10	ft/yr	Loss due to RSLR			-1,162,935	-61,207			
Shoreline Recession: Silt Loss	20		Offshore losses			-2,385,980	-125,578			
RSLR	0.0164	ft/yr								
Overwash distance from SBEACH	34	ft/yr	Overwash into back bay			4,373,967	-4,373,967			
Gulf Intertidal Perimeter	32,162	ft								
Bay Intertidal Perimeter	27,444	ft	Subsidence out of bay intertidal				-318,388	318,388		
Bay Subtidal Perimeter	24,781	ft	Subsidence out of bay subtidal					-191,307	191,307	
Open Water Perimeter	58,538	ft	Subsidence out of SAV Area						-451,917	
Gulf Intertidal Slope 1V:	580									
Bay Subtidal Slope 1V:	386	H								
Subsidence	-0.005	ft/yr								
Open Water Length	58,538									
Bay Subtidal Length	31,123	ft								
Bay Intertidal Length	27,444	ft	SAV loss due to bay intertidal loss						-14,919,537	
Bay Change Rate	14	ft/yr	Bay gain from gulf loss (overwash)			-1,514,905	1,514,905			
TY14			**Total Acres in TY14**	**0**	**0**	**0**	**615**	**376**	**4,195**	**5,186**

Input	Value	Units	Process	Dune	Supratidal	Gulf Intertidal	Bay Intertidal	Bay Subtidal	SAV Area	Total
TY15										
Years passed	1									
Years left of gulf intertidal acreage	1									
Gulf Intertidal Length	32,162	ft								
Supratidal Length	26,222	ft								
Total island length loss	330	ft/yr								
Shoreline recession: Longshore Loss	18	ft/yr	Loss due to longshore transport				-587,091			
Shoreline recession: Overwash	11	ft/yr	Loss due to Overwash				-360,200			
Shoreline recession: RSLR	10	ft/yr	Loss due to RSLR				-306,035			
Shoreline Recession: Silt Loss	20		Offshore losses				-627,889			
RSLR	0.0164	ft/yr								
Overwash distance from SBEACH	34	ft/yr	Overwash into back bay							
Gulf Intertidal Perimeter	32,162	ft								
Bay Intertidal Perimeter	27,444	ft	Subsidence out of bay intertidal				-79,597	79,597		
Bay Subtidal Perimeter	24,115	ft	Subsidence out of bay subtidal					-46,542	46,542	
Open Water Perimeter	58,538	ft	Subsidence out of SAV Area						-112,979	
Gulf Intertidal Slope 1V:	580									
Bay Subtidal Slope 1V:	386	H								
Subsidence	-0.005	ft/yr								
Open Water Length	58,538									
Bay Subtidal Length	31,123	ft								
Bay Intertidal Length	27,444	ft	SAV loss due to bay intertidal loss						-13,370,076	
Bay Change Rate	14	ft/yr	Bay gain from gulf loss (overwash)							
TY15			**Total Acres in TY15**	**0**	**0**	**0**	**570**	**377**	**3,886**	**4,834**

Input	Value	Units	Process	Dune	Supratidal	Gulf Intertidal	Bay Intertidal	Bay Subtidal	SAV Area	Total
TY20										
Years passed	5									
Years left of bay intertidal acreage	5									
Gulf Intertidal Length	32,162	ft								
Supratidal Length	24,572	ft								
Total island length loss	330	ft/yr								
Shoreline recession: Longshore Loss	18	ft/yr	Loss due to longshore transport				-2,935,453			
Shoreline recession: Overwash	11	ft/yr	Loss due to Overwash				-1,800,998			
Shoreline recession: RSLR	10	ft/yr	Loss due to RSLR				-1,530,177			
Shoreline Recession: Silt Loss	20		Offshore losses				-3,139,447			
RSLR	0.0164	ft/yr								
Overwash distance from SBEACH	34	ft/yr	Overwash into back bay							
Gulf Intertidal Perimeter	32,162	ft								
Bay Intertidal Perimeter	27,444	ft	Subsidence out of bay intertidal				-397,986	397,986		
Bay Subtidal Perimeter	22,450	ft	Subsidence out of bay subtidal					-216,647	216,647	
Open Water Perimeter	58,538	ft	Subsidence out of SAV Area						-564,896	
Gulf Intertidal Slope 1V:	580									
Bay Subtidal Slope 1V:	386	H								
Subsidence	-0.005	ft/yr								
Open Water Length	58,538									
Bay Subtidal Length	31,123	ft								
Bay Intertidal Length	27,444	ft	SAV loss due to bay intertidal loss						-66,824,154	
Bay Change Rate	14	ft/yr	Bay gain from gulf loss (overwash)							
TY20			**Total Acres in TY20**	**0**	**0**	**0**	**345**	**381**	**2,344**	**3,071**

Input	Value	Units	Process	Dune	Supratidal	Gulf Intertidal	Bay Intertidal	Bay Subtidal	SAV Area	Total
TY25										
Years passed	5									
Years left of bay intertidal acreage	5									
Gulf Intertidal Length	32,162	ft								
Supratidal Length	22,922	ft								
Total island length loss	330	ft/yr								
Shoreline recession: Longshore Loss	18	ft/yr	Loss due to longshore transport				-2,935,453			
Shoreline recession: Overwash	11	ft/yr	Loss due to Overwash				-1,800,998			
Shoreline recession: RSLR	10	ft/yr	Loss due to RSLR				-1,530,177			
Shoreline Recession: Silt Loss	20		Offshore losses				-3,139,447			
RSLR	0.0164	ft/yr								
Overwash distance from SBEACH	34	ft/yr	Overwash into back bay							
Gulf Intertidal Perimeter	32,162	ft								
Bay Intertidal Perimeter	27,444	ft	Subsidence out of bay intertidal				-397,986	397,986		
Bay Subtidal Perimeter	20,786	ft	Subsidence out of bay subtidal					-200,584	200,584	
Open Water Perimeter	58,538	ft	Subsidence out of SAV Area						-564,896	
Gulf Intertidal Slope 1V:	580									
Bay Subtidal Slope 1V:	386	H								
Subsidence	-0.005	ft/yr								
Open Water Length	58,538									
Bay Subtidal Length	31,123	ft								
Bay Intertidal Length	27,444	ft	SAV loss due to bay intertidal loss						-66,597,044	
Bay Change Rate	14	ft/yr	Bay gain from gulf loss (overwash)							
TY25			**Total Acres in TY25**	**0**	**0**	**0**	**120**	**386**	**807**	**1,313**

Input	Value	Units	Process	Dune	Supratidal	Gulf Intertidal	Bay Intertidal	Bay Subtidal	SAV Area	Total
TY28										
Years passed	3									
Years left of bay intertidal acreage	3.1									
Gulf Intertidal Length	32,162	ft								
Supratidal Length	21,932	ft								
Total island length loss	330	ft/yr								
Shoreline recession: Longshore Loss	18	ft/yr	Loss due to longshore transport				-1,553,019	50,097		
Shoreline recession: Overwash	11	ft/yr	Loss due to Overwash				-952,828	30,736		
Shoreline recession: RSLR	10	ft/yr	Loss due to RSLR				-809,549	26,114		
Shoreline Recession: Silt Loss	20		Offshore losses				-1,660,943	53,579		
RSLR	0.0164	ft/yr								
Overwash distance from SBEACH	34	ft/yr	Overwash into back bay							
Gulf Intertidal Perimeter	32,162	ft								
Bay Intertidal Perimeter	27,444	ft	Subsidence out of bay intertidal				-246,751	246,751		
Bay Subtidal Perimeter	19,787	ft	Subsidence out of bay subtidal					-114,568	114,568	
Open Water Perimeter	58,538	ft	Subsidence out of SAV Area						-338,937	
Gulf Intertidal Slope 1V:	580									
Bay Subtidal Slope 1V:	386	H								
Subsidence	-0.005	ft/yr								
Open Water Length	58,538									
Bay Subtidal Length	31,123	ft								
Bay Intertidal Length	27,444	ft	SAV loss due to bay intertidal loss						-35,115,544	
Bay Change Rate	14	ft/yr	Bay gain from gulf loss (overwash)							
TY28			**Total Acres in TY28**	**0**	**0**	**0**	**0**	**393**	**0**	**393**

Input	Value	Units	Process	Dune	Supratidal	Gulf Intertidal	Bay Intertidal	Bay Subtidal	SAV Area	Total
TY30										
Years passed	2									
Years left of bay intertidal acreage	2									
Gulf Intertidal Length	32,162	ft								
Supratidal Length	22,262	ft								
Total island length loss	330	ft/yr								
Shoreline recession: Longshore Loss	18	ft/yr	Loss due to longshore transport					-1,001,948		
Shoreline recession: Overwash	11	ft/yr	Loss due to Overwash					-614,728		
Shoreline recession: RSLR	10	ft/yr	Loss due to RSLR					-522,290		
Shoreline Recession: Silt Loss	20		Offshore losses					-1,071,576		
RSLR	0.0164	ft/yr								
Overwash distance from SBEACH	34	ft/yr	Overwash into back bay							
Gulf Intertidal Perimeter	32,162	ft								
Bay Intertidal Perimeter	27,444	ft	Subsidence out of bay intertidal					0		
Bay Subtidal Perimeter	20,120	ft	Subsidence out of bay subtidal					-77,664		
Open Water Perimeter	58,538	ft	Subsidence out of SAV Area							
Gulf Intertidal Slope 1V:	580									
Bay Subtidal Slope 1V:	386	H								
Subsidence	-0.005	ft/yr								
Open Water Length	58,538									
Bay Subtidal Length	31,123	ft								
Bay Intertidal Length	27,444	ft	SAV loss due to bay intertidal loss							
Bay Change Rate	14	ft/yr	Bay gain from gulf loss (overwash)							
TY30			**Total Acres in TY30**	**0**	**0**	**0**	**0**	**317**	**0**	**317**

Input	Value	Units	Process	Dune	Supratidal	Gulf Intertidal	Bay Intertidal	Bay Subtidal	SAV Area	Total
TY31										
Years passed	1									
Years left of bay intertidal acreage	1									
Gulf Intertidal Length	32,162	ft								
Supratidal Length	21,602	ft								
Total island length loss	330	ft/yr								
Shoreline recession: Longshore Loss	18	ft/yr	Loss due to longshore transport					-500,974		
Shoreline recession: Overwash	11	ft/yr	Loss due to Overwash					-307,364		
Shoreline recession: RSLR	10	ft/yr	Loss due to RSLR					-261,145		
Shoreline Recession: Silt Loss	20		Offshore losses					-535,788		
RSLR	0.0164	ft/yr								
Overwash distance from SBEACH	34	ft/yr	Overwash into back bay							
Gulf Intertidal Perimeter	32,162	ft								
Bay Intertidal Perimeter	27,444	ft	Subsidence out of bay intertidal					0		
Bay Subtidal Perimeter	19,454	ft	Subsidence out of bay subtidal					-37,547		
Open Water Perimeter	58,538	ft	Subsidence out of SAV Area							
Gulf Intertidal Slope 1V:	580									
Bay Subtidal Slope 1V:	386	H								
Subsidence	-0.005	ft/yr								
Open Water Length	58,538									
Bay Subtidal Length	31,123	ft								
Bay Intertidal Length	27,444	ft	SAV loss due to bay intertidal loss							
Bay Change Rate	14	ft/yr	Bay gain from gulf loss (overwash)							
TY31			**Total Acres in TY31**	**0**	**0**	**0**	**0**	**279**	**0**	**279**

Input	Value	Units	Process	Dune	Supratidal	Gulf Intertidal	Bay Intertidal	Bay Subtidal	SAV Area	Total
TY39										
Years passed	8									
Years left of subtidal acreage	7.42									
Gulf Intertidal Length	32,162	ft								
Supratidal Length	18,962	ft								
Total island length loss	330	ft/yr								
Shoreline recession: Longshore Loss	18	ft/yr	Loss due to longshore transport					-3,717,225		
Shoreline recession: Overwash	11	ft/yr	Loss due to Overwash					-2,280,640		
Shoreline recession: RSLR	10	ft/yr	Loss due to RSLR					-1,937,695		
Shoreline Recession: Silt Loss	20		Offshore losses					-3,975,547		
RSLR	0.0164	ft/yr								
Overwash distance from SBEACH	34	ft/yr	Overwash into back bay							
Gulf Intertidal Perimeter	32,162	ft								
Bay Intertidal Perimeter	27,444	ft	Subsidence out of bay intertidal					0		
Bay Subtidal Perimeter	16,791	ft	Subsidence out of bay subtidal					-240,459		
Open Water Perimeter	58,538	ft	Subsidence out of SAV Area							
Gulf Intertidal Slope 1V:	580									
Bay Subtidal Slope 1V:	386	H								
Subsidence	-0.005	ft/yr								
Open Water Length	58,538									
Bay Subtidal Length	31,123	ft								
Bay Intertidal Length	27,444	ft	SAV loss due to bay intertidal loss							
Bay Change Rate	14	ft/yr	Bay gain from gulf loss (overwash)							
TY39			**Total Acres in TY39**	**0**	**0**	**0**	**0**	**0**	**0**	**0**

Input	Value	Units	Process	Dune	Supratidal	Gulf Intertidal	Bay Intertidal	Bay Subtidal	SAV Area	Total
TY50										
Years passed	11									
Years left of subtidal acreage										
Gulf Intertidal Length	32,162	ft								
Supratidal Length	15,332	ft								
Total island length loss	330	ft/yr								
Shoreline recession: Longshore Loss	18	ft/yr	Loss due to longshore transport							
Shoreline recession: Overwash	11	ft/yr	Loss due to Overwash							
Shoreline recession: RSLR	10	ft/yr	Loss due to RSLR							
Shoreline Recession: Silt Loss	20		Offshore losses							
RSLR	0.0164	ft/yr								
Overwash distance from SBEACH	34	ft/yr	Overwash into back bay							
Gulf Intertidal Perimeter	32,162	ft								
Bay Intertidal Perimeter	27,444	ft	Subsidence out of bay intertidal							
Bay Subtidal Perimeter	13,129	ft	Subsidence out of bay subtidal							
Open Water Perimeter	58,538	ft	Subsidence out of SAV Area							
Gulf Intertidal Slope 1V:	580									
Bay Subtidal Slope 1V:	386	H								
Subsidence	-0.005	ft/yr								
Open Water Length	58,538									
Bay Subtidal Length	31,123	ft								
Bay Intertidal Length	27,444	ft	SAV loss due to bay intertidal loss							
Bay Change Rate	14	ft/yr	Bay gain from gulf loss (overwash)							
TY50			**Total Acres in TY50**	**0**	**0**	**0**	**0**	**0**	**0**	**0**

Table 4. Chandeleur Islands – Future Without Project – HSI Calculations

Variable		TY0 (Pre-con) Value	SI	TY1 Post-Con Value	SI	TY3 Value	SI
V1	% Dune	0	0.10	0	0.10	0.00	0.10
V2	% Supratidal	0	0.10	0	0.10	0.00	0.10
V3	% Intertidal	100	0.10	100	0.10	100	0.10
V4	% Vegetative Cover	50	0.79	50	0.79	50	0.79
V5	% Woody Cover	0.5	0.15	0.0	0.10	0.0	0.10
V6	Interspersion	%	0.40	%	0.40	%	0.40
	Class 1	0		0		0	
	Class 2	0		0		0	
	Class 3	0		0		0	
	Class 4	100		100		100	
	Class 5						
V7	Beach/surf Zone	1	1.00	1	1.00	1	1.00
V8	% Aquatic	41.0	0.47	41.0	0.47	41.0	0.47
		HSI = 0.383		**HSI = 0.379**		**HSI = 0.379**	

876

Variable		TY5 Value	TY5 SI	TY10 Value	TY10 SI	TY14 Value	TY14 SI
V1	% Dune	0	0.10	0	0.10	0	0.10
V2	% Supratidal	0	0.10	0	0.10	0	0.10
V3	% Intertidal	100	0.10	100	0.10	100	0.10
V4	% Vegetative Cover	45	0.72	40	0.65	35	0.58
V5	% Woody Cover	0.0	0.10	0.0	0.10	0.0	0.10
V6	Interspersion	%	0.40	%	0.40	%	0.40
	Class 1	0		0		0	
	Class 2	0		0		0	
	Class 3	0		0		0	
	Class 4	100		100		100	
	Class 5						
V7	Beach/surf Zone	1	1.00	1	1.00	1	1.00
V8	% Aquatic	35	0.42	30	0.37	25	0.33
		HSI =	**0.360**	**HSI =**	**0.343**	**HSI =**	**0.325**

Variable		TY15 Value	SI	TY20 Value	SI	TY25 Value	SI
V1	% Dune	0	0.10	0	0.10	0	0.10
V2	% Supratidal	0	0.10	0	0.10	0	0.10
V3	% Intertidal	100	0.10	100	0.10	100	0.10
V4	% Vegetative Cover	30	0.51	30	0.51	10	0.24
V5	% Woody Cover	0.0	0.10	0.0	0.10	0.0	0.10
V6	Interspersion	%	0.40	%	0.40	%	0.40
	Class 1	0		0		0	
	Class 2	0		0		0	
	Class 3	0		0		0	
	Class 4	100		100		100	
	Class 5						
V7	Beach/surf Zone	1	1.00	1	1.00	1	1.00
V8	% Aquatic	20	0.28	10	0.19	5	0.15
		HSI = 0.308		**HSI = 0.299**		**HSI = 0.242**	

878

Variable		TY28 Value	TY28 SI	TY30 Value	TY30 SI	TY31 Value	TY31 SI
V1	% Dune	0	0.10	0	0.10	0.00	0.10
V2	% Supratidal	0	0.10	0	0.10	0.00	0.10
V3	% Intertidal	0	0.10	0	0.10	0	0.10
V4	% Vegetative Cover	0	0.10	0	0.10	0	0.10
V5	% Woody Cover	0.0	0.10	0.0	0.10	0.0	0.10
V6	Interspersion	%	0.10	%	0.10	%	0.10
	Class 1	0		0		0	
	Class 2	0		0		0	
	Class 3	0		0		0	
	Class 4	0		0		0	
	Class 5	100		100		100	
V7	Beach/surf Zone	1	1.00	1	1.00	1	1.00
V8	% Aquatic	0	0.10	0	0.10	0	0.10
		HSI =	**0.172**	**HSI =**	**0.172**	**HSI =**	**0.172**

Variable		TY39 Value	SI	TY50 Value	SI
V1	% Dune	0	0.10	0	0.10
V2	% Supratidal	0	0.10	0	0.10
V3	% Intertidal	0	0.10	0	0.10
V4	% Vegetative Cover	0	0.10	0	0.10
V5	% Woody Cover	0.0	0.10	0.0	0.10
V6	Interspersion	%	0.10	%	0.10
	Class 1	0		0	
	Class 2	0		0	
	Class 3	0		0	
	Class 4	0		0	
	Class 5	100		100	
V7	Beach/surf Zone	1	1.00	1	1.00
V8	% Aquatic	0	0.10	0	0.10
		HSI = 0.172		**HSI = 0.172**	

Table 5. Chandeleur Islands – Future With Project – Acreage Summary

Target Year	Habitat (acres)						Total
	Dune	Supratidal	Gulf Intertidal	Bay Intertidal	Bay Subtidal	SAV Area	
TY0 Pre-Con	0	0	365	765	367	5,239	6,736
TY1 Post-Con	0	374	231	1,392	344	4,869	7,211
TY3	0	301	258	1,327	345	4,672	6,903
TY5	0	228	285	1,261	346	4,474	6,594
TY10	0	45	352	1,097	348	3,975	5,817
TY13	0	0	297	1,070	349	3,885	5,602
TY15	0	0	225	1,066	350	3,869	5,510
TY20	0	0	43	1,057	353	3,829	5,282
TY24	0	0	0	1,022	354	3,738	5,114
TY25	0	0	0	979	355	3,581	4,914
TY30	0	0	0	765	357	2,792	3,914
TY40	0	0	0	337	362	1,219	1,918
TY48	0	0	0	0	361	0	361
TY50	0	0	0	0	358	0	358

Table 6. Chandeleur Islands – Future With Project – Summary of Acreage Benefits

Target Year	Acres	x HSI	Total HUs	Cumulative HUs
0	6736	0.383	2,577	0
1	7211	0.653	4,706	3,620
3	6903	0.704	4,859	9,571
5	6594	0.717	4,729	9,589
10	5817	0.598	3,481	20,446
13	5602	0.564	3,158	9,954
15	5510	0.557	3,067	6,224
20	5282	0.547	2,890	14,891
24	5114	0.523	2,676	11,130
25	4914	0.509	2,501	2,588
30	3914	0.471	1,843	10,829
40	1918	0.406	778	12,888
48	361	0.172	62	2,875
50	358	0.000	0	62
FWP Average Annual Habitat Units				2,292
FWOP Average Annual Habitat Units				828
Net Average Annual Habitat Units				1,464

Table 7. Chandeleur Islands – Future With Project – Acreage Calculations

Input	Value	Units	Process	Dune	Supratidal	Gulf Intertidal	Bay Intertidal	Bay Subtidal	SAV Area	Total
2007 + Construction Template				**0**	**177**	**376**	**835**	**364**	**5,726**	**7,477**
Losses from 2007 to 2014 (pre-construction) based on FWOP					-7,698,568	-466,580	-3,039,141	136,711	-21,220,426	
Years passed	7									
Years left of Supratidal Acreage	17									
Total Gulf Length	48,335	ft								
Existing Islands w/o berm Gulf Length	17,102	ft								
Supratidal length	48,335	ft								
Total island length loss	330	ft/yr								
Shoreline recession: Longshore Loss	-11.2	ft/yr	Loss due to longshore transport							
Shoreline recession: Overwash	-4.2	ft/yr	Loss due to Overwash							
Shoreline recession: RSLR	-9.56	ft/yr	Loss due to RSLR							
Shoreline Recession: Silt Loss	-12.0	ft/yr	Offshore losses							
RSLR	0.0164	ft/yr								
Overwash distance from Sbeach	34	ft/yr	Overwash of existing into back bay							
Gulf Intertidal Perimeter	48,335	ft								
Bay Intertidal Perimeter	27,444	ft	Subsidence out of bay intertidal							
Bay Subtidal Perimeter	31,123	ft	Subsidence out of bay subtidal							
Open Water Perimeter	58,538	ft	Subsidence out of bay open water							
Gulf Intertidal Slope 1V:	580	H								
Bay Subtidal Slope 1V:	386	H								
Subsidence	-0.005	ft/yr								
Open Water Length	58,538	ft								
Bay Subtidal Length	51,839	ft								
Bay Intertidal Length	27,444	ft								
Bay Change Rate	13.8	ft/yr								
Open Water Berm Overwash	-46	ft/yr	Overwash of berm into open water							
Open Water Berm Length	16,895	ft								
Island Berm Overwash	94	ft/yr	Overwash of berm covering intertidal							
Island Berm Length	14,338	ft								
TY0 Pre Construction (2014)			**Total Acres in TY0**	**0**	**0**	**365**	**765**	**367**	**5,239**	**6,736**

Input	Value	Units	Process	Dune	Supratidal	Gulf Intertidal	Bay Intertidal	Bay Subtidal	SAV Area	Total
Years passed	1									
Years left of Supratidal Acreage	3									
Construction					23,992,046	-4,639,998		-988,792	-16,124,912	
Total Gulf Length	48,335	ft								
Existing Islands w/o berm Gulf Length	17,102	ft								
Supratidal length	48,335	ft								
Total island length loss	330	ft/yr								
Shoreline recession: Longshore Loss	-11	ft/yr	Loss due to longshore transport							
Shoreline recession: Overwash	-4	ft/yr	Loss due to Overwash							
Shoreline recession: RSLR	-10	ft/yr	Loss due to RSLR							
Shoreline Recession: Silt Loss	-12	ft/yr	Offshore losses							
RSLR	0.0164	ft/yr								
Overwash distance from Sbeach	34	ft/yr	Overwash of existing into back bay							
Gulf Intertidal Perimeter	48,335	ft								
Bay Intertidal Perimeter	27,444	ft	Subsidence out of bay intertidal							
Bay Subtidal Perimeter	31,123	ft	Subsidence out of bay subtidal							
Open Water Perimeter	58,538	ft	Subsidence out of bay open water							
Gulf Intertidal Slope 1V:	580	H								
Bay Subtidal Slope 1V:	386	H								
Subsidence	-0.005	ft/yr								
Open Water Length	58,538	ft								
Bay Subtidal Length	51,839	ft								
Bay Intertidal Length	27,444	ft								
Bay Change Rate	14	ft/yr	Loss of SAV due to loss of Bay Intertidal							
Open Water Berm Overwash	-46	ft/yr	Overwash of berm into open water							
Open Water Berm Length	16,895	ft								
Island Berm Overwash	94	ft/yr	Overwash of berm covering intertidal							
Island Berm Length	14,338	ft								
TY1			**Total Acres in TY1**	**0**	**374**	**231**	**1,392**	**344**	**4,869**	**7,211**

Input	Value	Units	Process	Dune	Supratidal	Gulf Intertidal	Bay Intertidal	Bay Subtidal	SAV Area	Total
Years passed	2									
Years left of Supratidal Acreage	2									
Total Gulf Length	48,335	ft								
Existing Islands w/o berm Gulf Length	17,102	ft								
Supratidal length	48,335	ft								
Total island length loss	330	ft/yr								
Shoreline recession: Longshore Loss	-11	ft/yr	Loss due to longshore transport		-1,082,612					
Shoreline recession: Overwash	-4	ft/yr	Loss due to Overwash		-402,149		402,149			
Shoreline recession: RSLR	-10	ft/yr	Loss due to RSLR		-924,516					
Shoreline Recession: Silt Loss	-12	ft/yr	Offshore losses		-1,157,846					
RSLR	0.0164	ft/yr								
Overwash distance from Sbeach	34	ft/yr	Overwash of existing into back bay			1,162,921	-1,162,921			
Gulf Intertidal Perimeter	48,335	ft								
Bay Intertidal Perimeter	27,444	ft	Subsidence out of bay intertidal				-159,194	159,194		
Bay Subtidal Perimeter	31,123	ft	Subsidence out of bay subtidal					-120,134	120,134	
Open Water Perimeter	58,538	ft	Subsidence out of bay open water						-225,958	
Gulf Intertidal Slope 1V:	580	H								
Bay Subtidal Slope 1V:	386	H								
Subsidence	-0.005	ft/yr								
Open Water Length	58,538	ft								
Bay Subtidal Length	51,839	ft								
Bay Intertidal Length	27,444	ft								
Bay Change Rate	14	ft/yr	Overwash to create bay intertidal (create)		-757,453		757,453			
Open Water Berm Overwash	-46	ft/yr	Overwash of berm into open water (conversion)		-1,558,470				1,558,470	
Open Water Berm Length	16,895	ft	Loss of SAV due to loss of Bay Intertidal						-10,001,913	
Island Berm Overwash	94	ft/yr	Overwash of berm covering intertidal (conversion)		2,697,841		-2,697,841			
Island Berm Length	14,338	ft								
TY3			**Total Acres in TY3**	**0**	**301**	**258**	**1,327**	**345**	**4,672**	**6,903**

Input	Value	Units	Process	Dune	Supratidal	Gulf Intertidal	Bay Intertidal	Bay Subtidal	SAV Area	Total
Years passed	2									
Years left of Supratidal Acreage	2									
Total Gulf Length	48,335	ft								
Existing Islands w/o berm Gulf Length	17,102	ft								
Supratidal length	48,335	ft								
Total island length loss	330	ft/yr								
Shoreline recession: Longshore Loss	-11	ft/yr	Loss due to longshore transport		-1,082,612					
Shoreline recession: Overwash	-4	ft/yr	Loss due to Overwash		-402,149		402,149			
Shoreline recession: RSLR	-10	ft/yr	Loss due to RSLR		-924,516					
Shoreline Recession: Silt Loss	-12	ft/yr	Offshore losses		-1,157,846					
RSLR	0.0164	ft/yr								
Overwash distance from Sbeach	34	ft/yr	Overwash of existing into back bay			1,162,921	-1,162,921			
Gulf Intertidal Perimeter	48,335	ft								
Bay Intertidal Perimeter	27,444	ft	Subsidence out of bay intertidal				-159,194	159,194		
Bay Subtidal Perimeter	31,123	ft	Subsidence out of bay subtidal					-120,134	120,134	
Open Water Perimeter	58,538	ft	Subsidence out of bay open water						-225,958	
Gulf Intertidal Slope 1V:	580	H								
Bay Subtidal Slope 1V:	386	H								
Subsidence	-0.005	ft/yr								
Open Water Length	58,538	ft								
Bay Subtidal Length	51,839	ft								
Bay Intertidal Length	27,444	ft								
Bay Change Rate	14	ft/yr	Overwash to create bay intertidal (create)		-757,453		757,453			
Open Water Berm Overwash	-46	ft/yr	Overwash of berm into open water (conversion)		-1,558,470				1,558,470	
Open Water Berm Length	16,895	ft	Loss of SAV due to loss of Bay Intertidal						-10,073,813	
Island Berm Overwash	94	ft/yr	Overwash of berm covering intertidal (conversion)		2,697,841		-2,697,841			
Island Berm Length	14,338	ft								
TY5			**Total Acres in TY5**	**0**	**228**	**285**	**1,261**	**346**	**4,474**	**6,594**

Input	Value	Units	Process	Dune	Supratidal	Gulf Intertidal	Bay Intertidal	Bay Subtidal	SAV Area	Total
Years passed	5									
Years left of Supratidal Acreage	5									
Total Gulf Length	48,335	ft								
Existing Islands w/o berm Gulf Length	17,102	ft								
Supratidal length	48,335	ft								
Total island length loss	330	ft/yr								
Shoreline recession: Longshore Loss	-11	ft/yr	Loss due to longshore transport		-2,706,529					
Shoreline recession: Overwash	-4	ft/yr	Loss due to Overwash		-1,005,374		1,005,374			
Shoreline recession: RSLR	-10	ft/yr	Loss due to RSLR		-2,311,290					
Shoreline Recession: Silt Loss	-12	ft/yr	Offshore losses		-2,894,614					
RSLR	0.0164	ft/yr								
Overwash distance from Sbeach	34	ft/yr	Overwash of existing into back bay			2,907,304	-2,907,304			
Gulf Intertidal Perimeter	48,335	ft								
Bay Intertidal Perimeter	27,444	ft	Subsidence out of bay intertidal				-397,986	397,986		
Bay Subtidal Perimeter	31,123	ft	Subsidence out of bay subtidal					-300,335	300,335	
Open Water Perimeter	58,538	ft	Subsidence out of bay open water						-564,896	
Gulf Intertidal Slope 1V:	580	H								
Bay Subtidal Slope 1V:	386	H								
Subsidence	-0.005	ft/yr								
Open Water Length	58,538	ft								
Bay Subtidal Length	51,839	ft								
Bay Intertidal Length	27,444	ft								
Bay Change Rate	14	ft/yr	Overwash to create bay intertidal (create)		-1,893,631		1,893,631			
Open Water Berm Overwash	-46	ft/yr	Overwash of berm into open water (conversion)		-3,896,174				3,896,174	
Open Water Berm Length	16,895	ft	Loss of SAV due to loss of Bay Intertidal						-25,373,641	
Island Berm Overwash	94	ft/yr	Overwash of berm covering intertidal (conversion)		6,744,602		-6,744,602			
Island Berm Length	14,338	ft								
TY10			**Total Acres in TY10**	**0**	**45**	**352**	**1,097**	**348**	**3,975**	**5,817**

Input	Value	Units	Process	Dune	Supratidal	Gulf Intertidal	Bay Intertidal	Bay Subtidal	SAV Area	Total
Years passed	3									
Years left of Supratidal Acreage	0.7									
Total Gulf Length	48,335	ft								
Existing Islands w/o berm Gulf Length	17,102	ft								
Supratidal length	48,335	ft								
Total island length loss	330	ft/yr								
Shoreline recession: Longshore Loss	-11	ft/yr	Loss due to longshore transport		-378,914	-1,245,004				
Shoreline recession: Overwash	-4	ft/yr	Loss due to Overwash		-140,752	-462,472	603,224			
Shoreline recession: RSLR	-10	ft/yr	Loss due to RSLR		-323,581	-1,063,193				
Shoreline Recession: Silt Loss	-12	ft/yr	Offshore losses		-405,246	-1,331,523				
RSLR	0.0164	ft/yr								
Overwash distance from Sbeach	34	ft/yr	Overwash of existing into back bay			1,744,382	-1,744,382			
Gulf Intertidal Perimeter	48,335	ft								
Bay Intertidal Perimeter	27,444	ft	Subsidence out of bay intertidal				-238,791	238,791		
Bay Subtidal Perimeter	31,123	ft	Subsidence out of bay subtidal					-180,201	180,201	
Open Water Perimeter	58,538	ft	Subsidence out of bay open water						-338,937	
Gulf Intertidal Slope 1V:	580	H								
Bay Subtidal Slope 1V:	386	H								
Subsidence	-0.005	ft/yr								
Open Water Length	58,538	ft								
Bay Subtidal Length	51,839	ft								
Bay Intertidal Length	27,444	ft								
Bay Change Rate	14	ft/yr	Overwash to create bay intertidal (create)		-1,136,179		1,136,179			
Open Water Berm Overwash	-46	ft/yr	Overwash of berm into open water (conversion)		-545,464				545,464	
Open Water Berm Length	16,895	ft	Loss of SAV due to loss of Bay Intertidal						-4,305,758	
Island Berm Overwash	94	ft/yr	Overwash of berm covering intertidal (conversion)		944,244		-944,244			
Island Berm Length	14,338	ft								
TY13			**Total Acres in TY13**	**0**	**0**	**297**	**1,070**	**349**	**3,885**	**5,602**

Input	Value	Units	Process	Dune	Supratidal	Gulf Intertidal	Bay Intertidal	Bay Subtidal	SAV Area	Total
Years passed	2									
Years left of Gulf Intertidal Acreage	2									
Total Gulf Length	48,335	ft								
Existing Islands w/o berm Gulf Length	17,102	ft								
Supratidal length	48,335	ft								
Total island length loss	330	ft/yr								
Shoreline recession: Longshore Loss	-11	ft/yr	Loss due to longshore transport			-1,082,612				
Shoreline recession: Overwash	-4	ft/yr	Loss due to Overwash			-402,149	402,149			
Shoreline recession: RSLR	-10	ft/yr	Loss due to RSLR			-924,516				
Shoreline Recession: Silt Loss	-12	ft/yr	Offshore losses			-1,157,846				
RSLR	0.0164	ft/yr								
Overwash distance from Sbeach	34	ft/yr	Overwash of existing into back bay			1,162,921	-1,162,921			
Gulf Intertidal Perimeter	48,335	ft								
Bay Intertidal Perimeter	27,444	ft	Subsidence out of bay intertidal				-159,194	159,194		
Bay Subtidal Perimeter	31,123	ft	Subsidence out of bay subtidal					-120,134	120,134	
Open Water Perimeter	58,538	ft	Subsidence out of bay open water						-225,958	
Gulf Intertidal Slope 1V:	580	H								
Bay Subtidal Slope 1V:	386	H								
Subsidence	-0.005	ft/yr								
Open Water Length	58,538	ft								
Bay Subtidal Length	51,839	ft								
Bay Intertidal Length	27,444	ft								
Bay Change Rate	14	ft/yr	Overwash to create bay intertidal (create)			-757,453	757,453			
Open Water Berm Overwash	-46	ft/yr	Overwash of berm into open water (conversion)							
Open Water Berm Length	16,895	ft	Loss of SAV due to loss of Bay Intertidal						-590,352	
Island Berm Overwash	94	ft/yr	Overwash of berm covering intertidal (conversion)							
Island Berm Length	14,338	ft								
TY15			**Total Acres in TY15**	**0**	**0**	**225**	**1,066**	**350**	**3,869**	**5,510**

Input	Value	Units	Process	Dune	Supratidal	Gulf Intertidal	Bay Intertidal	Bay Subtidal	SAV Area	Total
Years passed	5									
Years left of Supratidal Acreage	5									
Total Gulf Length	48,335	ft								
Existing Islands w/o berm Gulf Length	17,102	ft								
Supratidal length	48,335	ft								
Total island length loss	330	ft/yr								
Shoreline recession: Longshore Loss	-11	ft/yr	Loss due to longshore transport			-2,706,529				
Shoreline recession: Overwash	-4	ft/yr	Loss due to Overwash			-1,005,374	1,005,374			
Shoreline recession: RSLR	-10	ft/yr	Loss due to RSLR			-2,311,290				
Shoreline Recession: Silt Loss	-12	ft/yr	Offshore losses			-2,894,614				
RSLR	0.0164	ft/yr								
Overwash distance from Sbeach	34	ft/yr	Overwash of existing into back bay			2,907,304	-2,907,304			
Gulf Intertidal Perimeter	48,335	ft								
Bay Intertidal Perimeter	27,444	ft	Subsidence out of bay intertidal				-397,986	397,986		
Bay Subtidal Perimeter	31,123	ft	Subsidence out of bay subtidal					-300,335	300,335	
Open Water Perimeter	58,538	ft	Subsidence out of bay open water						-564,896	
Gulf Intertidal Slope 1V:	580	H								
Bay Subtidal Slope 1V:	386	H								
Subsidence	-0.005	ft/yr								
Open Water Length	58,538	ft								
Bay Subtidal Length	51,839	ft								
Bay Intertidal Length	27,444	ft								
Bay Change Rate	14	ft/yr	Overwash to create bay intertidal (create)			-1,893,631	1,893,631			
Open Water Berm Overwash	-46	ft/yr	Overwash of berm into open water (conversion)							
Open Water Berm Length	16,895	ft	Loss of SAV due to loss of Bay Intertidal						-1,474,955	
Island Berm Overwash	94	ft/yr	Overwash of berm covering intertidal (conversion)							
Island Berm Length	14,338	ft								
TY20			**Total Acres in TY20**	**0**	**0**	**43**	**1,057**	**353**	**3,829**	**5,282**

Input	Value	Units	Process	Dune	Supratidal	Gulf Intertidal	Bay Intertidal	Bay Subtidal	SAV Area	Total
Years passed	4									
Years left of Supratidal Acreage	3.4									
Total Gulf Length	48,335	ft								
Existing Islands w/o berm Gulf Length	17,102	ft								
Supratidal length	48,335	ft								
Total island length loss	330	ft/yr								
Shoreline recession: Longshore Loss	-11	ft/yr	Loss due to longshore transport			-1,840,440	-324,784			
Shoreline recession: Overwash	-4	ft/yr	Loss due to Overwash			-683,654	563,009			
Shoreline recession: RSLR	-10	ft/yr	Loss due to RSLR			-1,571,677	-277,355			
Shoreline Recession: Silt Loss	-12	ft/yr	Offshore losses			-1,968,338	-347,354			
RSLR	0.0164	ft/yr								
Overwash distance from Sbeach	34	ft/yr	Overwash of existing into back bay			2,325,843	-2,325,843			
Gulf Intertidal Perimeter	48,335	ft								
Bay Intertidal Perimeter	27,444	ft	Subsidence out of bay intertidal				-318,388	318,388		
Bay Subtidal Perimeter	31,123	ft	Subsidence out of bay subtidal					-240,268	240,268	
Open Water Perimeter	58,538	ft	Subsidence out of bay open water						-451,917	
Gulf Intertidal Slope 1V:	580	H								
Bay Subtidal Slope 1V:	386	H								
Subsidence	-0.005	ft/yr								
Open Water Length	58,538	ft								
Bay Subtidal Length	51,839	ft								
Bay Intertidal Length	27,444	ft								
Bay Change Rate	14	ft/yr	Overwash to create bay intertidal (create)			-1,514,905	1,514,905			
Open Water Berm Overwash	-46	ft/yr	Overwash of berm into open water (conversion)							
Open Water Berm Length	16,895	ft	Loss of SAV due to loss of Bay Intertidal						-5,494,207	
Island Berm Overwash	94	ft/yr	Overwash of berm covering intertidal (conversion)							
Island Berm Length	14,338	ft								
TY24			**Total Acres in TY24**	**0**	**0**	**0**	**1,022**	**354**	**3,738**	**5,114**

Input	Value	Units	Process	Dune	Supratidal	Gulf Intertidal	Bay Intertidal	Bay Subtidal	SAV Area	Total
Years passed	1									
Years left of Supratidal Acreage	1									
Total Gulf Length	48,335	ft								
Existing Islands w/o berm Gulf Length	17,102	ft								
Supratidal length	48,335	ft								
Total island length loss	330	ft/yr								
Shoreline recession: Longshore Loss	-11	ft/yr	Loss due to longshore transport				-541,306			
Shoreline recession: Overwash	-4	ft/yr	Loss due to Overwash				-201,075			
Shoreline recession: RSLR	-10	ft/yr	Loss due to RSLR				-462,258			
Shoreline Recession: Silt Loss	-12	ft/yr	Offshore losses				-578,923			
RSLR	0.0164	ft/yr								
Overwash distance from Sbeach	34	ft/yr	Overwash of existing into back bay							
Gulf Intertidal Perimeter	48,335	ft								
Bay Intertidal Perimeter	27,444	ft	Subsidence out of bay intertidal				-79,597	79,597		
Bay Subtidal Perimeter	31,123	ft	Subsidence out of bay subtidal					-60,067	60,067	
Open Water Perimeter	58,538	ft	Subsidence out of bay open water						-112,979	
Gulf Intertidal Slope 1V:	580	H								
Bay Subtidal Slope 1V:	386	H								
Subsidence	-0.005	ft/yr								
Open Water Length	58,538	ft								
Bay Subtidal Length	51,839	ft								
Bay Intertidal Length	27,444	ft								
Bay Change Rate	14	ft/yr	Overwash to create bay intertidal (create)							
Open Water Berm Overwash	-46	ft/yr	Overwash of berm into open water (conversion)						0	
Open Water Berm Length	16,895	ft	Loss of SAV due to loss of Bay Intertidal						-6,817,172	
Island Berm Overwash	94	ft/yr	Overwash of berm covering intertidal (conversion)							
Island Berm Length	14,338	ft								
TY25			**Total Acres in TY25**	**0**	**0**	**0**	**979**	**355**	**3,581**	**4,914**

Input	Value	Units	Process	Dune	Supratidal	Gulf Intertidal	Bay Intertidal	Bay Subtidal	SAV Area	Total
Years passed	5									
Years left of Supratidal Acreage	5									
Total Gulf Length	48,335	ft								
Existing Islands w/o berm Gulf Length	17,102	ft								
Supratidal length	48,335	ft								
Total island length loss	330	ft/yr								
Shoreline recession: Longshore Loss	-11	ft/yr	Loss due to longshore transport				-2,706,529			
Shoreline recession: Overwash	-4	ft/yr	Loss due to Overwash				-1,005,374			
Shoreline recession: RSLR	-10	ft/yr	Loss due to RSLR				-2,311,290			
Shoreline Recession: Silt Loss	-12	ft/yr	Offshore losses				-2,894,614			
RSLR	0.0164	ft/yr								
Overwash distance from Sbeach	34	ft/yr	Overwash of existing into back bay							
Gulf Intertidal Perimeter	48,335	ft								
Bay Intertidal Perimeter	27,444	ft	Subsidence out of bay intertidal				-397,986	397,986		
Bay Subtidal Perimeter	31,123	ft	Subsidence out of bay subtidal					-300,335	300,335	
Open Water Perimeter	58,538	ft	Subsidence out of bay open water						-564,896	
Gulf Intertidal Slope 1V:	580	H								
Bay Subtidal Slope 1V:	386	H								
Subsidence	-0.005	ft/yr								
Open Water Length	58,538	ft								
Bay Subtidal Length	51,839	ft								
Bay Intertidal Length	27,444	ft								
Bay Change Rate	14	ft/yr	Overwash to create bay intertidal (create)							
Open Water Berm Overwash	-46	ft/yr	Overwash of berm into open water (conversion)							
Open Water Berm Length	16,895	ft	Loss of SAV due to loss of Bay Intertidal						-34,074,302	
Island Berm Overwash	94	ft/yr	Overwash of berm covering intertidal (conversion)							
Island Berm Length	14,338	ft								
TY30			**Total Acres in TY30**	**0**	**0**	**0**	**765**	**357**	**2,792**	**3,914**

Input	Value	Units	Process	Dune	Supratidal	Gulf Intertidal	Bay Intertidal	Bay Subtidal	SAV Area	Total
Years passed	10									
	10									
Total Gulf Length	48,335	ft								
Existing Islands w/o berm Gulf Length	17,102	ft								
Supratidal length	48,335	ft								
Total island length loss	330	ft/yr								
Shoreline recession: Longshore Loss	-11	ft/yr	Loss due to longshore transport				-5,413,059			
Shoreline recession: Overwash	-4	ft/yr	Loss due to Overwash				-2,010,747			
Shoreline recession: RSLR	-10	ft/yr	Loss due to RSLR				-4,622,580			
Shoreline Recession: Silt Loss	-12	ft/yr	Offshore losses				-5,789,229			
RSLR	0.0164	ft/yr								
Overwash distance from Sbeach	34	ft/yr	Overwash of existing into back bay							
Gulf Intertidal Perimeter	48,335	ft								
Bay Intertidal Perimeter	27,444	ft	Subsidence out of bay intertidal				-795,971	795,971		
Bay Subtidal Perimeter	31,123	ft	Subsidence out of bay subtidal					-600,670	600,670	
Open Water Perimeter	58,538	ft	Subsidence out of bay open water						-1,129,791	
Gulf Intertidal Slope 1V:	580	H								
Bay Subtidal Slope 1V:	386	H								
Subsidence	-0.005	ft/yr								
Open Water Length	58,538	ft								
Bay Subtidal Length	51,839	ft								
Bay Intertidal Length	27,444	ft								
Bay Change Rate	14	ft/yr	Overwash to create bay intertidal (create)							
Open Water Berm Overwash	-46	ft/yr	Overwash of berm into open water (conversion)							
Open Water Berm Length	16,895	ft	Loss of SAV due to loss of Bay Intertidal						-68,000,700	
Island Berm Overwash	94	ft/yr	Overwash of berm covering intertidal (conversion)							
Island Berm Length	14,338	ft								
TY40			**Total Acres in TY40**	**0**	**0**	**0**	**337**	**362**	**1,219**	**1,918**

Input	Value	Units	Process	Dune	Supratidal	Gulf Intertidal	Bay Intertidal	Bay Subtidal	SAV Area	Total
Years passed	8									
Years left of Supratidal Acreage	7.9									
Total Gulf Length	48,335	ft								
Existing Islands w/o berm Gulf Length	17,102	ft								
Supratidal length	48,335	ft								
Total island length loss	330	ft/yr								
Shoreline recession: Longshore Loss	-11	ft/yr	Loss due to longshore transport				-4,276,317	-58,055		
Shoreline recession: Overwash	-4	ft/yr	Loss due to Overwash				-1,588,491	-21,565		
Shoreline recession: RSLR	-10	ft/yr	Loss due to RSLR				-3,651,838	-49,577		
Shoreline Recession: Silt Loss	-12	ft/yr	Offshore losses				-4,573,491	-62,089		
RSLR	0.0164	ft/yr								
Overwash distance from Sbeach	34	ft/yr	Overwash of existing into back bay							
Gulf Intertidal Perimeter	48,335	ft								
Bay Intertidal Perimeter	27,444	ft	Subsidence out of bay intertidal				-628,817	628,817		
Bay Subtidal Perimeter	31,123	ft	Subsidence out of bay subtidal					-480,536	480,536	
Open Water Perimeter	58,538	ft	Subsidence out of bay open water						-903,833	
Gulf Intertidal Slope 1V:	580	H								
Bay Subtidal Slope 1V:	386	H								
Subsidence	-0.005	ft/yr								
Open Water Length	58,538	ft								
Bay Subtidal Length	51,839	ft								
Bay Intertidal Length	27,444	ft								
Bay Change Rate	14	ft/yr	Overwash to create bay intertidal (create)							
Open Water Berm Overwash	-46	ft/yr	Overwash of berm into open water (conversion)							
Open Water Berm Length	16,895	ft	Loss of SAV due to loss of Bay Intertidal						-53,105,697	
Island Berm Overwash	94	ft/yr	Overwash of berm covering intertidal (conversion)							
Island Berm Length	14,338	ft								
TY48			**Total Acres in TY48**	**0**	**0**	**0**	**0**	**361**	**0**	**361**

Input	Value	Units	Process	Dune	Supratidal	Gulf Intertidal	Bay Intertidal	Bay Subtidal	SAV Area	Total
Years passed	2									
Years left of Supratidal Acreage	2									
Total Gulf Length	48,335	ft								
Existing Islands w/o berm Gulf Length	17,102	ft								
Supratidal length	48,335	ft								
Total island length loss	330	ft/yr								
Shoreline recession: Longshore Loss	-11	ft/yr	Loss due to longshore transport							
Shoreline recession: Overwash	-4	ft/yr	Loss due to Overwash							
Shoreline recession: RSLR	-10	ft/yr	Loss due to RSLR							
Shoreline Recession: Silt Loss	-12	ft/yr	Offshore losses							
RSLR	0.0164	ft/yr								
Overwash distance from Sbeach	34	ft/yr	Overwash of existing into back bay							
Gulf Intertidal Perimeter	48,335	ft								
Bay Intertidal Perimeter	27,444	ft	Subsidence out of bay intertidal							
Bay Subtidal Perimeter	31,123	ft	Subsidence out of bay subtidal					-120,134		
Open Water Perimeter	58,538	ft	Subsidence out of bay open water							
Gulf Intertidal Slope 1V:	580	H								
Bay Subtidal Slope 1V:	386	H								
Subsidence	-0.005	ft/yr								
Open Water Length	58,538	ft								
Bay Subtidal Length	51,839	ft								
Bay Intertidal Length	27,444	ft								
Bay Change Rate	14	ft/yr	Overwash to create bay intertidal (create)							
Open Water Berm Overwash	-46	ft/yr	Overwash of berm into open water (conversion)							
Open Water Berm Length	16,895	ft	Loss of SAV due to loss of Bay Intertidal							
Island Berm Overwash	94	ft/yr	Overwash of berm covering intertidal (conversion)							
Island Berm Length	14,338	ft								
			Total Acres in TY50	**0**	**0**	**0**	**0**	**358**	**0**	**358**

893

Table 8. Chandeleur Islands – Future With Project – HSI Calculations

Variable		TY0 Pre-Con Value	TY0 Pre-Con SI	TY1 Post-Con Value	TY1 Post-Con SI	TY3 Value	TY3 SI
V1	% Dune	0	0.10	0	0.10	0.00	0.10
V2	% Supratidal	0	0.10	19	0.94	16	0.82
V3	% Intertidal	100	0.10	81	0.66	84	0.58
V4	% Vegetative Cover	50	0.79	52	0.82	59.9	0.93
V5	% Woody Cover	0.5	0.15	5.0	0.55	8.0	0.82
V6	Interspersion	%	0.40	%	0.52	%	0.75
	Class 1	0		0		58	
	Class 2	0		0		0	
	Class 3	0		58		0	
	Class 4	100		42		42	
	Class 5						
V7	Beach/surf Zone	1	1.00	1	1.00	1	1.00
V8	% Aquatic	41.0	0.47	60.0	0.64	70.0	0.73
		HSI =	**0.383**	**HSI =**	**0.653**	**HSI =**	**0.704**

896

Variable		TY5 Value	TY5 SI	TY10 Value	TY10 SI	TY13 Value	TY13 SI
V1	% Dune	0	0.10	0	0.10	0	0.10
V2	% Supratidal	13	0.68	3	0.24	0.0	0.10
V3	% Intertidal	87	0.49	97	0.19	100	0.10
V4	% Vegetative Cover	69	1.00	70	1.00	70	1.00
V5	% Woody Cover	10.0	1.00	10.0	1.00	10.0	1.00
V6	Interspersion	%	0.75	%	0.71	%	0.69
	Class 1	58		39		29	
	Class 2	0		19		29	
	Class 3	0		0		0	
	Class 4	42		42		42	
	Class 5						
V7	Beach/surf Zone	1	1.00	1	1.00	1	1.00
V8	% Aquatic	90	0.91	80	0.82	80	0.82
		HSI =	**0.717**	**HSI =**	**0.598**	**HSI =**	**0.564**

897

Variable		TY15 Value	TY15 SI	TY20 Value	TY20 SI	TY24 Value	TY24 SI
V1	% Dune	0	0.10	0	0.10	0	0.10
V2	% Supratidal	0	0.10	0	0.10	0	0.10
V3	% Intertidal	100	0.10	100	0.10	100	0.10
V4	% Vegetative Cover	70	1.00	75	1.00	75	1.00
V5	% Woody Cover	10.0	1.00	10.0	1.00	8.0	0.82
V6	Interspersion	%	0.67	%	0.63	%	0.59
	Class 1	19		0		0	
	Class 2	39		58		39	
	Class 3	0		0		19	
	Class 4	42		42		42	
	Class 5						
V7	Beach/surf Zone	1	1.00	1	1.00	1	1.00
V8	% Aquatic	75	0.78	70	0.73	65	0.69
		HSI =	**0.557**	**HSI =**	**0.547**	**HSI =**	**0.523**

898

Variable		TY25 Value	SI	TY30 Value	SI	TY40 Value	SI
V1	% Dune	0	0.10	0	0.10	0.00	0.10
V2	% Supratidal	0	0.10	0	0.10	0.00	0.10
V3	% Intertidal	100	0.10	100	0.10	100	0.10
V4	% Vegetative Cover	70	1.00	65	1.00	55	0.86
V5	% Woody Cover	7.0	0.73	4.0	0.46	2.0	0.28
V6	Interspersion	%	0.57	%	0.52	%	0.40
	Class 1	0		0		0	
	Class 2	29		0		0	
	Class 3	29		58		0	
	Class 4	42		42		100	
	Class 5						
V7	Beach/surf Zone	1	1.00	1	1.00	1	1.00
V8	% Aquatic	60	0.64	50	0.55	40	0.46
		HSI = 0.509		**HSI = 0.471**		**HSI = 0.406**	

668

Variable		TY48 Value	SI	TY50 Value	SI
V1	% Dune	0	0.10	0	0.10
V2	% Supratidal	0	0.10	0	0.10
V3	% Intertidal	0	0.10	0	0.10
V4	% Vegetative Cover	0	0.10	0	0.10
V5	% Woody Cover	0.0	0.10	0.0	0.10
V6	Interspersion	%	0.10	%	0.10
	Class 1	0		0	
	Class 2	0		0	
	Class 3	0		0	
	Class 4	0		0	
	Class 5	100		100	
V7	Beach/surf Zone	1	1.00	1	1.00
V8	% Aquatic	0	0.10	0	0.10
		HSI = 0.172		**HSI = 0.172**	

900

Breton Island

Table 9. Breton Island – Future Without Project – Acreage Summary

Target Year	Habitat (acres)					Total
	Dune	Supratidal	Gulf Intertidal	Bay Intertidal	Bay Subtidal	
TY0 Pre-Con	0	0	0	0	0	0
TY1 Post-Con	0	0	0	0	0	0
TY50	0	0	0	0	0	0

Table 10. Breton Island – Future Without Project – Summary of Acreage Benefits

Target Year	Acres	x HSI	Total HUs	Cumulative HUs
0	0	0.190	0	0
1	0	0.190	0	0
50	0	0.190	0	0
FWOP Average Annual Habitat Units				0

Table 11. Breton Island – Future Without Project – Acreage Calculations

Input	Value	Units	Process	Dune	Supratidal	Gulf Intertidal	Bay Intertidal	Bay Subtidal	Total
2007				**0**	**14**	**5**	**25**	**32**	**76**
Years passed	2.9								
Years left of supratidal acreage	0.54								
Years left of gulf intertidal acreage	0.2								
Years left of bay intertidal acreage	1.08								
Years left of bay subtidal acreage	1.08								
Gulf Intertidal Length	4,670	ft							
Supratidal Length	4,310	ft							
Shoreline recession due Longshore Loss	141.6	ft/yr	Loss due to longshore transport		-329,505	-132,236	-559,839	-680,304	
Shoreline recession due to Overwash	35.6	ft/yr	Loss due to Overwash		-82,830	-33,241	-140,730	-171,012	
Shoreline recession due to RSLR	9.52	ft/yr	Loss due to RSLR		-22,146	-8,887	-37,626	-45,722	
Shoreline Recession due to Silt Loss	87.9	ft/yr	Offshore losses		-204,462	-82,054	-347,386	-422,136	
RSLR	0.0164	ft/yr							
Overwash distance from SBEACH	34	ft/yr	Overwash into back bay		79,128	31,755	-110,884		
Gulf Intertidal Perimeter	4,670	ft	Overwash of bay intertidal onto subtidal				134,441	-134,441	
Bay Intertidal Perimeter	3,661	ft	Subsidence out of bay intertidal				-7,858	7,858	
Bay Subtidal Perimeter	4,449	ft	Subsidence out of bay subtidal					-15,628	
Gulf Intertidal Slope 1V:	580	H							
Bay Subtidal Slope 1V:	386	H							
Subsidence	-0.005	ft/yr							
Bay Subtidal Length	4,449	ft							
Bay Intertidal Length	3,661	ft							
Bay Change Rate	19.3	ft/yr	Gain in bay from loss in gulf (overwash)		-44,872	-14,118	58,991		
			Gain in bay from loss in gulf (overwash)				-76,239	76,239	
TY0 Pre Construction (2014)			**Total Acres in TY0**	**0**	**0**	**0**	**0**	**0**	**0**

Input	Value	Units	Process	Dune	Supratidal	Gulf Intertidal	Bay Intertidal	Bay Subtidal	Total
TY1									
Years passed	1								
Years left of subtidal acreage	1								
Gulf Intertidal Length	4,670	ft							
Supratidal Length	4,310	ft							
Shoreline recession due Longshore Loss	142	ft/yr	Loss due to longshore transport						
Shoreline recession due to Overwash	36	ft/yr	Loss due to Overwash						
Shoreline recession due to RSLR	10	ft/yr	Loss due to RSLR						
Shoreline Recession due to Silt Loss	87.9	ft/yr	Offshore losses						
RSLR	0.0164	ft/yr							
Overwash distance from SBEACH	34	ft/yr	Overwash into back bay						
Gulf Intertidal Perimeter	4,670	ft	Overwash of bay intertidal onto subtidal						
Bay Intertidal Perimeter	3,661	ft	Subsidence out of bay intertidal						
Bay Subtidal Perimeter	4,449	ft	Subsidence out of bay subtidal						
Gulf Intertidal Slope 1V:	580	H							
Bay Subtidal Slope 1V:	386	H							
Subsidence	-0.005	ft/yr							
Bay Subtidal Length	4,449	ft							
Bay Intertidal Length	3,661	ft							
Bay Change Rate	19.3	ft/yr	Gain in bay from loss in gulf (overwash)						
			Gain in bay from loss in gulf (overwash)						
TY1 Post-Construction			**Total Acres in TY1**	**0**	**0**	**0**	**0**	**0**	**0**

Input	Value	Units	Process	Dune	Supratidal	Gulf Intertidal	Bay Intertidal	Bay Subtidal	Total
TY50									
Years passed	49								
Years left of gulf intertidal acreage									
Gulf Intertidal Length	4,670	ft							
Supratidal Length	4,310	ft							
Shoreline recession due Longshore Loss	142	ft/yr	Loss due to longshore transport					0	
Shoreline recession due to Overwash	36	ft/yr	Loss due to Overwash					0	
Shoreline recession due to RSLR	10	ft/yr	Loss due to RSLR					0	
Shoreline Recession due to Silt Loss	87.9	ft/yr	Offshore losses					0	
RSLR	0.0164	ft/yr							
Overwash distance from SBEACH	34	ft/yr	Overwash into back bay						
Gulf Intertidal Perimeter	4,670	ft	Overwash of bay intertidal onto subtidal						
Bay Intertidal Perimeter	3,661	ft	Subsidence out of bay intertidal						
Bay Subtidal Perimeter	4,449	ft	Subsidence out of bay subtidal					0	
Gulf Intertidal Slope 1V:	580	H							
Bay Subtidal Slope 1V:	386	H							
Subsidence	-0.005	ft/yr							
Bay Subtidal Length	4,449	ft							
Bay Intertidal Length	3,661	ft							
Bay Change Rate	19.3	ft/yr	Gain in bay from loss in gulf (overwash)						
			Gain in bay from loss in gulf (overwash)						
TY50			**Total Acres in TY50**	**0**	**0**	**0**	**0**	**0**	**0**

904

Table 12. Breton Island – Future Without Project – HSI Calculations

Variable		TY0 Pre-Con Value	TY0 Pre-Con SI	TY1 Post-Con Value	TY1 Post-Con SI	TY50 Value	TY50 SI
V1	% Dune	0	0.10	0	0.10	0.00	0.10
V2	% Supratidal	0	0.10	0	0.10	0.00	0.10
V3	% Intertidal	0	0.10	0	0.10	0	0.10
V4	% Vegetative Cover	0	0.10	0	0.10	0	0.10
V5	% Woody Cover	0.0	0.10	0.0	0.10	0.0	0.10
V6	Interspersion	%	0.10	%	0.10	%	0.10
	Class 1						
	Class 2						
	Class 3						
	Class 4						
	Class 5	100		100		100	
V7	Beach/surf Zone	1	1.00	1	1.00	1	1.00
		HSI = 0.190		**HSI = 0.190**		**HSI = 0.190**	

905

Table 13. Breton Island – Future With Project Alternative 1 – Acreage Summary

Target Year	Habitat (acres)					Total
	Dune	Supratidal	Gulf Intertidal	Bay Intertidal	Bay Subtidal	
TY0 Pre-Con	0	0	0	0	0	0
TY1 Post-Con	0	517	49	1066	3	1634
TY3	0	373	49	1027	3	1453
TY5	0	230	49	988	4	1271
TY8	0	14	49	930	5	998
TY9	0	0	0	902	6	907
TY10	0	0	0	811	6	817
TY15	0	0	0	355	8	363
TY19	0	0	0	0	0	0
TY50	0	0	0	0	0	0

Table 14. Breton Island – Future With Project Alternative 1 – Summary of Acreage Benefits

Target Year	Acres	x HSI	Total HUs	Cumulative HUs
0	0	0.190	0	0
1	1635	0.647	1058	405
3	1452	0.785	1140	2207
5	1271	0.787	1000	2140
8	998	0.581	580	2342
9	908	0.517	469	524
10	817	0.499	408	438
15	363	0.451	164	1410
19	0	0.190	0	264
50	0	0.235	0	0
FWP Average Annual Habitat Units				195
FWOP Average Annual Habitat Units				0
Net Average Annual Habitat Units				195

Table 15. Breton Island – Future With Project Alternative 1 – Acreage Calculations

Input	Value	Units	Process	Dune	Supratidal	Gulf Intertidal	Bay Intertidal	Bay Subtidal	Total
2007				**0**	**14**	**5**	**25**	**32**	**76**
Years passed	2.9								
Years left of supratidal acreage	0.54								
Years left of gulf intertidal acreage	0.2								
Years left of bay intertidal acreage	1.08								
Years left of bay subtidal acreage	1.08								
Gulf Intertidal Length	4,670	ft							
Supratidal Length	4,310	ft							
Shoreline recession: Longshore Loss	142	ft/yr	Loss due to longshore transport		-329,505	-132,236	-559,839	-680,304	
Shoreline recession: Overwash	36	ft/yr	Loss due to Overwash		-82,830	-33,241	-140,730	-171,012	
Shoreline recession: RSLR	10	ft/yr	Loss due to RSLR		-22,146	-8,887	-37,626	-45,722	
Shoreline Recession: Silt Loss	88	ft/yr	Offshore losses		-204,462	-82,054	-347,386	-422,136	
RSLR	0.0164	ft/yr							
Overwash distance from SBEACH	34	ft/yr	Overwash into back bay		79,128	31,755	-110,884		
Gulf Intertidal Perimeter	4,670	ft	Overwash of bay intertidal onto subtidal				134,441	-134,441	
Bay Intertidal Perimeter	3,661	ft	Subsidence out of bay intertidal				-7,858	7,858	
Bay Subtidal Perimeter	4,449	ft	Subsidence out of bay subtidal					-15,628	
Gulf Intertidal Slope 1V:	580	H							
Bay Subtidal Slope 1V:	386	H							
Subsidence	0	ft/yr							
Bay Subtidal Length	4,449	ft							
Bay Intertidal Length	3,661	ft							
Bay Change Rate	19	ft/yr	Bay gain from gulf loss (overwash)		-44,872	-14,118	58,991		
			Bay gain from gulf loss (overwash)				-76,239	76,239	
TY0 Pre Construction (2014)			**Total Acres in TY0**	**0**	**0**	**0**	**0**	**0**	**0**

Input	Value	Units	Process	Dune	Supratidal	Gulf Intertidal	Bay Intertidal	Bay Subtidal	Total
TY1									
Years passed	1								
Gulf Intertidal Length	4,670	ft							
Supratidal Length	4,310	ft							
Shoreline recession: Longshore Loss	142	ft/yr	Loss due to longshore transport						
Shoreline recession: Overwash	36	ft/yr	Loss due to Overwash						
Shoreline recession: RSLR	10	ft/yr	Loss due to RSLR						
Shoreline Recession: Silt Loss	88	ft/yr	Offshore losses						
RSLR	0.0164	ft/yr							
Overwash distance from SBEACH	34	ft/yr	Overwash into back bay						
Gulf Intertidal Perimeter	4,670	ft	Overwash of bay intertidal onto subtidal						
Bay Intertidal Perimeter	3,661	ft	Subsidence out of bay intertidal						
Bay Subtidal Perimeter	4,449	ft	Subsidence out of bay subtidal						
Gulf Intertidal Slope 1V:	580	H							
Bay Subtidal Slope 1V:	386	H							
Subsidence	-0.005	ft/yr							
Bay Subtidal Length	4,449	ft							
Bay Intertidal Length	3,661	ft							
Bay Change Rate	19	ft/yr							
TY1 Post-Construction			**Total Acres in TY1**	**0**	**517**	**49**	**1,066**	**3**	**1,634**

Input	Value	Units	Process	Dune	Supratidal	Gulf Intertidal	Bay Intertidal	Bay Subtidal	Total
TY3									
Years passed	2								
Years left of supratidal acreage	2								
Gulf Intertidal Length	23,706	ft							
Supratidal Length	23,438	ft							
Shoreline recession: Longshore Loss	35	ft/yr	Loss due to longshore transport		-1,619,960				
Shoreline recession: Overwash	36	ft/yr	Loss due to Overwash		-1,668,319				
Shoreline recession: RSLR	10	ft/yr	Loss due to RSLR		-446,047				
Shoreline Recession: Silt Loss	87.9	ft/yr	Offshore losses		-4,118,165				
RSLR	0.0164	ft/yr							
Overwash distance from SBEACH	34	ft/yr	Overwash into back bay		1,593,764		-1,593,764		
Gulf Intertidal Perimeter	23,706	ft							
Bay Intertidal Perimeter	18,050	ft	Subsidence out of bay intertidal				-104,705	104,705	
Bay Subtidal Perimeter	18,050	ft	Subsidence out of bay subtidal					-69,675	
Gulf Intertidal Slope 1V:	580	H							
Bay Subtidal Slope 1V:	386	H							
Subsidence	-0.005	ft/yr							
Bay Subtidal Length	18,050	ft							
Bay Intertidal Length	18,050	ft							
Bay Change Rate	19.3	ft/yr							
TY3			**Total Acres in TY3**	**0**	**373**	**49**	**1,027**	**3**	**1,453**

606

Input	Value	Units	Process	Dune	Supratidal	Gulf Intertidal	Bay Intertidal	Bay Subtidal	Total
TY5									
Years passed	2								
Years left of supratidal acreage									
Gulf Intertidal Length	23,706	ft							
Supratidal Length	23,438	ft							
Shoreline recession: Longshore Loss	35	ft/yr	Loss due to longshore transport		-1,619,960				
Shoreline recession: Overwash	36	ft/yr	Loss due to Overwash		-1,668,319				
Shoreline recession: RSLR	10	ft/yr	Loss due to RSLR		-446,047				
Shoreline Recession: Silt Loss	88	ft/yr	Offshore losses		-4,118,165				
RSLR	0.0164	ft/yr							
Overwash distance from SBEACH	34	ft/yr	Overwash into back bay		1,593,764		-1,593,764		
Gulf Intertidal Perimeter	23,706	ft							
Bay Intertidal Perimeter	18,050	ft	Subsidence out of bay intertidal				-104,705	104,705	
Bay Subtidal Perimeter	18,050	ft	Subsidence out of bay subtidal					-69,675	
Gulf Intertidal Slope 1V:	580	H							
Bay Subtidal Slope 1V:	386	H							
Subsidence	-0.005	ft/yr							
Bay Subtidal Length	18,050	ft							
Bay Intertidal Length	18,050	ft							
Bay Change Rate	19.3	ft/yr							
TY5			**Total Acres in TY5**	**0**	**230**	**49**	**988**	**4**	**1,271**

Input	Value	Units	Process	Dune	Supratidal	Gulf Intertidal	Bay Intertidal	Bay Subtidal	Total
TY8									
Years passed	3								
Years left of supratidal acreage	3								
Gulf Intertidal Length	23,706	ft							
Supratidal Length	23,438	ft							
Shoreline recession: Longshore Loss	35	ft/yr	Loss due to longshore transport		-2,429,939	0			
Shoreline recession: Overwash	36	ft/yr	Loss due to Overwash		-2,502,479	0			
Shoreline recession: RSLR	10	ft/yr	Loss due to RSLR		-669,070	0			
Shoreline Recession: Silt Loss	88	ft/yr	Offshore losses		-6,177,248	0			
RSLR	0.0164	ft/yr							
Overwash distance from SBEACH	34	ft/yr	Overwash into back bay		2,390,647	0	-2,390,647		
Gulf Intertidal Perimeter	23,706	ft							
Bay Intertidal Perimeter	18,050	ft	Subsidence out of bay intertidal				-157,058	157,058	
Bay Subtidal Perimeter	18,050	ft	Subsidence out of bay subtidal					-104,512	
Gulf Intertidal Slope 1V:	580	H							
Bay Subtidal Slope 1V:	386	H							
Subsidence	0	ft/yr							
Bay Subtidal Length	18,050	ft							
Bay Intertidal Length	18,050	ft							
Bay Change Rate	19	ft/yr							
TY8			**Total Acres in TY8**	**0**	**14**	**49**	**930**	**5**	**998**

Input	Value	Units	Process	Dune	Supratidal	Gulf Intertidal	Bay Intertidal	Bay Subtidal	Total
TY9									
Years passed	1								
Years left of supratidal acreage	0.2	0.68							
Gulf Intertidal Length	23,706	ft							
Supratidal Length	23,438	ft							
Shoreline recession: Longshore Loss	35	ft/yr	Loss due to longshore transport		-161,996	-550,786	-97,198		
Shoreline recession: Overwash	36	ft/yr	Loss due to Overwash		-166,832	-567,228	-100,099		
Shoreline recession: RSLR	10	ft/yr	Loss due to RSLR		-44,605	-151,656	-26,763		
Shoreline Recession: Silt Loss	88	ft/yr	Offshore losses		-411,817	-1,400,176	-247,090		
RSLR	0.0164	ft/yr							
Overwash distance from SBEACH	34	ft/yr	Overwash into back bay		159,376	541,880	-701,256		
Gulf Intertidal Perimeter	23,706	ft							
Bay Intertidal Perimeter	18,050	ft	Subsidence out of bay intertidal				-52,353	52,353	
Bay Subtidal Perimeter	18,050	ft	Subsidence out of bay subtidal					-34,837	
Gulf Intertidal Slope 1V:	580	H							
Bay Subtidal Slope 1V:	386	H							
Subsidence	-0.005	ft/yr							
Bay Subtidal Length	18,050	ft							
Bay Intertidal Length	18,050	ft							
Bay Change Rate	19.3	ft/yr							
TY9			**Total Acres in TY9**	**0**	**0**	**0**	**902**	**6**	**907**

Input	Value	Units	Process	Dune	Supratidal	Gulf Intertidal	Bay Intertidal	Bay Subtidal	Total
TY10									
Years passed	1								
Years left of supratidal acreage	1								
Gulf Intertidal Length	23,706	ft							
Supratidal Length	23,438	ft							
Shoreline recession: Longshore Loss	35	ft/yr	Loss due to longshore transport				-809,980		
Shoreline recession: Overwash	36	ft/yr	Loss due to Overwash				-834,160		
Shoreline recession: RSLR	10	ft/yr	Loss due to RSLR				-223,023		
Shoreline Recession: Silt Loss	88	ft/yr	Offshore losses				-2,059,083		
RSLR	0.0164	ft/yr							
Overwash distance from SBEACH	34	ft/yr	Overwash into back bay						
Gulf Intertidal Perimeter	23,706	ft							
Bay Intertidal Perimeter	18,050	ft	Subsidence out of bay intertidal						
Bay Subtidal Perimeter	18,050	ft	Subsidence out of bay subtidal						
Gulf Intertidal Slope 1V:	580	H							
Bay Subtidal Slope 1V:	386	H							
Subsidence	-0.005	ft/yr							
Bay Subtidal Length	18,050	ft							
Bay Intertidal Length	18,050	ft							
Bay Change Rate	19.3	ft/yr							
TY10			**Total Acres in TY10**	**0**	**0**	**0**	**811**	**6**	**817**

Input	Value	Units	Process	Dune	Supratidal	Gulf Intertidal	Bay Intertidal	Bay Subtidal	Total
TY15									
Years passed	5								
Years left of supratidal acreage	5								
Gulf Intertidal Length	23,706	ft							
Supratidal Length	23,438	ft							
Shoreline recession: Longshore Loss	35	ft/yr	Loss due to longshore transport				-4,049,899		
Shoreline recession: Overwash	36	ft/yr	Loss due to Overwash				-4,170,798		
Shoreline recession: RSLR	10	ft/yr	Loss due to RSLR				-1,115,117		
Shoreline Recession: Silt Loss	88	ft/yr	Offshore losses				-10,295,413		
RSLR	0.0164	ft/yr							
Overwash distance from SBEACH	34	ft/yr	Overwash into back bay						
Gulf Intertidal Perimeter	23,706	ft							
Bay Intertidal Perimeter	18,050	ft	Subsidence out of bay intertidal				-261,764	261,764	
Bay Subtidal Perimeter	18,050	ft	Subsidence out of bay subtidal					-174,187	
Gulf Intertidal Slope 1V:	580	H							
Bay Subtidal Slope 1V:	386	H							
Subsidence	-0.005	ft/yr							
Bay Subtidal Length	18,050	ft							
Bay Intertidal Length	18,050	ft							
Bay Change Rate	19.3	ft/yr							
TY15			**Total Acres in TY15**	**0**	**0**	**0**	**355**	**8**	**363**

Input	Value	Units	Process	Dune	Supratidal	Gulf Intertidal	Bay Intertidal	Bay Subtidal	Total
TY19									
Years passed	4								
Years left of supratidal acreage	3.94								
Gulf Intertidal Length	23,706	ft							
Supratidal Length	23,438	ft							
Shoreline recession: Longshore Loss	35	ft/yr	Loss due to longshore transport				-3,191,320	-48,599	
Shoreline recession: Overwash	36	ft/yr	Loss due to Overwash				-3,286,589	-50,050	
Shoreline recession: RSLR	10	ft/yr	Loss due to RSLR				-878,712	-13,381	
Shoreline Recession: Silt Loss	88	ft/yr	Offshore losses				-8,112,786	-123,545	
RSLR	0.0164	ft/yr							
Overwash distance from SBEACH	34	ft/yr	Overwash into back bay						
Gulf Intertidal Perimeter	23,706	ft							
Bay Intertidal Perimeter	18,050	ft	Subsidence out of bay intertidal						
Bay Subtidal Perimeter	18,050	ft	Subsidence out of bay subtidal					-139,350	
Gulf Intertidal Slope 1V:	580	H							
Bay Subtidal Slope 1V:	386	H							
Subsidence	-0.005	ft/yr							
Bay Subtidal Length	18,050	ft							
Bay Intertidal Length	18,050	ft							
Bay Change Rate	19.3	ft/yr							
TY19			**Total Acres in TY19**	**0**	**0**	**0**	**0**	**0**	**0**

Input	Value	Units	Process	Dune	Supratidal	Gulf Intertidal	Bay Intertidal	Bay Subtidal	Total
TY50									
Years passed	30								
Years left of supratidal acreage									
Gulf Intertidal Length	23,706	ft							
Supratidal Length	23,438	ft							
Shoreline recession: Longshore Loss	35	ft/yr	Loss due to longshore transport						
Shoreline recession: Overwash	36	ft/yr	Loss due to Overwash						
Shoreline recession: RSLR	10	ft/yr	Loss due to RSLR						
Shoreline Recession: Silt Loss	88	ft/yr	Offshore losses						
RSLR	0.0164	ft/yr							
Overwash distance from SBEACH	34	ft/yr	Overwash into back bay						
Gulf Intertidal Perimeter	23,706	ft							
Bay Intertidal Perimeter	18,050	ft	Subsidence out of bay intertidal						
Bay Subtidal Perimeter	18,050	ft	Subsidence out of bay subtidal						
Gulf Intertidal Slope 1V:	580	H							
Bay Subtidal Slope 1V:	386	H							
Subsidence	-0.005	ft/yr							
Bay Subtidal Length	18,050	ft							
Bay Intertidal Length	18,050	ft							
Bay Change Rate	19.3	ft/yr							
TY50			**Total Acres in TY50**	**0**	**0**	**0**	**0**	**0**	**0**

Table 16. Breton Island – Future With Project Alternative 1 – HSI Calculations

Variable		TY0 Pre-Con Value	TY0 Pre-Con SI	TY1 Post-Con Value	TY1 Post-Con SI	TY3 Value	TY3 SI
V1	% Dune	0	0.10	0	0.10	0	0.10
V2	% Supratidal	0	0.10	32	1.00	26	1.00
V3	% Intertidal	0	0.10	68	1.00	74	0.87
V4	% Vegetative Cover	0	0.10	21	0.39	47	0.75
V5	% Woody Cover	0.0	0.10	5.0	0.55	8.0	0.82
V6	Interspersion	%	0.10	%	0.60	%	1.00
	Class 1					100	
	Class 2						
	Class 3			100			
	Class 4			0		0	
	Class 5	100					
V7	Beach/surf Zone	1	1.00	1	1.00	1	1.00
		HSI = 0.190		**HSI = 0.647**		**HSI = 0.785**	

917

Variable		TY5 Value	TY5 SI	TY8 Value	TY8 SI	TY9 Value	TY9 SI
V1	% Dune	0	0.10	0	0.10	0	0.10
V2	% Supratidal	18	0.92	1	0.16	0	0.10
V3	% Intertidal	82	0.64	99	0.14	100	0.10
V4	% Vegetative Cover	72	1.00	80	1.00	80	1.00
V5	% Woody Cover	10.0	1.00	10.0	1.00	8.0	0.82
V6	Interspersion	%	0.90	%	0.80	%	0.60
	Class 1	50					
	Class 2	50		100			
	Class 3	0		0		100	
	Class 4	0		0		0	
	Class 5						
V7	Beach/surf Zone	1	1.00	1	1.00	1	1.00
		HSI = 0.787		**HSI = 0.581**		**HSI = 0.517**	

Variable		TY10 Value	TY10 SI	TY15 Value	TY15 SI	TY19 Value	TY19 SI
V1	% Dune	0	0.10	0	0.10	0	0.10
V2	% Supratidal	0	0.10	0	0.10	0	0.10
V3	% Intertidal	100	0.10	100	0.10	0	0.10
V4	% Vegetative Cover	75	1.00	70	1.00	0	0.10
V5	% Woody Cover	6.0	0.64	4.0	0.46	0.0	0.10
V6	Interspersion	%	0.60	%	0.40	%	0.10
	Class 1						
	Class 2						
	Class 3	100		0		0	
	Class 4	0		100		0	
	Class 5					100	
V7	Beach/surf Zone	1	1.00	1	1.00	1	1.00
		HSI = 0.499		**HSI = 0.451**		**HSI = 0.190**	

919

Variable		TY50 Value	SI
V1	% Dune	0	0.10
V2	% Supratidal	0	0.10
V3	% Intertidal	0	0.10
V4	% Vegetative Cover	0	0.10
V5	% Woody Cover	0.0	0.10
V6	Interspersion	%	0.40
	Class 1		
	Class 2		
	Class 3	0	
	Class 4	100	
	Class 5		
V7	Beach/surf Zone	1	1.00
		HSI =	**0.235**

Table 17. Breton Island – Future With Project Alternative 2 – Acreage Summary

Target Year	Habitat (acres)					Total
	Dune	Supratidal	Gulf Intertidal	Bay Intertidal	Bay Subtidal	
TY0 Pre-Con	0	0	0	0	0	0
TY1 Post-Con	400	141	43	52	39	674
TY2	343	141	43	52	39	617
TY5	171	141	43	52	39	445
TY7	0	219	43	52	39	353
TY10	0	23	43	52	39	156
TY11	0	0	0	52	39	90
TY12	0	0	0	0	32	32
TY13	0	0	0	0	0	0
TY50	0	0	0	0	0	0

Table 18. Breton Island – Future With Project Alternative 2 – Summary of Acreage Benefits

Target Year	Acres	x HSI	Total HUs	Cumulative HUs
0	0	0.190	0	0
1	674	0.379	255	107
2	617	0.513	316	287
5	445	0.647	288	918
7	353	0.633	223	511
10	156	0.751	117	523
11	90	0.481	43	77
12	32	0.190	6	22
13	0	0.190	0	3
50	0	0.190	0	0
FWP Average Annual Habitat Units				49
FWOP Average Annual Habitat Units				0
Net Average Annual Habitat Units				49

Table 19. Breton Island – Future With Project Alternative 2 – Acreage Calculations

Input	Value	Units	Process	Dune	Supratidal	Gulf Intertidal	Bay Intertidal	Bay Subtidal	Total
2007				**0**	**14**	**5**	**25**	**32**	**76**
Years passed	2.9								
Years left of supratidal acreage	0.54								
Years left of gulf intertidal acreage	0.2								
Years left of bay intertidal acreage	1.08								
Years left of bay subtidal acreage	1.08								
Gulf Intertidal Length	4,670	ft							
Supratidal Length	4,310	ft							
Shoreline recession: Longshore Loss	142	ft/yr	Loss due to longshore transport		-329,505	-132,236	-559,839	-680,304	
Shoreline recession: Overwash	36	ft/yr	Loss due to Overwash		-82,830	-33,241	-140,730	-171,012	
Shoreline recession: RSLR	10	ft/yr	Loss due to RSLR		-22,146	-8,887	-37,626	-45,722	
Shoreline Recession: Silt Loss	88	ft/yr	Offshore losses		-204,462	-82,054	-347,386	-422,136	
RSLR	0.0164	ft/yr							
Overwash distance from SBEACH	34	ft/yr	Overwash into back bay		79,128	31,755	-110,884		
Gulf Intertidal Perimeter	4,670	ft	Overwash of bay intertidal onto subtidal				134,441	-134,441	
Bay Intertidal Perimeter	3,661	ft	Subsidence out of bay intertidal				-7,858	7,858	
Bay Subtidal Perimeter	4,449	ft	Subsidence out of bay subtidal					-15,628	
Gulf Intertidal Slope 1V:	580	H							
Bay Subtidal Slope 1V:	386	H							
Subsidence	0	ft/yr							
Bay Subtidal Length	4,449	ft							
Bay Intertidal Length	3,661	ft							
Bay Change Rate	19	ft/yr	Bay gain from gulf loss (overwash)		-44,872	-14,118	58,991		
			Bay gain from gulf loss (overwash)				-76,239	76,239	
TY0 Pre Construction (2014)			**Total Acres in TY0**	**0**	**0**	**0**	**0**	**0**	**0**

Input	Value	Units	Process	Dune	Supratidal	Gulf Intertidal	Bay Intertidal	Bay Subtidal	Total
TY1									
Years passed	1								
TY1 Post-Construction			**Total Acres in TY1**	**400**	**141**	**43**	**52**	**39**	**674**
TY2									
Years passed	1								
Years left of dune acreage	1								
Supratidal Length	21,392	ft							
Shoreline recession: Longshore Loss	29	ft/yr	Loss due to longshore transport	-613,879					
Shoreline recession: RSLR	10	ft/yr	Loss due to RSLR	-203,561					
Shoreline Recession: Silt Loss	78.0	ft/yr	Offshore losses	-1,669,638					
Gulf Slope 1V:	45	H							
Subsidence	-0.005	ft/yr	Subsidence out of highest elevation	-4,813					
TY2			**Total Acres in TY2**	**343**	**141**	**43**	**52**	**39**	**617**
TY5									
Years passed	3								
Years left of dune acreage	3								
Supratidal Length	21,392	ft							
Shoreline recession: Longshore Loss	29	ft/yr	Loss due to longshore transport	-1,841,636					
Shoreline recession: RSLR	10	ft/yr	Loss due to RSLR	-610,682					
Shoreline Recession: Silt Loss	78	ft/yr	Offshore losses	-5,008,913					
Gulf Slope 1V:	45	H							
Subsidence	-0.005	ft/yr	Subsidence out of highest elevation	-14,440					
TY5			**Total Acres in TY5**	**171**	**141**	**43**	**52**	**39**	**445**

Input	Value	Units	Process	Dune	Supratidal	Gulf Intertidal	Bay Intertidal	Bay Subtidal	Total
TY7									
Years passed	2								
Years left of dune acreage	2								
Supratidal Length	21,392	ft							
Shoreline recession: Longshore Loss	29	ft/yr	Loss due to longshore transport	-1,227,757					
Shoreline recession: RSLR	10	ft/yr	Loss due to RSLR	-407,121					
Shoreline Recession: Silt Loss	78	ft/yr	Offshore losses	-3,339,275					
Overwash distance from SBEACH	44	ft	Overwash - widening of island	-2,484,332	3,425,596				
Gulf Slope 1V:	45	H							
Subsidence	-0.005	ft/yr	Subsidence out of highest elevation	-9,627					
TY7			**Total Acres in TY7**	**0**	**219**	**43**	**52**	**39**	**353**
TY10									
Years passed	3								
Years left of supratidal acreage	3								
Supratidal Length	21,392	ft							
Shoreline recession: Longshore Loss	29	ft/yr	Loss due to longshore transport		-1,841,636				
Shoreline recession: RSLR	10	ft/yr	Loss due to RSLR		-610,682				
Shoreline Recession: Silt Loss	78	ft/yr	Offshore losses		-5,008,913				
Overwash distance from SBEACH	-17	ft/yr	Net overwash exchange		-1,091,010				
TY10			**Total Acres in TY10**	**0**	**23**	**43**	**52**	**39**	**156**
TY11									
Years passed	1								
Years left of supratidal acreage	0.35								
Years left of gulf intertidal acreage	0.65								
Gulf Intertidal Length	21,601	ft							
Supratidal Length	21,392	ft							
Shoreline recession: Longshore Loss	29	ft/yr	Loss due to longshore transport		-214,858	-402,906			
Shoreline recession: RSLR	10	ft/yr	Loss due to RSLR		-71,246	-133,602			
Shoreline Recession: Silt Loss	78	ft/yr	Offshore losses		-584,373	-1,095,829			
Overwash distance from SBEACH	-17	ft/yr	Net overwash exchange		-127,285	-238,687			
TY11			**Total Acres in TY11**	**0**	**0**	**0**	**52**	**39**	**90**

Input	Value	Units	Process	Dune	Supratidal	Gulf Intertidal	Bay Intertidal	Bay Subtidal	Total
TY12									
Years passed	1								
Years left of bay intertidal acreage	0.88								
Years left of bay subtidal acreage	0.12								
Shoreline recession: Longshore Loss	29	ft/yr	Loss due to longshore transport				-484,227	-65,630	
Shoreline recession: RSLR	10	ft/yr	Loss due to RSLR				-160,568	-21,763	
Shoreline Recession: Silt Loss	78	ft/yr	Offshore losses				-1,317,008	-178,501	
Overwash distance from SBEACH	-17	ft/yr	Overwash into back bay				-286,863	-38,880	
Bay Intertidal Length	19,175	ft	Subsidence out of bay subtidal						
Bay Subtidal Length	19,059	ft							
TY12			**Total Acres in TY12**	**0**	**0**	**0**	**0**	**32**	**32**
TY13									
Years passed	1								
Years left of bay subtidal acreage	0.55								
Shoreline recession: Longshore Loss	29	ft/yr	Loss due to longshore transport					-300,803	
Shoreline recession: RSLR	10	ft/yr	Loss due to RSLR					-99,745	
Shoreline Recession: Silt Loss	78	ft/yr	Offshore losses					-818,128	
Overwash distance from SBEACH	-17	ft/yr	Overwash into back bay					-178,200	
Bay Intertidal Length	19,175	ft	Subsidence out of bay subtidal						
Bay Subtidal Length	19,059	ft							
TY13			**Total Acres in TY13**	**0**	**0**	**0**	**0**	**0**	**0**
TY50									
Years passed	37								
TY50			**Total Acres in TY50**	**0**	**0**	**0**	**0**	**0**	**0**

Table 20. Breton Island – Future With Project Alternative 2 – HSI Calculations

Variable		TY0 Pre-Con Value	TY0 Pre-Con SI	TY1 Post-Con Value	TY1 Post-Con SI	TY2 Value	TY2 SI
V1	% Dune	0	0.10	63	0.10	59	0.10
V2	% Supratidal	0	0.10	22	1.00	24	1.00
V3	% Intertidal	0	0.10	15	0.10	16	0.10
V4	% Vegetative Cover	0	0.10	7	0.19	18	0.35
V5	% Woody Cover	0.0	0.10	5.0	0.55	8.0	0.82
V6	Interspersion	%	0.10	%	0.10	%	0.60
	Class 1						
	Class 2						
	Class 3					100	
	Class 4						
	Class 5	100		100			
V7	Beach/surf Zone	1	1.00	1	1.00	1	1.00
		HSI =	**0.190**	**HSI =**	**0.379**	**HSI =**	**0.513**

926

Variable		TY5 Value	TY5 SI	TY7 Value	TY7 SI	TY10 Value	TY10 SI
V1	% Dune	42	0.10	0	0.10	0	0.10
V2	% Supratidal	35	1.00	70	0.55	19	0.98
V3	% Intertidal	23	0.10	30	0.11	81	0.68
V4	% Vegetative Cover	38	0.63	65	0.99	80	1.00
V5	% Woody Cover	10.0	1.00	8.0	0.82	6.0	0.64
V6	Interspersion	%	1.00	%	0.95	%	0.80
	Class 1	100		75			
	Class 2			25		100	
	Class 3						
	Class 4						
	Class 5						
V7	Beach/surf Zone	1	1.00	1	1.00	1	1.00
		HSI = 0.647		**HSI = 0.633**		**HSI = 0.751**	

927

Variable		TY11 Value	TY11 SI	TY12 Value	TY12 SI	TY13 Value	TY13 SI
V1	% Dune	0	0.10	0	0.10	0	0.10
V2	% Supratidal	0	0.10	0	0.10	0	0.10
V3	% Intertidal	100	0.10	0	0.10	0	0.10
V4	% Vegetative Cover	75	1.00	0	0.10	0	0.10
V5	% Woody Cover	4.0	0.46	0.0	0.10	0.0	0.10
V6	Interspersion	%	0.60	%	0.10	%	0.10
	Class 1						
	Class 2						
	Class 3	100					
	Class 4						
	Class 5			100		100	
V7	Beach/surf Zone	1	1.00	1	1.00	1	1.00
		HSI = 0.481		**HSI = 0.190**		**HSI = 0.190**	

928

Variable		TY50 Value	SI
V1	% Dune	0	0.10
V2	% Supratidal	0	0.10
V3	% Intertidal	0	0.10
V4	% Vegetative Cover	0	0.10
V5	% Woody Cover	0.0	0.10
V6	Interspersion	%	0.10
	Class 1		
	Class 2		
	Class 3		
	Class 4		
	Class 5	100	
V7	Beach/surf Zone	1	1.00
		HSI =	**0.190**

929

Table 21. Breton Island – Future With Project Alternative 3 – Acreage Summary

Target Year	Habitat (acres)					Total
	Dune	Supratidal	Gulf Intertidal	Bay Intertidal	Bay Subtidal	
TY0 Pre-Con	0	0	0	0	0	0
TY1 Post-Con	271	108	15	61	46	501
TY2	247	107	15	61	46	477
TY5	176	103	15	61	46	402
TY10	58	97	15	61	46	277
TY13	0	81	15	58	46	200
TY15	0	33	15	47	46	142
TY18	0	0	3	47	46	97
TY19	0	0	0	29	46	76
TY20	0	0	0	8	46	55
TY21	0	0	0	0	30	31
TY22	0	0	0	0	0	0
TY50	0	0	0	0	0	0

Table 22. Breton Island – Future With Project Alternative 3 – Summary of Acreage Benefits

Target Year	Acres	x HSI	Total HUs	Cumulative HUs
0	0	0.175	0	0
1	501	0.380	190	78
2	477	0.515	246	219
5	402	0.633	255	755
10	277	0.757	210	1173
13	200	0.780	156	549
15	142	0.789	112	268
18	97	0.481	47	231
19	76	0.454	35	40
20	55	0.415	23	29
21	31	0.190	6	13
22	0	0.190	0	3
50	0	0.190	0	0
FWP Average Annual Habitat Units				67
FWOP Average Annual Habitat Units				0
Net Average Annual Habitat Units				67

Table 23. Breton Island – Future With Project Alternative 3 – Acreage Calculations

Input	Value	Units	Process	Dune	Supratidal	Gulf Intertidal	Bay Intertidal	Bay Subtidal	Total
2007				**0**	**14**	**5**	**25**	**32**	**76**
Years passed	2.9								
Years left of supratidal acreage	0.54								
Years left of gulf intertidal acreage	0.2								
Years left of bay intertidal acreage	1.08								
Years left of bay subtidal acreage	1.08								
Gulf Intertidal Length	4,670	ft							
Supratidal Length	4,310	ft							
Shoreline recession: Longshore Loss	142	ft/yr	Loss due to longshore transport		-329,505	-132,236	-559,839	-680,304	
Shoreline recession: Overwash	36	ft/yr	Loss due to Overwash		-82,830	-33,241	-140,730	-171,012	
Shoreline recession: RSLR	10	ft/yr	Loss due to RSLR		-22,146	-8,887	-37,626	-45,722	
Shoreline Recession: Silt Loss	88	ft/yr	Offshore losses		-204,462	-82,054	-347,386	-422,136	
RSLR	0.0164	ft/yr							
Overwash distance from SBEACH	34	ft/yr	Overwash into back bay		79,128	31,755	-110,884		
Gulf Intertidal Perimeter	4,670	ft	Overwash of bay intertidal onto subtidal				134,441	-134,441	
Bay Intertidal Perimeter	3,661	ft	Subsidence out of bay intertidal				-7,858	7,858	
Bay Subtidal Perimeter	4,449	ft	Subsidence out of bay subtidal					-15,628	
Gulf Intertidal Slope 1V:	580	H							
Bay Subtidal Slope 1V:	386	H							
Subsidence	-0.005	ft/yr							
Bay Subtidal Length	4,449	ft							
Bay Intertidal Length	3,661	ft							
Bay Change Rate	19	ft/yr	Bay gain from gulf loss (overwash)		-44,872	-14,118	58,991		
			Bay gain from gulf loss (overwash)				-76,239	76,239	
TY0 Pre Construction (2014)			**Total Acres in TY0**	**0**	**0**	**0**	**0**	**0**	**0**

Input	Value	Units	Process	Dune	Supratidal	Gulf Intertidal	Bay Intertidal	Bay Subtidal	Total
TY1									
Years passed	1								
TY1 Post-Construction			**Total Acres in TY1**	**271**	**108**	**15**	**61**	**46**	**501**
TY2									
Years passed	1								
Gulf Intertidal Length	7,484	ft							
Supratidal Length	6,678	ft							
Shoreline recession: Longshore Loss	71	ft/yr	Loss due to longshore transport	-474,048					
Shoreline recession: Overwash	36	ft/yr	Loss due to overwash on run off slope		-54,087				
Shoreline recession: RSLR	10	ft/yr	Loss due to RSLR	-63,544					
Shoreline Recession: Silt Loss	74	ft/yr	Offshore losses	-491,078					
Gulf Slope 1V:	45	H							
Subsidence	0.005	ft/yr	Subsidence out of highest elevation	-1,503					
Longshore supratidal length of run-off slope	1,520								
TY2			**Total Acres in TY2**	**247**	**107**	**15**	**61**	**46**	**477**
TY5									
Years passed	3								
Gulf Intertidal Length	7,484	ft							
Supratidal Length	6,678	ft							
Shoreline recession: Longshore Loss	71	ft/yr	Loss due to longshore transport	-1,422,144					
Shoreline recession: Overwash	36	ft/yr	Loss due to overwash on run off slope		-162,260				
Shoreline recession: RSLR	10	ft/yr	Loss due to RSLR	-190,633					
Shoreline Recession: Silt Loss	74	ft/yr	Offshore losses	-1,473,233					
Gulf Slope 1V:	45	H							
Subsidence	0.005	ft/yr	Subsidence out of highest elevation	-4,508					
Longshore supratidal length of run-off slope	1,520								
TY5			**Total Acres in TY5**	**176**	**103**	**15**	**61**	**46**	**402**

Input	Value	Units	Process	Dune	Supratidal	Gulf Intertidal	Bay Intertidal	Bay Subtidal	Total
TY10									
Years passed	5								
Gulf Intertidal Length	7,484	ft							
Supratidal Length	6,678	ft							
Shoreline recession: Longshore Loss	71	ft/yr	Loss due to longshore transport	-2,370,239					
Shoreline recession: Overwash	36	ft/yr	Loss due to overwash on run off slope		-270,434				
Shoreline recession: RSLR	10	ft/yr	Loss due to RSLR	-317,722					
Shoreline Recession: Silt Loss	74	ft/yr	Offshore losses	-2,455,388					
Gulf Slope 1V:	45 H								
Subsidence	0.005	ft/yr	Subsidence out of highest elevation	-7,513					
Longshore supratidal length of run-off slope	1,520								
TY10			**Total Acres in TY10**	**58**	**97**	**15**	**61**	**46**	**277**
TY13									
Years passed	3								
Years left of dune acreage	2.44								
Years left of supratidal acreage	0.56								
Supratidal Length	6,678	ft							
Shoreline recession: Longshore Loss	71	ft/yr	Loss due to longshore transport	-1,156,677	-265,467				
Shoreline recession: Overwash	36	ft/yr	Loss due to overwash		-265,067				
Shoreline recession: RSLR	10	ft/yr	Loss due to RSLR	-155,048	-35,585				
Shoreline Recession: Silt Loss	74	ft/yr	Offshore losses	-1,198,229	-275,003				
Overwash distance from SBEACH	34	ft/yr	Overwash over dune platform		127,148		-127,148		
Gulf Slope 1V:	45 H								
Subsidence	0.005	ft/yr	Subsidence out of highest elevation	-3,666					
Longshore supratidal length of run-off slope	1,520								
TY13			**Total Acres in TY13**	**0**	**81**	**15**	**58**	**46**	**200**

Input	Value	Units	Process	Dune	Supratidal	Gulf Intertidal	Bay Intertidal	Bay Subtidal	Total
TY15									
Years passed	2								
Supratidal Length	6,678	ft							
Shoreline recession: Longshore Loss	71	ft/yr	Loss due to longshore transport		-948,096				
Shoreline recession: Overwash	36	ft/yr	Loss due to overwash - dune		-475,342				
Shoreline recession: RSLR	10	ft/yr	Loss due to RSLR		-127,089				
Shoreline Recession: Silt Loss	74	ft/yr	Offshore losses		-982,155				
Overwash distance from SBEACH	34	ft/yr	Overwash over dune platform		454,099		-454,099		
TY15			**Total Acres in TY15**	**0**	**33**	**15**	**47**	**46**	**142**
TY18									
Years passed	3								
Years left of supratidal acreage	2.55								
Years left of gulf intertidal acreage	0.45								
Gulf Intertidal Length	7,484	ft							
Supratidal Length	6,678	ft							
Shoreline recession: Longshore Loss	71	ft/yr	Loss due to longshore transport		-1,208,822	-239,067			
Shoreline recession: Overwash	36	ft/yr	Loss due to overwash - dune		606,061	-119,860			
Shoreline recession: RSLR	10	ft/yr	Loss due to RSLR		-162,038	-32,046			
Shoreline Recession: Silt Loss	74	ft/yr	Offshore losses		-1,252,248	-247,655			
Overwash distance from SBEACH	34	ft/yr	Overwash over dune platform		578,977	114,503			
TY18			**Total Acres in TY18**	**0**	**0**	**3**	**47**	**46**	**97**

Input	Value	Units	Process	Dune	Supratidal	Gulf Intertidal	Bay Intertidal	Bay Subtidal	Total
TY19									
Years passed	1								
Years left of gulf intertidal acreage	0.11								
Years left of bay intertidal acreage	0.89								
Gulf Intertidal Length	7,484	ft							
Shoreline recession: Longshore Loss	71	ft/yr	Loss due to longshore transport			-58,438	-360,022		
Shoreline recession: Overwash	36	ft/yr	Loss due to overwash - dune			-29,299	-180,503		
Shoreline recession: RSLR	10	ft/yr	Loss due to RSLR			-7,833	-48,260		
Shoreline Recession: Silt Loss	74	ft/yr	Offshore losses			-60,538	-372,956		
Overwash distance from SBEACH	34	ft/yr	Overwash over dune platform			27,990	144,446		
Bay Intertidal Length	5,698	ft							
TY19			**Total Acres in TY19**	**0**	**0**	**0**	**29**	**46**	**76**
TY20									
Years passed	1								
Years left of gulf intertidal acreage	1								
Shoreline recession: Longshore Loss	71	ft/yr	Loss due to longshore transport				-404,519		
Shoreline recession: Overwash	36	ft/yr	Loss due to overwash - dune				-202,812		
Shoreline recession: RSLR	10	ft/yr	Loss due to RSLR				-54,224		
Shoreline Recession: Silt Loss	74	ft/yr	Offshore losses				-419,051		
Overwash distance from SBEACH	34	ft/yr	Overwash over dune platform				193,748		
Bay Subtidal Length	6,232	ft							
Bay Intertidal Length	5,698	ft							
TY20			**Total Acres in TY20**	**0**	**0**	**0**	**8**	**46**	**55**

Input	Value	Units	Process	Dune	Supratidal	Gulf Intertidal	Bay Intertidal	Bay Subtidal	Total
TY21									
Years passed	1								
Years left of gulf intertidal acreage	0.4								
Years left of bay intertidal acreage	0.6								
Shoreline recession: Longshore Loss	71	ft/yr	Loss due to longshore transport				-161,808	-265,428	
Shoreline recession: Overwash	36	ft/yr	Loss due to overwash - dune				-81,125	-133,076	
Shoreline recession: RSLR	10	ft/yr	Loss due to RSLR				-21,690	-35,580	
Shoreline Recession: Silt Loss	74	ft/yr	Offshore losses				-167,621	-274,963	
Overwash distance from SBEACH	34	ft/yr	Overwash over dune platform				77,499		
Bay Subtidal Length	6,232	ft							
Bay Intertidal Length	5,698	ft							
TY21			**Total Acres in TY21**	**0**	**0**	**0**	**0**	**30**	**31**
TY22									
Years passed	2								
Years left of bay intertidal acreage	1.12								
Shoreline recession: Longshore Loss	71	ft/yr	Loss due to longshore transport					-495,465	
Shoreline recession: Overwash	36	ft/yr	Loss due to overwash - dune					-248,409	
Shoreline recession: RSLR	10	ft/yr	Loss due to RSLR					-66,415	
Shoreline Recession: Silt Loss	74	ft/yr	Offshore losses					-513,264	
Bay Subtidal Length	6,232	ft							
TY22			**Total Acres in TY22**	**0**	**0**	**0**	**0**	**0**	**0**
TY50									
Years passed	28								
TY50			**Total Acres in TY50**	**0**	**0**	**0**	**0**	**0**	**0**

Table 24. Breton Island – Future With Project Alternative 3 – HSI Calculations

Variable		TY0 Pre-Con Value	TY0 Pre-Con SI	TY1 Post-Con Value	TY1 Post-Con SI	TY2 Value	TY2 SI
V1	% Dune	0	0.10	60	0.10	57	0.10
V2	% Supratidal	0	0.10	24	1.00	25	1.00
V3	% Intertidal	0	0.10	17	0.10	18	0.10
V4	% Vegetative Cover	0	0.10	7	0.20	19	0.36
V5	% Woody Cover	0.0	0.10	5.0	0.55	8.0	0.82
V6	Interspersion	%		%	0.10	%	0.60
	Class 1						
	Class 2						
	Class 3					100	
	Class 4						
	Class 5			100			
V7	Beach/surf Zone	1	1.00	1	1.00	1	1.00
		HSI = 0.175		**HSI = 0.380**		**HSI = 0.515**	

Variable		TY5 Value	TY5 SI	TY10 Value	TY10 SI	TY13 Value	TY13 SI
V1	% Dune	50	0.10	25	0.64	0	0.10
V2	% Supratidal	29	1.00	42	0.97	53	0.81
V3	% Intertidal	21	0.10	33	0.23	47	0.88
V4	% Vegetative Cover	33	0.56	50	0.79	80	1.00
V5	% Woody Cover	10.0	1.00	10.0	1.00	8.0	0.82
V6	Interspersion	%	1.00	%	0.90	%	0.80
	Class 1	100		50			
	Class 2			50		100	
	Class 3						
	Class 4						
	Class 5						
V7	Beach/surf Zone	1	1.00	1	1.00	1	1.00
		HSI = 0.633		**HSI = 0.757**		**HSI = 0.780**	

Variable		TY15 Value	TY15 SI	TY18 Value	TY18 SI	TY19 Value	TY19 SI
V1	% Dune	0	0.10	0	0.10	0	0.10
V2	% Supratidal	35	1.00	0	0.10	0	0.10
V3	% Intertidal	65	1.00	100	0.10	100	0.10
V4	% Vegetative Cover	64	0.98	73	1.00	75	1.00
V5	% Woody Cover	6.0	0.64	4.0	0.46	1.0	0.19
V6	Interspersion	%	0.70	%	0.60	%	0.60
	Class 1						
	Class 2	50					
	Class 3	50		100		100	
	Class 4						
	Class 5						
V7	Beach/surf Zone	1	1.00	1	1.00	1	1.00
		HSI = 0.789		**HSI = 0.481**		**HSI = 0.454**	

Variable		TY20 Value	TY20 SI	TY21 Value	TY21 SI	TY22 Value	TY22 SI
V1	% Dune	0	0.10	0	0.10	0	0.10
V2	% Supratidal	0	0.10	0	0.10	0	0.10
V3	% Intertidal	100	0.10	0	0.10	0	0.10
V4	% Vegetative Cover	75	1.00	0	0.10	0	0.10
V5	% Woody Cover	0.0	0.10	0.0	0.10	0.0	0.10
V6	Interspersion	%	0.40	%	0.10	%	0.10
	Class 1						
	Class 2						
	Class 3						
	Class 4	100					
	Class 5			100		100	
V7	Beach/surf Zone	1	1.00	1	1.00	1	1.00
		HSI = 0.415		**HSI = 0.190**		**HSI = 0.190**	

940

Variable		TY50 Value	SI
V1	% Dune	0	0.10
V2	% Supratidal	0	0.10
V3	% Intertidal	0	0.10
V4	% Vegetative Cover	0	0.10
V5	% Woody Cover	0.0	0.10
V6	Interspersion Class 1 Class 2 Class 3 Class 4 Class 5	% 100	0.10
V7	Beach/surf Zone	1	1.00
		HSI =	**0.190**

941

Table 25. Breton Island – Future With Project Alternative 4A – Acreage Summary

Target Year	Habitat (acres)					Total
	Dune	Supratidal	Gulf Intertidal	Bay Intertidal	Bay Subtidal	
TY0 Pre-Con	0	0	0	0	0	0
TY1 Post-Con	266	41	28	37	28	401
TY2	230	41	28	37	28	365
TY5	121	41	28	37	28	256
TY7	0	102	28	37	28	195
TY10	0	0	7	37	28	73
TY11	0	0	0	8	28	37
TY12	0	0	0	0	2	2
TY13	0	0	0	0	0	0
TY50	0	0	0	0	0	0

Table 26. Breton Island – Future With Project Alternative 4B – Acreage Summary

Target Year	Habitat (acres)					Total
	Dune	Supratidal	Gulf Intertidal	Bay Intertidal	Bay Subtidal	
TY0 Pre-Con	0	0	0	0	0	0
TY1 Post-Con	135	22	22	14	14	207
TY2	122	28	22	14	14	200
TY5	118	42	22	14	14	211
TY7	0	176	22	14	14	227
TY10	0	163	22	14	14	214
TY11	0	153	22	14	14	204
TY12	0	142	22	14	14	193
TY13	0	132	22	14	14	183
TY20	0	59	22	14	14	109
TY22	0	15	22	14	14	65
TY23	0	0	16	14	14	45
TY24	0	0	0	4	14	19
TY25	0	0	0	0	1	1
TY26	0	0	0	0	0	0
TY50	0	0	0	0	0	0

Table 27. Breton Island – Future With Project Alternative 4 – Acreage Summary

Target Year	Habitat (acres)					Total
	Dune	Supratidal	Gulf Intertidal	Bay Intertidal	Subtidal	
TY0 Pre-Con	0	0	0	0	0	0
TY1 Post-Con	401	63	50	51	42	608
TY2	352	69	50	51	42	565
TY5	239	83	50	51	42	467
TY7	0	278	50	51	42	422
TY10	0	163	29	51	42	287
TY11	0	153	22	22	42	241
TY12	0	142	22	14	16	195
TY13	0	132	22	14	14	183
TY20	0	59	22	14	14	109
TY22	0	15	22	14	14	65
TY23	0	0	16	14	14	45
TY24	0	0	0	4	14	19
TY25	0	0	0	0	1	1
TY26	0	0	0	0	0	0
TY50	0	0	0	0	0	0

Table 28. Breton Island – Future With Project Alternative 4 – Summary of Acreage Benefits

Target Year	Acres	x HSI	Total HUs	Cumulative HUs
0	0	0.190	0	0
1	608	0.322	196	85
2	565	0.462	261	229
5	467	0.621	290	834
7	422	0.633	267	557
10	287	0.656	188	684
11	241	0.589	142	165
12	195	0.530	103	122
13	183	0.522	96	99
20	109	0.598	65	569
22	65	0.757	49	117
23	45	0.417	19	33
24	19	0.415	8	13
25	1	0.190	0	3
26	0	0.190	0	0
50	0	0.190	0	0
FWP Average Annual Habitat Units				70
FWOP Average Annual Habitat Units				0
Net Average Annual Habitat Units				70

Table 29. Breton Island – Future With Project Alternative 4A – Acreage Calculations

Input	Value	Units	Process	Dune	Supratidal	Gulf Intertidal	Bay Intertidal	Bay Subtidal	Total
2007				**0**	**14**	**5**	**25**	**32**	**76**
Years passed	2.9								
Years left of supratidal acreage	0.54								
Years left of gulf intertidal acreage	0.2								
Years left of bay intertidal acreage	1.08								
Years left of bay subtidal acreage	1.08								
Gulf Intertidal Length	4,670	ft							
Supratidal Length	4,310	ft							
Shoreline recession: Longshore Loss	142	ft/yr	Loss due to longshore transport		-329,505	-132,236	-559,839	-680,304	
Shoreline recession: Overwash	36	ft/yr	Loss due to Overwash		-82,830	-33,241	-140,730	-171,012	
Shoreline recession: RSLR	10	ft/yr	Loss due to RSLR		-22,146	-8,887	-37,626	-45,722	
Shoreline Recession: Silt Loss	88	ft/yr	Offshore losses		-204,462	-82,054	-347,386	-422,136	
RSLR	0.0164	ft/yr							
Overwash distance from SBEACH	34	ft/yr	Overwash into back bay		79,128	31,755	-110,884		
Gulf Intertidal Perimeter	4,670	ft	Overwash of bay intertidal onto subtidal				134,441	-134,441	
Bay Intertidal Perimeter	3,661	ft	Subsidence out of bay intertidal				-7,858	7,858	
Bay Subtidal Perimeter	4,449	ft	Subsidence out of bay subtidal					-15,628	
Gulf Intertidal Slope 1V:	580	H							
Bay Subtidal Slope 1V:	386	H							
Subsidence	-0.005	ft/yr							
Bay Subtidal Length	4,449	ft							
Bay Intertidal Length	3,661	ft							
Bay Change Rate	19	ft/yr	Bay gain from gulf loss (overwash)		-44,872	-14,118	58,991		
			Bay gain from gulf loss (overwash)				-76,239	76,239	
TY0 Pre Construction (2014)			**Total Acres in TY0**	**0**	**0**	**0**	**0**	**0**	**0**

Input	Value	Units	Process	Dune	Supratidal	Gulf Intertidal	Bay Intertidal	Bay Subtidal	Total
TY1									
Years passed	1								
TY1 Post-Construction			**Total Acres in TY1**	**266**	**41**	**28**	**37**	**28**	**401**
TY2									
Years passed	1								
Years left of dune acreage	1								
Supratidal Length	11,779	ft							
Shoreline recession: Longshore Loss	46	ft/yr	Loss due to longshore transport	-544,649					
Shoreline recession: RSLR	10	ft/yr	Loss due to RSLR	-112,086					
Shoreline Recession: Silt Loss	78.0	ft/yr	Offshore losses	-919,351					
Gulf Slope 1V:	45	H							
Subsidence	-0.005	ft/yr	Subsidence out of highest elevation	-2,650					
TY2			**Total Acres in TY2**	**230**	**41**	**28**	**37**	**28**	**365**
TY5									
Years passed	3								
Years left of dune acreage	3								
Supratidal Length	11,779	ft							
Shoreline recession: Longshore Loss	46	ft/yr	Loss due to longshore transport	-1,633,947					
Shoreline recession: RSLR	10	ft/yr	Loss due to RSLR	-336,259					
Shoreline Recession: Silt Loss	78	ft/yr	Offshore losses	-2,758,054					
Gulf Slope 1V:	45	H							
Subsidence	-0.005	ft/yr	Subsidence out of highest elevation	-7,951					
TY5			**Total Acres in TY5**	**121**	**41**	**28**	**37**	**28**	**256**

Input	Value	Units	Process	Dune	Supratidal	Gulf Intertidal	Bay Intertidal	Bay Subtidal	Total
TY7									
Years passed	2								
Years left of dune acreage	2								
Supratidal Length	11,779	ft							
Shoreline recession: Longshore Loss	46	ft/yr	Loss due to longshore transport	-1,089,298					
Shoreline recession: RSLR	10	ft/yr	Loss due to RSLR	-224,173					
Shoreline Recession: Silt Loss	78	ft/yr	Offshore losses	-1,838,703					
Overwash distance from SBEACH	44	ft	Overwash - widening of island	-2,106,817	2,625,104				
Gulf Slope 1V:	45	H							
Subsidence	-0.005	ft/yr	Subsidence out of highest elevation	-5,301					
TY7			**Total Acres in TY7**	**0**	**102**	**28**	**37**	**28**	**195**
TY10									
Years passed	3								
Years left of supratidal acreage	2.49								
Years left of gulf intertidal acreage	0.51								
Gulf Intertidal Length	11,938								
Supratidal Length	11,779	ft							
Shoreline recession: Longshore Loss	46	ft/yr	Loss due to longshore transport		-1,356,176	-281,518			
Shoreline recession: RSLR	10	ft/yr	Loss due to RSLR		-279,095	-57,935			
Shoreline Recession: Silt Loss	78	ft/yr	Offshore losses		-2,289,185	-475,193			
Overwash distance from SBEACH	-17	ft/yr	Net overwash exchange		-498,616	-103,504			
TY10			**Total Acres in TY10**	**0**	**0**	**7**	**37**	**28**	**73**

Input	Value	Units	Process	Dune	Supratidal	Gulf Intertidal	Bay Intertidal	Bay Subtidal	Total
TY11									
Years passed	1								
Years left of gulf intertidal acreage	0.17								
Years left of bay intertidal acreage	0.83								
Gulf Intertidal Length	11,938	ft							
Shoreline recession: Longshore Loss	46	ft/yr	Loss due to longshore transport			-93,839	-385,720		
Shoreline recession: RSLR	10	ft/yr	Loss due to RSLR			-19,312	-79,380		
Shoreline Recession: Silt Loss	78	ft/yr	Offshore losses			-158,398	-651,084		
Overwash distance from SBEACH	-17	ft/yr	Net overwash exchange			-34,501	-141,815		
Bay Intertidal Length	10,051	ft							
TY11			**Total Acres in TY11**	**0**	**0**	**0**	**8**	**28**	**37**
TY12									
Years passed	1								
Years left of bay intertidal acreage	0.24								
Years left of bay subtidal acreage	0.76								
Shoreline recession: Longshore Loss	46	ft/yr	Loss due to longshore transport				-111,533	-349,737	
Shoreline recession: RSLR	10	ft/yr	Loss due to RSLR				-22,953	-71,974	
Shoreline Recession: Silt Loss	78	ft/yr	Offshore losses				-188,265	-590,346	
Overwash distance from SBEACH	-17	ft/yr	Overwash into back bay				-41,007	-128,585	
Bay Intertidal Length	10,051	ft							
Bay Subtidal Length	9,952	ft							
TY12			**Total Acres in TY12**	**0**	**0**	**0**	**0**	**2**	**2**

Input	Value	Units	Process	Dune	Supratidal	Gulf Intertidal	Bay Intertidal	Bay Subtidal	Total
TY13									
Years passed	1								
Years left of bay subtidal acreage	0.06								
Shoreline recession: Longshore Loss	46	ft/yr	Loss due to longshore transport					-27,611	
Shoreline recession: RSLR	10	ft/yr	Loss due to RSLR					-5,682	
Shoreline Recession: Silt Loss	78	ft/yr	Offshore losses					-46,606	
Overwash distance from SBEACH	-17	ft/yr	Overwash into back bay					-10,151	
Bay Subtidal Length	9,952	ft							
TY13			**Total Acres in TY13**	**0**	**0**	**0**	**0**	**0**	**0**
TY50									
Years passed	37								
TY50			**Total Acres in TY50**	**0**	**0**	**0**	**0**	**0**	**0**

Table 30. Breton Island – Future With Project Alternative 4B – Acreage Calculations

Input	Value	Units	Process	Dune	Supratidal	Gulf Intertidal	Bay Intertidal	Bay Subtidal	Total
2007				**0**	**14**	**5**	**25**	**32**	**76**
Years passed	2.9								
Years left of supratidal acreage	0.54								
Years left of gulf intertidal acreage	0.2								
Years left of bay intertidal acreage	1.08								
Years left of bay subtidal acreage	1.08								
Gulf Intertidal Length	4,670	ft							
Supratidal Length	4,310	ft							
Shoreline recession: Longshore Loss	142	ft/yr	Loss due to longshore transport		-329,505	-132,236	-559,839	-680,304	
Shoreline recession: Overwash	36	ft/yr	Loss due to Overwash		-82,830	-33,241	-140,730	-171,012	
Shoreline recession: RSLR	10	ft/yr	Loss due to RSLR		-22,146	-8,887	-37,626	-45,722	
Shoreline Recession: Silt Loss	88	ft/yr	Offshore losses		-204,462	-82,054	-347,386	-422,136	
RSLR	0.0164	ft/yr							
Overwash distance from SBEACH	34	ft/yr	Overwash into back bay		79,128	31,755	-110,884		
Gulf Intertidal Perimeter	4,670	ft	Overwash of bay intertidal onto subtidal				134,441	-134,441	
Bay Intertidal Perimeter	3,661	ft	Subsidence out of bay intertidal				-7,858	7,858	
Bay Subtidal Perimeter	4,449	ft	Subsidence out of bay subtidal					-15,628	
Gulf Intertidal Slope 1V:	580	H							
Bay Subtidal Slope 1V:	386	H							
Subsidence	-0.005	ft/yr							
Bay Subtidal Length	4,449	ft							
Bay Intertidal Length	3,661	ft							
Bay Change Rate	19	ft/yr	Bay gain from gulf loss (overwash)		-44,872	-14,118	58,991		
			Bay gain from gulf loss (overwash)				-76,239	76,239	
TY0 Pre Construction (2014)			**Total Acres in TY0**	**0**	**0**	**0**	**0**	**0**	**0**

Input	Value	Units	Process	Dune	Supratidal	Gulf Intertidal	Bay Intertidal	Bay Subtidal	Total
TY1									
Years passed	1								
TY1 Post-Construction			**Total Acres in TY1**	**135**	**22**	**22**	**14**	**14**	**207**
TY2									
Years passed	1								
Years left of dune acreage	1								
Supratidal Length	7,000	ft							
Shoreline recession: Longshore Loss	-39	ft/yr	Gain due to longshore transport		270,000				
Shoreline recession: RSLR	10	ft/yr	Loss due to RSLR	-66,609					
Shoreline Recession: Silt Loss	72.2	ft/yr	Offshore losses	-505,157					
Gulf Slope 1V:	45	H							
Subsidence	- 0.005	ft/yr	Subsidence out of highest elevation	-1,575					
Length of fillet	3,695	ft							
TY2			**Total Acres in TY2**	**122**	**28**	**22**	**14**	**14**	**200**
TY5									
Years passed	3								
Years left of dune acreage	3								
Supratidal Length	7,000	ft							
Shoreline recession: Longshore Loss	-39	ft/yr	Gain due to longshore transport		810,000				
Shoreline recession: RSLR	10	ft/yr	Loss due to RSLR	-21,225	-178,603				
Shoreline Recession: Silt Loss	72	ft/yr	Offshore losses	-160,965					
Gulf Slope 1V:	45	H							
Subsidence	- 0.005	ft/yr	Subsidence out of highest elevation	-4,725					
Length of fillet	6,256	ft							
TY5			**Total Acres in TY5**	**118**	**42**	**22**	**14**	**14**	**211**

Input	Value	Units	Process	Dune	Supratidal	Gulf Intertidal	Bay Intertidal	Bay Subtidal	Total
TY7									
Years passed	2								
Years left of dune acreage	2								
Supratidal Length	7,000	ft							
Shoreline recession: Longshore Loss	-39	ft/yr	Gain due to longshore transport		540,000				
Shoreline recession: RSLR	10	ft/yr	Loss due to RSLR	-530	-132,689				
Shoreline Recession: Silt Loss	72	ft/yr	Offshore losses	-4,016					
Overwash distance from SBEACH	44	ft	Overwash	-5,112,049	5,420,049				
Gulf Slope 1V:	45	H							
Subsidence	- 0.005	ft/yr	Subsidence out of highest elevation	-3,150					
Length of fillet	6,972	ft							
TY7			**Total Acres in TY7**	**0**	**176**	**22**	**14**	**14**	**227**
TY10									
Years passed	3								
Years left of supratidal acreage	3.00								
Years left of gulf intertidal acreage	0.00								
Gulf Intertidal Length	7,000								
Supratidal Length	7,000	ft							
Shoreline recession: Longshore Loss	0	ft/yr	Loss due to longshore transport		0				
Shoreline recession: RSLR	10	ft/yr	Loss due to RSLR		-199,827				
Shoreline Recession: Silt Loss	0	ft/yr	Offshore losses		0				
Overwash distance from SBEACH	-17	ft/yr	Net overwash exchange		-357,000				
TY10			**Total Acres in TY10**	**0**	**163**	**22**	**14**	**14**	**214**
TY11									
Years passed	1								
Gulf Intertidal Length	7,000	ft							
Shoreline recession: Longshore Loss	39	ft/yr	Loss due to longshore transport		-270,000				
Shoreline recession: RSLR	10	ft/yr	Loss due to RSLR		-66,609				
Shoreline Recession: Silt Loss	0	ft/yr	Offshore losses						
Overwash distance from SBEACH	-17	ft/yr	Net overwash exchange		-119,000				
TY11			**Total Acres in TY11**	**0**	**153**	**22**	**14**	**14**	**204**

Input	Value	Units	Process	Dune	Supratidal	Gulf Intertidal	Bay Intertidal	Bay Subtidal	Total
TY12									
Years passed	1								
Gulf Intertidal Length	7,000	ft							
Shoreline recession: Longshore Loss	39	ft/yr	Loss due to longshore transport		-270,000				
Shoreline recession: RSLR	10	ft/yr	Loss due to RSLR		-66,609				
Shoreline Recession: Silt Loss	0	ft/yr	Offshore losses						
Overwash distance from SBEACH	-17	ft/yr	Net overwash exchange		-119,000				
TY12			**Total Acres in TY12**	**0**	**142**	**22**	**14**	**14**	**193**
TY13									
Years passed	1								
Gulf Intertidal Length	7,000	ft							
Shoreline recession: Longshore Loss	39	ft/yr	Loss due to longshore transport		-270,000				
Shoreline recession: RSLR	10	ft/yr	Loss due to RSLR		-66,609				
Shoreline Recession: Silt Loss	0	ft/yr	Offshore losses						
Overwash distance from SBEACH	-17	ft/yr	Net overwash exchange		-119,000			0	
TY13			**Total Acres in TY13**	**0**	**132**	**22**	**14**	**14**	**183**
TY20									
Years passed	7								
Gulf Intertidal Length	7,000	ft							
Shoreline recession: Longshore Loss	39	ft/yr	Loss due to longshore transport		-1,890,000				
Shoreline recession: RSLR	10	ft/yr	Loss due to RSLR		-466,263				
Shoreline Recession: Silt Loss	0	ft/yr	Offshore losses						
Overwash distance from SBEACH	-17	ft/yr	Net overwash exchange		-833,000				
TY20			**Total Acres in TY20**	**0**	**59**	**22**	**14**	**14**	**109**

Input	Value	Units	Process	Dune	Supratidal	Gulf Intertidal	Bay Intertidal	Bay Subtidal	Total
TY22									
Years passed	2								
Gulf Intertidal Length	7,000	ft							
Shoreline recession: Longshore Loss	39	ft/yr	Loss due to longshore transport		-540,000				
Shoreline recession: RSLR	10	ft/yr	Loss due to RSLR		-133,218				
Shoreline Recession: Silt Loss	72	ft/yr	Offshore losses		-1,010,314				
Overwash distance from SBEACH	-17	ft/yr	Net overwash exchange		-238,000				
TY22			**Total Acres in TY22**	**0**	**15**	**22**	**14**	**14**	**65**
TY23									
Years passed	1								
Years of Supratidal	0.665								
Gulf Intertidal Length	7,000	ft							
Shoreline recession: Longshore Loss	39	ft/yr	Loss due to longshore transport		-179,550	-90,450			
Shoreline recession: RSLR	10	ft/yr	Loss due to RSLR		-44,295	-22,314			
Shoreline Recession: Silt Loss	72	ft/yr	Offshore losses		-335,929	-169,228			
Overwash distance from SBEACH	-17	ft/yr	Net overwash exchange		-79,135	39,865			
TY23			**Total Acres in TY23**	**0**	**0**	**16**	**14**	**14**	**45**
TY24									
Years passed	1								
Years of Supratidal	0.73								
Gulf Intertidal Length	7,000	ft							
Shoreline recession: Longshore Loss	39	ft/yr	Loss due to longshore transport			-197,100	72,900		
Shoreline recession: RSLR	10	ft/yr	Loss due to RSLR			-48,625	17,984		
Shoreline Recession: Silt Loss	72	ft/yr	Offshore losses			-368,765	136,392		
Overwash distance from SBEACH	-17	ft/yr	Net overwash exchange			-86,870	-32,130		
TY24			**Total Acres in TY24**	**0**	**0**	**0**	**4**	**14**	**19**

Input	Value	Units	Process	Dune	Supratidal	Gulf Intertidal	Bay Intertidal	Bay Subtidal	Total
TY25									
Years passed	1								
Years of Supratidal	0.203								
Gulf Intertidal Length	7,000	ft							
Shoreline recession: Longshore Loss	39	ft/yr	Loss due to longshore transport				-54,810	-215,190	
Shoreline recession: RSLR	10	ft/yr	Loss due to RSLR				-13,522	-53,087	
Shoreline Recession: Silt Loss	72	ft/yr	Offshore losses				-102,547	-402,610	
Overwash distance from SBEACH	-17	ft/yr	Net overwash exchange				-24,157	94,843	
TY25			**Total Acres in TY25**	**0**	**0**	**0**	**0**	**1**	**1**
TY26									
Years passed	1								
Years of Supratidal	0.057								
Gulf Intertidal Length	7,000	ft							
Shoreline recession: Longshore Loss	39	ft/yr	Loss due to longshore transport					-15,390	
Shoreline recession: RSLR	10	ft/yr	Loss due to RSLR					-3,797	
Shoreline Recession: Silt Loss	72	ft/yr	Offshore losses					-28,794	
Overwash distance from SBEACH	-17	ft/yr	Net overwash exchange					-6,783	
TY26			**Total Acres in TY26**	**0**	**0**	**0**	**0**	**0**	**0**
TY50									
Years passed	24								
TY50			**Total Acres in TY50**	**0**	**0**	**0**	**0**	**0**	**0**

Table 31. Breton Island – Future With Project Alternative 4 – HSI Calculations

Variable		TY0 Pre-Con Value	TY0 Pre-Con SI	TY1 Post-Con Value	TY1 Post-Con SI	TY2 Value	TY2 SI
V1	% Dune	0	0.10	71	0.10	67	0.10
V2	% Supratidal	0	0.10	11	0.60	13	0.69
V3	% Intertidal	0	0.10	18	0.10	19	0.10
V4	% Vegetative Cover	0	0.10	6	0.18	15	0.31
V5	% Woody Cover	0.0	0.10	5.0	0.55	8.0	0.82
V6	Interspersion	%	0.10	%	0.10	%	0.60
	Class 1						
	Class 2						
	Class 3					100	
	Class 4						
	Class 5	100		100			
V7	Beach/surf Zone	1	1.00	1	1.00	1	1.00
		HSI =	**0.190**	**HSI =**	**0.322**	**HSI =**	**0.462**

Variable		TY5 Value	TY5 SI	TY7 Value	TY7 SI	TY10 Value	TY10 SI
V1	% Dune	57	0.10	0	0.10	0	0.10
V2	% Supratidal	20	0.98	73	0.50	67	0.59
V3	% Intertidal	24	0.10	27	0.10	33	0.23
V4	% Vegetative Cover	30	0.51	64	0.98	65	1.00
V5	% Woody Cover	10.0	1.00	10.0	1.00	10.0	1.00
V6	Interspersion	%	1.00	%	0.90	%	0.80
	Class 1	100		50			
	Class 2			50		100	
	Class 3						
	Class 4						
	Class 5						
V7	Beach/surf Zone	1	1.00	1	1.00	1	1.00
		HSI = 0.621		**HSI = 0.633**		**HSI = 0.656**	

956

Variable		TY11 Value	TY11 SI	TY12 Value	TY12 SI	TY13 Value	TY13 SI
V1	% Dune	0	0.10	0	0.10	0	0.10
V2	% Supratidal	78	0.44	80	0.40	79	0.42
V3	% Intertidal	22	0.10	20	0.10	21	0.10
V4	% Vegetative Cover	63	0.97	58	0.91	58	0.90
V5	% Woody Cover	8.0	0.82	6.0	0.64	4.0	0.46
V6	Interspersion	%	0.80	%	0.65	%	0.70
	Class 1						
	Class 2	100		25		50	
	Class 3			75		50	
	Class 4						
	Class 5						
V7	Beach/surf Zone	1	1.00	1	1.00	1	1.00
		HSI = 0.589		**HSI = 0.530**		**HSI = 0.522**	

927

Variable		TY20		TY22		TY23	
		Value	SI	Value	SI	Value	SI
V1	% Dune	0	0.10	0	0.10	0	0.10
V2	% Supratidal	62	0.67	29	1.00	0	0.10
V3	% Intertidal	38	0.46	71	0.98	100	0.10
V4	% Vegetative Cover	57	0.89	77	1.00	55	0.86
V5	% Woody Cover	4.0	0.46	4.0	0.46	0.0	0.10
V6	Interspersion Class 1 Class 2 Class 3 Class 4 Class 5	% 100	0.60	% 100	0.60	% 100	0.60
V7	Beach/surf Zone	1	1.00	1	1.00	1	1.00
		HSI = 0.598		**HSI = 0.757**		**HSI = 0.417**	

Variable		TY24 Value	SI	TY25 Value	SI	TY26 Value	SI
V1	% Dune	0	0.10	0	0.10	0	0.10
V2	% Supratidal	0	0.10	0	0.10	0	0.10
V3	% Intertidal	100	0.10	0	0.10	0	0.10
V4	% Vegetative Cover	75	1.00	0	0.10	0	0.10
V5	% Woody Cover	0.0	0.10	0.0	0.10	0.0	0.10
V6	Interspersion Class 1 Class 2 Class 3 Class 4 Class 5	% 100 	0.40	% 100	0.10	% 100	0.10
V7	Beach/surf Zone	1	1.00	1	1.00	1	1.00
		HSI = 0.415		**HSI = 0.190**		**HSI = 0.190**	

Variable		TY50 Value	SI
V1	% Dune	0	0.10
V2	% Supratidal	0	0.10
V3	% Intertidal	0	0.10
V4	% Vegetative Cover	0	0.10
V5	% Woody Cover	0.0	0.10
V6	Interspersion Class 1 Class 2 Class 3 Class 4 Class 5	% 100	0.10
V7	Beach/surf Zone	1	1.00
		HSI =	**0.190**

960

Table 32. Breton Island – Future With Project Alternative 5 – Acreage Summary

Target Year	Habitat (acres)					
	Dune	Supratidal	Gulf Intertidal	Bay Intertidal	Bay Subtidal	Total
TY0 Pre-Con	0	0	0	0	0	0
TY1 Post-Con	0	0	0	0	0	0
TY50	0	0	0	0	0	0

Table 33. Breton Island – Future With Project Alternative 5 – Summary of Acreage Benefits

Target Year	Acres	x HSI	Total HUs	Cumulative HUs
0	0	0.190	0	0
1	0	0.190	0	0
50	0	0.190	0	0
FWP Average Annual Habitat Units				0
FWOP Average Annual Habitat Units				0
Net Average Annual Habitat Units				0

Table 34. Breton Island – Future With Project Alternative 5 – HSI Calculations

Variable		TY0 Pre-Con Value	TY0 Pre-Con SI	TY1 Post-Con Value	TY1 Post-Con SI	TY50 Value	TY50 SI
V1	% Dune	0	0.10	0	0.10	0	0.10
V2	% Supratidal	0	0.10	0	0.10	0	0.10
V3	% Intertidal	0	0.10	0	0.10	0	0.10
V4	% Vegetative Cover	0	0.10	0	0.10	0	0.10
V5	% Woody Cover	0.0	0.10	0.0	0.10	0.0	0.10
V6	Interspersion	%	0.10	%	0.10	%	0.10
	Class 1						
	Class 2						
	Class 3						
	Class 4						
	Class 5	100		100		100	
V7	Beach/surf Zone	1	1.00	1	1.00	1	1.00
		HSI =	**0.190**	**HSI =**	**0.190**	**HSI =**	**0.190**

962

MRGO ECOSYSTEM RESTORATION
FEASIBILITY STUDY
(W912P8-09-D-0007)

APPENDIX B

COST ESTIMATES

CHANDELEUR ISLANDS
ST. BERNARD SHOALS BORROW AREA
HOPPER DREDGE

149,074 pay c.y. per month	UNIT COST..	$12.27	PER C.Y.	Select Dredge: GENERIC MEDIUM
295 c.y. per hour	EXCAV. COST	$93,853,230		
3.5 Loads/Day	TIME.....	51.31	MONTHS	

PROJECT TITLES: PG 1 of 12

Project Name.....	Chandeleur Islands
Project Location.....	Saint Bernard Parish
Invit. or Contr. No.....	Planning Estimate
Date of Estimate.....	November 7, 2009
Estimator.....	Andrew Wycklendt
Checked by.....	Gordon Thomson

Ver. 1.0

For Information, Call:
Julie Davin
Ph: 509-527-7514

(Input Project Descriptions on Sheet A) [Goto Sheet A]

Mobilization Bid Item..... 1

Excavation Bid Item..... 2 [Goto Area Factors]

TYPE OF ESTIMATE PG 2 of 12

Type of Estimate..... 1 Planning Estimate
(1) Planning, (2) Bid, or (3) Mod [Estimate Descriptions]

INDIRECT COSTS:

Contractor's Overhead...	12.0	Percent of contract
Contractor's Profit.....	10.0	Percent of contract
Contractor's Bond.....	0.8	Percent of contract

ESTIMATED DREDGING QUANTITY: PG 3 of 12

Non-Pay Computation Method: 3
(1) Surface Area, (2) % of Pay O.D., (3) % of Net Pay, (4) % of Gross

BANK HEIGHT: 10 FT.

DREDGING PRISM:

Required....	7,649,000	C.Y.		
+ Pay O.D....	0	C.Y.		
Bid Quantity	7,649,000	C.Y.		
- Not Dug..	0	C.Y.	LOSSES:	
Net Pay	7,649,000	C.Y.		
+ Non-Pay	2,294,700	C.Y.	@ 30.0	% of Net Pay
Gross Volume	9,943,700	C.Y.	10.0	FT. BANK HT.

149,074 pay c.y. per month	UNIT COST..	$12.27	PER C.Y.	Select Dredge
295 c.y. per hour	EXCAV. COST	$93,853,230		GENERIC MEDIUM
3.5 Loads/Day	TIME.....	51.31	MONTHS	

PRODUCTION WORKSHEET: part 1 of 3 PG 4 of 12

Material Classification:
10 % MUD
90 % SAND
0 % GRAVEL

Volume of Hopper (cyds)..... 3,800 (From Database)
Max Safe Load (cyds of Sand). 2,500 (From Database)

	Override	Calculated	Used
Effect Capacity (cyds)..		1,824	1,824
Excavation Rate (cy/hr) using 2 Dragheads.....		1,313	1,313
		Database	
Dragheads Used (ea).....	2	2	2

Excavation based upon 2.0 Dragheads. (cy/hr)..... 1,313
(Excavation Time per Cycle = 83 min)

PRODUCTION WORKSHEET: part 2 of 3 PG 5 of 12

Turns/Cycle..... 0 Each
Time Per Turn..... 5 Minutes
(Turning Time per Cycle = 0 min)

One-Way Haul Distance..... 18 Miles (Statute)

Speed to Disposal Area..... 11.5 mph
Max Speed Loaded..... 11.5 mph
Speed Used to D/A..... 11.5 mph
(Hauling Time to D/A per Cycle = 94 min)

Speed from Disp Area..... 12.7 mph
Max Speed Light..... 12.7 mph
Speed Used from D/A..... 12.7 mph
(Hauling Time from D/A per Cycle = 85 min)
(Total Haul Time = 179 min)

PRODUCTION WORKSHEET: part 3 of 3 PG 6 of 12

Will Pumpout be Used?..... 1 YES (0=NO)

	Override	Database	Used
Pumpout Rate (cy/hr)....		1800	1800
Pipeline Used.....	9000 lf		

Max Pipe without using a Booster..... 6,000 lf
(Pumpout Time per Cycle = 61 min)

Connect & Disconnect.... 15 Minutes per Cycle

Cleanup Dredging..... 10 % Additional Time
Time Efficiency..... 90.0 % of Effective Working Time
657 Hours Per Month

149,074 pay c.y. per month	UNIT COST..	$12.27	PER C.Y.	Select Dredge
295 c.y. per hour	EXCAV. COST	$93,853,230		GENERIC MEDIUM
3.5 Loads/Day	TIME.....	51.31	MONTHS	

PLANT OWNERSHIP AND OPERATING: part 1 of 2 — PG 7 of 12

DREDGE	Override	Database	Used
Dredge Acquisition.....	$0	$16,600,000	$ 16,600,000
Capital Improvements %..	0 %	10%	10%
REQUIRED PLANT (Monthly Costs)			
Dredge Propulsion Tug...	$0	self prop.	self prop.
Survey Vessel.....	$30,000	$0	$30,000

Goto Oper Adj Factors

PLANT OWNERSHIP AND OPERATING: part 2 of 2 — PG 8 of 12

OPTIONAL PLANT (Monthly Costs)

Booster.....Include?	0	NO (1=YES)	$100,000	<--Database
.....Override>	$300,000		$0	<--Used
Crane Barge.....Include?	0	NO (1=YES)	$7,000	<--Database
.....Override>	$0		$0	<--Used
Tender Tug.....Include?	0	NO (1=YES)	$0	<--Database
.....Override>	$1,500		$0	<--Used
Other Marine.....	$0			
Shore Equip.....	$0			

OTHER PRICING ADJUSTMENTS: — PG 9 of 12

Other Monthly Costs: — Goto Travel & Provisions

1st Input..... $200,000 Per Month
Description..... Shore Equipment and Transport
(For Additional Inputs Go to Sheet D\3) — **Goto Sheet D/3**

Fixed Costs:

1st Input..... $0 Lump Sum
Description.....
(For Additional Inputs Go to Sheet E) — **Goto Sheet E**

(To Adjust Labor Go To Sheet DB_L) — Goto Sheet DB_L

(To Adjust Equipment Go to Sheet DB_E) — Goto Sheet DB_E

149,074 pay c.y. per month	UNIT COST..	$12.27	PER C.Y.	Select Dredge
295 c.y. per hour	EXCAV. COST	$93,853,230		GENERIC MEDIUM
3.5 Loads/Day	TIME.....	51.31	MONTHS	

The Factors below normally will not change for every estimate.

LOCAL AREA FACTORS: PG 10 of 12

Present Year.....	2009	(Equipment Calculations)
Economic Index.....	7667	(EP-1110-1-8, APP E)
Labor Adjustment Factor.	0.830	(EP-1110-1-8, APP B)
Full Cost of Money Rate.	4.875	Percent per Year
Dates for Money Rate....	Jan to June 2007	
Annual Months Available for Dredging:		
Pipeline....	9	Months per Year
Bucket.....	10	Months per Year
Hopper.....	10	Months per Year
Current Fuel Price.....	$3.75	Per Gallon

Return

DREDGE OPERATING ADJUSTMENT FACTORS (OPTIONAL): PG 11 of 12

	Overide		Assumed	Used
Pump Load Factor.....	0	%	50%	50%
Adj to Exist Repair Cost... (Range .80 to 1.20)	0.00		1.00	1.00
Jet Pump Useage.....	0	%	100%	100%

Return

	Overide	Calculated	Used
Fuel Usage (Gal/Day)....	0	3,595	3,595

TRAVEL & PROVISIONS: PG 12 of 12

TRAVEL FOR DREDGE CREW:

Frequency Of Travel.....	28	days
Cost of Ticket.....	$400	per Round Trip

Return

EXTRA MEALS PROVIDED:

Gov Personnel On Dredge.	3	<-
Prov & Supplies.....	$15.00	/Man-Day

CHANDELEUR ISLANDS
HEWES POINT BORROW AREA
CUTTERHEAD DREDGE

Saint Bernard Parish	UNIT COST..	$22.35	PER C.Y.	Select Dredge
Planning Estimate	EXCAV. COST	$170,955,150		30" Cutter-Suction
30" Cutter-Suction Dredge	TIME.....	38.71	MONTHS	

PROJECT TITLES: PG 1 of 11

Ver. 1.0

Project Name.....	Chandeleur Islands
Project Location.....	Saint Bernard Parish
Invit. or Contr. No.....	Planning Estimate
Date of Estimate.....	November 7, 2009
Estimator.....	Andrew Wycklendt
Checked by.....	Gordon Thomson

(Input Project Descriptions on Sheet A) **Goto Sheet A**

Mobilization Bid Item..... 1

Excavation Bid Item..... 2 Goto Area Factors

TYPE OF ESTIMATE PG 2 of 11

Type of Estimate..... 1 Planning Estimate

(1) Planning, (2) Bid, or (3) Mod **Estimate Descriptions**

INDIRECT COSTS:

Contractor's Overhead...	12.8	Percent of contract
Contractor's Profit.....	10.0	Percent of contract
Contractor's Bond.....	0.8	Percent of contract

ESTIMATED DREDGING QUANTITY: PG 3 of 11

Non-Pay Computation Method: 3

(1) Surface Area, (2) % of Pay O.D., (3) % of Net Pay, (4) % of Gross

BANK HEIGHT: 10 FT.

DREDGING PRISM:

Required....	7,649,000	C.Y.		
+ Pay O.D....	0	C.Y.		
Bid Quantity	7,649,000	C.Y.		
- Not Dug..	0	C.Y.	LOSSES:	
Net Pay	7,649,000	C.Y.	@	
+ Non-Pay	3,824,500	C.Y.	50.0	% of Net Pay
Gross Volume	11,473,500	C.Y.	10.0	FT. BANK HT.

Saint Bernard Parish	UNIT COST..	$22.35	PER C.Y.	**Select Dredge**
Planning Estimate	EXCAV. COST	$170,955,150		30" Cutter-Suction
30" Cutter-Suction Dredge	TIME.....	38.71	MONTHS	

MATERIAL FACTORS: PG 4 of 11

DESCRIPTION	FACTOR	PERCENTAGE		
MUD & SILT	3	0	%	
MUD & SILT	2.5	0	%	
MUD & SILT	2	10	%	DIRECT ENTRY
LOOSE SAND	1.3	0	%	FACTOR= 0.00
LOOSE SAND	1	90	%	
COMP. SAND	0.9	0	%	
STIFF CLAY	0.6	0	%	
COMP. SHELL	0.5	0	%	RESULTANT MATERIAL
SOFT ROCK	0.4	0	%	FACTOR= 1.05
BLAST. ROCK	0.25	0	%	

PIPELINE CONSIDERATIONS: PG 5 of 11

MAXIMUM PIPELINE REQUIRED:

Floating Pipeline.....	1,750	Feet
Submerged Pipeline.....	55,000	Feet
Shore Pipeline.....	55,000	Feet
Total Pipeline on Job:	111,750	Feet

Ave Pumping Distance.... 84,250 Feet of Pipeline =Floating + Subline + (0.5)Total Shorepipe

Pipeline Cost Category..... 0 SAND

(0) Computed from Material Factor,
(1) Mud, (2) Sand, or (3) Rock

Equivalent Pipe..... 0 Feet (Theoretical)

Description.....

Basis of Production: 84,250 Feet (Ave + Equiv)

PRODUCTION ANALYSIS: PG 6 of 11

4 BOOSTER(S) 97,347 L.F. POSSIBLE based on 29800 Tot. H.P.

84,250 Ft Ave Pumping Distance

111,750 L.F. Max. on jobsite

75.0 % X 730 HRS/MO = EWT OF (without Boosters) 548 HRS/MO

Goto HP Adjustments

X 0.66 Booster Factor

49.5 % X 730 HRS/MO = EWT OF (with Boosters) 361 HRS/MO

Saint Bernard Parish	UNIT COST..	$22.35	PER C.Y.	Select Dredge
Planning Estimate	EXCAV. COST	$170,955,150		30" Cutter-Suction
30" Cutter-Suction Dredge	TIME.....	38.71	MONTHS	

OTHER PRODUCTION FACTORS: PG 7 of 11

CURRENT DREDGE SELECTED: 30" Cutter-Suction Dredge

Bank Factor for 10.0 ft of Bank ----> 1.10 (From Chart)

Bank Factor Override.... 0 1.10 (Used)

Description..... >

Other Factor..... 0.9

Description..... Wave Action

Cleanup Dredging..... 2 Percent Additional Time
(Cleanup Factor = 0.98)

HISTORICAL PRODUCTION OVERRIDES: PG 8 of 11

(In order to use this screen, Overrides must be entered for all three categories.)

	Override	Computed	Used
Production (Cy/Hr).....	0	821	821
Operating Time (Hrs/Mo).	0	361	361
Number of Boosters.....	0	4	4

OTHER PRICING ADJUSTMENTS: PG 9 of 11

Other Monthly Costs:

1st Input..... $0 Per Month

Description..... Shore Equipment

(For Additional Inputs Go to Sheet D\4) Goto Sheet D\4

Fixed Costs:

1st Input..... Lump Sum

Description.....

(For Additional Inputs Go to Sheet E) Goto Sheet E

(To Adjust Labor Go To Sheet DB_L) Goto Sheet DB_L

(To Adjust Equipment Go To Sheet DB_E) Goto Sheet DB_E

Saint Bernard Parish	UNIT COST..	$22.35	PER C.Y.	Select Dredge
Planning Estimate	EXCAV. COST	$170,955,150		30" Cutter-Suction
30" Cutter-Suction Dredge	TIME.....	38.71	MONTHS	

The Factors below normally will not change for every estimate.

LOCAL AREA FACTORS: PG 10 of 11

Present Year.....	2009	(Equipment Calculations)
Economic Index.....	7667	(EP-1110-1-8, APP E)
Labor Adjustment Factor.	0.830	(EP-1110-1-8, APP B)
Full Cost of Money Rate.	4.875	Percent per Year
Dates for Money Rate....	January to June 2008	
Annual Months Available for Dredging:		
Pipeline....	11	Months per Year
Bucket.....	10	Months per Year
Hopper.....	11	Months per Year
Current Fuel Price.....	$3.75	Per Gallon

2008 Marine Equipment Region 3 (SE) - 2007

Return

HP & BOOSTER FACTOR ADJUSTMENTS: PG 11 of 11

	Override	Database	Used
Total Available Pump Horsepower.....	0	9,000	9,000
Booster Pump HP.....		5,200	5,200
% Loss per booster, when job lasts:			
Less than 1 month (%)	0	15%	15%
More than 1 month (%)	0	10%	10%

Return

Without Booster Losses, this job would last 25.53 months, therefore, the 10% figure will be used.

CHANDELEUR ISLANDS
HEWES POINT BORROW AREA
HOPPER DREDGE

201,131 pay c.y. per month	UNIT COST..	$9.26	PER C.Y.	Select Dredge: GENERIC MEDIUM
398 c.y. per hour	EXCAV. COST	$70,829,740		
4.6 Loads/Day	TIME.....	38.03	MONTHS	

PROJECT TITLES: PG 1 of 12

Project Name.....	Chandeleur Islands
Project Location.....	Saint Bernard Parish
Invit. or Contr. No.....	Planning Estimate
Date of Estimate.....	November 7, 2009
Estimator.....	Andrew Wycklendt
Checked by.....	Gordon Thomson

Ver. 1.0

For Information, Call:
Julie Davin
Ph: 509-527-7514

(Input Project Descriptions on Sheet A) Goto Sheet A

Mobilization Bid Item..... 1

Excavation Bid Item..... 2 Goto Area Factors

TYPE OF ESTIMATE PG 2 of 12

Type of Estimate..... 1 Planning Estimate
(1) Planning, (2) Bid, or (3) Mod — Estimate Descriptions

INDIRECT COSTS:

Contractor's Overhead...	12.0	Percent of contract
Contractor's Profit.....	10.0	Percent of contract
Contractor's Bond.....	0.8	Percent of contract

ESTIMATED DREDGING QUANTITY: PG 3 of 12

Non-Pay Computation Method: 3
(1) Surface Area, (2) % of Pay O.D., (3) % of Net Pay, (4) % of Gross

BANK HEIGHT: 10 FT.

DREDGING PRISM:

Required....	7,649,000	C.Y.		
+ Pay O.D....	0	C.Y.		
Bid Quantity	7,649,000	C.Y.		
- Not Dug..	0	C.Y.	LOSSES:	
Net Pay	7,649,000	C.Y.		
+ Non-Pay	2,294,700	C.Y.	@ 30.0	% of Net Pay
Gross Volume	9,943,700	C.Y.	10.0	FT. BANK HT.

201,131 pay c.y. per month	UNIT COST..	$9.26	PER C.Y.	Select Dredge
398 c.y. per hour	EXCAV. COST	$70,829,740		GENERIC MEDIUM
4.6 Loads/Day	TIME.....	38.03	MONTHS	

PRODUCTION WORKSHEET: part 1 of 3 PG 4 of 12

Material Classification:
5 % MUD
95 % SAND
0 % GRAVEL

Volume of Hopper (cyds)..... 3,800 (From Database)
Max Safe Load (cyds of Sand). 2,500 (From Database)

	Override	Calculated	Used
Effect Capacity (cyds)..		1,862	1,862
Excavation Rate (cy/hr) using 2 Dragheads.....		1,286	1,286
		Database	
Dragheads Used (ea).....	2	2	2

Excavation based upon 2.0 Dragheads. (cy/hr)..... 1,286
(Excavation Time per Cycle = 87 min)

PRODUCTION WORKSHEET: part 2 of 3 PG 5 of 12

Turns/Cycle..... 0 Each
Time Per Turn..... 5 Minutes
(Turning Time per Cycle = 0 min)

One-Way Haul Distance..... 10.4 Miles (Statute)

Speed to Disposal Area..... 11.5 mph
Max Speed Loaded..... 11.5 mph
Speed Used to D/A..... 11.5 mph
(Hauling Time to D/A per Cycle = 54 min)

Speed from Disp Area..... 12.7 mph
Max Speed Light..... 12.7 mph
Speed Used from D/A..... 12.7 mph
(Hauling Time from D/A per Cycle = 49 min)
(Total Haul Time = 103 min)

PRODUCTION WORKSHEET: part 3 of 3 PG 6 of 12

Will Pumpout be Used?..... 1 YES (0=NO)

	Override	Database	Used
Pumpout Rate (cy/hr)....		1800	1800
Pipeline Used.....	9000 lf		

Max Pipe without using a Booster..... 6,000 lf
(Pumpout Time per Cycle = 62 min)

Connect & Disconnect.... 15 Minutes per Cycle

Cleanup Dredging..... 5 % Additional Time
Time Efficiency..... 90.0 % of Effective Working Time
657 Hours Per Month

201,131 pay c.y. per month	UNIT COST..	$9.26	PER C.Y.	Select Dredge
398 c.y. per hour	EXCAV. COST	$70,829,740		GENERIC MEDIUM
4.6 Loads/Day	TIME.....	38.03	MONTHS	

PLANT OWNERSHIP AND OPERATING: part 1 of 2 — PG 7 of 12

DREDGE	Override	Database	Used
Dredge Acquisition.....	$0	$16,600,000	$ 16,600,000
Capital Improvements %..	0 %	10%	10%
REQUIRED PLANT (Monthly Costs)			
Dredge Propulsion Tug...	$0	self prop.	self prop.
Survey Vessel.....	$30,000	$0	$30,000

Goto Oper Adj Factors

PLANT OWNERSHIP AND OPERATING: part 2 of 2 — PG 8 of 12

OPTIONAL PLANT (Monthly Costs)				
Booster.....Include?	0	NO (1=YES)	$100,000	<--Database
.....Override>	$300,000		$0	<--Used
Crane Barge.....Include?	0	NO (1=YES)	$7,000	<--Database
.....Override>	$0		$0	<--Used
Tender Tug.....Include?	0	NO (1=YES)	$0	<--Database
.....Override>	$1,500		$0	<--Used
Other Marine.....	$0			
Shore Equip.....	$0			

OTHER PRICING ADJUSTMENTS: — PG 9 of 12

Other Monthly Costs: — Goto Travel & Provisions

1st Input..... $200,000 Per Month
Description..... Shore Equipment and Transport
(For Additional Inputs Go to Sheet D\3) — **Goto Sheet D/3**

Fixed Costs:

1st Input..... $0 Lump Sum
Description..... >

(For Additional Inputs Go to Sheet E) — **Goto Sheet E**

(To Adjust Labor Go To Sheet DB_L) — Goto Sheet DB_L

(To Adjust Equipment Go to Sheet DB_E) — Goto Sheet DB_E

201,131 pay c.y. per month	UNIT COST..	$9.26	PER C.Y.	Select Dredge
398 c.y. per hour	EXCAV. COST	$70,829,740		GENERIC MEDIUM
4.6 Loads/Day	TIME.....	38.03	MONTHS	

The Factors below normally will not change for every estimate.

LOCAL AREA FACTORS: PG 10 of 12

Present Year.....	2009	(Equipment Calculations)
Economic Index.....	7667	(EP-1110-1-8, APP E)
Labor Adjustment Factor.	0.830	(EP-1110-1-8, APP B)
Full Cost of Money Rate.	4.875	Percent per Year
Dates for Money Rate....	Jan to June 2007	
Annual Months Available for Dredging:		
Pipeline....	9	Months per Year
Bucket.....	10	Months per Year
Hopper.....	10	Months per Year
Current Fuel Price.....	$3.75	Per Gallon

Return

DREDGE OPERATING ADJUSTMENT FACTORS (OPTIONAL): PG 11 of 12

	Overide		Assumed	Used
Pump Load Factor.....	0	%	50%	50%
Adj to Exist Repair Cost... (Range .80 to 1.20)	0.00		1.00	1.00
Jet Pump Useage.....	0	%	100%	100%

Return

	Overide	Calculated	Used
Fuel Usage (Gal/Day)....	0	3,547	3,547

TRAVEL & PROVISIONS: PG 12 of 12

TRAVEL FOR DREDGE CREW:

Frequency Of Travel.....	28	days
Cost of Ticket.....	$400	per Round Trip

Return

EXTRA MEALS PROVIDED:

Gov Personnel On Dredge.	3	<-
Prov & Supplies.....	$15.00	/Man-Day

BRETON ISLAND – ALTERNATIVE 1
ST. BERNARD SHOALS BORROW AREA
HOPPER DREDGE

101,076 pay c.y. per month	UNIT COST..	$21.38	PER C.Y.	Select Dredge
200 c.y. per hour	EXCAV. COST	$423,815,740		GENERIC MEDIUM
2.4 Loads/Day	TIME.....	196.12	MONTHS	

PROJECT TITLES: PG 1 of 12

Project Name.....	Breton Island
Project Location.....	Saint Bernard Parish
Invit. or Contr. No.....	Planning Estimate
Date of Estimate.....	November 7, 2009
Estimator.....	Andrew Wycklendt
Checked by.....	Gordon Thomson

Ver. 1.0
For Information, Call:
Julie Davin
Ph: 509-527-7514

(Input Project Descriptions on Sheet A) Goto Sheet A

Mobilization Bid Item..... 1
Excavation Bid Item..... 2 Goto Area Factors

TYPE OF ESTIMATE PG 2 of 12

Type of Estimate..... 1 Planning Estimate
(1) Planning, (2) Bid, or (3) Mod Estimate Descriptions

INDIRECT COSTS:

Contractor's Overhead...	12.0	Percent of contract
Contractor's Profit.....	10.0	Percent of contract
Contractor's Bond.....	0.8	Percent of contract

ESTIMATED DREDGING QUANTITY: PG 3 of 12

Non-Pay Computation Method: 3
(1) Surface Area, (2) % of Pay O.D., (3) % of Net Pay, (4) % of Gross

BANK HEIGHT: 10 FT.

DREDGING PRISM:

Required....	19,823,000	C.Y.		
+ Pay O.D....	0	C.Y.		
Bid Quantity	19,823,000	C.Y.		
- Not Dug..	0	C.Y.		LOSSES:
Net Pay	19,823,000	C.Y.		
+ Non-Pay	5,946,900	C.Y.	@	30.0 % of Net Pay
Gross Volume	25,769,900	C.Y.		10.0 FT. BANK HT.

101,076 pay c.y. per month	UNIT COST..	$21.38	PER C.Y.	Select Dredge
200 c.y. per hour	EXCAV. COST	$423,815,740		GENERIC MEDIUM
2.4 Loads/Day	TIME.....	196.12	MONTHS	

PRODUCTION WORKSHEET: part 1 of 3 PG 4 of 12

Material Classification:
- 10 % MUD
- 90 % SAND
- 0 % GRAVEL

Volume of Hopper (cyds)..... 3,800 (From Database)
Max Safe Load (cyds of Sand). 2,500 (From Database)

	Override	Calculated	Used
Effect Capacity (cyds)..		1,824	1,824
Excavation Rate (cy/hr) using 2 Dragheads.....		1,313	1,313
		Database	
Dragheads Used (ea).....	2	2	2

Excavation based upon 2.0 Dragheads. (cy/hr)..... 1,313
(Excavation Time per Cycle = 83 min)

PRODUCTION WORKSHEET: part 2 of 3 PG 5 of 12

Turns/Cycle..... 0 Each
Time Per Turn..... 5 Minutes
(Turning Time per Cycle = 0 min)

One-Way Haul Distance..... 34 Miles (Statute)

Speed to Disposal Area..... 11.5 mph
Max Speed Loaded..... 11.5 mph
Speed Used to D/A..... 11.5 mph
(Hauling Time to D/A per Cycle = 177 min)

Speed from Disp Area..... 12.7 mph
Max Speed Light..... 12.7 mph
Speed Used from D/A..... 12.7 mph
(Hauling Time from D/A per Cycle = 161 min)
(Total Haul Time = 338 min)

PRODUCTION WORKSHEET: part 3 of 3 PG 6 of 12

Will Pumpout be Used?..... 1 YES (0=NO)

	Override	Database	Used
Pumpout Rate (cy/hr)....		1800	1800

Pipeline Used..... 6000 lf
Max Pipe without using a Booster..... 6,000 lf
(Pumpout Time per Cycle = 61 min)

Connect & Disconnect.... 15 Minutes per Cycle

Cleanup Dredging..... 10 % Additional Time
Time Efficiency..... 90.0 % of Effective Working Time
657 Hours Per Month

101,076 pay c.y. per month	UNIT COST..	$21.38	PER C.Y.	Select Dredge
200 c.y. per hour	EXCAV. COST	$423,815,740		GENERIC MEDIUM
2.4 Loads/Day	TIME.....	196.12	MONTHS	

PLANT OWNERSHIP AND OPERATING: part 1 of 2 — PG 7 of 12

DREDGE	Override	Database	Used
Dredge Acquisition.....	$0	$16,600,000	$ 16,600,000
Capital Improvements %..	0 %	10%	10%
REQUIRED PLANT (Monthly Costs)			
Dredge Propulsion Tug...	$0	self prop.	self prop.
Survey Vessel.....	$30,000	$0	$30,000

Goto Oper Adj Factors

PLANT OWNERSHIP AND OPERATING: part 2 of 2 — PG 8 of 12

OPTIONAL PLANT (Monthly Costs)

Booster.....Include?	1	YES (0=NO)	$100,000	<--Database
.....Override>	$300,000		$300,000	<--Used
Crane Barge.....Include?	0	NO (1=YES)	$7,000	<--Database
.....Override>	$0		$0	<--Used
Tender Tug.....Include?	0	NO (1=YES)	$0	<--Database
.....Override>	$1,500		$0	<--Used
Other Marine.....	$0			
Shore Equip.....	$0			

OTHER PRICING ADJUSTMENTS: — PG 9 of 12

Other Monthly Costs: — Goto Travel & Provisions

1st Input.....	$200,000	Per Month
Description.....	Shore Equipment and Transport	

(For Additional Inputs Go to Sheet D\3) — **Goto Sheet D/3**

Fixed Costs:

1st Input.....	$0	Lump Sum
Description.....	>	

(For Additional Inputs Go to Sheet E) — **Goto Sheet E**

(To Adjust Labor Go To Sheet DB_L) — Goto Sheet DB_L

(To Adjust Equipment Go to Sheet DB_E) — Goto Sheet DB_E

101,076 pay c.y. per month	UNIT COST..	$21.38	PER C.Y.	Select Dredge
200 c.y. per hour	EXCAV. COST	$423,815,740		GENERIC MEDIUM
2.4 Loads/Day	TIME.....	196.12	MONTHS	

The Factors below normally will not change for every estimate.

LOCAL AREA FACTORS: PG 10 of 12

Present Year.....	2009	(Equipment Calculations)
Economic Index.....	7667	(EP-1110-1-8, APP E)
Labor Adjustment Factor.	0.830	(EP-1110-1-8, APP B)
Full Cost of Money Rate.	4.875	Percent per Year
Dates for Money Rate....	Jan to June 2007	
Annual Months Available for Dredging:		
Pipeline....	9	Months per Year
Bucket.....	10	Months per Year
Hopper.....	10	Months per Year
Current Fuel Price.....	$3.75	Per Gallon

Return

DREDGE OPERATING ADJUSTMENT FACTORS (OPTIONAL): PG 11 of 12

	Overide		Assumed	Used
Pump Load Factor.....	0	%	50%	50%
Adj to Exist Repair Cost... (Range .80 to 1.20)	0.00		1.00	1.00
Jet Pump Useage.....	0	%	100%	100%

Return

	Overide	Calculated	Used
Fuel Usage (Gal/Day)....	0	3,653	3,653

TRAVEL & PROVISIONS: PG 12 of 12

TRAVEL FOR DREDGE CREW:

Frequency Of Travel.....	28	days
Cost of Ticket.....	$400	per Round Trip

Return

EXTRA MEALS PROVIDED:

Gov Personnel On Dredge.	3	<-
Prov & Supplies.....	$15.00	/Man-Day

BRETON ISLAND – ALTERNATIVE 1
HEWES POINT BORROW AREA
HOPPER DREDGE

87,430 pay c.y. per month	UNIT COST..	$24.67	PER C.Y.	Select Dredge
173 c.y. per hour	EXCAV. COST	$489,033,410		GENERIC MEDIUM
2.0 Loads/Day	TIME.....	226.73	MONTHS	

PROJECT TITLES: PG 1 of 12

Project Name.....	Breton Island
Project Location.....	Saint Bernard Parish
Invit. or Contr. No.....	Planning Estimate
Date of Estimate.....	November 7, 2009
Estimator.....	Andrew Wycklendt
Checked by.....	Gordon Thomson

Ver. 1.0

For Information, Call:
Julie Davin
Ph: 509-527-7514

(Input Project Descriptions on Sheet A) Goto Sheet A

Mobilization Bid Item..... 1

Excavation Bid Item..... 2 Goto Area Factors

TYPE OF ESTIMATE PG 2 of 12

Type of Estimate..... 1 Planning Estimate
(1) Planning, (2) Bid, or (3) Mod Estimate Descriptions

INDIRECT COSTS:

Contractor's Overhead...	12.0	Percent of contract
Contractor's Profit.....	10.0	Percent of contract
Contractor's Bond.....	0.8	Percent of contract

ESTIMATED DREDGING QUANTITY: PG 3 of 12

Non-Pay Computation Method: 3
(1) Surface Area, (2) % of Pay O.D., (3) % of Net Pay, (4) % of Gross

BANK HEIGHT: 10 FT.

DREDGING PRISM:

Required....	19,823,000	C.Y.		
+ Pay O.D....	0	C.Y.		
Bid Quantity	19,823,000	C.Y.		
- Not Dug..	0	C.Y.	LOSSES:	
Net Pay	19,823,000	C.Y.		
+ Non-Pay	5,946,900	C.Y.	@ 30.0	% of Net Pay
Gross Volume	25,769,900	C.Y.	10.0	FT. BANK HT.

87,430 pay c.y. per month	UNIT COST..	$24.67	PER C.Y.	Select Dredge
173 c.y. per hour	EXCAV. COST	$489,033,410		GENERIC MEDIUM
2.0 Loads/Day	TIME.....	226.73	MONTHS	

PRODUCTION WORKSHEET: part 1 of 3 PG 4 of 12

Material Classification:
10 % MUD
90 % SAND
0 % GRAVEL

Volume of Hopper (cyds)..... 3,800 (From Database)
Max Safe Load (cyds of Sand). 2,500 (From Database)

	Override	Calculated	Used
Effect Capacity (cyds)..		1,824	1,824
Excavation Rate (cy/hr) using 2 Dragheads.....		1,313	1,313
		Database	
Dragheads Used (ea).....	2	2	2

Excavation based upon 2.0 Dragheads. (cy/hr)..... 1,313
(Excavation Time per Cycle = 83 min)

PRODUCTION WORKSHEET: part 2 of 3 PG 5 of 12

Turns/Cycle..... 0 Each
Time Per Turn..... 5 Minutes
(Turning Time per Cycle = 0 min)

One-Way Haul Distance..... 42 Miles (Statute)

Speed to Disposal Area..... 11.5 mph
Max Speed Loaded..... 11.5 mph
Speed Used to D/A..... 11.5 mph
(Hauling Time to D/A per Cycle = 219 min)

Speed from Disp Area..... 12.7 mph
Max Speed Light..... 12.7 mph
Speed Used from D/A..... 12.7 mph
(Hauling Time from D/A per Cycle = 198 min)
(Total Haul Time = 417 min)

PRODUCTION WORKSHEET: part 3 of 3 PG 6 of 12

Will Pumpout be Used?..... 1 YES (0=NO)

	Override	Database	Used
Pumpout Rate (cy/hr)....		1800	1800
Pipeline Used.....	6000 lf		

Max Pipe without using a Booster..... 6,000 lf
(Pumpout Time per Cycle = 61 min)

Connect & Disconnect.... 15 Minutes per Cycle

Cleanup Dredging..... 10 % Additional Time
Time Efficiency..... 90.0 % of Effective Working Time
657 Hours Per Month

87,430 pay c.y. per month	UNIT COST..	$24.67	PER C.Y.	Select Dredge
173 c.y. per hour	EXCAV. COST	$489,033,410		GENERIC MEDIUM
2.0 Loads/Day	TIME.....	226.73	MONTHS	

PLANT OWNERSHIP AND OPERATING: part 1 of 2 — PG 7 of 12

DREDGE	Override	Database	Used
Dredge Acquisition.....	$0	$16,600,000	$ 16,600,000
Capital Improvements %..	0 %	10%	10%
REQUIRED PLANT (Monthly Costs)			
Dredge Propulsion Tug...	$0	self prop.	self prop.
Survey Vessel.....	$30,000	$0	$30,000

Goto Oper Adj Factors

PLANT OWNERSHIP AND OPERATING: part 2 of 2 — PG 8 of 12

OPTIONAL PLANT (Monthly Costs)

Booster.....Include?	1	YES (0=NO)	$100,000	<--Database
.....Override>	$300,000		$300,000	<--Used
Crane Barge.....Include?	0	NO (1=YES)	$7,000	<--Database
.....Override>	$0		$0	<--Used
Tender Tug.....Include?	0	NO (1=YES)	$0	<--Database
.....Override>	$1,500		$0	<--Used
Other Marine.....	$0			
Shore Equip.....	$0			

OTHER PRICING ADJUSTMENTS: — PG 9 of 12

Other Monthly Costs: — Goto Travel & Provisions

1st Input..... $200,000 Per Month
Description..... Shore Equipment and Transport
(For Additional Inputs Go to Sheet D\3) — **Goto Sheet D/3**

Fixed Costs:

1st Input..... $0 Lump Sum
Description..... >

(For Additional Inputs Go to Sheet E) — **Goto Sheet E**

(To Adjust Labor Go To Sheet DB_L) — Goto Sheet DB_L

(To Adjust Equipment Go to Sheet DB_E) — Goto Sheet DB_E

87,430 pay c.y. per month	UNIT COST..	$24.67	PER C.Y.	Select Dredge
173 c.y. per hour	EXCAV. COST	$489,033,410		GENERIC MEDIUM
2.0 Loads/Day	TIME.....	226.73	MONTHS	

The Factors below normally will not change for every estimate.

LOCAL AREA FACTORS: PG 10 of 12

Present Year.....	2009	(Equipment Calculations)
Economic Index.....	7667	(EP-1110-1-8, APP E)
Labor Adjustment Factor.	0.830	(EP-1110-1-8, APP B)
Full Cost of Money Rate.	4.875	Percent per Year
Dates for Money Rate....	Jan to June 2007	
Annual Months Available for Dredging:		
Pipeline....	9	Months per Year
Bucket.....	10	Months per Year
Hopper.....	10	Months per Year
Current Fuel Price.....	$3.75	Per Gallon

Return

DREDGE OPERATING ADJUSTMENT FACTORS (OPTIONAL): PG 11 of 12

	Overide		Assumed	Used
Pump Load Factor.....	0	%	50%	50%
Adj to Exist Repair Cost... (Range .80 to 1.20)	0.00		1.00	1.00
Jet Pump Useage.....	0	%	100%	100%

Return

	Overide	Calculated	Used
Fuel Usage (Gal/Day)....	0	3,672	3,672

TRAVEL & PROVISIONS: PG 12 of 12

TRAVEL FOR DREDGE CREW:

Frequency Of Travel.....	28	days
Cost of Ticket.....	$400	per Round Trip

Return

EXTRA MEALS PROVIDED:

Gov Personnel On Dredge.	3	<-
Prov & Supplies.....	$15.00	/Man-Day

BRETON ISLAND – ALTERNATIVE 1
MRGO BORROW AREA
CUTTERHEAD DREDGE

456,856 pay c.y. per month	UNIT COST..	$6.73	PER C.Y.	Select Dredge
1,390 cy per hour	EXCAV. COST	$133,408,790		30" Cutter-Suction
30" Cutter-Suction Dredge	TIME.....	43.39	MONTHS	

PROJECT TITLES: PG 1 of 11

Ver. 1.0

Project Name.....	Breton Island
Project Location.....	Saint Bernard Parish
Invit. or Contr. No.....	Planning Estimate
Date of Estimate.....	April 12, 2010
Estimator.....	David Swigler
Checked by.....	Gordon Thomson

(Input Project Descriptions on Sheet A) **Goto Sheet A**

Mobilization Bid Item..... 1

Excavation Bid Item..... 2 Goto Area Factors

TYPE OF ESTIMATE PG 2 of 11

Type of Estimate..... 1 Planning Estimate

(1) Planning, (2) Bid, or (3) Mod **Estimate Descriptions**

INDIRECT COSTS:

Contractor's Overhead...	12.8	Percent of contract
Contractor's Profit.....	10.0	Percent of contract
Contractor's Bond.....	0.8	Percent of contract

ESTIMATED DREDGING QUANTITY: PG 3 of 11

Non-Pay Computation Method: 3

(1) Surface Area, (2) % of Pay O.D., (3) % of Net Pay, (4) % of Gross

BANK HEIGHT: 10 FT.

DREDGING PRISM:

Required....	19,823,000	C.Y.		
+ Pay O.D....	0	C.Y.		
Bid Quantity	19,823,000	C.Y.		
- Not Dug..	0	C.Y.	LOSSES:	
Net Pay	19,823,000	C.Y.	@	
+ Non-Pay	9,911,500	C.Y.	50.0	% of Net Pay
Gross Volume	29,734,500	C.Y.	10.0	FT. BANK HT.

456,856 pay c.y. per month	UNIT COST..	$6.73	PER C.Y.	Select Dredge
1,390 cy per hour	EXCAV. COST	$133,408,790		30" Cutter-Suction
30" Cutter-Suction Dredge	TIME.....	43.39	MONTHS	

MATERIAL FACTORS: PG 4 of 11

DESCRIPTION	FACTOR	PERCENTAGE		
MUD & SILT	3	0	%	
MUD & SILT	2.5	0	%	
MUD & SILT	2	10	%	DIRECT ENTRY
LOOSE SAND	1.3	0	%	FACTOR= 0.00
LOOSE SAND	1	90	%	
COMP. SAND	0.9	0	%	
STIFF CLAY	0.6	0	%	
COMP. SHELL	0.5	0	%	RESULTANT MATERIAL
SOFT ROCK	0.4	0	%	FACTOR= 1.05
BLAST. ROCK	0.25	0	%	

PIPELINE CONSIDERATIONS: PG 5 of 11

MAXIMUM PIPELINE REQUIRED:

Floating Pipeline.....	1,750	Feet
Submerged Pipeline.....	17,400	Feet
Shore Pipeline.....	17,200	Feet
Total Pipeline on Job:	36,350	Feet

Ave Pumping Distance.... 27,750 Feet of Pipeline =Floating + Subline + (0.5)Total Shorepipe

Pipeline Cost Category..... 0 SAND

(0) Computed from Material Factor,
(1) Mud, (2) Sand, or (3) Rock

Equivalent Pipe..... 0 Feet (Theoretical)

Description.....

Basis of Production: 27,750 Feet (Ave + Equiv)

PRODUCTION ANALYSIS: PG 6 of 11

1 BOOSTER(S)

46,468 L.F. POSSIBLE based on 14200 Tot. H.P.
27,750 Ft Ave Pumping Distance
36,350 L.F. Max. on jobsite

75.0 % X 730 HRS/MO = EWT OF (without Boosters) 548 HRS/MO

Goto HP Adjustments

X 0.90 Booster Factor

67.5 % X 730 HRS/MO = EWT OF (with Boosters) 493 HRS/MO

456,856 pay c.y. per month	UNIT COST..	$6.73	PER C.Y.	Select Dredge
1,390 cy per hour	EXCAV. COST	$133,408,790		30" Cutter-Suction
30" Cutter-Suction Dredge	TIME.....	43.39	MONTHS	

OTHER PRODUCTION FACTORS: PG 7 of 11

CURRENT DREDGE SELECTED: 30" Cutter-Suction Dredge

Bank Factor for 10.0 ft of Bank ---->		1.10	(From Chart)
Bank Factor Override....	0	1.10	(Used)
Description.....	>		
Other Factor.....	0.9		
Description.....	Wave Action		
Cleanup Dredging.....	2	Percent Additional Time	
		(Cleanup Factor = 0.98)	

HISTORICAL PRODUCTION OVERRIDES: PG 8 of 11

(In order to use this screen, Overrides must be entered for all three categories.)

	Override	Computed	Used
Production (Cy/Hr).....	0	1390	1,390
Operating Time (Hrs/Mo).	0	493	493
Number of Boosters.....	0	1	1

OTHER PRICING ADJUSTMENTS: PG 9 of 11

Other Monthly Costs:

1st Input.....	$0	Per Month
Description.....	Shore Equipment	
(For Additional Inputs Go to Sheet D\4)	Goto Sheet D\4	

Fixed Costs:

1st Input.....		Lump Sum
Description.....		
(For Additional Inputs Go to Sheet E)	Goto Sheet E	
(To Adjust Labor Go To Sheet DB_L)	Goto Sheet DB_L	
(To Adjust Equipment Go To Sheet DB_E)	Goto Sheet DB_E	

456,856 pay c.y. per month	UNIT COST..	$6.73	PER C.Y.	Select Dredge
1,390 cy per hour	EXCAV. COST	$133,408,790		30" Cutter-Suction
30" Cutter-Suction Dredge	TIME.....	43.39	MONTHS	

The Factors below normally will not change for every estimate.

LOCAL AREA FACTORS: PG 10 of 11

Present Year.....	2009	(Equipment Calculations)
Economic Index.....	7667	(EP-1110-1-8, APP E)
Labor Adjustment Factor.	0.830	(EP-1110-1-8, APP B)
Full Cost of Money Rate.	4.875	Percent per Year
Dates for Money Rate....	January to June 2008	
Annual Months Available for Dredging:		
Pipeline....	11	Months per Year
Bucket.....	10	Months per Year
Hopper.....	11	Months per Year
Current Fuel Price.....	$3.75	Per Gallon

2008 Marine Equipment
Region 3 (SE) - 2007

Return

HP & BOOSTER FACTOR ADJUSTMENTS: PG 11 of 11

	Override	Database	Used
Total Available Pump Horsepower.....	0	9,000	9,000
Booster Pump HP.....		5,200	5,200
% Loss per booster, when job lasts:			
Less than 1 month (%)	0	15%	15%
More than 1 month (%)	0	10%	10%

Return

Without Booster Losses, this job would last 39.07 months, therefore, the 10% figure will be used.

BRETON ISLAND – ALTERNATIVE 2
MRGO BORROW AREA
CUTTERHEAD DREDGE

458,789 pay c.y. per month	UNIT COST..	$6.70	PER C.Y.	Select Dredge
1,396 cy per hour	EXCAV. COST	$60,739,956		30" Cutter-Suction
30" Cutter-Suction Dredge	TIME.....	19.76	MONTHS	

PROJECT TITLES: PG 1 of 11

Ver. 1.0

Project Name.....	Breton Island
Project Location.....	Saint Bernard Parish
Invit. or Contr. No.....	Planning Estimate
Date of Estimate.....	April 12, 2010
Estimator.....	David Swigler
Checked by.....	Gordon Thomson

(Input Project Descriptions on Sheet A) **Goto Sheet A**

Mobilization Bid Item..... 1

Excavation Bid Item..... 2 Goto Area Factors

TYPE OF ESTIMATE PG 2 of 11

Type of Estimate..... 1 Planning Estimate

(1) Planning, (2) Bid, or (3) Mod **Estimate Descriptions**

INDIRECT COSTS:

Contractor's Overhead...	12.8	Percent of contract
Contractor's Profit.....	10.0	Percent of contract
Contractor's Bond.....	0.8	Percent of contract

ESTIMATED DREDGING QUANTITY: PG 3 of 11

Non-Pay Computation Method: 3

(1) Surface Area, (2) % of Pay O.D., (3) % of Net Pay, (4) % of Gross

BANK HEIGHT: 10 FT.

DREDGING PRISM:

Required....	9,065,665	C.Y.		
+ Pay O.D....	0	C.Y.		
Bid Quantity	9,065,665	C.Y.		
- Not Dug..	0	C.Y.		LOSSES:
Net Pay	9,065,665	C.Y.	@	
+ Non-Pay	4,532,800	C.Y.		50.0 % of Net Pay
Gross Volume	13,598,465	C.Y.		10.0 FT. BANK HT.

458,789 pay c.y. per month	UNIT COST..	$6.70	PER C.Y.	Select Dredge
1,396 cy per hour	EXCAV. COST	$60,739,956		30" Cutter-Suction
30" Cutter-Suction Dredge	TIME.....	19.76	MONTHS	

MATERIAL FACTORS: PG 4 of 11

DESCRIPTION	FACTOR	PERCENTAGE	
MUD & SILT	3	0	%
MUD & SILT	2.5	0	%
MUD & SILT	2	10	% DIRECT ENTRY
LOOSE SAND	1.3	0	% FACTOR= 0.00
LOOSE SAND	1	90	%
COMP. SAND	0.9	0	%
STIFF CLAY	0.6	0	%
COMP. SHELL	0.5	0	% RESULTANT MATERIAL
SOFT ROCK	0.4	0	% FACTOR= 1.05
BLAST. ROCK	0.25	0	%

PIPELINE CONSIDERATIONS: PG 5 of 11

MAXIMUM PIPELINE REQUIRED:

Floating Pipeline.....	1,750	Feet
Submerged Pipeline.....	17,400	Feet
Shore Pipeline.....	16,900	Feet
Total Pipeline on Job:	36,050	Feet

Ave Pumping Distance.... 27,600 Feet of Pipeline =Floating + Subline + (0.5)Total Shorepipe

Pipeline Cost Category..... 0 SAND

(0) Computed from Material Factor,
(1) Mud, (2) Sand, or (3) Rock

Equivalent Pipe..... 0 Feet (Theoretical)

Description.....

Basis of Production: 27,600 Feet (Ave + Equiv)

PRODUCTION ANALYSIS: PG 6 of 11

1 BOOSTER(S) 46,468 L.F. POSSIBLE based on 14200 Tot. H.P.
27,600 Ft Ave Pumping Distance
36,050 L.F. Max. on jobsite

75.0 % X 730 HRS/MO = EWT OF (without Boosters) 548 HRS/MO

Goto HP Adjustments

X 0.90 Booster Factor

67.5 % X 730 HRS/MO = EWT OF (with Boosters) 493 HRS/MO

458,789 pay c.y. per month	UNIT COST..	$6.70	PER C.Y.	**Select Dredge**
1,396 cy per hour	EXCAV. COST	$60,739,956		30" Cutter-Suction
30" Cutter-Suction Dredge	TIME.....	19.76	MONTHS	

OTHER PRODUCTION FACTORS: PG 7 of 11

CURRENT DREDGE SELECTED: 30" Cutter-Suction Dredge

Bank Factor for 10.0 ft of Bank ----> 1.10 (From Chart)

Bank Factor Override.... 0 1.10 (Used)

Description..... >

Other Factor..... 0.9

Description..... Wave Action

Cleanup Dredging..... 2 Percent Additional Time
(Cleanup Factor = 0.98)

HISTORICAL PRODUCTION OVERRIDES: PG 8 of 11

(In order to use this screen, Overrides must be entered for all three categories.)

	Override	Computed	Used
Production (Cy/Hr).....	0	1396	1,396
Operating Time (Hrs/Mo).	0	493	493
Number of Boosters.....	0	1	1

OTHER PRICING ADJUSTMENTS: PG 9 of 11

Other Monthly Costs:

1st Input..... $0 Per Month

Description..... Shore Equipment

(For Additional Inputs Go to Sheet D\4) Goto Sheet D\4

Fixed Costs:

1st Input..... Lump Sum

Description.....

(For Additional Inputs Go to Sheet E) Goto Sheet E

(To Adjust Labor Go To Sheet DB_L) Goto Sheet DB_L

(To Adjust Equipment Go To Sheet DB_E) Goto Sheet DB_E

458,789 pay c.y. per month	UNIT COST..	$6.70	PER C.Y.	Select Dredge
1,396 cy per hour	EXCAV. COST	$60,739,956		30" Cutter-Suction
30" Cutter-Suction Dredge	TIME.....	19.76	MONTHS	

The Factors below normally will not change for every estimate.

LOCAL AREA FACTORS: PG 10 of 11

Present Year.....	2009	(Equipment Calculations)
Economic Index.....	7667	(EP-1110-1-8, APP E)
Labor Adjustment Factor.	0.830	(EP-1110-1-8, APP B)
Full Cost of Money Rate.	4.875	Percent per Year
Dates for Money Rate....	January to June 2008	
Annual Months Available for Dredging:		
Pipeline....	11	Months per Year
Bucket.....	10	Months per Year
Hopper.....	11	Months per Year
Current Fuel Price.....	$3.75	Per Gallon

2008 Marine Equipment Region 3 (SE) - 2007

Return

HP & BOOSTER FACTOR ADJUSTMENTS: PG 11 of 11

	Override	Database	Used
Total Available Pump Horsepower.....	0	9,000	9,000
Booster Pump HP.....		5,200	5,200
% Loss per booster, when job lasts:			
Less than 1 month (%)	0	15%	15%
More than 1 month (%)	0	10%	10%

Return

Without Booster Losses, this job would last 17.79 months, therefore, the 10% figure will be used.

BRETON ISLAND – ALTERNATIVE 3
MRGO BORROW AREA
CUTTERHEAD DREDGE

429,890 pay c.y. per month	UNIT COST..	$5.81	PER C.Y.	Select Dredge
1,177 cy per hour	EXCAV. COST	$41,710,908		30" Cutter-Suction
30" Cutter-Suction Dredge	TIME.....	16.70	MONTHS	

PROJECT TITLES: PG 1 of 11

Ver. 1.0

Project Name.....	Breton Island
Project Location.....	Saint Bernard Parish
Invit. or Contr. No.....	Planning Estimate
Date of Estimate.....	April 12, 2010
Estimator.....	David Swigler
Checked by.....	Gordon Thomson

(Input Project Descriptions on Sheet A) **Goto Sheet A**

Mobilization Bid Item..... 1

Excavation Bid Item..... 2 Goto Area Factors

TYPE OF ESTIMATE PG 2 of 11

Type of Estimate..... 1 Planning Estimate

(1) Planning, (2) Bid, or (3) Mod **Estimate Descriptions**

INDIRECT COSTS:

Contractor's Overhead...	12.8	Percent of contract
Contractor's Profit.....	10.0	Percent of contract
Contractor's Bond.....	0.8	Percent of contract

ESTIMATED DREDGING QUANTITY: PG 3 of 11

Non-Pay Computation Method: 3

(1) Surface Area, (2) % of Pay O.D., (3) % of Net Pay, (4) % of Gross

BANK HEIGHT: 10 FT.

DREDGING PRISM:

Required....	7,179,158	C.Y.		
+ Pay O.D....	0	C.Y.		
Bid Quantity	7,179,158	C.Y.		
- Not Dug..	0	C.Y.	LOSSES:	
Net Pay	7,179,158	C.Y.	@	
+ Non-Pay	3,589,600	C.Y.	50.0	% of Net Pay
Gross Volume	10,768,758	C.Y.	10.0	FT. BANK HT.

429,890 pay c.y. per month	UNIT COST..	$5.81	PER C.Y.	Select Dredge
1,177 cy per hour	EXCAV. COST	$41,710,908		30" Cutter-Suction
30" Cutter-Suction Dredge	TIME.....	16.70	MONTHS	

MATERIAL FACTORS: PG 4 of 11

DESCRIPTION	FACTOR	PERCENTAGE		
MUD & SILT	3	0	%	
MUD & SILT	2.5	0	%	
MUD & SILT	2	10	%	DIRECT ENTRY
LOOSE SAND	1.3	0	%	FACTOR= 0.00
LOOSE SAND	1	90	%	
COMP. SAND	0.9	0	%	
STIFF CLAY	0.6	0	%	
COMP. SHELL	0.5	0	%	RESULTANT MATERIAL
SOFT ROCK	0.4	0	%	FACTOR= 1.05
BLAST. ROCK	0.25	0	%	

PIPELINE CONSIDERATIONS: PG 5 of 11

MAXIMUM PIPELINE REQUIRED:

Floating Pipeline.....	1,750	Feet
Submerged Pipeline.....	17,400	Feet
Shore Pipeline.....	3,600	Feet
Total Pipeline on Job:	22,750	Feet

Ave Pumping Distance.... 20,950 Feet of Pipeline =Floating + Subline + (0.5)Total Shorepipe

Pipeline Cost Category..... 0 SAND

(0) Computed from Material Factor,
(1) Mud, (2) Sand, or (3) Rock

Equivalent Pipe..... 0 Feet (Theoretical)

Description.....

Basis of Production: 20,950 Feet (Ave + Equiv)

PRODUCTION ANALYSIS: PG 6 of 11

0 BOOSTER(S)

29,410 L.F. POSSIBLE based on 9000 Tot. H.P.
20,950 Ft Ave Pumping Distance
22,750 L.F. Max. on jobsite

75.0 % X 730 HRS/MO = EWT OF (without Boosters) 548 HRS/MO

Goto HP Adjustments

X 1.00 Booster Factor

75.0 % X 730 HRS/MO = EWT OF (with Boosters) 548 HRS/MO

429,890 pay c.y. per month	UNIT COST..	$5.81	PER C.Y.	Select Dredge
1,177 cy per hour	EXCAV. COST	$41,710,908		30" Cutter-Suction
30" Cutter-Suction Dredge	TIME.....	16.70	MONTHS	

OTHER PRODUCTION FACTORS: PG 7 of 11

CURRENT DREDGE SELECTED: 30" Cutter-Suction Dredge

Bank Factor for 10.0 ft of Bank ----> 1.10 (From Chart)

Bank Factor Override.... 0 1.10 (Used)

Description..... >

Other Factor..... 0.9

Description..... Wave Action

Cleanup Dredging..... 2 Percent Additional Time
(Cleanup Factor = 0.98)

HISTORICAL PRODUCTION OVERRIDES: PG 8 of 11

(In order to use this screen, Overrides must be entered for all three categories.)

	Override	Computed	Used
Production (Cy/Hr).....	0	1177	1,177
Operating Time (Hrs/Mo).	0	548	548
Number of Boosters.....	0	0	0

OTHER PRICING ADJUSTMENTS: PG 9 of 11

Other Monthly Costs:

1st Input..... $0 Per Month

Description..... Shore Equipment

(For Additional Inputs Go to Sheet D\4) Goto Sheet D\4

Fixed Costs:

1st Input..... Lump Sum

Description.....

(For Additional Inputs Go to Sheet E) Goto Sheet E

(To Adjust Labor Go To Sheet DB_L) Goto Sheet DB_L

(To Adjust Equipment Go To Sheet DB_E) Goto Sheet DB_E

429,890 pay c.y. per month	UNIT COST..	$5.81	PER C.Y.	Select Dredge
1,177 cy per hour	EXCAV. COST	$41,710,908		30" Cutter-Suction
30" Cutter-Suction Dredge	TIME.....	16.70	MONTHS	

The Factors below normally will not change for every estimate.

LOCAL AREA FACTORS: PG 10 of 11

Present Year.....	2009	(Equipment Calculations)
Economic Index.....	7667	(EP-1110-1-8, APP E)
Labor Adjustment Factor.	0.830	(EP-1110-1-8, APP B)
Full Cost of Money Rate.	4.875	Percent per Year
Dates for Money Rate....	January to June 2008	
Annual Months Available for Dredging:		
Pipeline....	11	Months per Year
Bucket.....	10	Months per Year
Hopper.....	11	Months per Year
Current Fuel Price.....	$3.75	Per Gallon

2008 Marine Equipment
Region 3 (SE) - 2007

Return

HP & BOOSTER FACTOR ADJUSTMENTS: PG 11 of 11

	Override	Database	Used
Total Available Pump Horsepower.....	0	9,000	9,000
Booster Pump HP.....		5,200	5,200
% Loss per booster, when job lasts:			
Less than 1 month (%)	0	15%	15%
More than 1 month (%)	0	10%	10%

Return

Without Booster Losses, this job would last 16.71 months, therefore, the 10% figure will be used.

BRETON ISLAND – ALTERNATIVE 4
MRGO BORROW AREA
CUTTERHEAD DREDGE

470,632 pay c.y. per month	UNIT COST..	$6.53	PER C.Y.	Select Dredge
1,432 cy per hour	EXCAV. COST	$129,444,190		30" Cutter-Suction
30" Cutter-Suction Dredge	TIME.....	42.12	MONTHS	

PROJECT TITLES: PG 1 of 11

Ver. 1.0

Project Name.....	Breton Island
Project Location.....	Saint Bernard Parish
Invit. or Contr. No.....	Planning Estimate
Date of Estimate.....	April 12, 2010
Estimator.....	David Swigler
Checked by.....	Gordon Thomson

(Input Project Descriptions on Sheet A) **Goto Sheet A**

Mobilization Bid Item..... 1

Excavation Bid Item..... 2 Goto Area Factors

TYPE OF ESTIMATE PG 2 of 11

Type of Estimate..... 1 Planning Estimate

(1) Planning, (2) Bid, or (3) Mod **Estimate Descriptions**

INDIRECT COSTS:

Contractor's Overhead...	12.8	Percent of contract
Contractor's Profit.....	10.0	Percent of contract
Contractor's Bond.....	0.8	Percent of contract

ESTIMATED DREDGING QUANTITY: PG 3 of 11

Non-Pay Computation Method: 3

(1) Surface Area, (2) % of Pay O.D., (3) % of Net Pay, (4) % of Gross

BANK HEIGHT: 10 FT.

DREDGING PRISM:

Required....	19,823,000	C.Y.		
+ Pay O.D....	0	C.Y.		
Bid Quantity	19,823,000	C.Y.		
- Not Dug..	0	C.Y.		LOSSES:
Net Pay	19,823,000	C.Y.	@	
+ Non-Pay	9,911,500	C.Y.		50.0 % of Net Pay
Gross Volume	29,734,500	C.Y.		10.0 FT. BANK HT.

470,632 pay c.y. per month	UNIT COST..	$6.53	PER C.Y.	**Select Dredge**
1,432 cy per hour	EXCAV. COST	$129,444,190		30" Cutter-Suction
30" Cutter-Suction Dredge	TIME.....	42.12	MONTHS	

MATERIAL FACTORS: PG 4 of 11

DESCRIPTION	FACTOR	PERCENTAGE		
MUD & SILT	3	0	%	
MUD & SILT	2.5	0	%	
MUD & SILT	2	10	%	DIRECT ENTRY
LOOSE SAND	1.3	0	%	FACTOR= 0.00
LOOSE SAND	1	90	%	
COMP. SAND	0.9	0	%	
STIFF CLAY	0.6	0	%	
COMP. SHELL	0.5	0	%	RESULTANT MATERIAL
SOFT ROCK	0.4	0	%	FACTOR= 1.05
BLAST. ROCK	0.25	0	%	

PIPELINE CONSIDERATIONS: PG 5 of 11

MAXIMUM PIPELINE REQUIRED:

Floating Pipeline.....	1,750	Feet
Submerged Pipeline.....	17,400	Feet
Shore Pipeline.....	15,000	Feet
Total Pipeline on Job:	34,150	Feet

Ave Pumping Distance.... 26,650 Feet of Pipeline =Floating + Subline + (0.5)Total Shorepipe

Pipeline Cost Category..... 0 SAND

(0) Computed from Material Factor,
(1) Mud, (2) Sand, or (3) Rock

Equivalent Pipe..... 0 Feet (Theoretical)

Description.....

Basis of Production: 26,650 Feet (Ave + Equiv)

PRODUCTION ANALYSIS: PG 6 of 11

1 BOOSTER(S) 46,468 L.F. POSSIBLE based on 14200 Tot. H.P.
26,650 Ft Ave Pumping Distance
34,150 L.F. Max. on jobsite

75.0 % X 730 HRS/MO = EWT OF (without Boosters) 548 HRS/MO

Goto HP Adjustments

X 0.90 Booster Factor

67.5 % X 730 HRS/MO = EWT OF (with Boosters) 493 HRS/MO

470,632 pay c.y. per month	UNIT COST..	$6.53	PER C.Y.	**Select Dredge**
1,432 cy per hour	EXCAV. COST	$129,444,190		30" Cutter-Suction
30" Cutter-Suction Dredge	TIME.....	42.12	MONTHS	

OTHER PRODUCTION FACTORS: PG 7 of 11

CURRENT DREDGE SELECTED: 30" Cutter-Suction Dredge

Bank Factor for 10.0 ft of Bank ----> 1.10 (From Chart)

Bank Factor Override.... 0 1.10 (Used)

Description..... >

Other Factor..... 0.9

Description..... Wave Action

Cleanup Dredging..... 2 Percent Additional Time
(Cleanup Factor = 0.98)

HISTORICAL PRODUCTION OVERRIDES: PG 8 of 11

(In order to use this screen, Overrides must be entered for all three categories.)

	Override	Computed	Used
Production (Cy/Hr).....	0	1432	1,432
Operating Time (Hrs/Mo).	0	493	493
Number of Boosters.....	0	1	1

OTHER PRICING ADJUSTMENTS: PG 9 of 11

Other Monthly Costs:

1st Input..... $0 Per Month

Description..... Shore Equipment

(For Additional Inputs Go to Sheet D\4) Goto Sheet D\4

Fixed Costs:

1st Input..... Lump Sum

Description.....

(For Additional Inputs Go to Sheet E) Goto Sheet E

(To Adjust Labor Go To Sheet DB_L) Goto Sheet DB_L

(To Adjust Equipment Go To Sheet DB_E) Goto Sheet DB_E

470,632 pay c.y. per month	UNIT COST..	$6.53	PER C.Y.	Select Dredge
1,432 cy per hour	EXCAV. COST	$129,444,190		30" Cutter-Suction
30" Cutter-Suction Dredge	TIME.....	42.12	MONTHS	

The Factors below normally will not change for every estimate.

LOCAL AREA FACTORS: PG 10 of 11

Present Year.....	2009	(Equipment Calculations)
Economic Index.....	7667	(EP-1110-1-8, APP E)
Labor Adjustment Factor.	0.830	(EP-1110-1-8, APP B)
Full Cost of Money Rate.	4.875	Percent per Year
Dates for Money Rate....	January to June 2008	
Annual Months Available for Dredging:		
Pipeline....	11	Months per Year
Bucket.....	10	Months per Year
Hopper.....	11	Months per Year
Current Fuel Price.....	$3.75	Per Gallon

2008 Marine Equipment Region 3 (SE) - 2007

Return

HP & BOOSTER FACTOR ADJUSTMENTS: PG 11 of 11

	Override	Database	Used
Total Available Pump Horsepower.....	0	9,000	9,000
Booster Pump HP.....		5,200	5,200
% Loss per booster, when job lasts:			
Less than 1 month (%)	0	15%	15%
More than 1 month (%)	0	10%	10%

Return

Without Booster Losses, this job would last 37.93 months, therefore, the 10% figure will be used.

BRETON ISLAND – ALTERNATIVE 5
MRGO BORROW AREA
CUTTERHEAD DREDGE

492,130 pay c.y. per month	UNIT COST..	$5.06	PER C.Y.	Select Dredge
1,347 cy per hour	EXCAV. COST	$100,304,380		30" Cutter-Suction
30" Cutter-Suction Dredge	TIME.....	40.28	MONTHS	

PROJECT TITLES: PG 1 of 11

Project Name.....	Breton Island
Project Location.....	Saint Bernard Parish
Invit. or Contr. No.....	Planning Estimate
Date of Estimate.....	April 12, 2010
Estimator.....	David Swigler
Checked by.....	Gordon Thomson

Ver. 1.0

(Input Project Descriptions on Sheet A) **Goto Sheet A**

Mobilization Bid Item..... 1

Excavation Bid Item..... 2 Goto Area Factors

TYPE OF ESTIMATE PG 2 of 11

Type of Estimate..... 1 Planning Estimate

(1) Planning, (2) Bid, or (3) Mod **Estimate Descriptions**

INDIRECT COSTS:

Contractor's Overhead...	12.8	Percent of contract
Contractor's Profit.....	10.0	Percent of contract
Contractor's Bond.....	0.8	Percent of contract

ESTIMATED DREDGING QUANTITY: PG 3 of 11

Non-Pay Computation Method: 3

(1) Surface Area, (2) % of Pay O.D., (3) % of Net Pay, (4) % of Gross

BANK HEIGHT: 10 FT.

DREDGING PRISM:

Required....	19,823,000	C.Y.		
+ Pay O.D....	0	C.Y.		
Bid Quantity	19,823,000	C.Y.		
- Not Dug..	0	C.Y.	LOSSES:	
Net Pay	19,823,000	C.Y.	@	
+ Non-Pay	9,911,500	C.Y.	50.0	% of Net Pay
Gross Volume	29,734,500	C.Y.	10.0	FT. BANK HT.

492,130 pay c.y. per month	UNIT COST..	$5.06	PER C.Y.	Select Dredge
1,347 cy per hour	EXCAV. COST	$100,304,380		30" Cutter-Suction
30" Cutter-Suction Dredge	TIME.....	40.28	MONTHS	

MATERIAL FACTORS: PG 4 of 11

DESCRIPTION	FACTOR	PERCENTAGE		
MUD & SILT	3	0	%	
MUD & SILT	2.5	0	%	
MUD & SILT	2	10	%	DIRECT ENTRY
LOOSE SAND	1.3	0	%	FACTOR= 0.00
LOOSE SAND	1	90	%	
COMP. SAND	0.9	0	%	
STIFF CLAY	0.6	0	%	
COMP. SHELL	0.5	0	%	RESULTANT MATERIAL
SOFT ROCK	0.4	0	%	FACTOR= 1.05
BLAST. ROCK	0.25	0	%	

PIPELINE CONSIDERATIONS: PG 5 of 11

MAXIMUM PIPELINE REQUIRED:

Floating Pipeline.....	1,750	Feet	
Submerged Pipeline.....	16,500	Feet	
Shore Pipeline.....	0	Feet	
Total Pipeline on Job:	18,250	Feet	
Ave Pumping Distance....	18,250	Feet of Pipeline	=Floating + Subline + (0.5)Total Shorepipe
Pipeline Cost Category.....		0	SAND

(0) Computed from Material Factor,
(1) Mud, (2) Sand, or (3) Rock

Equivalent Pipe.....	0	Feet (Theoretical)
Description.....		
Basis of Production:	18,250	Feet (Ave + Equiv)

PRODUCTION ANALYSIS: PG 6 of 11

0	BOOSTER(S)	29,410 L.F. POSSIBLE based on 9000 Tot. H.P.
		18,250 Ft Ave Pumping Distance
		18,250 L.F. Max. on jobsite

75.0	% X 730 HRS/MO = EWT OF (without Boosters)	548 HRS/MO
X 1.00	Booster Factor	Goto HP Adjustments
75.0	% X 730 HRS/MO = EWT OF (with Boosters)	548 HRS/MO

492,130 pay c.y. per month	UNIT COST..	$5.06	PER C.Y.	Select Dredge
1,347 cy per hour	EXCAV. COST	$100,304,380		30" Cutter-Suction
30" Cutter-Suction Dredge	TIME.....	40.28	MONTHS	

OTHER PRODUCTION FACTORS: PG 7 of 11

CURRENT DREDGE SELECTED: 30" Cutter-Suction Dredge

Bank Factor for 10.0 ft of Bank ---->		1.10	(From Chart)
Bank Factor Override....	0	1.10	(Used)
Description.....	>		
Other Factor.....	0.9		
Description.....	Wave Action		
Cleanup Dredging.....	2	Percent Additional Time (Cleanup Factor = 0.98)	

HISTORICAL PRODUCTION OVERRIDES: PG 8 of 11

(In order to use this screen, Overrides must be entered for all three categories.)

	Override	Computed	Used
Production (Cy/Hr).....	0	1347	1,347
Operating Time (Hrs/Mo).	0	548	548
Number of Boosters.....	0	0	0

OTHER PRICING ADJUSTMENTS: PG 9 of 11

Other Monthly Costs:

1st Input.....	$0	Per Month
Description.....	Shore Equipment	
(For Additional Inputs Go to Sheet D\4)	Goto Sheet D\4	

Fixed Costs:

1st Input.....		Lump Sum
Description.....		
(For Additional Inputs Go to Sheet E)	Goto Sheet E	
(To Adjust Labor Go To Sheet DB_L)	Goto Sheet DB_L	
(To Adjust Equipment Go To Sheet DB_E)	Goto Sheet DB_E	

492,130 pay c.y. per month	UNIT COST..	$5.06	PER C.Y.	Select Dredge
1,347 cy per hour	EXCAV. COST	$100,304,380		30" Cutter-Suction
30" Cutter-Suction Dredge	TIME.....	40.28	MONTHS	

The Factors below normally will not change for every estimate.

LOCAL AREA FACTORS: PG 10 of 11

Present Year.....	2009	(Equipment Calculations)
Economic Index.....	7667	(EP-1110-1-8, APP E)
Labor Adjustment Factor.	0.830	(EP-1110-1-8, APP B)
Full Cost of Money Rate.	4.875	Percent per Year
Dates for Money Rate....	January to June 2008	
Annual Months Available for Dredging:		
Pipeline....	11	Months per Year
Bucket.....	10	Months per Year
Hopper.....	11	Months per Year
Current Fuel Price.....	$3.75	Per Gallon

2008 Marine Equipment
Region 3 (SE) - 2007

Return

HP & BOOSTER FACTOR ADJUSTMENTS: PG 11 of 11

	Override	Database	Used
Total Available Pump Horsepower.....	0	9,000	9,000
Booster Pump HP.....		5,200	5,200
% Loss per booster, when job lasts:			
Less than 1 month (%)	0	15%	15%
More than 1 month (%)	0	10%	10%

Return

Without Booster Losses, this job would last 40.32 months, therefore, the 10% figure will be used.

MRGO ECOSYSTEM RESTORATION FEASIBILITY STUDY (W912P8-09-D-0007)

APPENDIX C

SBEACH MODELING

MRGO ECOSYSTEM RESTORATION
FEASIBILITY STUDY
(W912P8-09-D-0007)

APPENDIX C

SBEACH MODELING

Table of Contents

1.0 BACKGROUND 1
1.1 Objectives 1
1.2 Methods 1
2.0 MODEL CALIBRATION 2
2.1 Survey Inventory 2
2.2 Storm Data 4
2.3 Grain Size 4
2.4 Calibration Results 8
3.0 FUTURE CONDITIONS 12
3.1 Beach Profiles 12
3.2 Storm Data 14
3.2.1 Waves 14
3.2.2 Storm Stages 17
3.2.3 Winds 17
3.2.4 Prototype Storms 18
3.2.5 Subsidence and Sea Level Rise 24
3.3 Design Cross-Sections 25
3.4 Results 26
3.4.1 Model Stability 26
3.4.2 Beach Profiles 27
3.4.3 Wave Setup / Total Water Level 28
4.0 CONCLUSIONS AND RECOMMENDATIONS 29
5.0 REFERENCES 31

List of Figures

FIGURE C-1. BEACH PROFILES USED IN SBEACH CALIBRATION 3
FIGURE C- 2. WAVE GAGES, TIDE GAGES, WAVE HINDCASTING STATIONS, AND STORM SURGE HINDCASTING STATIONS 5
FIGURE C- 3. WAVE DATA USED IN THE CALIBRATION OF THE SBEACH MODEL 6

FIGURE C- 4. WATER LEVELS AND WIND SPEEDS USED IN THE CALIBRATION OF THE SBEACH MODEL. 7
FIGURE C- 5. AVERAGE BEACH PROFILE WITH BEST FIT $Y = AX^{2/3}$ EQUILIBRIUM PROFILE. 8
FIGURE C- 6. TYPICAL SBEACH CALIBRATION RESULTS, CHANDELEUR ISLANDS SOUTH REACH. 10
FIGURE C- 7. TYPICAL SBEACH CALIBRATION RESULTS, CHANDELEUR ISLANDS MIDDLE REACH. 11
FIGURE C- 8. TYPICAL SBEACH CALIBRATION RESULTS, CHANDELEUR ISLANDS NORTH REACH. 11
FIGURE C- 9. BEACH PROFILES USED IN THE SBEACH FUTURE CONDITIONS SIMULATIONS. 13
FIGURE C- 10. EXTREMAL (STORM) WAVE STATISTICS - 1980 TO 2008, NOAA BUOY 42007 & WIS STATION 144 CHANDELEUR ISLANDS, LA & GULFPORT, MS. 16
FIGURE C- 11. WAVE HISTORIES FOR THE 1-5 YEAR STORMS. 19
FIGURE C- 12. WIND VELOCITIES AND WAVE DIRECTIONS FOR THE 1-5 YEAR STORMS. 20
FIGURE C- 13. WATER LEVELS FOR THE 1-5 YEAR STORMS. 21
FIGURE C- 14.WATER LEVELS DURING HURRICANE IVAN (2004). 21
FIGURE C- 15. WAVE HISTORIES FOR THE 10-100 YEAR STORMS. 22
FIGURE C- 16. WIND VELOCITIES AND WAVE DIRECTIONS FOR THE 10-100 YEAR STORMS. 23
FIGURE C- 17. WATER LEVELS FOR THE 10-100 YEAR STORMS. 24

List of Tables

Table C-1. RECENT SURVEY INVENTORY, CHANDELEUR AND BRETON ISLANDS, LA 2
Table C- 2. CHANDELEUR ISLANDS, LA SBEACH CALIBRATION 9
Table C- 3. FINAL SBEACH CALIBRATION PARAMETERS, CHANDELEUR ISLANDS, LA 12
Table C- 4. EXTREMAL (STORM) WAVE STATISTICS - 1980 TO 2008, NOAA BUOY 42007 & WIS STATION 144, CHANDELEUR ISLANDS, LA & GULFPORT, MS 15
Table C- 5. BRETON & CHANDELEUR ISLANDS, LA, STORM STAGE VALUES (FEMA, 1984) 17
Table C- 6. EXTREMAL WIND STATISTICS, CHANDELEUR ISLANDS, LA & GULFPORT, MS, (USACE, 1985, Station 750) 18
Table C- 7. WAVE SETUP ELEAVTIONS, WITHOUT PROJECT CONDITIONS AT YEAR 0, BRETON & CHANDELEUR ISLANDS, LA 29

1 BACKGROUND

1.1 Objectives

Beach erosion, shoreline recession, and overwash often occur during storm events as a result of cross-shore sediment transport processes. These storm impacts must be taken into account in the design of the Mississippi River Gulf Outlet Ecosystem Restoration. Cross-shore storm impact evaluations on the Chandeleur and Breton Islands are conducted using the Storm Induced Beach Change Model (SBEACH) (Larson and Kraus, 1989, Larson, et al, 2004, Larson, et al, 2005). The goal of this analysis is to:

1. Determine cross-shore response of the island.

2. Estimate average annual overwash.

The design life for this project is 50 years. These main goals focus on the response of the beach/dune profile to any given storm event at any point within the 50-year project life.

1.2 Methods

SBEACH 4.03 is a one-dimensional model which simulates beach profile changes that result from varying storm waves and water levels. These profile changes include the formation and movement of morphological features such as longshore bars, troughs, berms, and dunes, along with overwash. SBEACH assumes that the simulated profile changes are produced only by cross-shore processes. Longshore sediment transport processes are neglected. SBEACH is an empirically based numerical model, formulated using both field data and the results of large-scale physical model tests. Input data required by SBEACH includes the beach and marsh cross-section, the median sediment grain size, several calibration parameters, and the historical wave, wind, and water surface elevations. SBEACH calculates the cross-shore variation in wave height and wave setup at discrete points along the profile from the offshore zone to the landward survey limit. The following basic assumptions underlie the SBEACH model:

• Breaking waves and variations in water level are the major causes of sand transport and profile change.

• The median sediment grain diameter on the profile is reasonably uniform across shore.

• The influence of structures blocking longshore transport is small, and the shoreline is straight (i.e., longshore effects are negligible during the term of simulation).

• Linear wave theory is applicable everywhere along the beach profile.

2 MODEL CALIBRATION

2.1 Survey Inventory

The calibration period for the SBEACH model was selected based on inventory of available recent survey data for the project area (Table C-1):

Table C-1. RECENT SURVEY INVENTORY, CHANDELEUR AND BRETON ISLANDS, LA

Survey	Method	Type	Area
Nov. 1998	LIDAR	Raw	Chandeleur & Breton Islands
Sep. 2005	LIDAR	Bare Earth	Chandeleur Islands only
Nov. 2005	LIDAR	Raw	Chandeleur Islands only
March 2006	LIDAR	Bare Earth	Chandeleur Islands only
June 2006	Hydrographic	Hydrographic	Chandeleur & Breton Islands
Sep. 2006	LIDAR	Bare Earth	Chandeleur Islands only
June 2007	LIDAR	Bare Earth	Chandeleur & Breton Islands

The majority of the surveys were Light Detection and Ranging (LIDAR) surveys. However, because of the water quality typically found along the project area, the LIDAR surveys only covered the land areas and intertidal areas. As a result, beach profiles drawn from the LIDAR surveys often exhibited wide gaps (~100 to 500 feet) across the profile or lacked data altogether, rendering much of the data unsuitable for use in the SBEACH model. In particular, there were no surveys suitable for calibrating the SBEACH model on Breton Island.

The data sets that were best suited for use in the SBEACH model were the 2006 surveys. The March 2006 LIDAR profiles were adjoined to the June 2006 hydrographic profiles to provide the initial condition for the model. The results of each calibration run were then compared to the shoreline changes and overwash estimates based on the March 2006 and September 2006 surveys. The specific profiles used in the SBEACH calibration appear in Figure C-1.

To facilitate the calibration of the model over a large area, the Chandeleur Islands were divided into 3 reaches:

- The South Reach (N-20 to N-39), with a shore-normal direction of 107°.
- The Middle Reach (N-44 to N-56), with a shore-normal direction of 93°.
- The North Reach (N-58 to N-71), with a shore-normal direction of 74°.

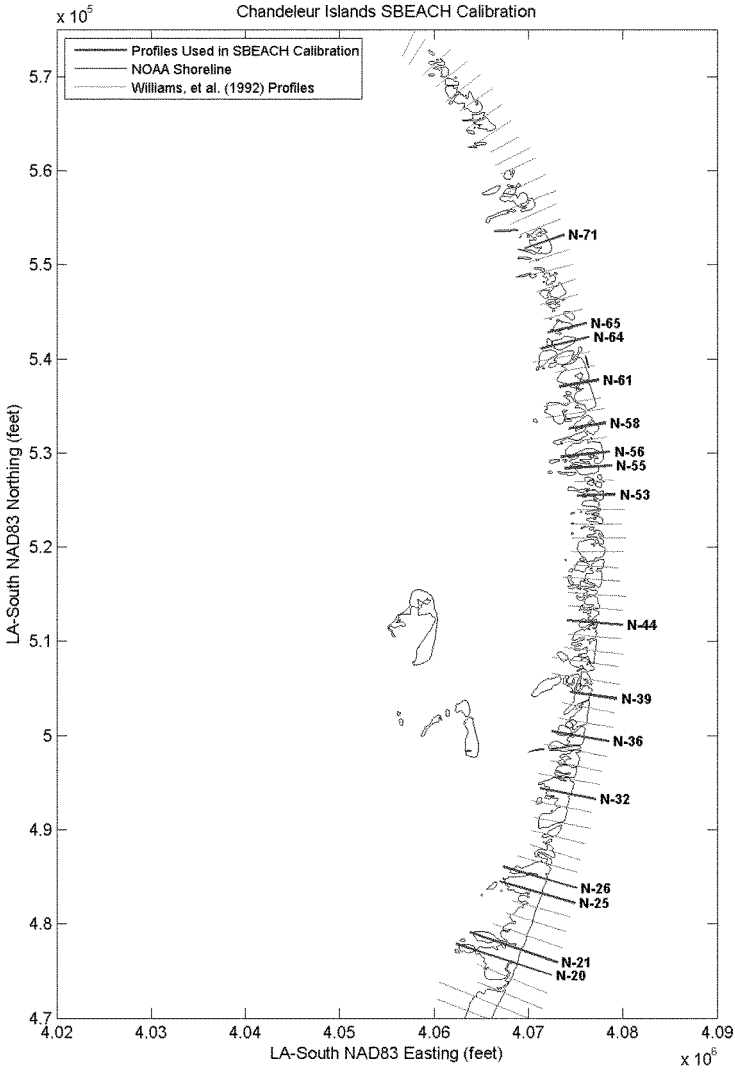


Figure C-1. Beach Profiles Used in SBEACH Calibration.

Calibration of the model was performed separately for each reach. Since there were no surveys suitable for calibrating the SBEACH model on Breton Island, calibration runs were performed on the Chandeleur Islands only.

2.2 Storm Data

The wave and wind data used in the calibration of the model was taken from concurrent observations at NOAA Buoy 42007 (Figures C-2 to C-4). Water levels were taken from the tide gage records at Gulfport, MS, which were the closest available. Although the surveys used in the calibration were taken in March and September of 2006, the highest waves and water levels occurred between April 28 and June 16. Wave activity outside this period was characterized by average waves. Two major storms occurred between April 28 and June 16: an extratropical storm on April 30 and Tropical Storm Alberto, which made landfall near Tallahassee, FL on June 13 (Unisys, 2006). Peak wave heights during the two storm events were on the order of 8-10 feet. Peak water levels were 1.4 to 3.6 feet above the astronomical tides. The average water temperature at NOAA Buoy 42007 was 27° C during this period.

2.3 Grain Size

SBEACH utilizes the input grain size to calculate sand transport. Native grain size information is not readily available for the project area. Therefore, the grain size used in the SBEACH model was based on the offshore beach profiles. In many cases, beach profiles generally follow the profile shape described by:

$$Y = AX^{2/3}$$

where

Y = Depth below the water line (+0.91' NAVD) in m
X = Horizontal distance seaward of the water line in m
A = Dean's A-factor in $m^{1/3}$

The value of Dean's A factor is generally related to grain size. Thus, where grain size information is not available, an "effective grain size" can be estimate based on the profile shape. For fine grained sands, grain size is related to Dean's A factor by the following:

$$A = 0.41\ d_{50}^{0.94}$$ (Hanson and Kraus, 1991, p. 56)

where d_{50} = median grain size in mm

The average of profiles N-20 to N-71 appears in Figure C-5. This profile was an average of the highlighted profiles in Figure C-1 and exhibited an A-factor on the order of 0.0446 $m^{1/3}$ (0.0662 $feet^{1/3}$). Based on the equations above, the corresponding grain size was 0.094 mm. This value was close to the minimum value allowed in the SBEACH, 0.1 mm. Accordingly, all simulations in this study used a grain size of 0.1 mm.

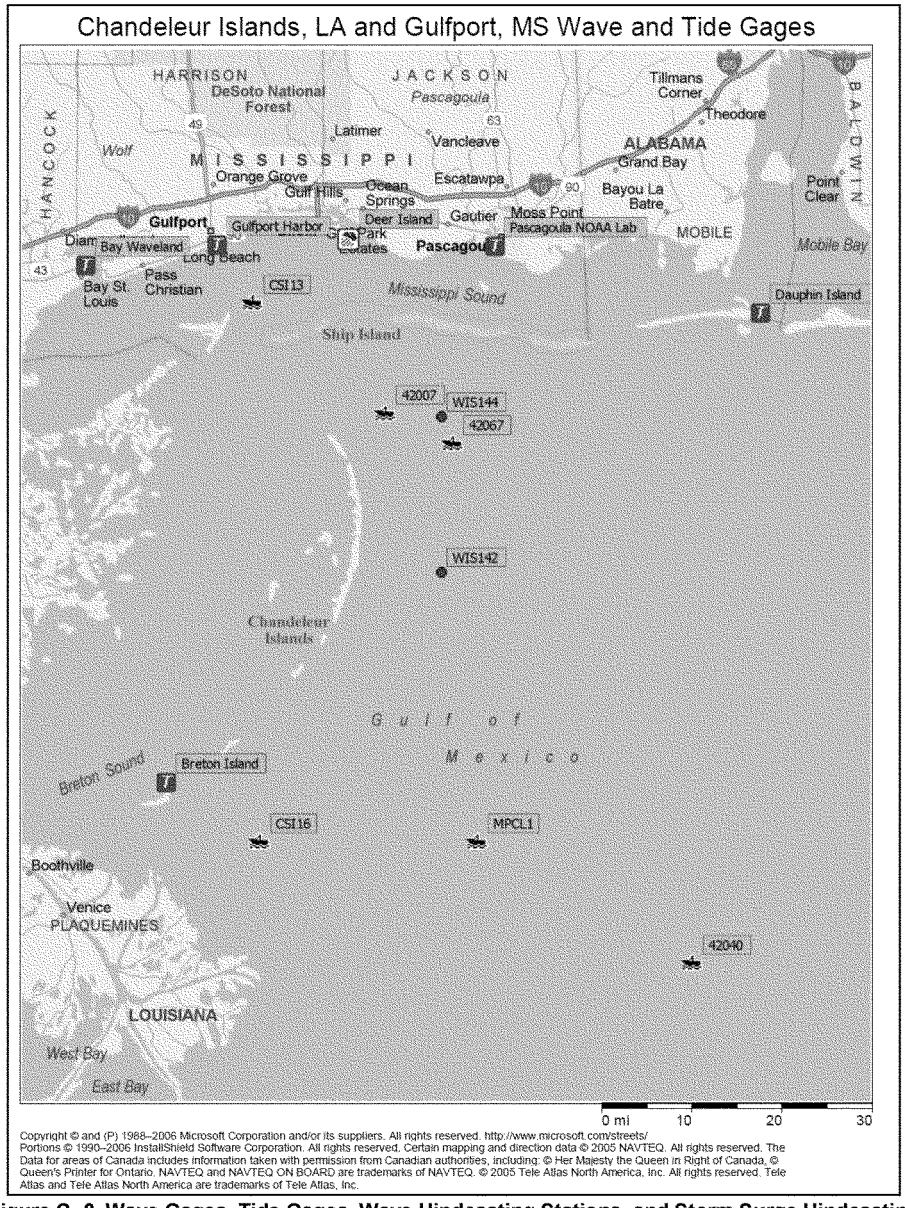


Figure C- 2. Wave Gages, Tide Gages, Wave Hindcasting Stations, and Storm Surge Hindcasting Stations.

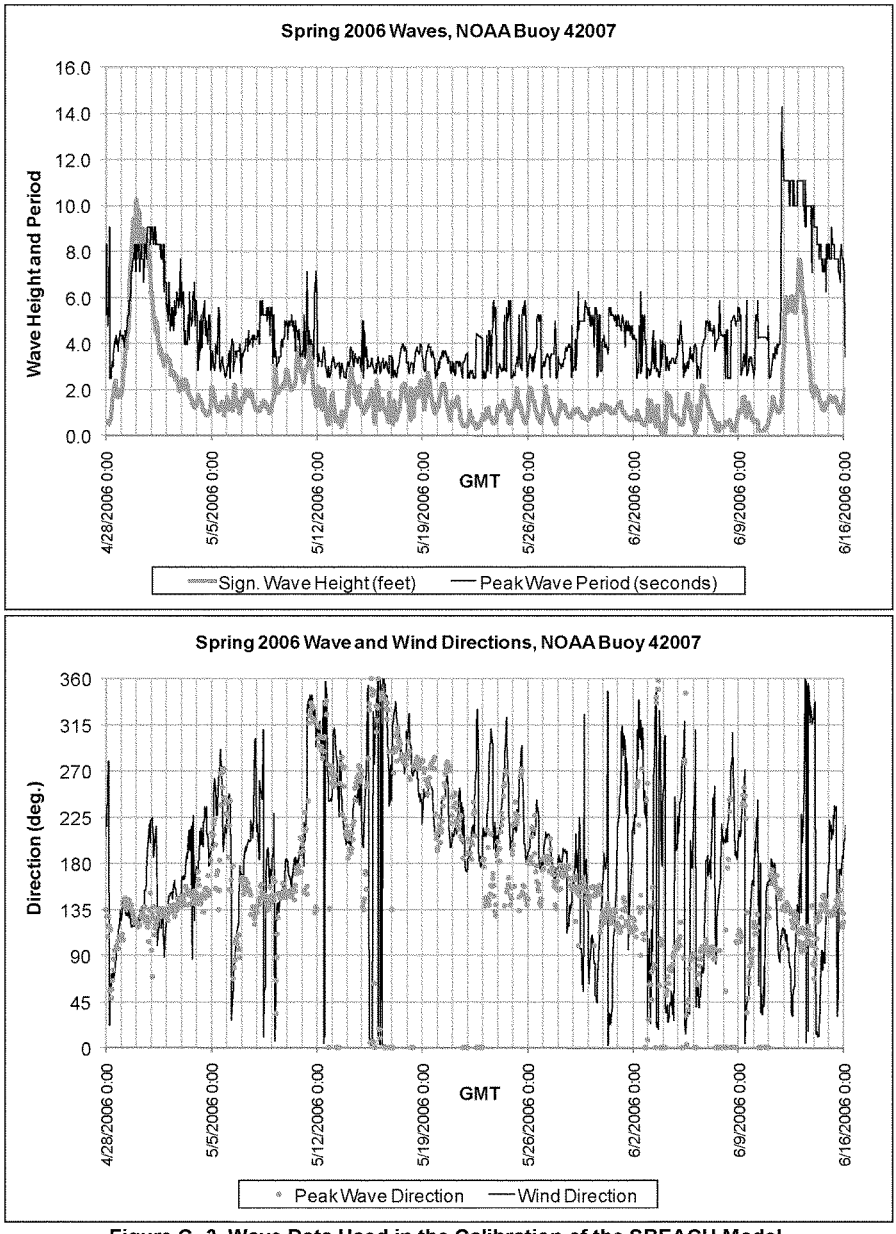


Figure C- 3. Wave Data Used in the Calibration of the SBEACH Model.

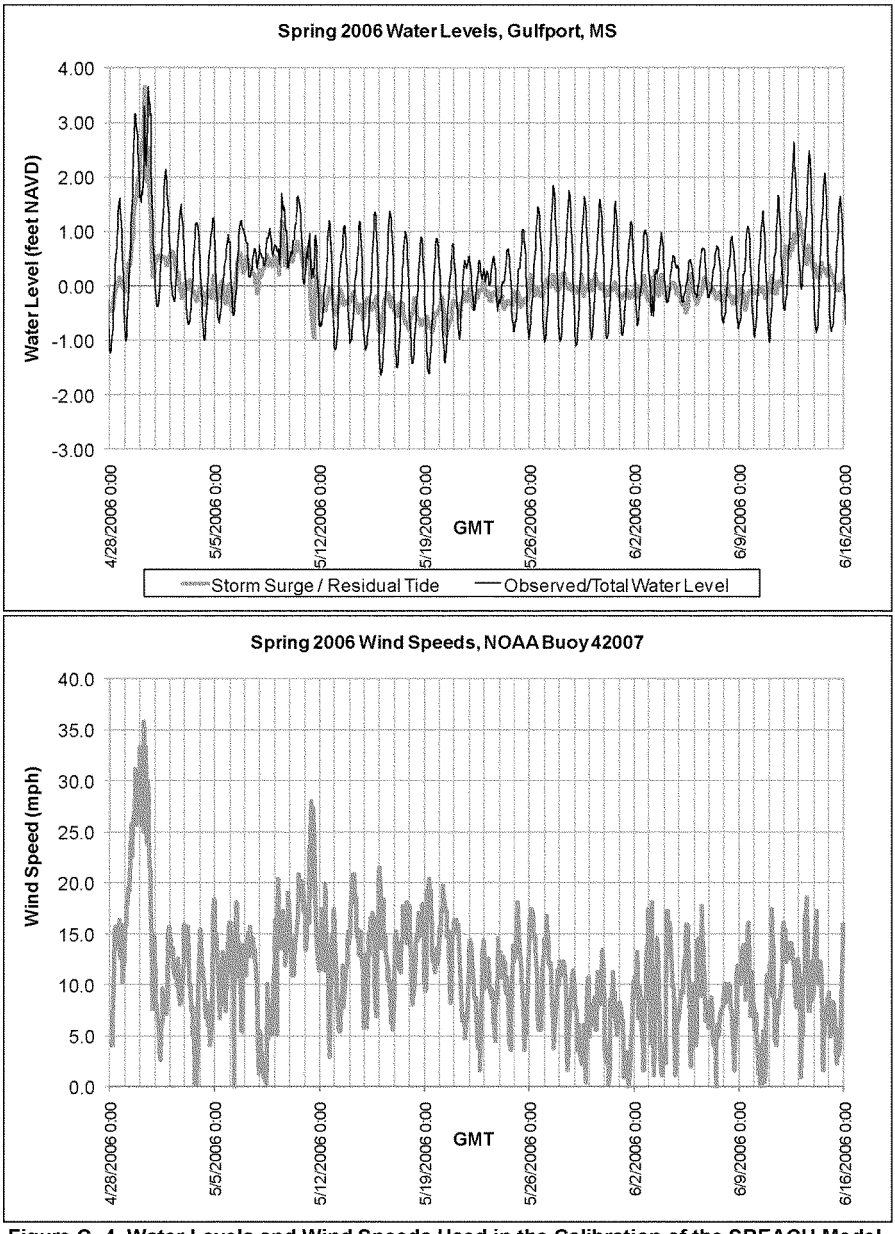


Figure C- 4. Water Levels and Wind Speeds Used in the Calibration of the SBEACH Model.

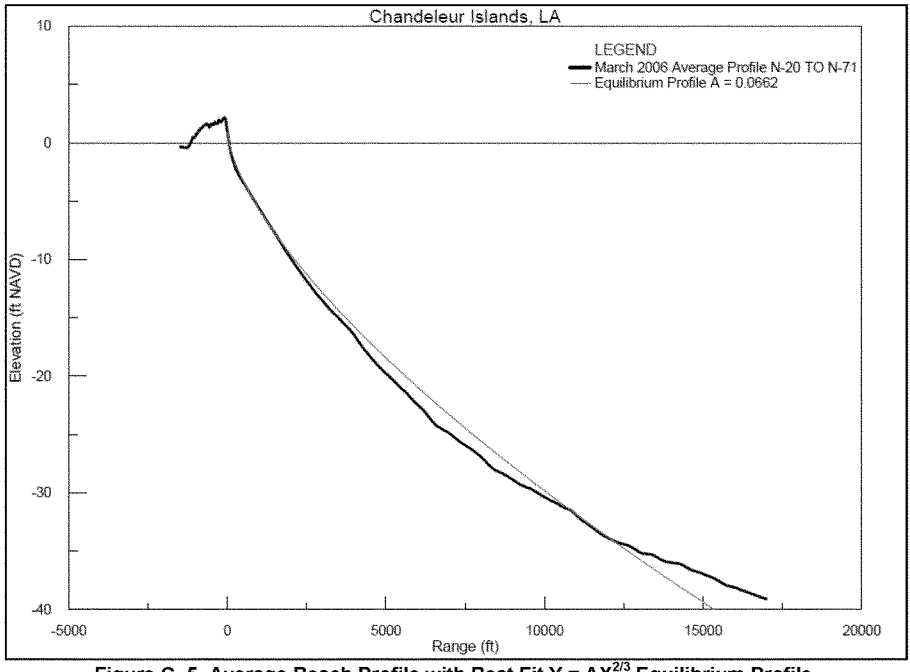


Figure C- 5. Average Beach Profile with Best Fit $Y = AX^{2/3}$ Equilibrium Profile.

2.4 Calibration Results

Given the quality of the beach profile data, the SBEACH model was calibrated in terms of the shoreline change and overwash values, rather than the best fit to the September 2006 beach profiles. In this Appendix, overwash was specifically calculated as the volume of material deposited landward of the post-storm dune crest. Calibration was conducted in terms of average values on each reach. This approach was taken for the following reasons:

- In general, the project area is characterized by a very discontinuous series of islands, rather than a single landmass (see Figures 18-21 of the main report). As a result, overwash and shoreline change tend to exhibit a great deal of variability. In addition, the discontinuous barrier islands make it difficult to represent the true beach profile using the surveys in Table C-1.

- The use of averages to calibrate the model provides for a setup that represents the study area as a whole, rather than a small number of profiles (3-4) at a particular location.

Since the model was calibrated in terms of averages, the results from the future conditions simulations in Section 3.0 will tend to represent average values. The actual variability may be on

the same order as the average values, as shown in the 2nd and 4th columns in Table C-2. The high degree of variability is not surprising given the discontinuous nature of the barrier island chain.

Table C- 2. CHANDELEUR ISLANDS, LA SBEACH CALIBRATION

Profile	Shoreline Change (feet)		Overwash (c.y./foot)	
	Observed	Final Calibration	Observed	Final Calibration
N-20	-66	28	3.1	5.5
N-21	-230	-175	0.9	6.1
N-25	-395	-117	2.3	3.2
N-26	-173	-74	2.9	3.5
N-32	-55	-404	1.3	4.7
N-36	-283	-347	5.6	1.4
N-39	-2	-109	10.5	1.2
South Reach Average N-20 to N-39	-172	-171	3.8	3.7
N-44	-433	-256	7.6	6.1
N-53	-597	-204	5.3	0.8
N-55	31	-166	1.9	7.6
N-56	-82	-158	9.5	6.6
Middle Reach Average N-44 to N-56	-270	-196	6.1	5.3
N-58	19	-140	0.6	7.0
N-61	-316	-134	1.4	1.5
N-64	-67	-147	18.8	6.4
N-65	-75	-76	8.0	5.1
N-71	-100	-68	0.4	4.6
North Reach Average N-58 to N-71	-108	-113	5.8	4.9

NOTES: Shoreline elevation = +0.91' NAVD.
Negative (-) shoreline changes indicate retreat.
Positive (+) shoreline changes indicate advance

Eight to 10 simulations were conducted on each reach. Grid spacing varied from 10 feet on the dry beach, 30 feet in the nearshore zone, and 90 feet offshore. During the calibration, the following parameters were examined:

- The Transport Rate Coefficient K.
- The Slope Dependent Term ε.
- The Transport Decay Multiplier λ.

- The Overwash Coefficient C_o.
- The Landward Surf Zone Depth D_{SURF}.

Calibration results appear in Table C-2 and Figures C-6 to C-8. Final calibration parameters appear in Table C-3. On the North and South Reaches, the model came close to the observed shoreline changes and overwash values. On the Middle Reach, there was no combination of parameters capable of reproducing the average shoreline change. However, the average overwash value was close to the observed value. The calibrated model did not provide exact matches between the simulated profile shape and the observed, September 2006 profiles. However, the model was generally able to reproduce the quantities required to evaluate the project's performance, such as shoreline change and overwash.

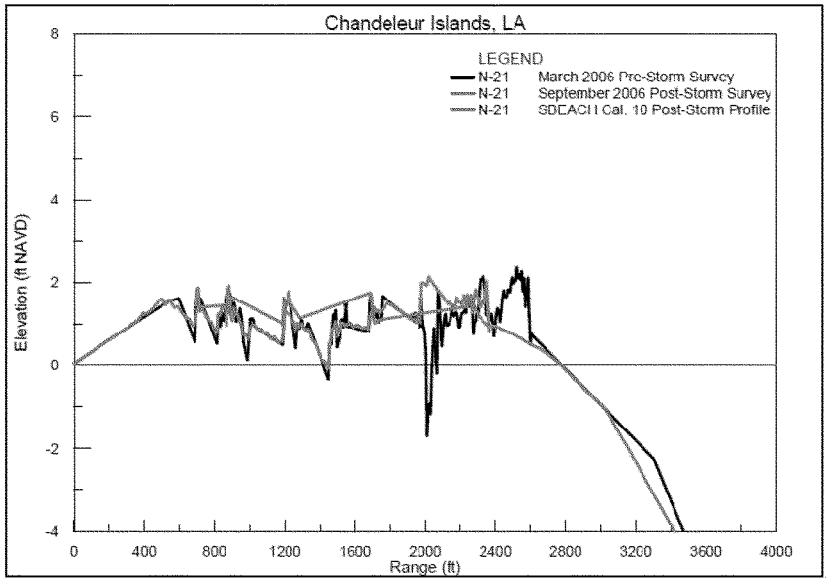


Figure C- 6. Typical SBEACH Calibration Results, Chandeleur Islands South Reach.

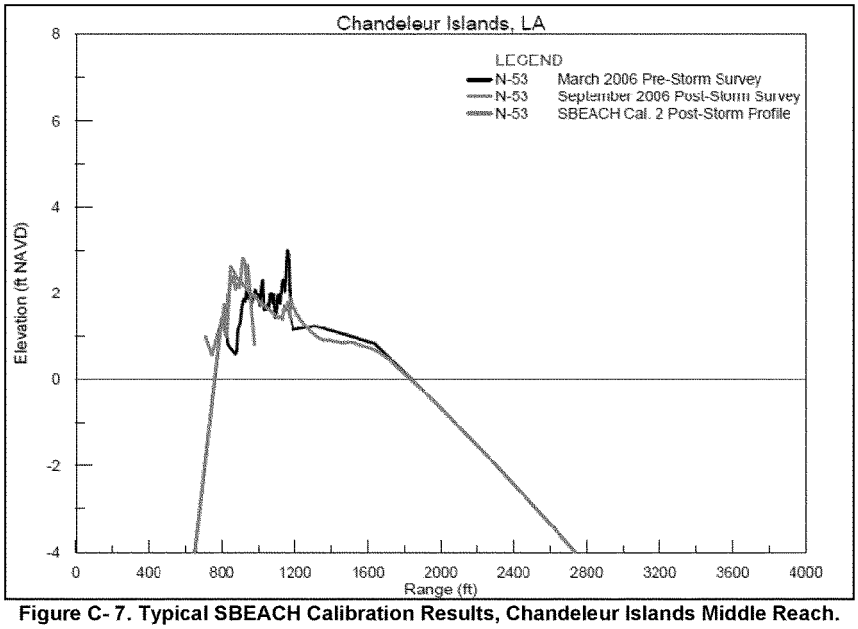


Figure C- 7. Typical SBEACH Calibration Results, Chandeleur Islands Middle Reach.

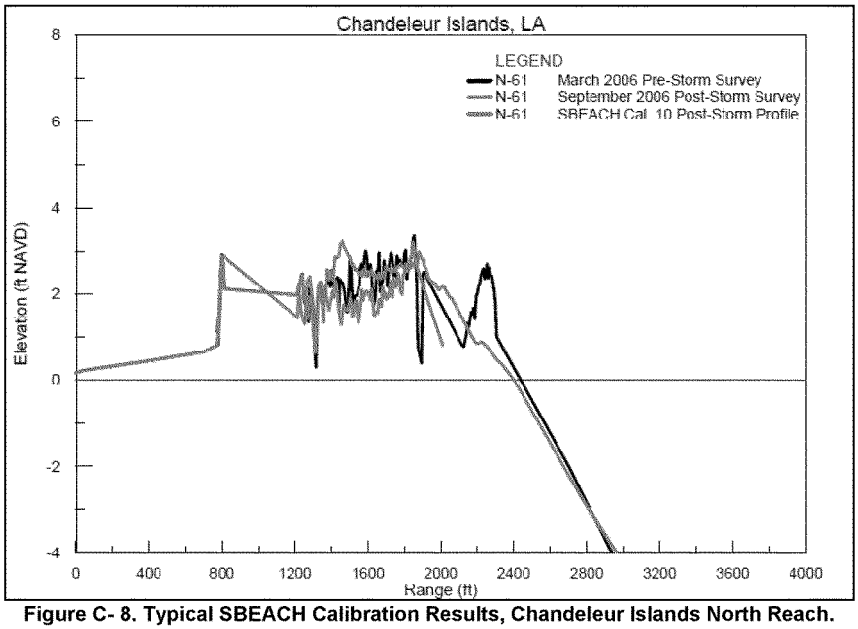


Figure C- 8. Typical SBEACH Calibration Results, Chandeleur Islands North Reach.

Table C- 3. FINAL SBEACH CALIBRATION PARAMETERS, CHANDELEUR ISLANDS, LA

	Typical or Allowed Values		Final Calibration		
	Minimum	Maximum	South	North	Middle
K (m^4/N)	$2.5x10^{-7}$	$2.5x10^{-6}$	$2.5x10^{-6}$	$2.5x10^{-6}$	$2.5x10^{-6}$
ε (m^2/s)	0.001	0.005	0.005	0.005	0.005
λ	0.1	0.5	0.3	0.3	0.1
C_o	0.002	0.01	0.005	0.005	0.008
D_{SURF} (feet)	0.5	1.6	1.6	1.6	1.6
Grain Size (mm)	0.10	1.00	0.10	0.10	0.10
Water Temperature (deg. C)	0	40	27	27	27

Differences between the surveyed and observed profile shapes in Figures C-6 to C-8 were probably due to:

- The range of dune elevations along the project area, which were only 1-2 feet above the mean high water line.
- The quality of the March 2006 and September 2006 surveys, which was generally poor.

Given the low relief of the study area and the low quality of the survey data, duplication of the post-storm profile shape was not feasible. Instead, the primary emphasis was to simulate the general processes that govern the overall performance of the project, including storm-driven shoreline retreat, overwash, and rollover. When the model was applied to examine the future conditions in Section 3.4.2, the overall shoreline retreat, overwash, and rollover trends were reasonable. The sensitivity of the model to the various parameters examined during the calibration is discussed in Sub-Appendix C-5.

3 FUTURE CONDITIONS

3.1 Beach Profiles

The beach profiles used in the future conditions simulations were based on the June 2007 LIDAR survey. The profiles were extended offshore and into the back bay using the June 2006 hydrographic survey. Based on the available LIDAR data and model stability considerations, the following profiles were simulated (Figure C-9):

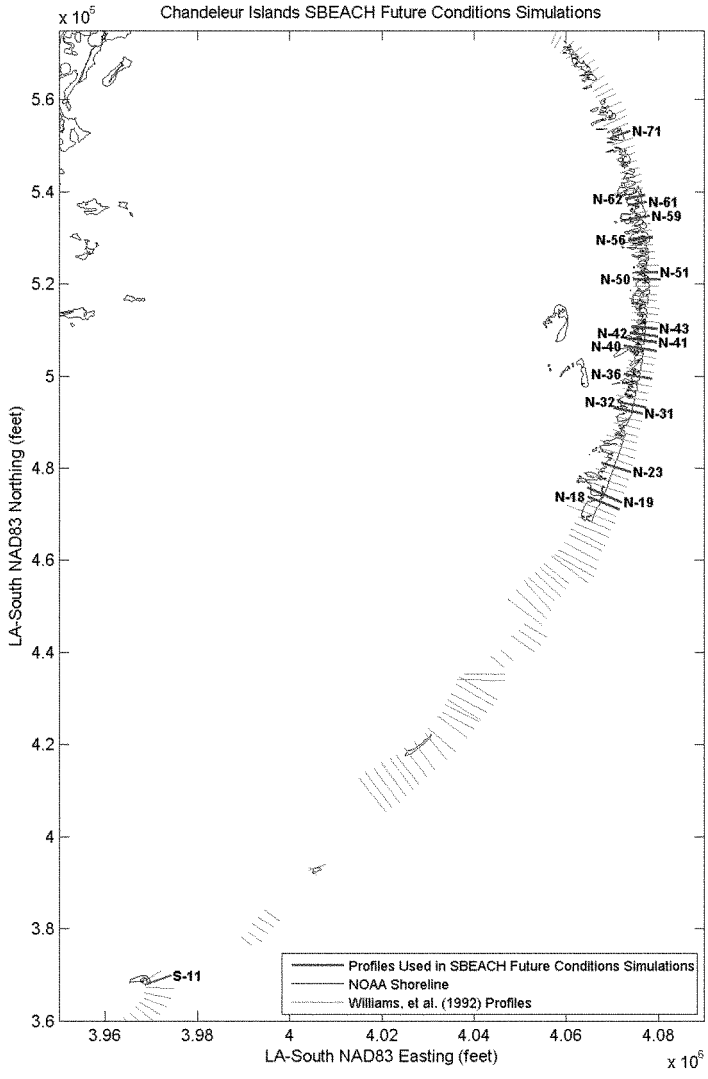


Figure C- 9. Beach Profiles Used in the SBEACH Future Conditions Simulations.

Breton Island: S-11.

Chandeleur Islands South Reach: N-18, N-19, N-23, N-31, N-32, N-36.

Chandeleur Islands Middle Reach: N-40, N-41, N-42, N-43, N-50, N-51, N-56.

Chandeleur Islands North Reach: N-59, N-61, N-62, N-71.

Four sets of runs were conducted using the profiles above:

- For the without-project scenario at Year 0, the initial condition for each simulation was the June 2007 / June 2006 profile.
- For the without-project scenario at Year 50, the initial condition for each simulation was the June 2007 / June 2006 profile lowered 0.54 feet to account for subsidence only. Eustatic sea level rise was accommodated by raising the input water levels. Subsidence and sea level rise are discussed in greater detail in the main report and later in this Appendix.
- For the with-project scenario at Year 0, the initial condition for each simulation was the June 2007 / June 2006 profile with fill. The fill cross-sections are discussed in greater detail in the main report and later in this Appendix.
- For the with-project scenario at Year 50, the initial condition for each simulation was the June 2007 / June 2006 profile with fill, lowered 0.54 feet to account for subsidence only.

Four additional set of runs were conducted on profiles S-11 and N-40 only:

- For the without-project scenario, the initial condition for each simulation at Year 0 was the 1 year post-storm profile from the corresponding simulation above.
- For the without-project scenario, the initial condition for each simulation at Year 50 was the 1 year post-storm profile from the corresponding simulation above.
- For the with-project scenario, the initial condition for each simulation at Year 0 was the 1 year post-storm profile from the corresponding simulation above.
- For the with-project scenario, the initial condition for each simulation at Year 50 was the 1 year post-storm profile from the corresponding simulation above.

3.2 Storm Data

3.2.1 Waves

Storm wave statistics for the project area are based on two sources: observed waves at NOAA Buoy 42007, and hindcast waves at WIS Station 144 (Figure C-2). The hindcast waves at WIS

Station 144 (USACE, 2003) were the primary data set from January 1980 to October 1996. The observed waves were the primary data set from October 1996 to December 2008. Gaps in the observed waves were filled using the hindcast waves at WIS Station 144 (USACE, 2003) prior to July 1999 and the hindcast waves at Buoy 42007 (NOAA, 2009) after July 1999. Combining the various data sets at the 2 locations provided a 29 year series of directional waves.

To delineate the table of wave height and wave period versus return period, the top 29 wave events were identified from the combined, 29 year data set. The Weibull distribution (i.e. Leenknecht, et al, 1992) was then applied to the wave heights and wave periods from each event (Figure C-10, Table C-4). The one year wave event exhibits a significant wave height of 10 feet and a peak wave period of 9 seconds. The 50 year wave event exhibits a significant wave height of 42 feet and a peak wave period of 18 seconds. In general, a Weibull distribution is valid up to return periods of 3 times the record length. Thus, wave values past the 87 year event are speculative.

Table C- 4. EXTREMAL (STORM) WAVE STATISTICS - 1980 TO 2008, NOAA BUOY 42007 & WIS STATION 144, CHANDELEUR ISLANDS, LA & GULFPORT, MS

Return Period (years)	Sign. Wave Height (feet)		Peak Wave Period (seconds)	
	Mean	± σ	Mean	± σ
1	9.7	1.5	8.9	0.5
2	12.8	2.0	10.5	0.5
3	15.5	2.8	11.5	0.7
4	17.6	3.6	12.1	0.8
5	19.4	4.2	12.6	0.9
6	20.9	4.8	13.1	1.0
7	22.2	5.3	13.4	1.1
8	23.4	5.7	13.7	1.2
9	24.4	6.1	14.0	1.3
10	25.4	6.5	14.2	1.3
15	29.2	8.0	15.2	1.6
20	32.0	9.1	15.8	1.8
25	34.2	10.0	16.3	1.9
30	36.1	10.8	16.7	2.0
35	37.7	11.4	17.1	2.1
40	39.1	12.0	17.4	2.2
45	40.4	12.5	17.7	2.3
50	41.5	12.9	17.9	2.3
60	43.5	13.7	18.3	2.4
70	45.2	14.4	18.7	2.5
80	46.7	15.0	19.0	2.6
90	*48.1*	*15.6*	*19.3*	*2.7*
100	*49.3*	*16.0*	*19.5*	*2.8*

Data Sources:
WIS Station 144, 30°4'59" N, 88°40'1" W, -55' NAVD, 1980-1996.
NOAA Buoy 42007, 30°5'25" N, 88°46'7" W, -44' NAVD, 1997-2008.
Values *in italics* past the 87 year event are speculative.

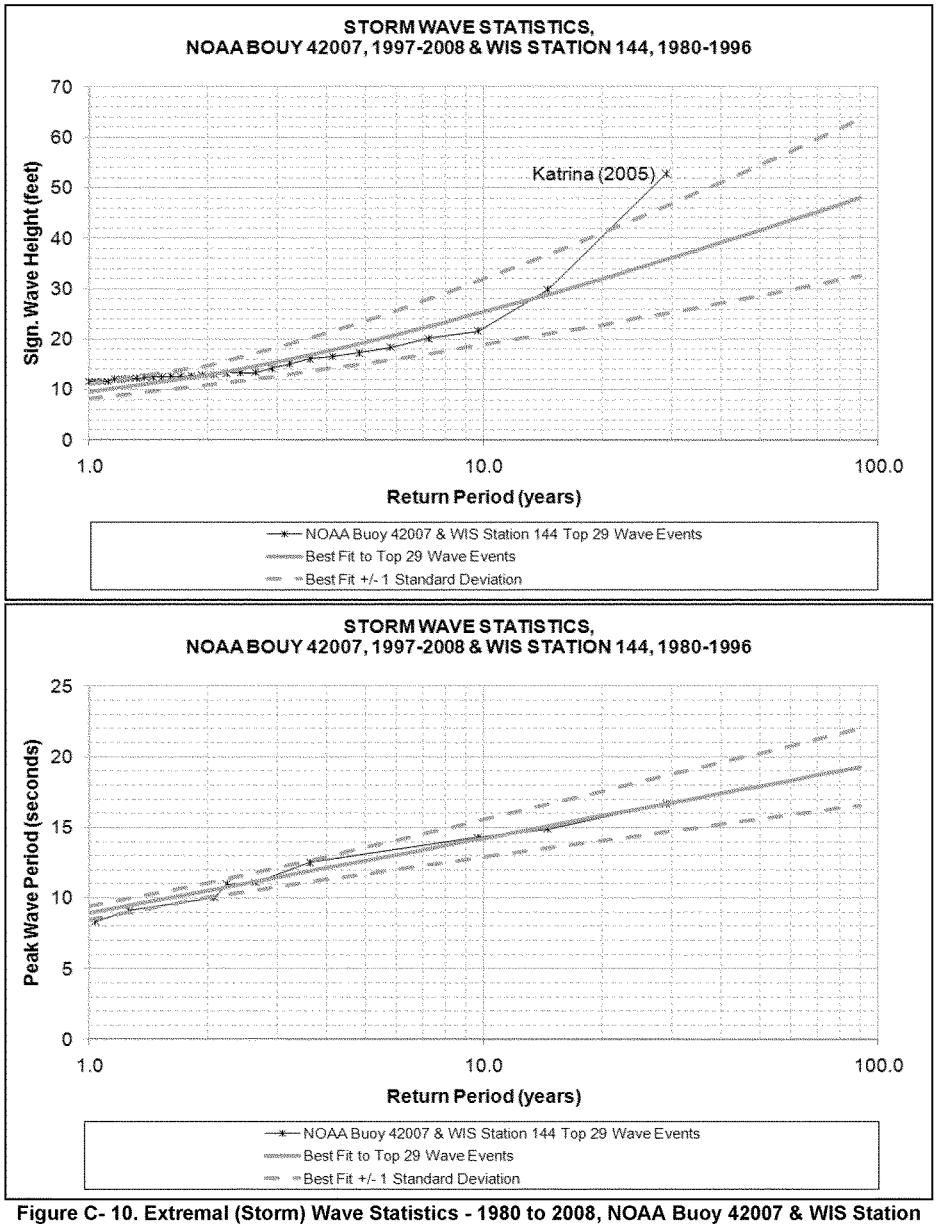


Figure C- 10. Extremal (Storm) Wave Statistics - 1980 to 2008, NOAA Buoy 42007 & WIS Station 144 Chandeleur Islands, LA & Gulfport, MS.

3.2.2 Storm Stages

Two major storm surge studies cover the project area: a 1984 study by the Federal Emergency Management Agency for St. Bernard Parish, and a 2007 study for the Coastal Protection and Restoration Authority of Louisiana. Based on the 1984 study, the 10 and 100 year "still water elevations" are 5.6 and 11.6 feet NAVD, excluding wave setup (FEMA, 1984, p. 17, Transect 4). The 1984 "base flood elevation" for the 100 year storm, which includes wave setup, is 13.8 to 16.8 feet NAVD (FEMA, 1984, p. 17). Based on the 2007 CPRALA study, the storm surge values in the back bay average 8 and 13 feet MSL during the 100 and 500 year storms (CPRALA, 2007, p. 21).

Although the 2007 study considers includes the effects of hurricanes Katrina (2005) and Rita (2005) (CPRALA, 2007, pp. 8-9), the 100 year storm surge value is considerably lower than the 1984 value. In addition, no values are given for any storm below the 100 year level. For these reasons, the storm stages used in this analysis are the FEMA (1984) values (Table C-5). Since these values do not include wave setup, they are ideal for use in the SBEACH model, which calculates wave setup internally.

Table C- 5. BRETON & CHANDELEUR ISLANDS, LA, STORM STAGE VALUES (FEMA, 1984)

Return Period (years)	Storm Stage (feet NAVD)
10	5.6
20	*7.4*
50	*9.8*
100	11.6

NOTE: Values in *italics* are interpolated.

Storms with an intensity of 10 years or higher utilize the peak water levels in Table C-5. However, if Table C-5 were extrapolated to the 1, 2, 3, 4, or 5 year return periods, the resulting storm stages would fall near or below Mean Higher High Water. For this reason, the 1, 2, 3, 4, and 5 year events assume the water levels of the October 2006 cold front. This storm is discussed later in this report.

3.2.3 Winds

Wind Speeds for the project area are based on Coastal Engineering Technical Note I-36, "Estimates of Hurricane Winds for the East and Gulf Coasts of the United States" (USACE, 1985). The selected values for the analysis were the wind speeds "at the coast" for the state of Mississippi. Wind speeds appear in Table C-6.

Table C- 6. EXTREMAL WIND STATISTICS, CHANDELEUR ISLANDS, LA & GULFPORT, MS, (USACE, 1985, Station 750)

Return Period (years)	Wind Speed (mph)
1	*19*
2	*32*
3	*40*
4	*46*
5	*50*
10	64
20	*78*
25	82
50	92
100	102
2000	136

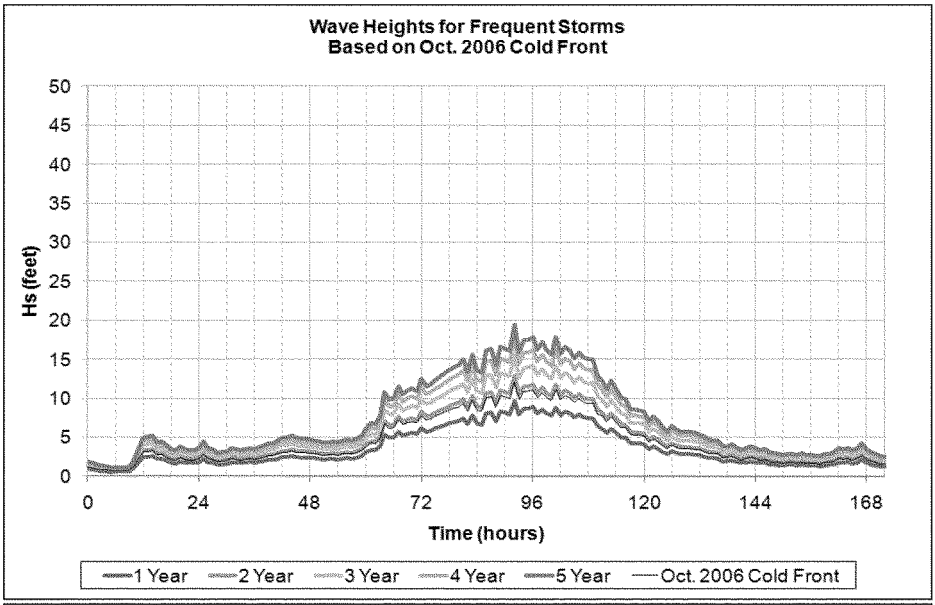
NOTE: Values in *italics* interpolated or extrapolated.

3.2.4 Prototype Storms

SBEACH allows the waves, water levels, and winds to be given as time histories. The time histories of the 1, 2, 3, 4, 5, 10, 20, 50, and 100 year events consider the two types of storms that affect the project area: cold fronts, which are more frequent but less severe, and tropical systems, which are less frequent but more intense.

The 1, 2, 3, 4, and 5 year events were based on October 2006 cold front (Figures C-11 to C-13). Measured wind, water level, and wave data was available for the entire duration of this event. The observed wave height during this storm was 12 feet, equivalent to a return period between 1 and 2 years (see Table C-4). Water levels during the October 2006 cold front reached +3.5 feet NAVD and were up to 2.6 feet above the normal tides.

The 10, 20, 50, and 100 year events were based on Hurricane Ivan (2004) (Figures C-14 to C-17). Although Hurricane Katrina (2005) was the highest wave event between 1980 and 2008, Buoy 42007 and the region's tide gages malfunctioned during Katrina. Hurricane Ivan was the second highest wave event. Buoy 42007 functioned properly for the entire duration of the event. In addition, measured water levels were available in the region. The observed wave height during Ivan was 30 feet, equivalent to a return period between 15 and 20 years (see Table C-4).



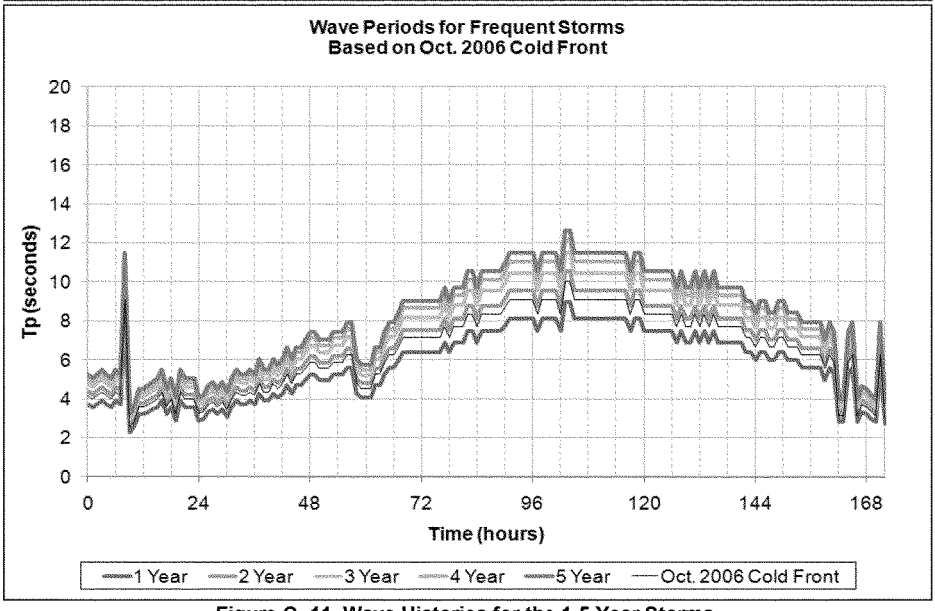
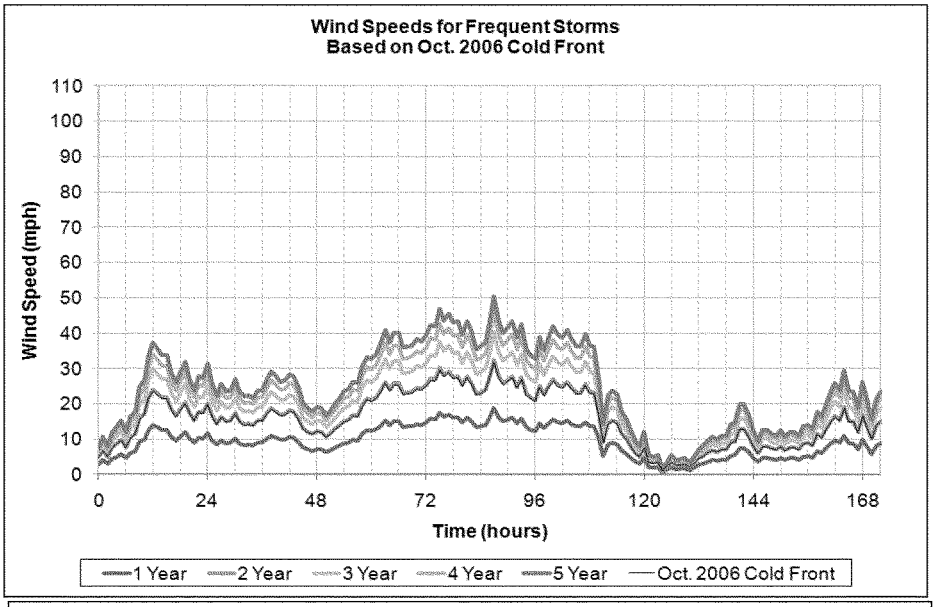


Figure C- 11. Wave Histories for the 1-5 Year Storms.



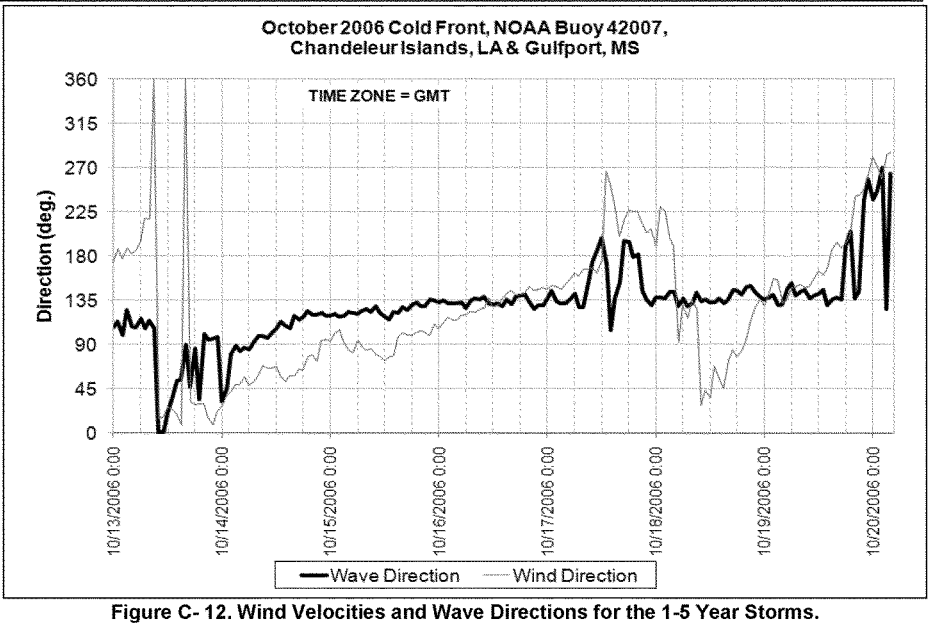


Figure C- 12. Wind Velocities and Wave Directions for the 1-5 Year Storms.

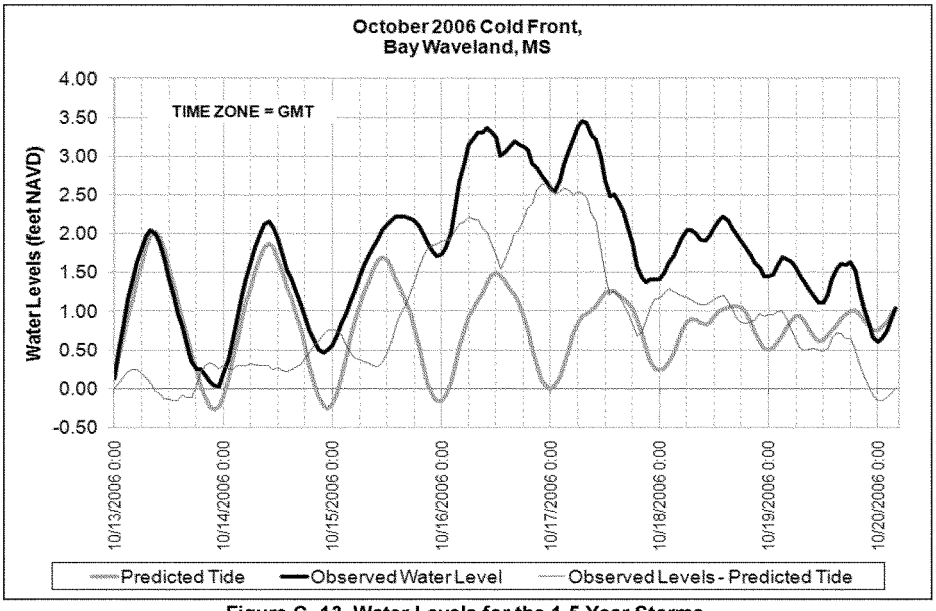


Figure C- 13. Water Levels for the 1-5 Year Storms.

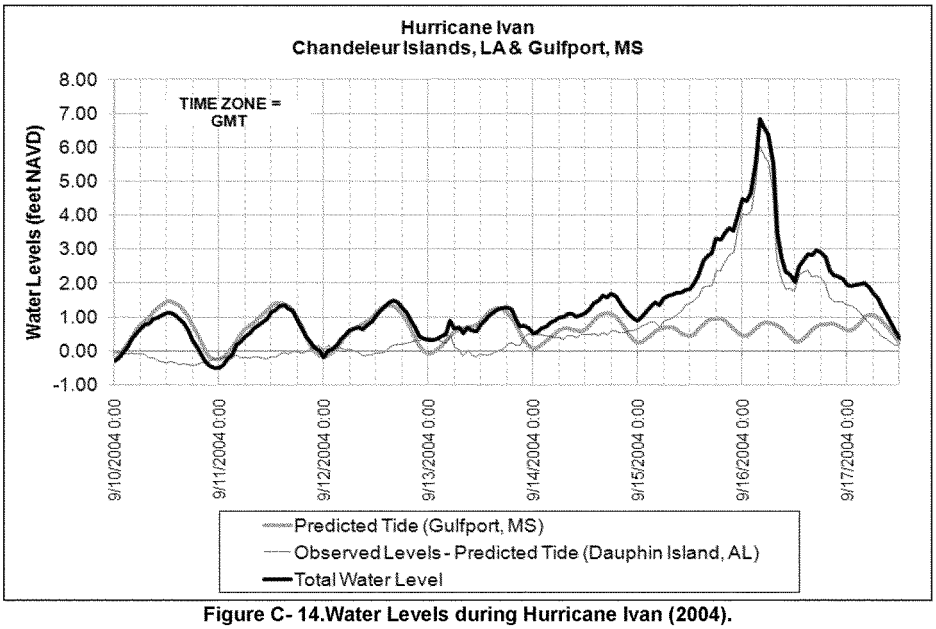
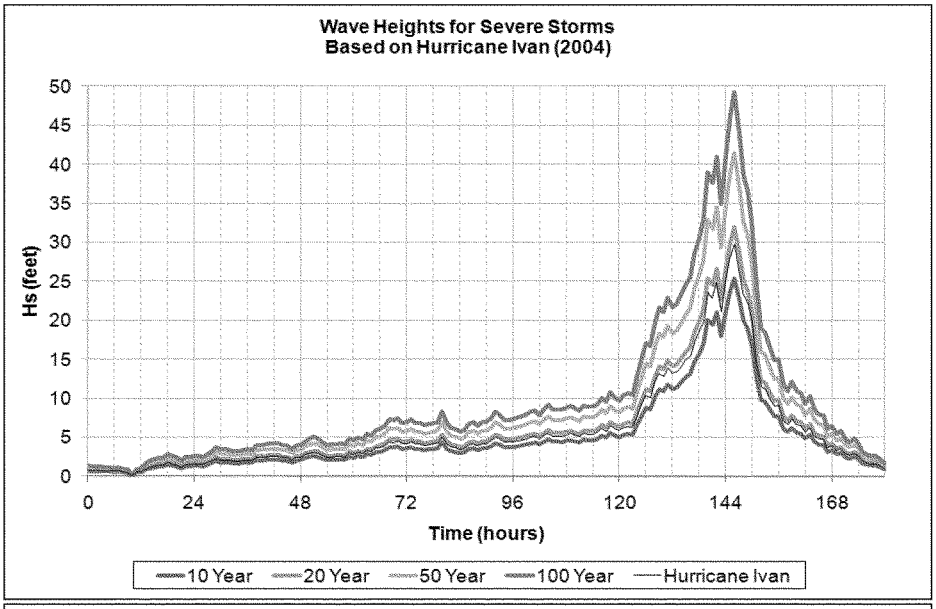


Figure C- 14.Water Levels during Hurricane Ivan (2004).



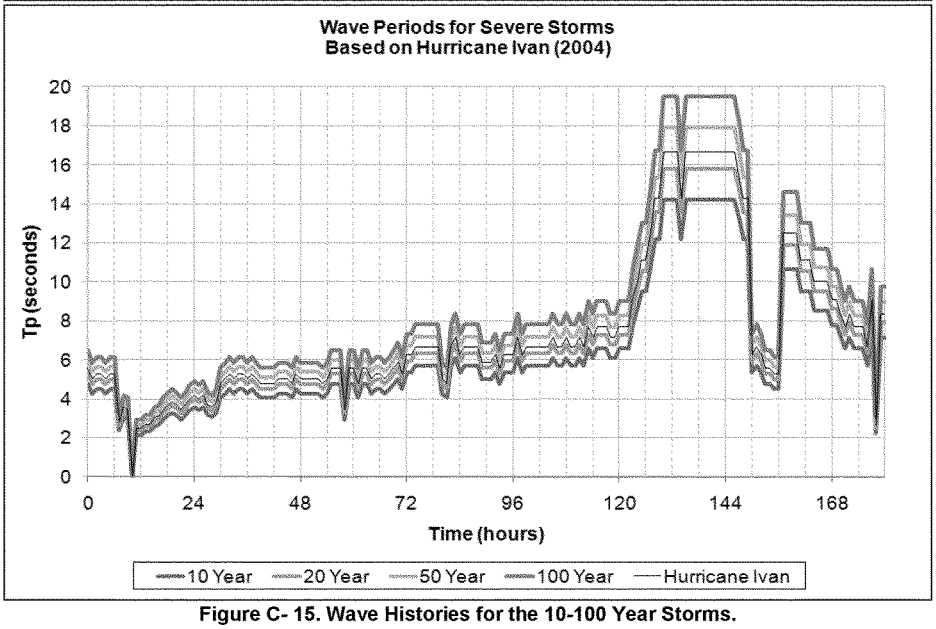


Figure C- 15. Wave Histories for the 10-100 Year Storms.

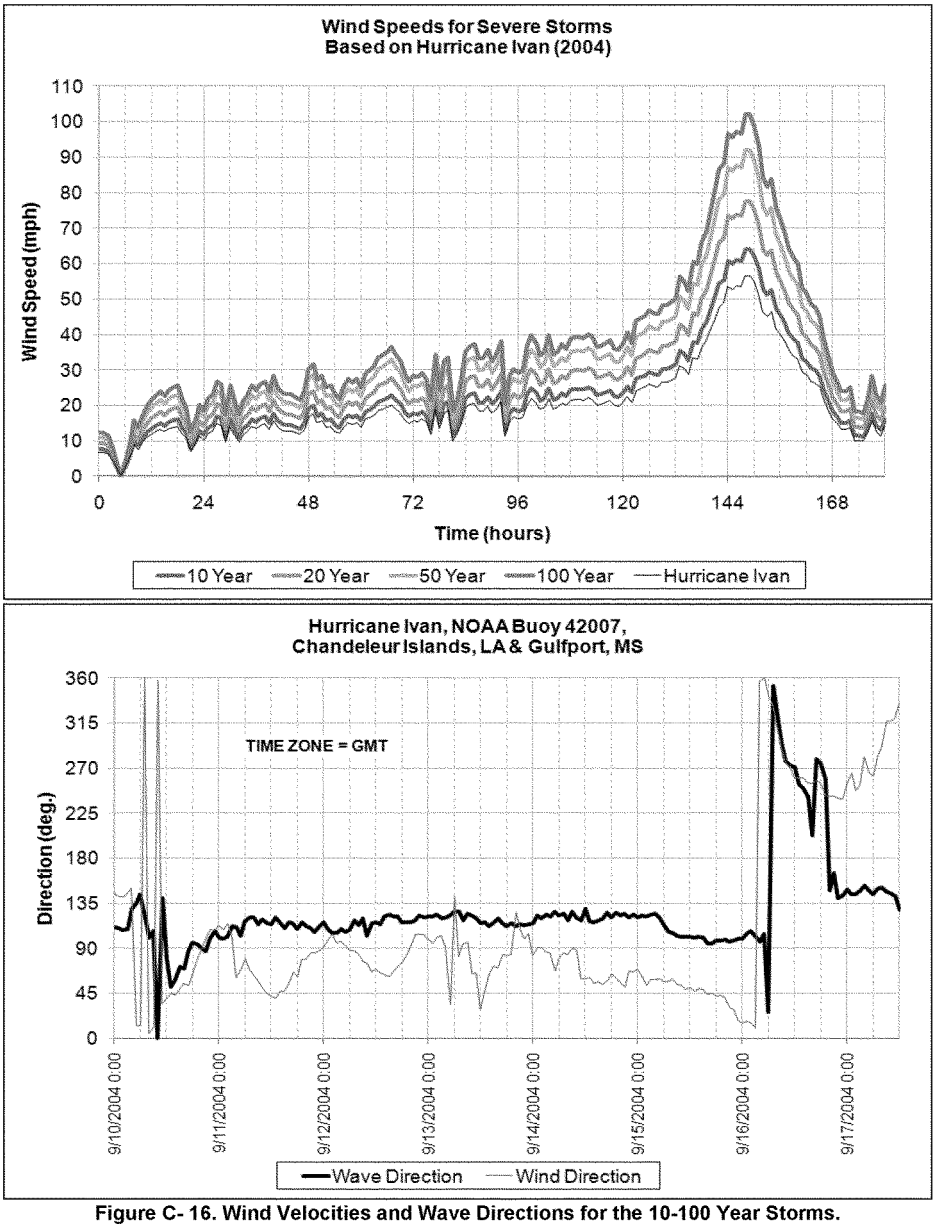


Figure C- 16. Wind Velocities and Wave Directions for the 10-100 Year Storms.

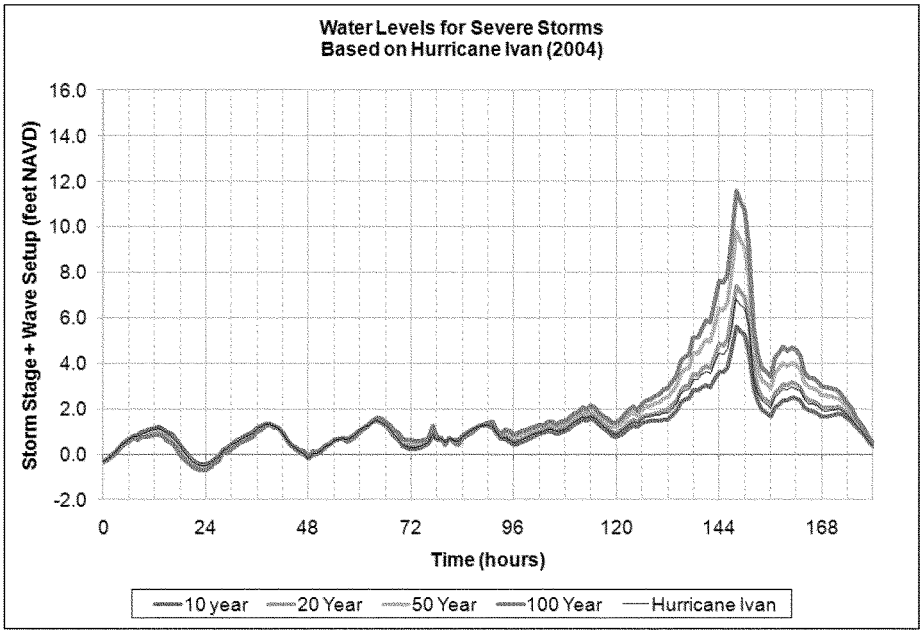


Figure C- 17. Water Levels for the 10-100 Year Storms.

3.2.5 Subsidence and Sea Level Rise

For each storm, the SBEACH simulations were performed based on the conditions at Year 0 and the conditions at Year 50. To account for subsidence and sea level rise, the following rates were assumed, based on the main report:

- Subsidence: 0.0108 feet/year (3.3 mm/year).

- Eustatic Sea Level Rise:
  - Low Rate: 0.0056 feet/year (1.7 mm/year).
  - Medium Rate: 0.0139 feet/year (4.2 mm/year).
  - High Rate: 0.0412 feet/year (12.6 mm/year).

Subsidence represents a lowering of the land surface, while eustatic sea level rise represents a rise in the water level. Accordingly, these processes were accommodated in two parts. To accommodate subsidence through Year 50, the input profiles were lowered 0.54 feet. To account for eustatic sea level rise, the water levels in Figures C-13 and C-17 were raised 0.28 feet for the low sea level rise scenario, 0.70 feet for the medium sea level rise scenario, and 2.06 feet for the high sea level rise scenario. In other words, each simulation at Year 50 was run 3 times, to represent 3 different rates of eustatic sea level rise. In the first set of simulations, the water level was raised 0.28 feet; in the second set, the water level was raised 0.70 feet, and in the third set,

the water level was raised 2.06 feet. All 3 sets of simulations used a profile lowered 0.54 feet as the initial condition.

3.3 Design Cross-Sections

3.3.1 Chandeleur Islands and Breton Island Alternative 1

Chandeleur Islands and Breton Island Alternative 1 generally features two types of fill areas:

- A long, continuous fill area from profiles N-27 to N-46. This fill area is to be placed on or near the eastern (seaward) faces of the existing barrier islands. It features a beach fill platform with a design elevation of +3 feet NAVD, side slopes of 1 vertical on 30 horizontal above +1 foot NAVD, and side slopes of 1 vertical on 60 horizontal below +1 foot NAVD.

- Rectangular fill areas that are oriented in the cross-shore direction. These fill areas are to be placed on the western (bay) side of the existing barrier islands. They feature a fill platform with a design elevation of +2 feet NAVD and side slopes of 1 vertical on 30 horizontal.

Among the profiles being simulated, profiles S-11, N-31, N-32, N-36, N-40, N-41, N-42, N-43, feature the first type of fill area, and profiles S-11, N-32, N-41, and N-50 feature the second type of fill area. With-project simulations were conducted for all of these profiles, except for profile N-50. The fill area on profile N-50 was too large to be properly simulated in the SBEACH model. Given the layout of the fill area on profile N-50 and the characteristics of the existing beach, the fill area on profile N-50 will probably perform in a manner similar to the corresponding fill area on N-41.

3.3.2 Breton Island Alternative 2

Breton Island Alternative 2 features a fill area with a crest elevation of +6 feet NAVD. The crest width along profile S-11 is 754 feet. Side slopes are 1 vertical on 45 horizontal.

3.3.3 Breton Island Alternative 3

Breton Island Alternative 3 features an irregular fill area with a maximum platform elevation of +10 feet NAVD. However, due to the layout of this feature and the orientations of profiles S-7, S-8, and S-11, the profile elevations, side slopes, and widths vary. The details of this alternative are discussed in the main report. Design cross-sections appear in the main report and on a limited number of profile plots in Sub-Appendices C-2 and C-6.

3.4 Results

3.4.1 Model Stability

SBEACH uses an explicit numerical scheme, in which the hydrodynamic forcing between two successive time steps is based on the "known" conditions at the earlier time step. Wider grid spacing and a shorter times step increase numerical stability, while a narrower grid spacing and longer time steps decrease numerical stability. The time step utilized in the future conditions simulations varied from 1 to 2 minutes, which was significantly less than the default value of 5 minutes. The minimum grid spacing was 10 feet, which is twice the more typical value of 5 feet. Despite these settings, the numerical stability was marginal during some of the simulations, particularly at Year 50.

The length of the time step was investigated as a means of resolving stability issues. However, despite using small time steps, stability issues persisted, particularly near the transition between the minimum grid spacing of 10 feet and the intermediate spacing of 90 feet offshore. Although uniform grid spacing could eliminate this issue, it would require profiles with several times more grid points than the 1,000 point limit allowed in the model unless a wave transformation model such as SWAN were used with SBEACH.

To investigate whether numerical stability issues compromised the results, the following output from the model was examined:

- Wave setup and wave height as a function of distance across the beach profile.
- The appearance of the profile above 0' NAVD.

If the storm surge + wave setup exhibited abrupt variations across the beach profile, this result would indicate that the hydrodynamic forcing was being adversely affected by the changes to the beach profile. Likewise, if the wave height exhibited abrupt variations across the beach profile, aside from final breaking, this result would also indicate the hydrodynamic forcing was being adversely affected. If the hydrodynamic forcing were adversely affected, the results of above 0' NAVD would be questionable regardless of the profile's appearance above 0' NAVD. In the runs in which numerical stability was marginal, the storm surge + wave setup did *not* exhibit unrealistic variations across the beach profile, nor did the wave height. Instead, their variations were similar to the runs in which numerical stability was good.

The appearance of the profile above 0' NAVD was reasonable for all runs shown in Sub-Appendices C-1 and C-2. Unphysical changes to beach profile above 0' NAVD were generally absent.

Overall, numerical stability issues did not compromise the wave setup elevations and wave refraction estimates during the runs listed in Sub-Appendices C-1 and C-2. In addition, the results above the Mean High Water (+0.91' NAVD) appeared to be reasonable. Accordingly, the results in Sub-Appendices C-1 and C-2 were adopted for use in this study.

3.4.2 Beach Profiles

SBEACH results for the without-project scenarios appear in Sub-Appendix C-1. Results for the with-project scenarios appear in Sub-Appendix C-2. The results therein include the shoreline changes, overwash volumes, the amount of erosion above the shoreline elevation (+0.91' NAVD), the post-storm dune elevations, and the post-storm beach profiles.

Additional runs were conducted for profiles S-11 and N-40 using the 1 year post-storm profile as the input, or pre-storm, profile. The purpose of these runs was to examine the cumulative effect of storm activity on the islands' cross-sections. These results appear in Sub-Appendices C-3 and C-4.

For Breton Island Alternatives 2 and 3 only, additional runs were conducted to support the Wetland Value Assessment (WVA). These results appear in Sub-Appendix 6. In the case of Breton Island Alternative 2, the seaward beach face was moved 665 feet landward to simulate retreat through Year 5. Using this eroded profile, a preliminary simulation was conducted for the 10 year storm. The post-storm profile from this preliminary simulation was then used as model input for the 1, 2, 3, 4, 5, 10, 20, 50, and 100 Year storms. In the case of Breton Island Alternative 3, the seaward beach face was moved 2,040 feet landward, and the profile as a whole was lowered 0.2 feet to simulate retreat and subsidence through Year 17. Using this eroded profile, a preliminary simulation was conducted for the 20 year storm, with water levels raised 0.1 feet to account for a low amount of eustatic sea level rise. The post-storm profile from this preliminary simulation was then used as model input for the 1, 2, 3, 4, 5, 10, 20, 50, and 100 Year storms at Year 17.

Given the existing conditions at Year 0 (Sub-Appendix C-1 table), dune elevations following the 50 year storm will average +1.2, +2.1, +2.3, and +2.8 feet NAVD on Breton Island, the South Reach (N-31 to N-36), the Middle Reach (N-40 to N-43), and the North Reach (N-59 to N-71), respectively. With the design cross-sections in place on the South Reach and Middle Reach (Sub-Appendix C-2 table), the corresponding dune elevations after the 50 year storm will be +3.1 and +2.9 feet NAVD. On Breton Island, dune elevations after the 50 year storm at Year 0 will be +4.4 feet NAVD given Alternative 1, +6.2 feet NAVD given Alternative 2, and +10.3 feet NAVD given Alternative 3 (see Sub-Appendix C-2 table).

Given a moderate sea level rise scenario without a project (Sub-Appendix C-1 table), dune elevations following the 50 year storm at Year 50 will average +1.4, +1.4, +1.6, and +2.3 feet NAVD on Breton Island, the South Reach (N-31 to N-36), the Middle Reach (N-40 to N-43), and the North Reach (N-59 to N-71), respectively. With the design cross-sections in place on the South Reach and Middle Reach, the corresponding dune elevations after the 50 year storm will be +2.2 and +2.3 feet NAVD at Year 50, respectively (see Sub-Appendix C-2 table). On Breton Island, dune elevations after the 50 year storm at Year 50 will be +3.9 feet NAVD given Alternative 1, +5.5 feet NAVD given Alternative 2, and +9.7 feet NAVD given Alternative 3 (see Sub-Appendix C-2 table).

On the Chandeleur Islands, shoreline retreat patterns during storms do not appear to exhibit substantial changes with the placement of fill (see Sub-Appendices C-1 and C-2 tables).

However, overwash volumes will be substantially higher at Year 0 and at Year 50 given the low and moderate sea level rise scenarios.

On Breton Island, shoreline changes during storms given Alternatives 1, 2, or 3 will decrease by roughly 1/3 at Year 0 and 1/2 at Year 50 versus the without-project scenario (see Sub-Appendices C-1 and C-2 tables). Overwash volumes will vary depending on which alternative is selected. Alternative 1 will lead to negligible overwash during the 1 and 2 year storms at Year 0, more overwash during the 3-100 year storms at Year 0, and considerably more overwash during all storms at Year 50. Alternative 2, which features a higher dune, will lead to negligible overwash during the 1-10 year storms at Year 0, more overwash during the 20-100 year storms at Year 0, less overwash during 1-5 year storms at Year 50, and more overwash during the 10-100 storms at Year 50. Alternative 3, which features the high marsh platform, will lead to negligible overwash during the 1-10 year storms at Year 0, more overwash during the 50-100 year storms at Year 0, less overwash during 1-20 year storms at Year 50, and more overwash during the 50-100 storms at Year 50.

On the Chandeleur Islands, most of the profiles under the without-project scenario or Alternative 1 exhibit "rollover" trends in the SBEACH model, with landward movement of the dune, overwash, and a loss of material from the seaward beach face (see Sub-Appendices C-2 and C-4 profiles). At Year 50, however, this tendency is less under the high sea level rise scenario than under the low and moderate scenarios. This may be due to the fact that the barrier islands are submerged for a much larger percentage of the time under the high sea level rise scenario than the other two. As a result, the effects of runup and overtopping are diminished. This is also the case given the without-project scenario and Alternative 1 on Breton Island. Where fill is placed on the landward side of the barrier island (profiles N-32 and N-41) on the Chandeleur Islands, the amount of erosion into the fill is negligible. However, deposition of material onto the fill platform can occur through overwash.

On Breton Island, the higher cross-sections under Alternatives 2 or 3 will tend to suppress overwash and rollover, as depicted on the profiles in Sub-Appendices C-2 and C-4. During storms in which overwash and rollover are insignificant, material eroded from above the waterline is deposited on the seaward slope of the profile below the water line, instead of the landward side of the island. Nevertheless, the simulations depicted in Sub-Appendix C-6 show that long-term shoreline retreat will increase the likelihood overwash and rollover.

Overall, the SBEACH model is able to predict the general trends governing storm-driven erosion along the project area. In spite of various limitations regarding input data, profile length, and numerical stability, the general overwash, shoreline change, and barrier island rollover patterns appear to be reasonable.

3.4.3 Wave Setup / Total Water Level

As noted earlier, the storm stages used in the SBEACH model were based on a 1984 report. A recent Flood Insurance Study for Harrison County, MS was prepared by FEMA (2007), listing the 10, 50, 100, and 500 year storm stage + wave setup elevations at Deer Island (see Figure C-2). The Harrison County study included the effects of Hurricane Katrina in its analysis. In

general, the wave setup elevations based on the SBEACH model exceeded the published estimates at Deer Island (Table C-7). Given the open-Gulf setting of the project area and the sheltered location at Deer Island, the wave setup elevations (in feet NAVD) predicted by the SBEACH model were reasonable. The older storm surge estimates (FEMA, 1984) used in the SBEACH model did not appear to compromise its results.

Table C- 7. WAVE SETUP ELEAVTIONS, WITHOUT PROJECT CONDITIONS AT YEAR 0, BRETON & CHANDELEUR ISLANDS, LA

Return Period (years)	Average Storm Stage + Wave Setup (feet NAVD) at Year 0				
	Deer Island, MS (FEMA, 2007, p. 27, Trans. 8)	Breton Island	South Chandeleurs	Middle Chandeleurs	North Chandeleurs
10	5.4	10.1	8.4	8.7	9.0
20	8.6	13.3	10.6	11.2	11.6
50	12.9	17.4	13.5	14.4	14.9
100	15.8	20.9	15.8	16.9	17.5

4 CONCLUSIONS AND RECOMMENDATIONS

To investigate storm erosion, the SBEACH model was calibrated based on erosion patterns during a cold front and a tropical storm between April 2006 and June 2006. The quality of the beach surveys and the limitations of the model posed challenges with respect to calibration and numerical stability. However, the model was able to predict the general patterns that govern storm-driven erosion along Breton Island and the Chandeleur Islands. In addition, it was able to confirm that the area would benefit from the placement of fill, with higher post-storm dune elevations and a larger amount of overwash. Finally, the wave setup elevations predicted by the model compared favorably with recent, published estimates along the Mississippi Coast.

The SBEACH model was appropriate for a preliminary analysis of the project being considered. However, if SBEACH were used for a more detailed analysis, the following procedures would improve the quality of the results:

- Conduct a land and hydrographic survey along selected profiles using conventional methods, rather than LIDAR, to provide a continuous, accurate representation of the barrier islands' cross-sections.
- Repeat the survey above using the same methods after the passage of a major cold front or tropical system.
- Recalibrate the model based on the two surveys above and concurrent wave, wind, and water level data.

- Use a wave transformation model such as SWAN to estimate the 5-100 year wave height and wave direction in shallow water. This step can also be taken for the wave conditions during the re-calibration period. By defining the input wave heights at -10 to -20 feet NAVD, the SBEACH model can be run using short profiles with a uniform grid spacing, thereby reducing the likelihood of instabilities in the SBEACH model.

An alternative to the SBEACH model would be a two dimensional (2DH) or three dimensional model such as Delft3D (Deltares, 2005), Mike Flow Model FM (DHI, 2009), or CMS-Flow (formerly M2D) (USACE, 2009), that estimates changes to a bathymetric grid surface, rather than a profile. A surface-based model would able to simulate erosion along the western (bay) side of the barrier islands and longshore transport processes on the eastern (sea) side, along with the cross-shore processes that are simulated in SBEACH.

5 REFERENCES

Coastal Planning & Engineering, Inc., 2009. West Belle Pass Barrier Headland Restoration Project (Te-52) 95% Design Report, Coastal Planning & Engineering, Inc., Boca Raton, FL.

Coastal Protection and Restoration Authority of Louisiana, 2007. Integrated Ecosystem Restoration and Hurricane Protection: Louisiana's Comprehensive Master Plan for a Sustainable Coast, Appendix E: Hurricane Surge Evaluations, Coastal Protection and Restoration Authority of Louisiana, Baton Rouge.

Deltares, 2005. Delft3D-FLOW, Simulation of Multi-Dimensional Hydrodynamic Flows and Transport Phenomena, Including Sediments, User Manual. Deltares, Delft, The Netherlands.

DHI, 2009. Coupled Model FM, DHI Group, Hørsholm, Denmark, http://www.dhigroup.com/Software/Marine/MIKE3/Details/SedimentsAndMorphology/CoupledModelFM.aspx.

Federal Emergency Management Agency, 1984. Flood Insurance Study, St. Bernard Parish, Louisiana, Unincorporated Areas, Federal Emergency Management Agency, Washington.

Federal Emergency Management Agency, 2007. Flood Insurance Study, Harrison County, Mississippi and Incorporated Areas, Federal Emergency Management Agency, Washington.

Hanson, H. and Kraus, N.C., 1989. GENESIS: Generalized Model for Simulating Shoreline Change, Report 1, Technical Reference. Coastal Engineering Research Center, Vicksburg, MS.

Hanson, M. and Howd, Peter, 2008. Louisiana Barrier Island Comprehensive Monitoring Program (BICM) Volume 4: Louisiana Light Detection and Ranging Data (Lidar), U.S. Geological Survey Florida Integrated Science Center, St. Petersburg, FL.

Leenknecht, D.A.; Szuwalski, A., and Sherlock A.R., 1992. Automated Coastal Engineering System Technical Reference. U.S. Army Corps of Engineers, Coastal Engineering Research Center.

Larson, M. and Kraus, N.C., 1989. SBEACH: Numerical Model for Simulating Storm-Induced Beach Change, Report 1, Empirical Foundation and Model Development. Coastal Engineering Research Center, Vicksburg, MS.

Larson, M., Wise, R.A., and Kraus, N.C., 2004. Coastal Overwash, Part 2: Upgrade to SBEACH. Regional Sediment Management Demonstration Technical Note, ERDC/RSM-TN-15. Vicksburg, Mississippi: U.S. Army Engineer Research and Development Center.

Larson, M., Wise, R.A., and Kraus, N.C., 2005. Modeling dune response due to overwash transport. *Proceedings 29th Coastal Engineering Conference*. Lisbon, Portugal: World Scientific Press, pp. 2133-2145.

Microsoft, 2006. Microsoft Streets and Trips 2007, Microsoft, Redmond, WA.

National Oceanographic and Atmospheric Administration, 2005. NOAA CSC Coastal LIDAR, http://www.csc.noaa.gov/digitalcoast/data/coastallidar/index.html.

National Oceanographic and Atmospheric Administration, 2008. National Geophysical Data Center Coastline Extractor, http://rimmer.ngdc.noaa.gov/mgg/coast/getcoast.html.

National Oceanographic and Atmospheric Administration, 2009. National Data Buoy Center, http://www.ndbc.noaa.gov/.

National Oceanographic and Atmospheric Administration, 2009. National Oceanographic and Atmospheric Administration Tides and Currents, http://tidesandcurrents.noaa.gov/.

Unisys, 2009. Atlantic Tropical Storm Tracking by Year, http://www.weather.unisys.com/hurricane/atlantic/index.html.

U.S. Army Corps of Engineers, 1985. Estimate of Hurricane Winds for the East and Gulf Coasts of the United States, Coastal Engineering Technical Note I-36, http://chl.erdc.usace.army.mil/library/publications/chetn/pdf/cetn-i-36.pdf.

U.S. Army Corps of Engineers, 2003. Coastal and Hydraulics Laboratory Wave Information Studies, http://frf.usace.army.mil/wis/wis_main.html.

U.S. Army Corps of Engineers, 2009. Coastal Modeling System (CMS), http://cirp.usace.army.mil/products/index.html.

U.S. Geological Survey, 2009. Louisiana Barrier Island Comprehensive Monitoring Program (BICM) Volume 3: Bathymetry and Historical Seafloor Change 1869-2007, U.S. Geological Survey Florida Integrated Science Center, St. Petersburg, FL.

Williams, S., S. Penland and A. Sallenger (1992). Louisiana Barrier Island Erosion Study, Atlas of Shoreline Changes in Louisiana from 1853 to 1989, U.S. Geological Survey. Series I-2150-A.

SUB-APPENDIX C-1

SBEACH RESULTS GIVEN THE WITHOUT PROJECT CONDITIONS

(Profiles are presented in electronic PDF format only)

SUB-APPENDIX C-1

SBEACH RESULTS - WITHOUT PROJECT CONDITIONS - CHANDELEUR & BRETON ISLANDS, LA

Profile	Return Period	Year 0				Year 50 Low Sea Level Rise				Year 50 Medium Sea Level Rise				Year 50 High Sea Level Rise			
		MHW Change (feet)	Vol. Change Above MHW (c.y. / foot)	Overwash (c.y. / foot)	Dune Elev. (feet NAVD)	MHW Change (feet)	Vol. Change Above MHW (c.y. / foot)	Overwash (c.y. / foot)	Dune Elev. (feet NAVD)	MHW Change (feet)	Vol. Change Above MHW (c.y. / foot)	Overwash (c.y. / foot)	Dune Elev. (feet NAVD)	MHW Change (feet)	Volume Change Above MHW (c.y. / foot)	Overwash (c.y. / foot)	Dune Elev. (feet NAVD)
BRETON ISLAND:																	
S-11	001_YEAR	-104	-0.8	0.2	2.6	-113	1.2	0.3	2.2	-70	-0.7	0.0	1.2	-94	-0.8	0.0	1.2
S-11	002_YEAR	-165	-3.5	0.4	1.9	-226	1.4	0.4	2.2	-104	0.9	0.3	2.1	-112	-0.8	0.0	1.2
S-11	003_YEAR	-158	-1.7	0.4	2.2	-284	0.0	0.6	1.6	-154	1.5	0.4	2.4	-125	-0.8	0.0	1.2
S-11	004_YEAR	-157	-1.7	0.5	2.5	-262	0.5	0.4	1.7	-135	1.3	0.3	2.1	-130	-0.9	0.0	1.2
S-11	005_YEAR	-155	-0.3	1.3	2.8	-245	0.4	0.7	1.6	-257	0.4	0.8	2.1	-133	-0.9	0.0	1.2
S-11	010_YEAR	-92	-4.0	3.1	1.5	-210	-0.1	1.0	1.4	-228	-0.2	0.9	1.7	-141	-1.0	0.0	1.1
S-11	020_YEAR	-76	-4.2	2.6	1.3	-268	-0.9	0.6	1.1	-222	-0.4	0.4	1.5	-138	-1.0	0.0	1.1
S-11	050_YEAR	-145	-5.1	1.3	1.2	-330	-0.8	0.5	1.3	-293	-0.7	0.9	1.4	-254	-1.0	0.0	1.1
S-11	100_YEAR	-181	-4.5	2.4	1.3	-371	-1.0	1.3	1.0	-247	-0.8	1.3	1.1	-258	-1.0	0.0	1.0
CHANDELEUR ISLANDS SOUTH REACH:																	
N-18	001_YEAR	-191	-5.5	2.2	2.8	-236	-5.2	0.4	2.3	-247	-4.7	0.4	2.7	-118	-6.2	0.0	1.7
N-18	002_YEAR	-163	-7.1	1.3	2.6	-278	-6.6	0.9	2.3	-238	-5.2	0.9	2.1	-179	-6.6	0.0	1.6
N-18	003_YEAR	-168	-7.4	2.5	2.8	-299	-6.6	0.9	1.7	-253	-4.8	0.2	2.6	-208	-6.9	0.0	1.5
N-18	004_YEAR	-208	-14.2	1.1	2.0	-308	-6.9	0.8	1.8	-274	-4.9	0.2	2.5	-199	-7.3	0.0	1.4
N-18	005_YEAR	-245	-13.1	3.0	3.1	-291	-7.4	1.0	1.6	-289	-5.4	0.5	2.3	-202	-7.2	0.0	1.5
N-18	010_YEAR	-110	-8.7	1.0	2.3	-234	-6.0	0.6	1.7	-275	-6.6	1.9	1.7	-178	-6.0	0.2	2.0
N-18	020_YEAR	-119	-10.4	2.9	2.1	-348	-8.7	1.3	1.3	-253	-7.3	1.2	1.5	-168	-6.8	0.0	1.4
N-18	050_YEAR	-138	-9.8	2.4	1.9	-212	-6.1	2.1	1.7	-243	-6.1	1.2	1.7	-187	-6.7	0.0	1.7
N-18	100_YEAR	-121	-10.4	2.2	1.9	-235	-6.0	1.1	1.5	-409	-8.5	1.2	1.5	-203	-5.7	0.1	2.0
N-19	001_YEAR	-160	-4.2	0.7	2.5	-118	-3.9	0.0	1.4	-82	-4.2	0.0	1.4	-167	-4.6	0.0	1.5
N-19	002_YEAR	-150	-7.3	1.0	2.2	-143	-3.8	0.2	1.6	-140	-4.3	0.0	1.4	-234	-5.0	0.0	1.3
N-19	003_YEAR	-173	-8.1	1.8	2.0	-241	-3.9	0.2	1.8	-173	-4.5	0.0	1.4	-215	-5.2	0.0	1.1
N-19	004_YEAR	-254	-8.9	2.1	2.1	-247	-3.8	0.4	1.8	-280	-2.5	0.6	2.2	-180	-5.2	0.0	1.0
N-19	005_YEAR	-277	-9.7	1.4	1.6	-285	-2.5	0.2	2.0	-252	-2.9	0.5	1.7	-131	-5.2	0.4	1.1
N-19	010_YEAR	-177	-5.2	1.2	2.2	-180	-4.2	0.9	1.4	-320	-4.0	0.5	1.8	-182	-5.0	0.0	1.3
N-19	020_YEAR	-133	-8.0	2.5	1.5	-438	-5.1	1.0	1.2	-291	-4.2	0.7	1.6	-111	-4.8	0.0	1.3
N-19	050_YEAR	-83	-6.5	1.2	1.8	-283	-4.9	2.5	1.2	-369	-4.7	0.5	1.4	-164	-4.4	0.0	1.5
N-19	100_YEAR	-130	-6.8	0.8	1.6	-472	-5.2	2.4	1.1	-397	-4.8	1.0	1.5	-169	-4.6	0.0	1.3
N-23	001_YEAR	-155	-7.9	2.1	2.5	-204	-5.2	3.0	1.8	-154	-5.0	1.6	2.0	-133	-5.7	0.0	1.4
N-23	002_YEAR	-237	-8.9	1.7	1.8	-225	-5.7	2.5	1.6	-149	-3.9	0.9	2.3	-103	-5.7	0.0	1.4
N-23	003_YEAR	-230	-10.4	2.3	1.6	-189	-5.2	2.1	1.9	-170	-4.4	1.5	2.2	-141	-5.6	0.0	1.4
N-23	004_YEAR	-197	-9.0	2.4	2.1	-171	-5.1	1.8	1.9	-130	-3.8	0.5	2.0	-146	-5.4	0.1	1.7
N-23	005_YEAR	-243	-10.4	1.3	1.6	-192	-4.7	2.4	2.2	-190	-4.6	2.9	2.2	-148	-4.9	0.1	2.0
N-23	010_YEAR	-83	-8.1	3.9	1.7	-144	-4.6	2.3	1.7	-242	-6.2	3.6	1.2	-147	-4.3	0.8	2.0
N-23	020_YEAR	-94	-6.2	2.5	2.1	-212	-5.9	3.0	1.3	-142	-5.4	2.7	1.6	-103	-5.1	0.1	1.7
N-23	050_YEAR	-57	-6.4	1.8	2.0	-139	-4.5	1.3	1.6	-260	-6.2	3.5	1.0	-144	-4.2	0.9	2.0
N-23	100_YEAR	-103	-8.4	5.0	1.6	-298	-6.2	2.2	1.0	-237	-6.2	4.0	1.1	-122	-4.7	0.2	1.8
N-31	001_YEAR	-7	-0.2	1.7	2.8	-36	-1.2	1.4	2.7	-39	-1.1	0.3	3.1	-8	-2.1	0.1	2.4
N-31	002_YEAR	14	-0.2	2.6	3.0	-56	0.1	0.5	2.7	-29	-1.1	0.2	3.1	-5	-2.0	0.0	2.3
N-31	003_YEAR	16	-0.2	3.1	2.9	-64	0.6	2.4	2.8	-23	-1.0	0.3	2.7	-17	-1.4	0.0	2.3
N-31	004_YEAR	14	0.0	6.0	2.9	-20	-0.2	2.0	2.8	-23	-1.0	1.4	2.6	-20	-1.1	0.4	2.4
N-31	005_YEAR	-14	1.0	7.7	2.9	-24	-0.2	2.6	2.9	-39	0.1	0.3	2.5	-41	-0.4	1.6	2.7
N-31	010_YEAR	21	-0.3	6.4	2.5	-20	-2.0	4.9	1.8	-30	-0.4	0.5	2.1	-24	-1.3	0.6	2.7
N-31	020_YEAR	-25	0.6	5.6	2.8	-7	-0.6	3.5	2.0	-23	-0.3	3.6	2.2	-17	-1.3	0.5	2.3
N-31	050_YEAR	13	-0.7	9.7	2.4	-23	-0.2	1.5	1.9	-22	-0.3	2.5	1.9	-34	-0.9	1.0	2.5
N-31	100_YEAR	28	-0.9	8.0	2.7	-46	-1.0	4.1	1.9	-48	-0.4	2.6	2.1	-37	-1.3	1.0	2.4

SUB-APPENDIX C-1

SBEACH RESULTS - WITHOUT PROJECT CONDITIONS - CHANDELEUR & BRETON ISLANDS, LA

Profile	Return Period	Year 0				Year 50 Low Sea Level Rise				Year 50 Medium Sea Level Rise				Year 50 High Sea Level Rise			
		MHW Change (feet)	Vol. Change Above MHW (c.y. / foot)	Overwash (c.y. / foot)	Dune Elev. (feet NAVD)	MHW Change (feet)	Vol. Change Above MHW (c.y. / foot)	Overwash (c.y. / foot)	Dune Elev. (feet NAVD)	MHW Change (feet)	Vol. Change Above MHW (c.y. / foot)	Overwash (c.y. / foot)	Dune Elev. (feet NAVD)	MHW Change (feet)	Volume Change Above MHW (c.y. / foot)	Overwash (c.y. / foot)	Dune Elev. (feet NAVD)
N-32	001_YEAR	-155	-2.4	0.3	2.3	-108	-0.5	0.1	1.6	-100	-0.4	0.1	1.6	-133	-0.8	0.0	1.5
N-32	002_YEAR	-214	-0.6	1.8	2.4	-364	-0.1	0.2	1.6	-141	0.0	0.6	2.0	-143	-0.8	0.0	1.5
N-32	003_YEAR	-179	-1.5	2.2	2.5	-365	0.0	0.2	1.6	-245	1.5	0.5	2.2	-140	-0.8	0.1	1.5
N-32	004_YEAR	-158	-1.5	2.5	2.6	-298	0.2	0.3	1.7	-265	1.4	0.2	2.2	-136	-0.7	0.1	1.5
N-32	005_YEAR	-159	-1.2	2.1	2.6	-389	1.0	0.4	2.0	-322	0.7	1.0	2.1	-131	-0.7	0.1	1.5
N-32	010_YEAR	-113	-2.3	3.8	1.8	-464	-0.1	0.7	1.4	-338	-0.4	1.0	1.6	-102	-0.6	0.0	1.5
N-32	020_YEAR	-100	-2.3	2.9	1.8	-566	0.4	0.7	1.5	-304	-0.6	1.2	1.6	-115	-0.6	0.0	1.5
N-32	050_YEAR	-83	-2.6	2.0	1.8	-516	0.8	0.6	1.4	-527	1.1	0.8	1.6	-122	-0.6	0.1	1.6
N-32	100_YEAR	-104	-1.1	4.2	1.8	-486	0.4	0.8	1.4	-547	0.1	1.0	1.5	-125	-0.6	0.1	1.6
N-36	001_YEAR	-76	-0.8	2.1	2.8	-76	-1.9	0.4	2.8	-63	-2.5	0.3	2.8	-32	-2.8	0.1	2.4
N-36	002_YEAR	-57	-0.9	6.5	2.7	-105	-1.6	0.4	2.7	-72	-1.8	0.4	2.9	-35	-2.7	0.1	2.2
N-36	003_YEAR	-42	-1.0	6.2	2.8	-75	-1.4	0.7	2.6	-61	-1.4	0.3	2.5	-63	-1.7	1.0	2.5
N-36	004_YEAR	-33	-1.0	7.0	2.8	-68	-1.0	0.4	3.1	-50	-1.2	0.3	2.4	-60	-1.5	0.8	2.5
N-36	005_YEAR	-35	-0.7	4.9	3.0	-73	-0.9	0.3	2.2	-51	-0.9	0.4	2.5	-60	-1.2	1.7	2.6
N-36	010_YEAR	-20	-0.6	3.1	2.3	-36	-0.7	3.4	1.8	-56	-1.1	1.1	2.1	-58	-1.9	0.8	2.7
N-36	020_YEAR	-29	-0.6	4.2	2.5	-46	-0.6	3.1	2.0	-61	-1.5	0.8	2.0	-56	-1.9	0.5	2.5
N-36	050_YEAR	-19	-1.7	2.8	2.2	-29	-0.7	4.2	1.6	-43	-0.7	1.1	1.8	-55	-1.4	0.7	2.5
N-36	100_YEAR	-9	-0.7	4.4	2.6	-34	-0.4	4.1	1.8	-41	-0.6	2.5	2.0	-60	-1.2	1.1	2.3
						CHANDELEUR ISLANDS MIDDLE REACH:											
N-40	001_YEAR	-66	-1.5	1.2	2.4	-124	-0.3	0.3	2.5	-114	-0.5	0.4	2.6	-61	-2.0	0.0	1.9
N-40	002_YEAR	-55	-1.1	2.6	2.8	-244	0.2	1.0	2.7	-99	-0.2	0.3	2.2	-37	-2.0	0.0	1.9
N-40	003_YEAR	-57	-0.8	1.9	2.6	-157	-0.1	0.2	3.1	-102	-0.3	0.8	2.1	-63	-1.9	0.0	1.9
N-40	004_YEAR	-58	-0.4	7.2	2.7	-119	-0.1	0.5	2.6	-118	0.0	0.4	2.2	-61	-1.7	0.0	1.9
N-40	005_YEAR	-50	-0.5	7.0	2.7	-102	0.1	0.6	2.3	-136	0.2	0.4	2.6	-60	-1.6	0.0	1.9
N-40	010_YEAR	-40	-0.8	6.2	2.3	-53	-0.2	1.2	1.7	-97	-0.7	1.1	1.8	-60	-1.2	0.1	2.2
N-40	020_YEAR	-36	-2.3	8.2	2.1	-71	-0.5	0.0	1.7	-96	-0.8	1.1	1.9	-60	-1.1	0.2	2.3
N-40	050_YEAR	-30	-0.8	5.6	2.2	-49	-0.9	2.0	1.5	-76	0.0	1.0	2.2	-75	-0.6	0.7	2.4
N-40	100_YEAR	-42	-0.4	4.4	2.1	-49	-0.4	3.2	1.6	-217	-0.2	1.9	1.7	-78	-0.4	1.0	2.3
N-41	001_YEAR	-81	-1.5	1.4	2.8	-101	-3.7	0.7	2.7	-88	-3.5	0.4	3.1	-50	-4.2	0.0	2.6
N-41	002_YEAR	-79	-1.7	4.0	3.0	-94	-2.9	0.4	2.7	-105	-4.4	0.3	2.8	-51	-4.2	0.0	2.5
N-41	003_YEAR	-70	-2.0	3.7	3.0	-122	-4.3	0.3	2.6	-84	-4.3	0.3	2.4	-83	-3.0	0.2	3.2
N-41	004_YEAR	-53	-2.6	4.3	2.8	-103	-5.0	0.5	2.7	-68	-4.2	0.2	2.3	-87	-2.9	0.4	3.4
N-41	005_YEAR	-48	-2.8	4.8	2.8	-105	-3.5	0.8	2.5	-78	-3.5	0.4	2.5	-85	-2.7	0.5	3.4
N-41	010_YEAR	-41	-1.9	7.1	3.0	-53	-3.4	6.6	1.9	-53	-3.6	3.4	2.0	-68	-2.8	0.6	2.9
N-41	020_YEAR	-39	-2.2	4.9	3.0	-70	-3.1	5.3	2.1	-73	-3.2	3.3	2.3	-75	-3.2	0.9	3.0
N-41	050_YEAR	-34	-2.3	3.1	2.5	-60	-3.3	3.5	2.0	-70	-3.1	0.0	1.9	-73	-2.9	1.1	2.5
N-41	100_YEAR	-66	-2.2	5.0	2.5	-73	-3.5	7.2	1.9	-71	-3.5	3.9	2.2	-88	-2.6	0.7	2.4
N-42	001_YEAR	-69	-3.3	2.2	2.9	-87	-2.7	1.2	2.8	-87	-3.3	0.5	3.3	-46	-3.9	0.1	2.6
N-42	002_YEAR	-67	-2.3	3.2	3.1	-89	-2.4	1.4	3.0	-97	-3.2	0.5	3.1	-73	-3.6	0.2	3.4
N-42	003_YEAR	-67	-3.4	6.1	3.2	-127	-3.0	0.5	2.8	-83	-4.6	0.6	2.5	-77	-3.7	0.4	3.4
N-42	004_YEAR	-77	-2.8	9.2	2.9	-104	-3.4	1.2	3.0	-84	-3.8	0.4	2.5	-81	-3.1	0.4	3.5
N-42	005_YEAR	-58	-3.9	4.8	3.2	-96	-2.8	1.2	3.0	-82	-3.7	0.4	2.6	-81	-2.6	0.7	2.6
N-42	010_YEAR	-55	-3.6	6.1	2.6	-55	-5.5	6.2	2.1	-62	-2.4	1.5	2.1	-68	-3.2	1.0	2.8
N-42	020_YEAR	-52	-5.0	8.2	2.8	-56	-4.6	5.6	1.9	-82	-3.0	4.6	2.3	-74	-3.2	0.2	2.7
N-42	050_YEAR	-51	-7.5	9.3	2.4	-62	-3.6	2.6	1.8	-67	-3.2	4.1	1.9	-75	-2.9	1.4	2.5
N-42	100_YEAR	-52	-7.2	9.9	2.4	-66	-4.8	5.6	1.7	-68	-2.6	3.0	2.1	-74	-3.0	0.4	2.5

SUB-APPENDIX C-1

SBEACH RESULTS - WITHOUT PROJECT CONDITIONS - CHANDELEUR & BRETON ISLANDS, LA

Profile	Return Period	Year 0				Year 50 Low Sea Level Rise				Year 50 Medium Sea Level Rise				Year 50 High Sea Level Rise			
		MHW Change (feet)	Vol. Change Above MHW (c.y. / foot)	Overwash (c.y. / foot)	Dune Elev. (feet NAVD)	MHW Change (feet)	Vol. Change Above MHW (c.y. / foot)	Overwash (c.y. / foot)	Dune Elev. (feet NAVD)	MHW Change (feet)	Vol. Change Above MHW (c.y. / foot)	Overwash (c.y. / foot)	Dune Elev. (feet NAVD)	MHW Change (feet)	Volume Change Above MHW (c.y. / foot)	Overwash (c.y. / foot)	Dune Elev. (feet NAVD)
N-43	001_YEAR	-63	-1.2	1.4	2.8	-58	-0.7	0.9	2.7	-66	-0.3	0.3	3.0	-24	-1.6	0.0	2.1
N-43	002_YEAR	-33	-0.8	1.8	2.6	-50	-0.7	0.3	2.8	-58	-0.3	0.3	3.1	-34	-1.6	0.0	2.1
N-43	003_YEAR	-15	-0.4	6.7	2.7	-59	-2.7	0.5	2.7	-54	-1.1	0.5	2.8	-28	-1.5	0.0	2.1
N-43	004_YEAR	-14	-0.4	4.1	2.7	-64	0.4	0.7	2.9	-50	-0.4	0.5	2.8	-23	-1.3	0.0	2.1
N-43	005_YEAR	-12	0.0	3.8	2.9	-52	0.5	1.9	3.0	-72	-0.8	0.4	2.5	-21	-1.1	0.0	2.1
N-43	010_YEAR	-2	-1.0	2.5	2.4	-18	-1.5	3.8	1.8	-37	-0.2	1.8	2.1	-40	-0.7	0.3	2.8
N-43	020_YEAR	-34	-1.5	4.1	2.3	-24	-0.5	2.5	2.0	-32	-0.7	1.1	2.1	-37	-0.7	0.5	2.4
N-43	050_YEAR	-37	-4.9	6.8	2.2	-13	-1.6	1.4	1.8	-22	-0.3	1.3	1.9	-40	-0.5	1.1	2.5
N-43	100_YEAR	1	-2.0	5.2	2.5	-23	-1.3	4.2	1.8	-52	0.1	2.8	2.0	-41	-0.3	1.0	2.4
N-50	001_YEAR	-135	0.0	7.7	2.7	-92	-1.4	0.3	2.7	-90	-1.2	0.3	3.0	-27	-2.6	0.0	2.1
N-50	002_YEAR	-119	-1.9	2.4	2.6	-195	-1.3	0.4	2.8	-101	-1.4	0.4	2.4	-57	-2.8	0.0	2.1
N-50	003_YEAR	-112	-1.9	2.8	2.8	-97	-1.9	0.2	2.3	-74	-1.7	0.8	2.1	-63	-2.2	0.2	2.3
N-50	004_YEAR	-133	-1.9	9.6	2.9	-91	-1.8	0.2	2.2	-95	-1.0	0.9	2.2	-74	-2.1	0.7	2.2
N-50	005_YEAR	-131	-2.9	9.3	2.7	-92	-1.4	0.2	2.1	-118	-1.2	0.4	2.5	-79	-1.5	0.6	2.5
N-50	010_YEAR	-103	-1.1	5.3	2.2	-53	-2.0	4.8	1.7	-70	-1.1	1.5	2.0	-69	-1.1	0.4	2.7
N-50	020_YEAR	-91	-4.3	3.1	1.9	-72	-2.0	3.3	1.7	-70	-1.0	1.0	2.1	-63	-1.9	0.3	2.2
N-50	050_YEAR	-105	-3.6	6.3	2.0	-91	-2.1	3.3	1.4	-86	-1.7	1.4	1.9	-92	-2.2	0.5	2.3
N-50	100_YEAR	-107	-2.8	5.8	2.0	-103	-1.5	0.9	1.8	-175	-1.8	1.1	1.6	-116	-2.0	0.7	2.4
N-51	001_YEAR	-195	-1.1	0.9	2.0	-52	0.3	0.9	1.6	-29	-0.6	0.1	1.3	334	-0.6	0.0	0.8
N-51	002_YEAR	-150	0.2	0.4	2.2	-99	0.1	0.6	1.6	-82	0.4	0.3	2.1	91	-0.6	0.0	0.8
N-51	003_YEAR	-211	-1.1	2.8	2.0	-108	0.6	0.3	1.8	-156	0.5	0.3	2.0	92	-0.6	0.0	0.8
N-51	004_YEAR	-240	-2.3	1.6	1.5	-150	1.0	0.2	1.8	-217	0.2	0.8	1.9	101	-0.6	0.0	0.8
N-51	005_YEAR	-224	-2.4	2.7	1.5	-225	-0.1	1.7	1.5	-223	-0.1	1.8	1.5	100	-0.6	0.0	0.8
N-51	010_YEAR	-54	-0.2	2.2	1.5	-246	-0.5	1.3	1.3	-154	0.0	0.9	1.4	90	-0.6	0.0	0.9
N-51	020_YEAR	-112	-1.7	2.1	1.4	-256	-0.6	2.1	1.1	-238	-0.4	1.3	1.3	95	-0.6	0.0	0.9
N-51	050_YEAR	-55	-2.1	1.6	1.4	-295	-0.6	1.5	0.9	-256	-0.6	2.2	1.1	102	-0.6	0.0	0.9
N-51	100_YEAR	-81	-1.1	0.8	1.5	111	-0.6	2.6	0.6	-243	-0.6	1.4	1.0	94	-0.6	0.0	0.9
N-56	001_YEAR	-66	-0.2	1.8	2.9	-75	-0.9	0.8	2.8	-68	-1.0	0.3	3.0	-28	-1.7	0.0	2.2
N-56	002_YEAR	-55	-0.2	2.2	2.8	-81	-1.5	0.3	2.7	-86	-0.7	0.5	3.0	-44	-1.6	0.1	2.3
N-56	003_YEAR	-52	-0.1	2.5	2.8	-69	-0.3	1.2	2.9	-73	-0.5	0.2	2.7	-47	-1.1	0.5	2.4
N-56	004_YEAR	-49	-0.1	5.8	2.9	-70	0.1	0.6	2.9	-67	-0.3	0.6	2.7	-60	-0.6	0.6	2.5
N-56	005_YEAR	-63	0.3	5.2	2.9	-67	0.1	0.6	3.1	-79	0.0	0.4	2.5	-61	-0.6	0.7	2.5
N-56	010_YEAR	-30	-0.5	5.8	2.9	-41	-0.2	4.7	1.8	-53	-0.3	1.2	2.0	-60	-0.6	0.4	2.8
N-56	020_YEAR	-35	-0.5	6.5	2.6	-35	-0.5	3.1	1.9	-48	-0.5	1.2	2.1	-46	-0.6	0.6	2.4
N-56	050_YEAR	-24	-1.5	7.8	2.5	-43	-0.1	0.0	1.7	-47	-0.1	2.0	1.9	-58	-0.4	0.9	2.4
N-56	100_YEAR	-18	-0.4	4.8	2.5	-40	-0.4	4.1	1.8	-51	-0.1	2.0	2.0	-61	-0.4	0.6	2.4

SUB-APPENDIX C-1

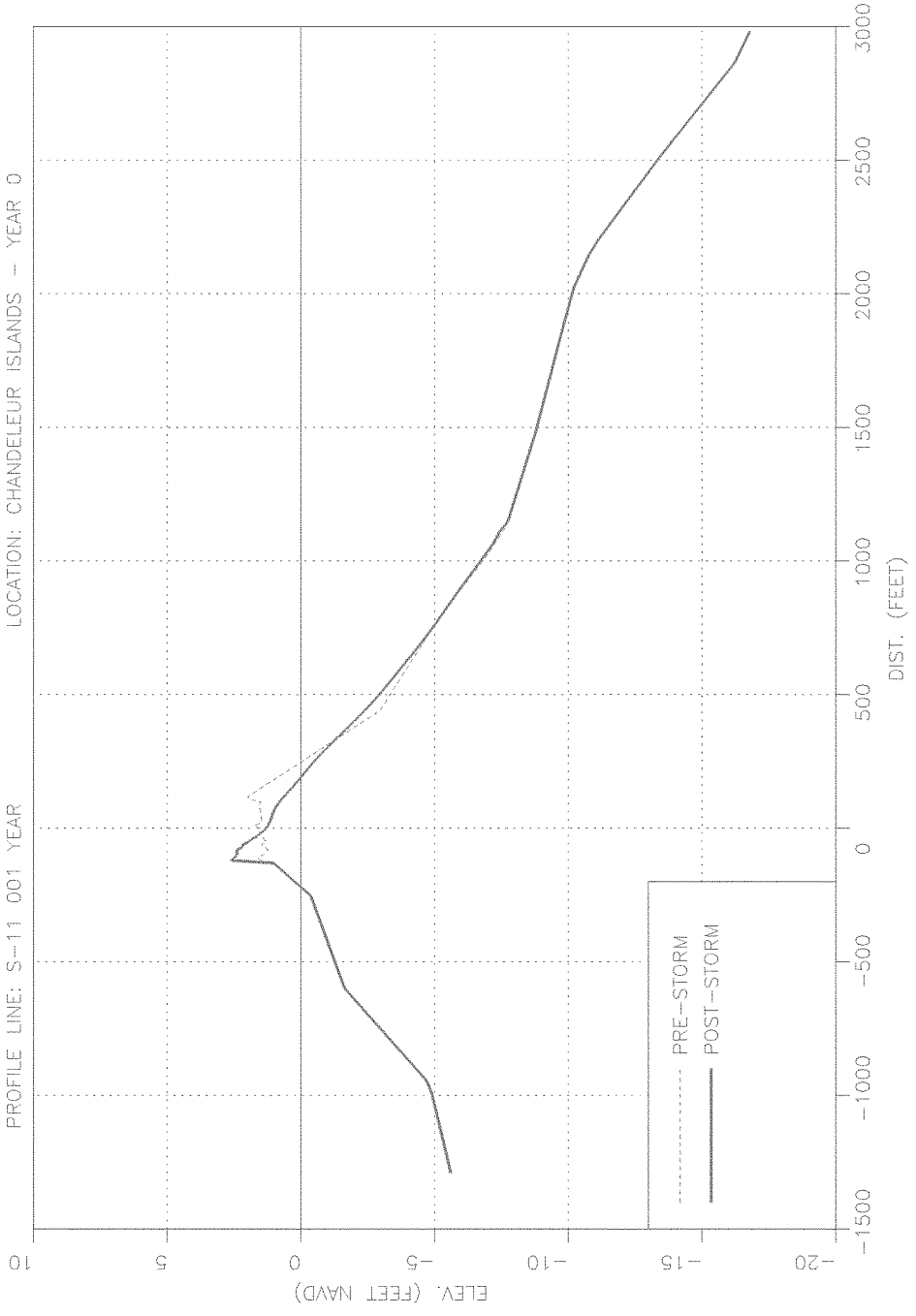
SBEACH RESULTS - WITHOUT PROJECT CONDITIONS - CHANDELEUR & BRETON ISLANDS, LA

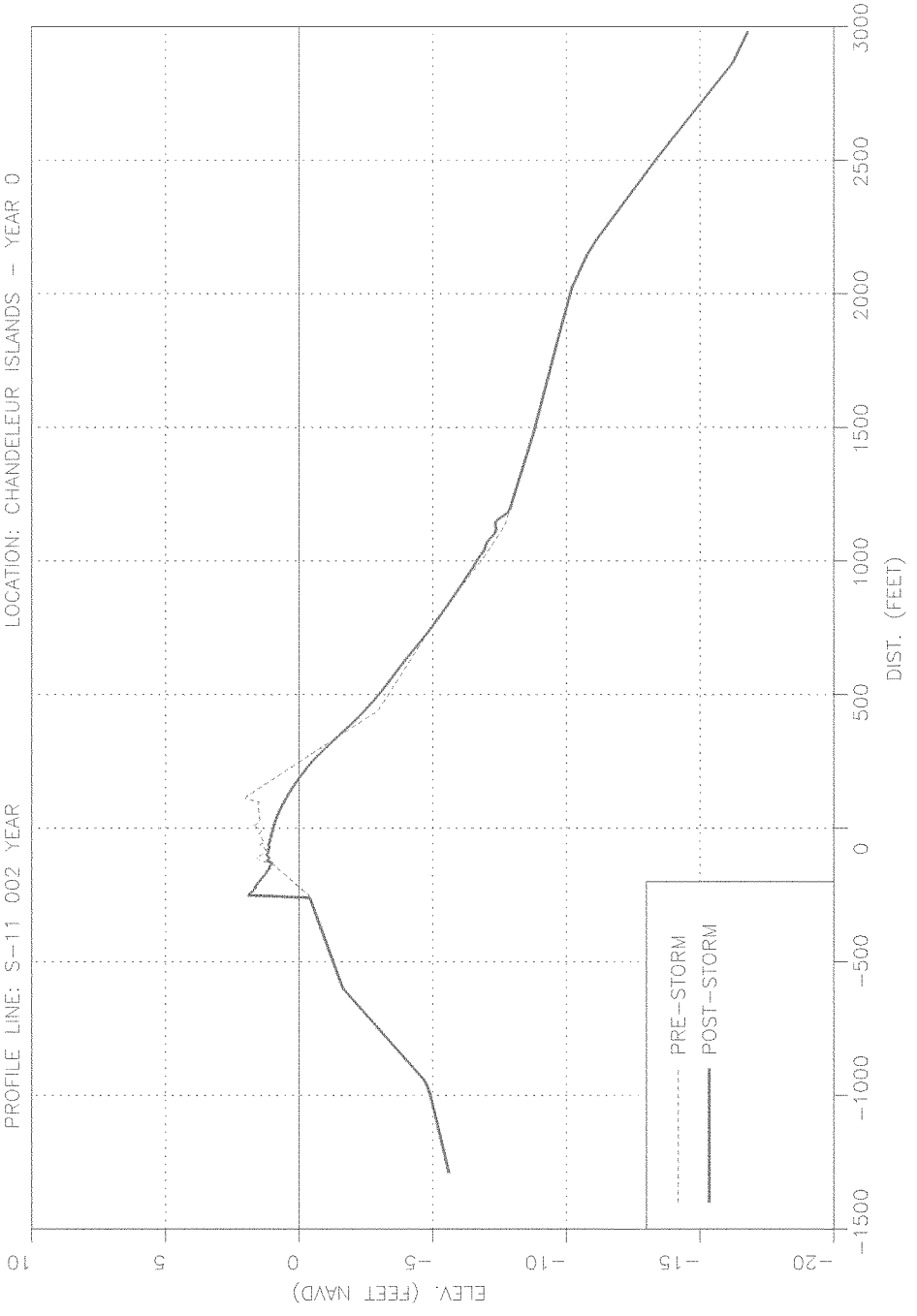
Profile	Return Period	Year 0				Year 50 Low Sea Level Rise				Year 50 Medium Sea Level Rise				Year 50 High Sea Level Rise			
		MHW Change (feet)	Vol. Change Above MHW (c.y. / foot)	Overwash (c.y. / foot)	Dune Elev. (feet NAVD)	MHW Change (feet)	Vol. Change Above MHW (c.y. / foot)	Overwash (c.y. / foot)	Dune Elev. (feet NAVD)	MHW Change (feet)	Vol. Change Above MHW (c.y. / foot)	Overwash (c.y. / foot)	Dune Elev. (feet NAVD)	MHW Change (feet)	Volume Change Above MHW (c.y. / foot)	Overwash (c.y. / foot)	Dune Elev. (feet NAVD)
CHANDELEUR ISLANDS NORTH REACH:																	
N-59	001_YEAR	-22	-1.3	0.0	4.8	-75	-2.1	0.8	3.9	-73	-2.4	1.5	3.4	-33	-3.3	0.4	3.9
N-59	002_YEAR	-13	-1.2	0.0	4.8	-71	-2.9	2.7	3.2	-74	-1.8	1.5	3.4	-62	-4.2	0.4	4.3
N-59	003_YEAR	-7	-1.1	0.0	4.8	-60	-1.2	5.3	3.3	-66	-1.8	2.3	3.6	-49	-3.0	0.5	3.4
N-59	004_YEAR	-4	-1.0	1.1	3.8	-40	-1.8	4.2	3.1	-51	-1.7	6.8	3.4	-54	-3.5	1.1	3.4
N-59	005_YEAR	-1	-0.9	0.0	5.1	-68	-2.2	3.1	2.9	-36	-2.9	2.7	3.4	-51	-3.6	0.8	3.2
N-59	010_YEAR	3	-1.3	7.2	3.6	-42	-1.4	8.8	3.0	-56	-1.1	3.3	3.4	-64	-2.6	0.3	3.4
N-59	020_YEAR	2	-1.1	7.5	3.4	-55	-0.7	2.3	3.4	-56	-1.2	3.2	3.8	-52	-3.0	1.3	3.4
N-59	050_YEAR	8	-1.4	6.3	3.8	-36	-1.4	5.1	3.5	-45	-3.3	9.7	2.9	-69	-2.4	1.1	3.2
N-59	100_YEAR	6	-1.5	9.5	4.0	-28	-3.6	7.9	2.7	-42	-1.0	4.7	3.1	-17	-3.1	1.9	3.0
N-61	001_YEAR	-97	-1.9	0.0	4.4	-97	-1.9	0.8	3.0	-103	-1.6	0.3	3.2	-89	-1.0	0.6	5.4
N-61	002_YEAR	-96	-2.0	0.0	4.5	-124	-2.5	1.4	2.8	-119	-2.3	1.7	2.7	-75	-2.6	0.9	3.3
N-61	003_YEAR	-83	-2.5	0.0	4.3	-145	-3.5	0.7	2.8	-125	-2.7	0.3	3.0	-86	-0.4	0.4	3.8
N-61	004_YEAR	-87	-2.0	0.0	3.1	-177	-1.4	0.8	4.8	-126	-3.6	1.1	3.1	-99	-1.4	0.7	3.4
N-61	005_YEAR	-83	-2.2	0.0	3.1	-142	-2.6	2.4	2.9	-146	-2.8	0.5	3.2	-98	-1.7	0.3	3.3
N-61	010_YEAR	-48	-2.0	4.7	3.0	-94	-3.9	1.1	2.6	-78	-3.9	0.8	2.6	-94	-1.9	1.1	3.7
N-61	020_YEAR	-54	-2.4	8.7	3.1	-85	-3.8	1.4	2.8	-84	-2.9	0.9	2.5	-96	-1.4	0.5	2.9
N-61	050_YEAR	-47	-4.1	9.2	3.0	-94	-3.3	4.1	2.7	-98	-3.4	1.0	2.7	-107	-1.0	0.5	3.0
N-61	100_YEAR	-41	-4.6	11.7	2.9	-87	-2.9	1.0	2.4	-83	-3.2	0.0	2.6	-96	-0.6	0.3	2.9
N-62	001_YEAR	-83	-1.5	6.6	2.5	-98	-1.9	0.3	2.6	-93	-2.3	0.3	2.5	-45	-3.1	0.0	2.1
N-62	002_YEAR	-81	-1.8	5.3	2.7	-270	-2.0	0.8	2.6	-115	-2.1	0.4	2.9	-121	-2.1	0.8	4.5
N-62	003_YEAR	-88	-2.4	4.2	4.0	-149	-2.4	0.9	2.8	-107	-4.1	0.1	2.0	-85	-2.4	1.1	3.9
N-62	004_YEAR	-104	-1.2	8.1	2.8	-270	-2.7	0.4	2.2	-184	-2.0	0.0	2.0	-105	-2.2	0.6	2.7
N-62	005_YEAR	-81	-1.3	3.9	2.9	-240	-2.1	0.7	2.2	-110	-2.8	0.0	2.1	-104	-2.1	0.6	2.4
N-62	010_YEAR	-84	-1.3	8.0	2.6	-53	-2.9	0.5	1.7	-74	-2.0	1.6	2.3	-69	-2.2	0.9	2.6
N-62	020_YEAR	-52	-5.7	2.8	2.2	-70	-1.9	3.4	1.9	-86	-3.0	0.1	2.2	-69	-2.2	0.5	2.4
N-62	050_YEAR	-56	-2.9	3.0	2.3	-136	-3.6	1.1	1.8	-79	-2.3	2.5	1.9	-78	-2.2	0.6	2.5
N-62	100_YEAR	-50	-2.5	2.8	2.1	-77	-2.2	5.7	1.7	-87	-2.3	0.0	1.9	-86	-2.4	1.2	2.3
N-71	001_YEAR	-133	1.6	0.4	2.7	-72	1.5	0.1	2.0	-40	1.1	0.0	2.0	-4	-0.1	0.0	1.7
N-71	002_YEAR	-70	0.8	1.4	2.5	-117	2.5	0.3	2.2	-112	2.6	0.3	2.9	-5	-0.1	0.0	1.7
N-71	003_YEAR	-145	1.3	2.1	2.5	-149	2.8	0.4	2.7	-107	2.4	0.3	2.5	-7	-0.1	0.0	1.8
N-71	004_YEAR	-90	0.7	4.2	2.6	-137	1.8	0.4	2.6	-125	1.8	1.3	2.1	-10	-0.1	0.0	1.8
N-71	005_YEAR	-90	0.6	5.0	2.6	-149	2.2	0.4	2.3	-107	2.2	1.1	2.1	-7	-0.1	0.0	1.9
N-71	010_YEAR	-58	0.6	2.3	2.1	-127	2.2	2.4	1.6	-124	2.8	0.7	2.0	-20	0.0	0.0	1.9
N-71	020_YEAR	-78	-1.3	5.8	2.0	-111	1.7	1.6	1.7	-129	2.3	0.7	2.1	-76	-0.5	0.0	1.9
N-71	050_YEAR	-50	-1.3	3.8	2.1	-125	0.4	2.1	1.5	-134	1.8	0.8	1.9	-87	-0.4	0.0	2.2
N-71	100_YEAR	-56	-0.7	3.6	1.9	-135	1.7	0.9	1.5	-141	-0.1	0.6	1.7	-45	-0.4	0.2	1.7

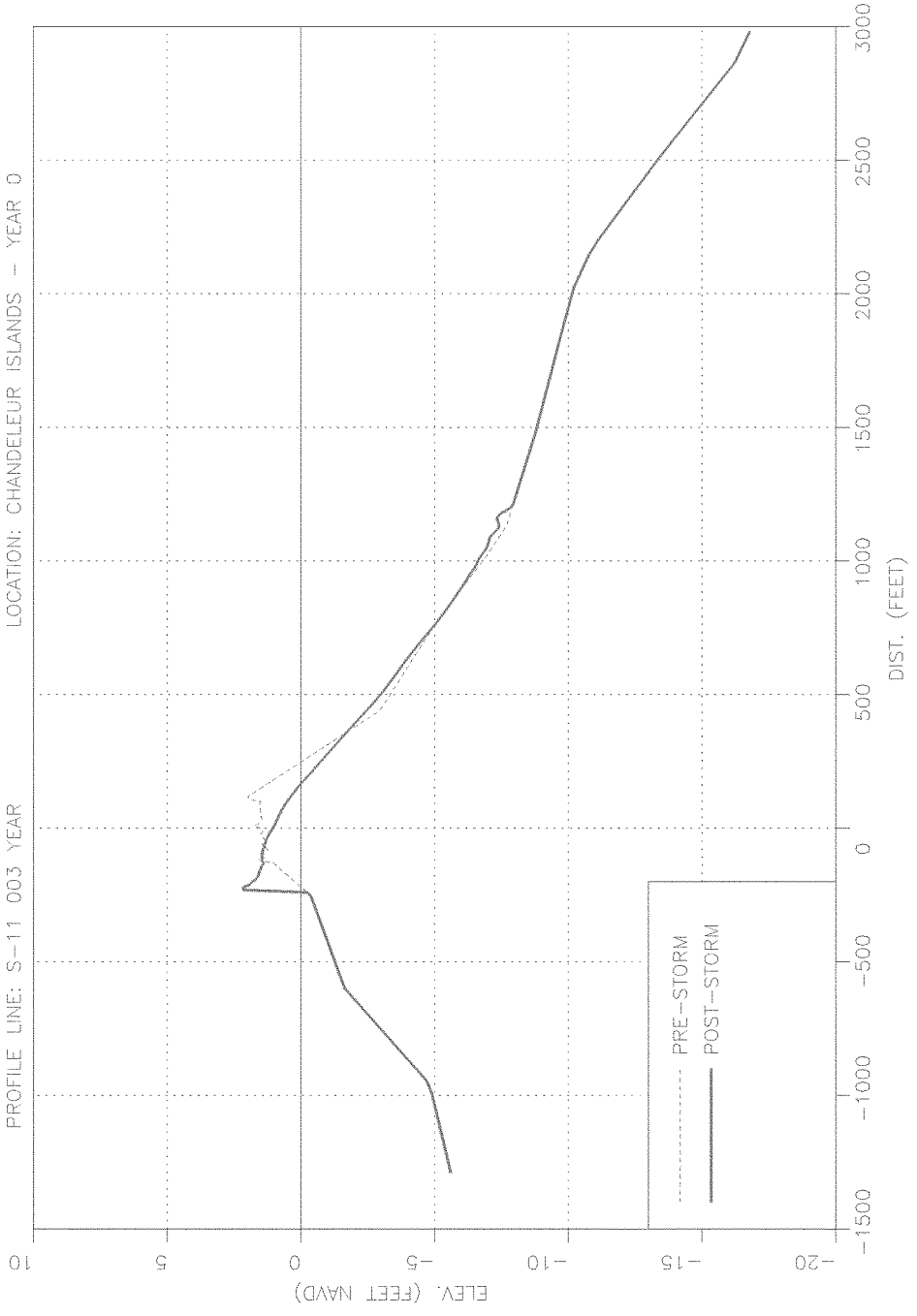
SUB-APPENDIX C-1

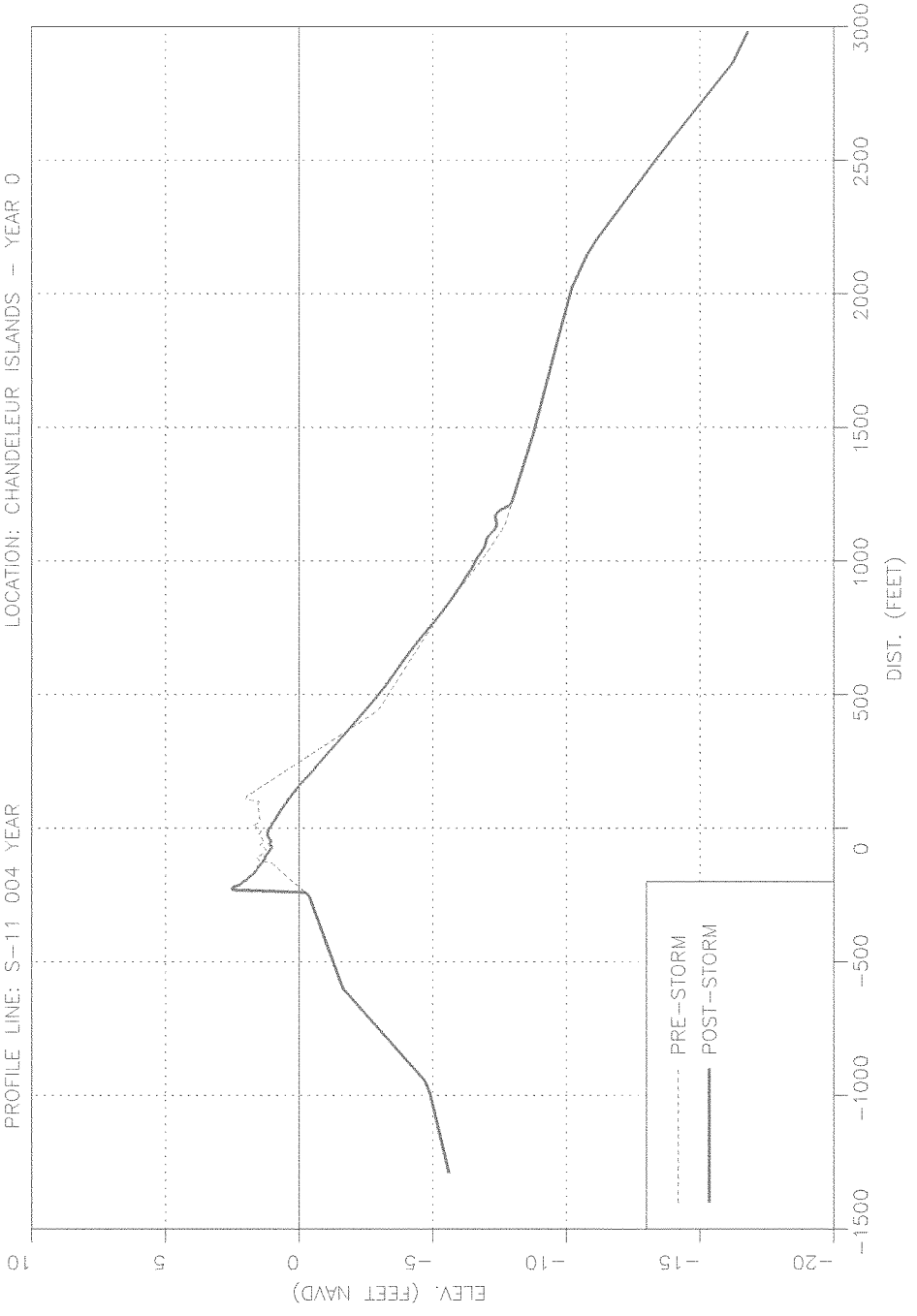
SBEACH RESULTS - WITHOUT PROJECT CONDITIONS - CHANDELEUR & BRETON ISLANDS, LA

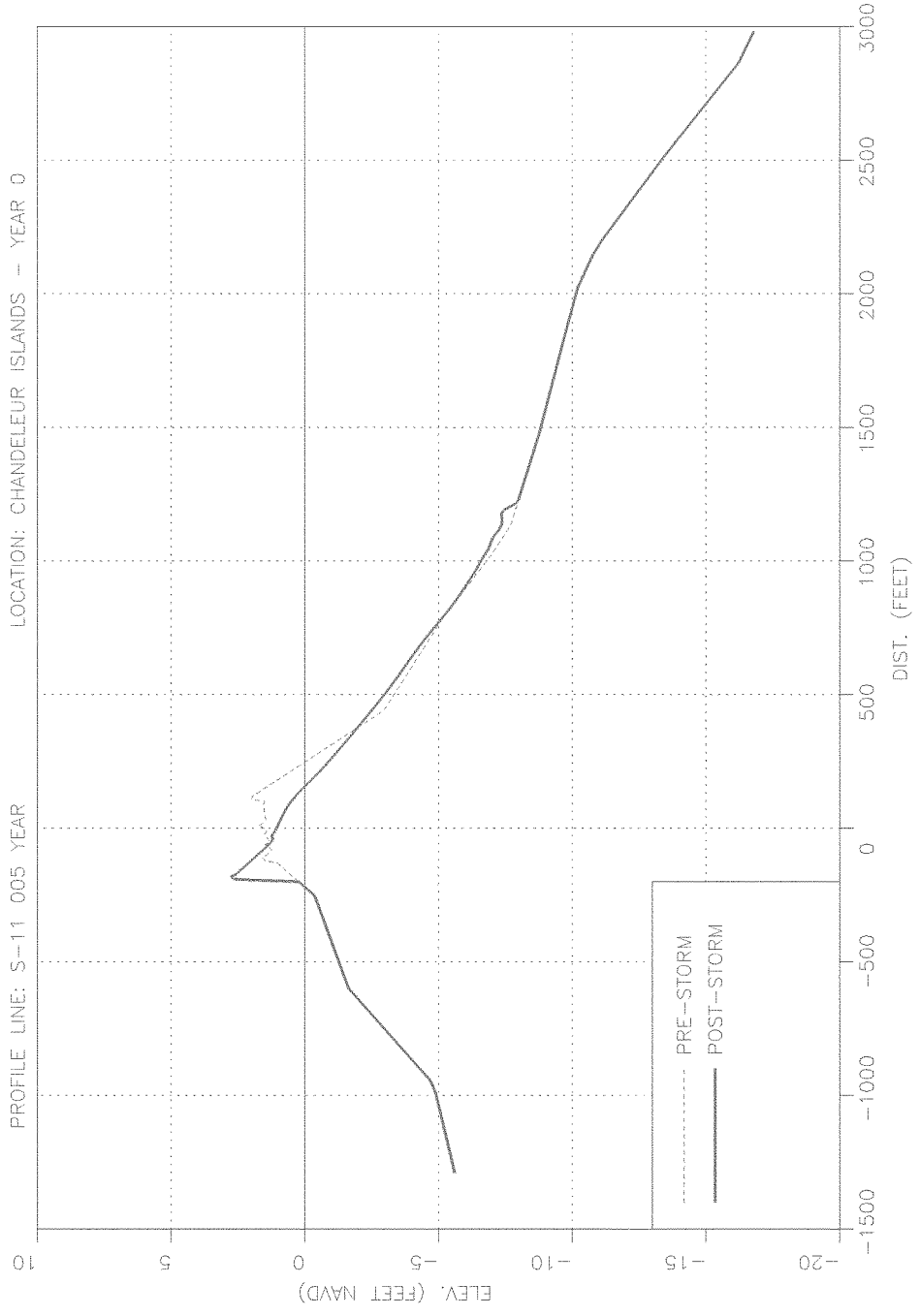
Profile	Return Period	Year 0				Year 50 Low Sea Level Rise				Year 50 Medium Sea Level Rise				Year 50 High Sea Level Rise			
		MHW Change (feet)	Vol. Change Above MHW (c.y. / foot)	Overwash (c.y. / foot)	Dune Elev. (feet NAVD)	MHW Change (feet)	Vol. Change Above MHW (c.y. / foot)	Overwash (c.y. / foot)	Dune Elev. (feet NAVD)	MHW Change (feet)	Vol. Change Above MHW (c.y. / foot)	Overwash (c.y. / foot)	Dune Elev. (feet NAVD)	MHW Change (feet)	Volume Change Above MHW (c.y. / foot)	Overwash (c.y. / foot)	Dune Elev. (feet NAVD)
CHAN. IS.	001_YEAR	-124	-3.5	1.5	2.6	-130	-3.0	0.9	2.1	-114	-3.0	0.4	2.3	-98	-3.7	0.0	1.8
SOUTH	002_YEAR	-135	-4.3	2.5	2.5	-195	-3.0	0.8	2.1	-126	-2.7	0.5	2.3	-117	-3.8	0.0	1.7
REACH	003_YEAR	-129	-4.8	3.0	2.4	-205	-2.8	1.1	2.1	-154	-2.4	0.5	2.3	-131	-3.6	0.2	1.7
AVERAGE	004_YEAR	-139	-5.8	3.5	2.4	-185	-2.8	1.0	2.2	-170	-2.0	0.5	2.3	-124	-3.5	0.2	1.8
	005_YEAR	-162	-5.7	3.4	2.5	-209	-2.5	1.2	2.2	-190	-2.2	0.9	2.2	-119	-3.3	0.6	1.9
N-18 to N-36	010_YEAR	-80	-4.2	3.3	2.1	-180	-2.9	2.1	1.6	-210	-3.1	1.4	1.8	-115	-3.2	0.4	2.0
	020_YEAR	-83	-4.5	3.4	2.1	-269	-3.4	2.1	1.6	-179	-3.2	1.7	1.7	-85	-3.4	0.2	1.8
	050_YEAR	-61	-4.6	3.3	2.0	-200	-2.6	2.0	1.6	-244	-2.8	1.6	1.6	-118	-3.0	0.5	2.0
	100_YEAR	-73	-4.7	4.1	2.0	-262	-3.1	2.4	1.5	-280	-3.4	2.1	1.6	-119	-3.0	0.4	1.9
CHAN. IS.	001_YEAR	-79	-1.1	1.4	2.6	-73	-1.2	0.6	2.4	-67	-1.3	0.2	2.5	-58	-1.9	0.0	2.1
SOUTH	002_YEAR	-86	-0.6	3.6	2.7	-175	-0.5	0.4	2.4	-51	-1.0	0.4	2.7	-61	-1.8	0.0	2.0
REACH	003_YEAR	-68	-0.9	3.8	2.8	-168	-0.3	1.1	2.3	-110	-0.3	0.3	2.5	-73	-1.3	0.4	2.1
	004_YEAR	-59	-0.8	5.2	2.7	-129	-0.3	0.9	2.6	-113	-0.3	0.6	2.4	-72	-1.1	0.4	2.1
Profiles	005_YEAR	-69	-0.3	4.9	2.8	-162	0.0	1.1	2.4	-138	0.0	0.6	2.4	-77	-0.8	1.1	2.2
N-31 to N-36	010_YEAR	-37	-1.1	4.5	2.2	-173	-0.9	3.0	1.7	-141	-0.6	0.9	1.9	-61	-1.3	0.5	2.3
Only	020_YEAR	-51	-0.8	4.2	2.3	-206	-0.3	2.4	1.9	-129	-0.8	1.9	1.9	-62	-1.3	0.3	2.1
	050_YEAR	-30	-1.7	4.8	2.1	-189	0.0	2.1	1.6	-197	0.0	1.4	1.8	-71	-1.0	0.6	2.2
	100_YEAR	-28	-0.9	5.5	2.3	-189	-0.3	3.0	1.7	-212	-0.3	2.1	1.9	-74	-1.0	0.7	2.1
CHAN. IS.	001_YEAR	-96	-1.3	2.4	2.6	-84	-1.3	0.7	2.5	-77	-1.5	0.3	2.8	14	-2.4	0.0	2.0
MIDDLE	002_YEAR	-80	-1.1	2.4	2.7	-122	-1.2	0.6	2.6	-90	-1.4	0.4	2.7	-29	-2.4	0.0	2.1
REACH	003_YEAR	-83	-1.4	3.8	2.7	-106	-1.7	0.5	2.6	-90	-1.7	0.5	2.4	-38	-2.0	0.2	2.3
AVERAGE	004_YEAR	-89	-1.5	6.0	2.6	-100	-1.3	0.6	2.6	-100	-1.3	0.5	2.4	-41	-1.8	0.3	2.3
	005_YEAR	-84	-1.7	5.4	2.7	-106	-1.0	1.0	2.5	-112	-1.3	0.6	2.4	-41	-1.5	0.3	2.3
N-40 to N-56	010_YEAR	-47	-1.3	5.0	2.4	-74	-1.9	4.1	1.8	-75	-1.2	1.6	1.9	-38	-1.5	0.4	2.5
	020_YEAR	-57	-2.5	5.3	2.3	-84	-1.7	3.1	1.8	-91	-1.4	2.0	2.0	-37	-1.6	0.4	2.3
	050_YEAR	-48	-3.2	5.8	2.2	-87	-1.7	2.0	1.6	-89	-1.3	1.7	1.8	-44	-1.5	0.8	2.2
	100_YEAR	-52	-2.3	5.1	2.2	-35	-1.8	4.0	1.6	-125	-1.2	2.3	1.8	-52	-1.3	0.6	2.2
CHAN. IS.	001_YEAR	-70	-1.9	1.6	2.7	-92	-1.8	0.8	2.7	-89	-1.9	0.4	3.0	-45	-2.9	0.0	2.3
MIDDLE	002_YEAR	-56	-1.5	2.9	2.9	-119	-1.4	0.8	2.8	-90	-2.0	0.4	2.8	-49	-2.9	0.1	2.5
REACH	003_YEAR	-52	-1.7	4.6	2.9	-116	-2.5	0.4	2.8	-81	-2.6	0.5	2.5	-63	-2.5	0.1	2.6
	004_YEAR	-51	-1.5	6.2	2.8	-97	-2.0	0.7	2.8	-80	-2.1	0.4	2.4	-63	-2.2	0.2	2.7
Profiles	005_YEAR	-42	-1.8	5.1	2.9	-89	-1.4	1.1	2.7	-92	-1.9	0.4	2.5	-62	-2.0	0.3	2.5
N-40 to N-43	010_YEAR	-35	-1.8	5.5	2.6	-45	-2.7	4.4	1.9	-62	-1.7	2.0	2.0	-57	-2.0	0.5	2.7
Only	020_YEAR	-40	-2.8	6.3	2.6	-55	-2.3	3.3	1.9	-71	-1.9	2.6	2.2	-61	-2.0	0.4	2.6
	050_YEAR	-38	-3.9	6.2	2.3	-46	-2.3	2.4	1.8	-59	-1.7	1.6	2.0	-66	-1.7	1.0	2.5
	100_YEAR	-40	-3.0	6.1	2.4	-53	-2.5	5.1	1.8	-102	-1.5	2.9	2.0	-70	-1.6	0.8	2.4
CHAN. IS.	001_YEAR	-84	-0.8	1.8	3.6	-85	-1.1	0.5	2.9	-77	-1.3	0.5	2.8	-43	-1.9	0.3	3.3
NORTH	002_YEAR	-65	-1.0	1.7	3.7	-146	-1.2	1.3	2.7	-105	-0.9	1.0	3.0	-67	-2.2	0.6	3.5
REACH	003_YEAR	-81	-1.2	1.6	3.9	-126	-1.1	1.6	2.9	-101	-1.6	0.8	2.8	-57	-1.5	0.5	3.3
AVERAGE	004_YEAR	-71	-0.9	3.4	3.1	-156	-1.0	1.4	3.2	-124	-1.4	2.3	2.7	-67	-1.8	0.6	2.8
	005_YEAR	-64	-0.9	2.2	3.4	-150	-1.2	1.6	2.6	-99	-1.6	1.1	2.7	-66	-1.9	0.4	2.7
N-59 to N-71	010_YEAR	-47	-1.0	5.6	2.8	-79	-1.5	2.4	2.2	-84	-1.0	1.6	2.6	-62	-1.7	0.6	2.9
	020_YEAR	-46	-2.6	6.2	2.7	-80	-1.2	2.2	2.5	-89	-1.2	1.2	2.6	-73	-1.8	0.6	2.7
	050_YEAR	-36	-2.4	5.6	2.8	-98	-2.0	3.1	2.4	-89	-1.2	3.5	2.3	-86	-1.5	0.6	2.7
	100_YEAR	-35	-2.3	6.9	2.7	-82	-1.8	3.9	2.1	-88	-1.6	1.3	2.3	-60	-1.6	0.9	2.5

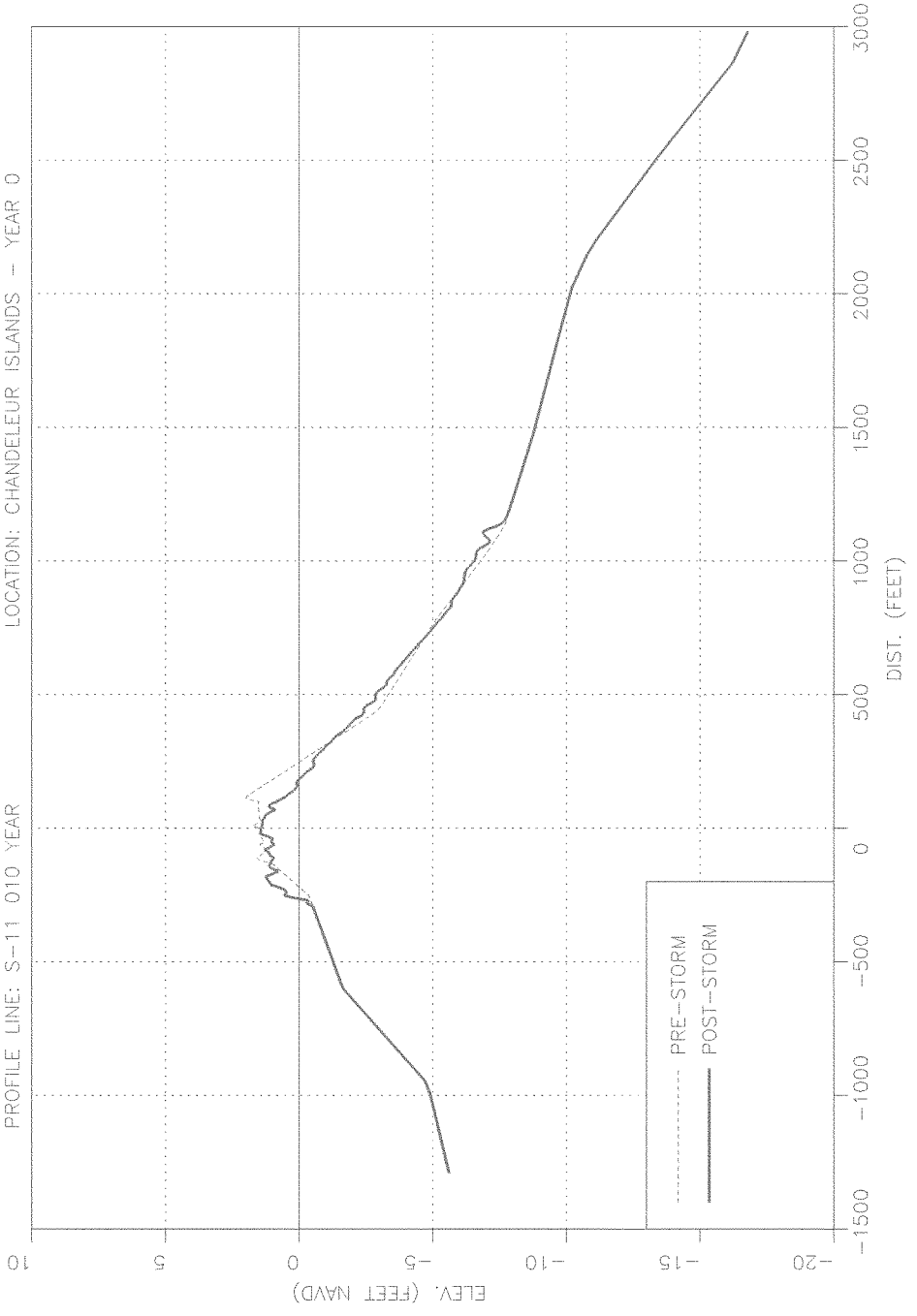

PROFILE LINE: S-11 001 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 0
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

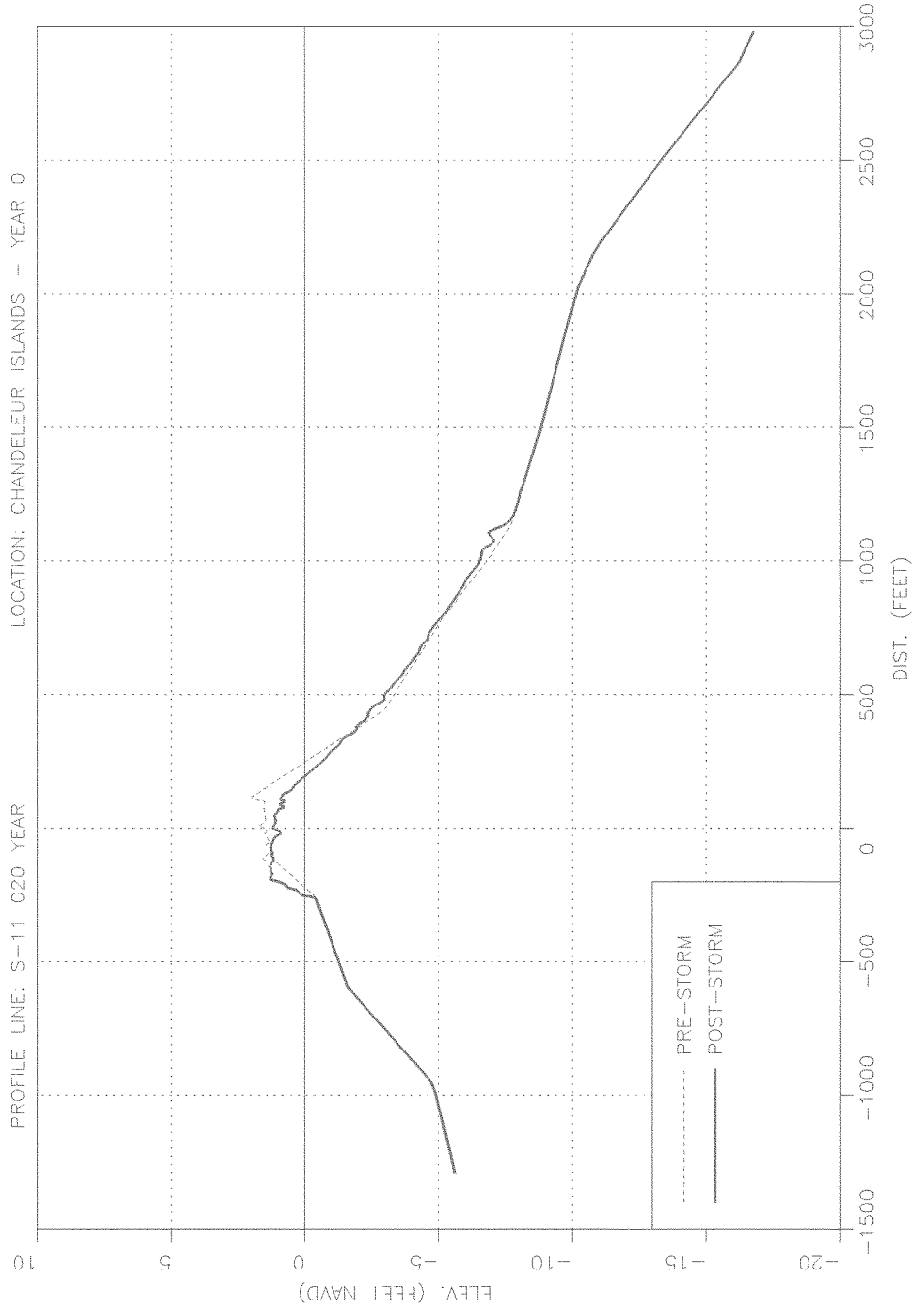

PROFILE LINE: S-11 002 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 0
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

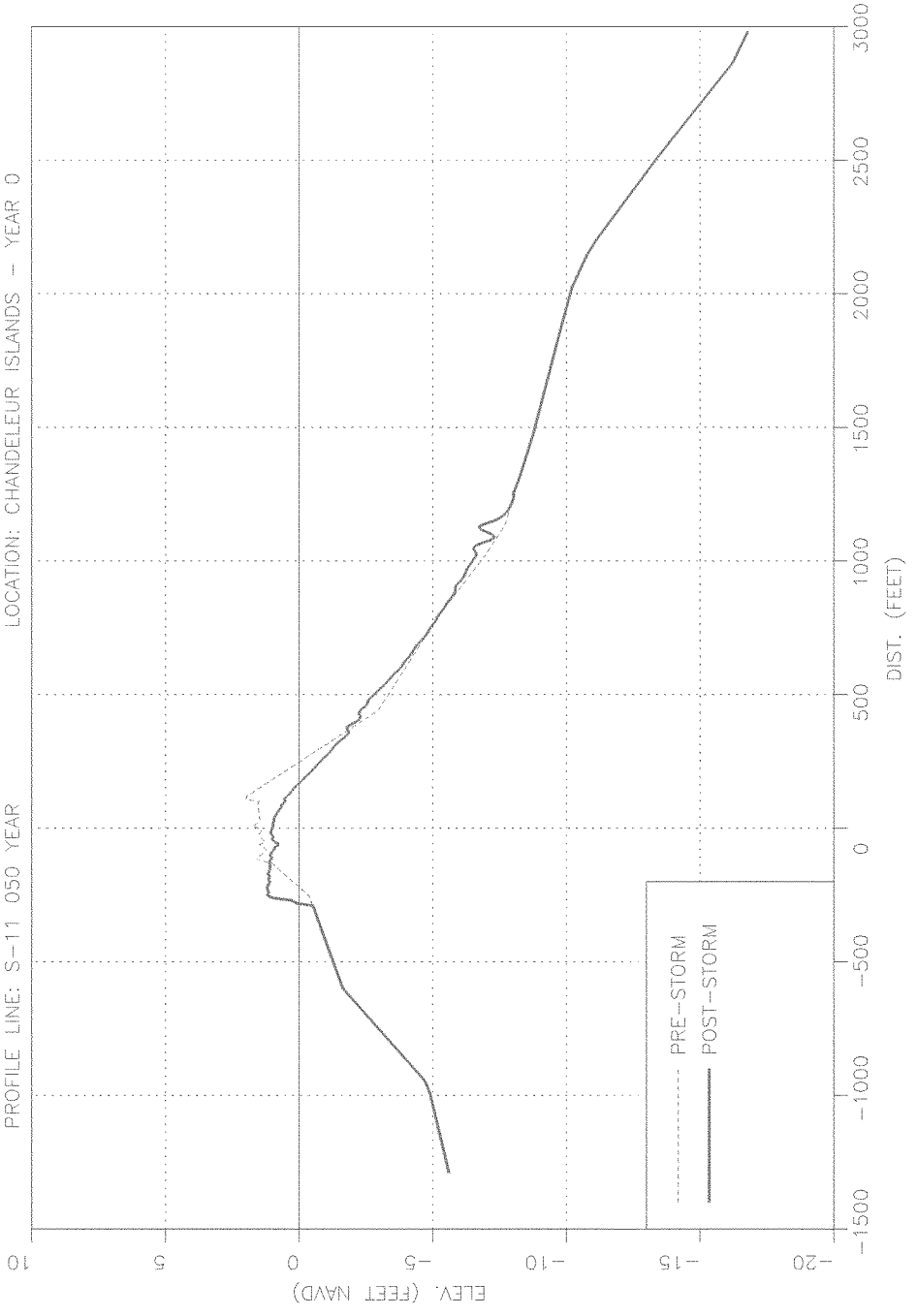

PROFILE LINE: S-11 003 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 0
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

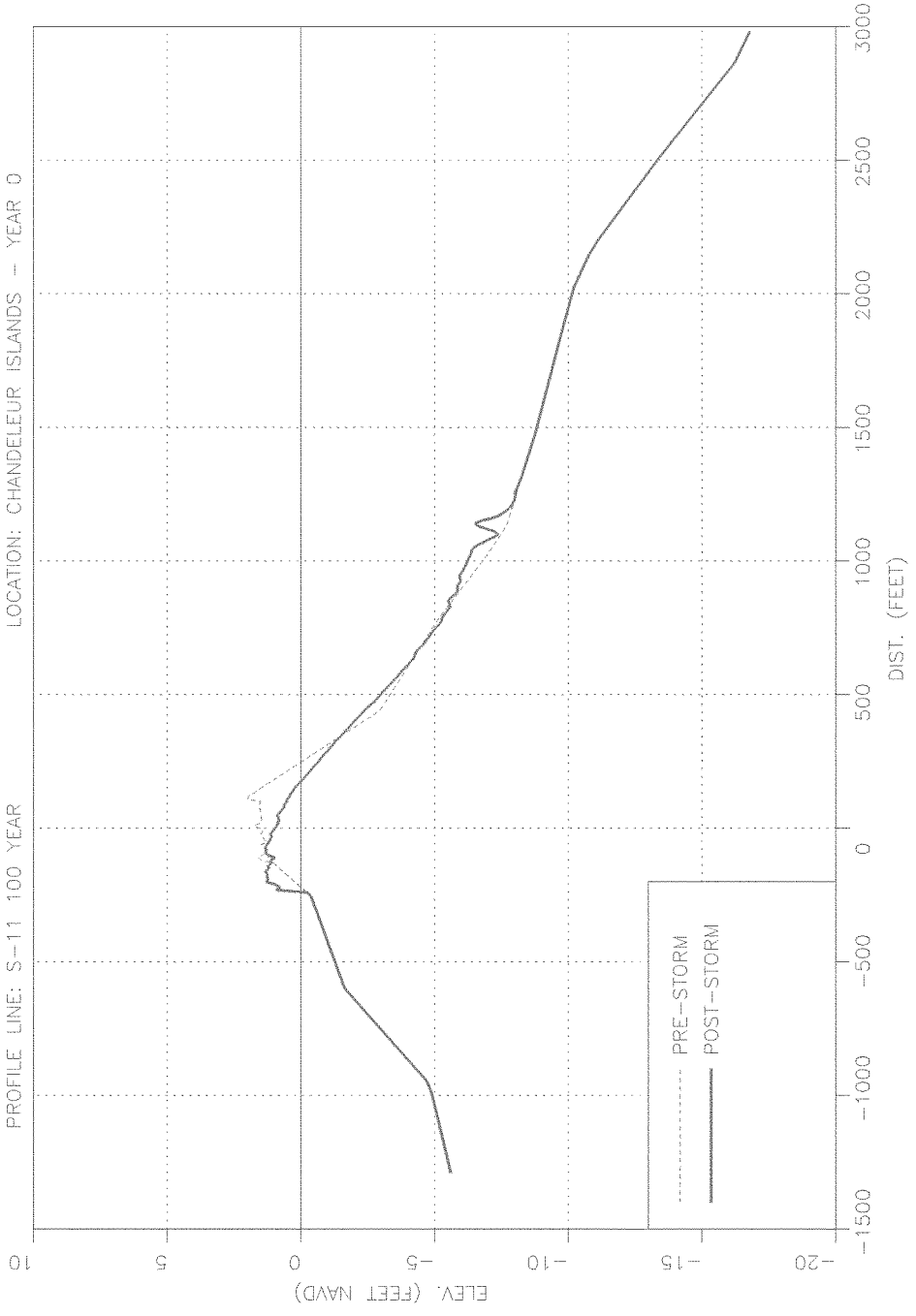

PROFILE LINE: S-11 004 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 0
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

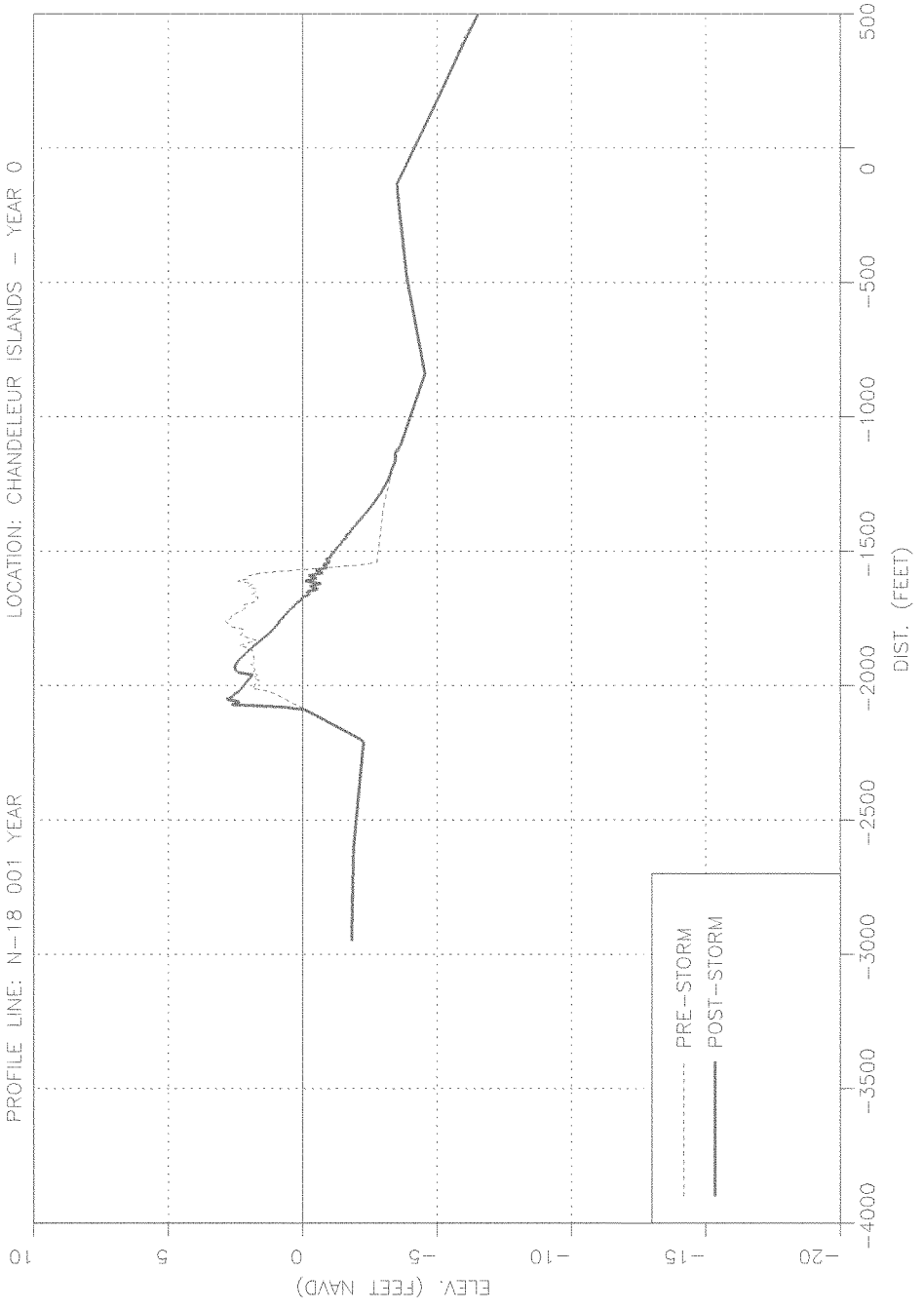

PROFILE LINE: S-11 005 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 0
PRE-STORM
POST-STORM
ELEV. (FEET NAVD)
DIST. (FEET)
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

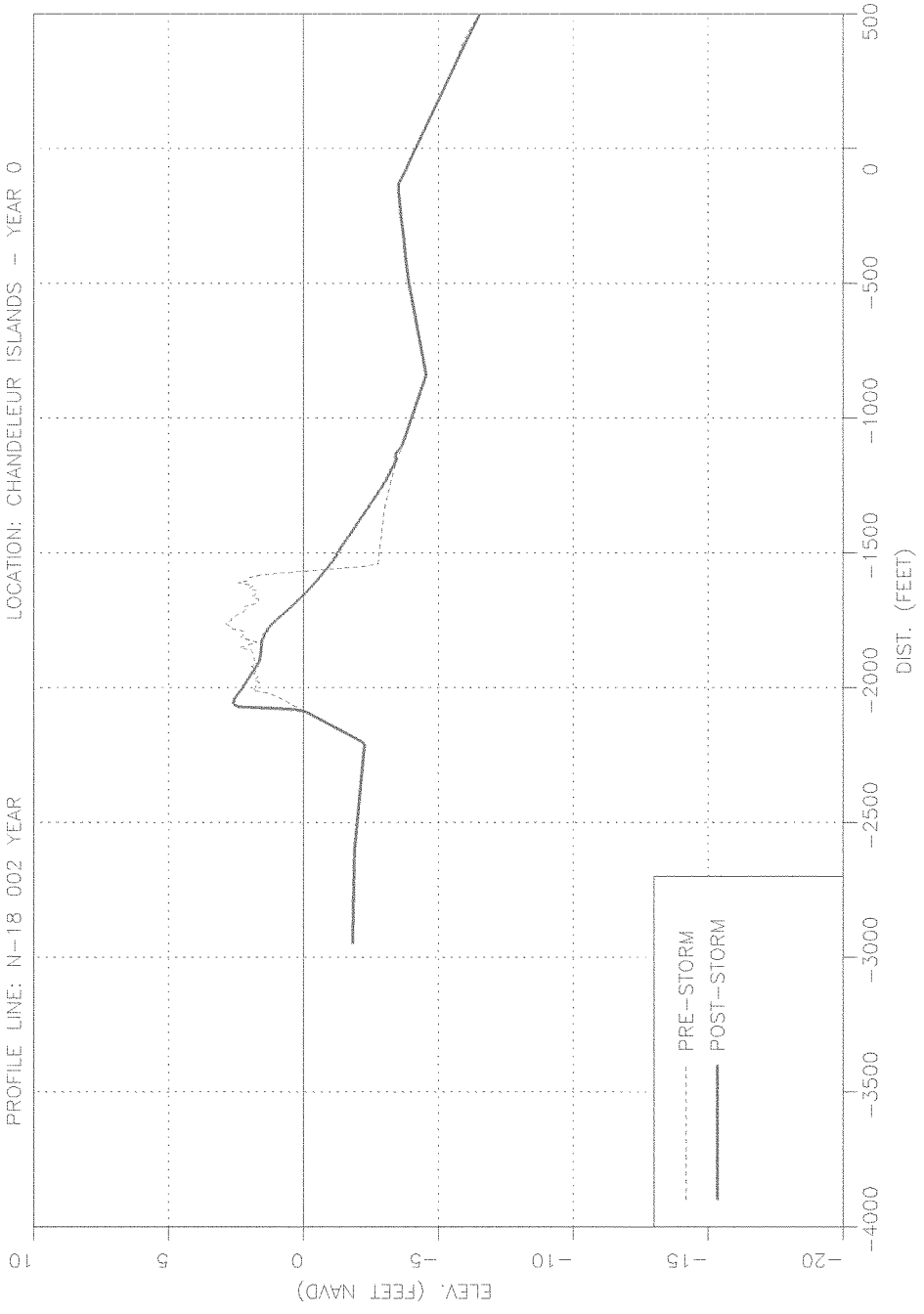

PROFILE LINE: S-11 010 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 0
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

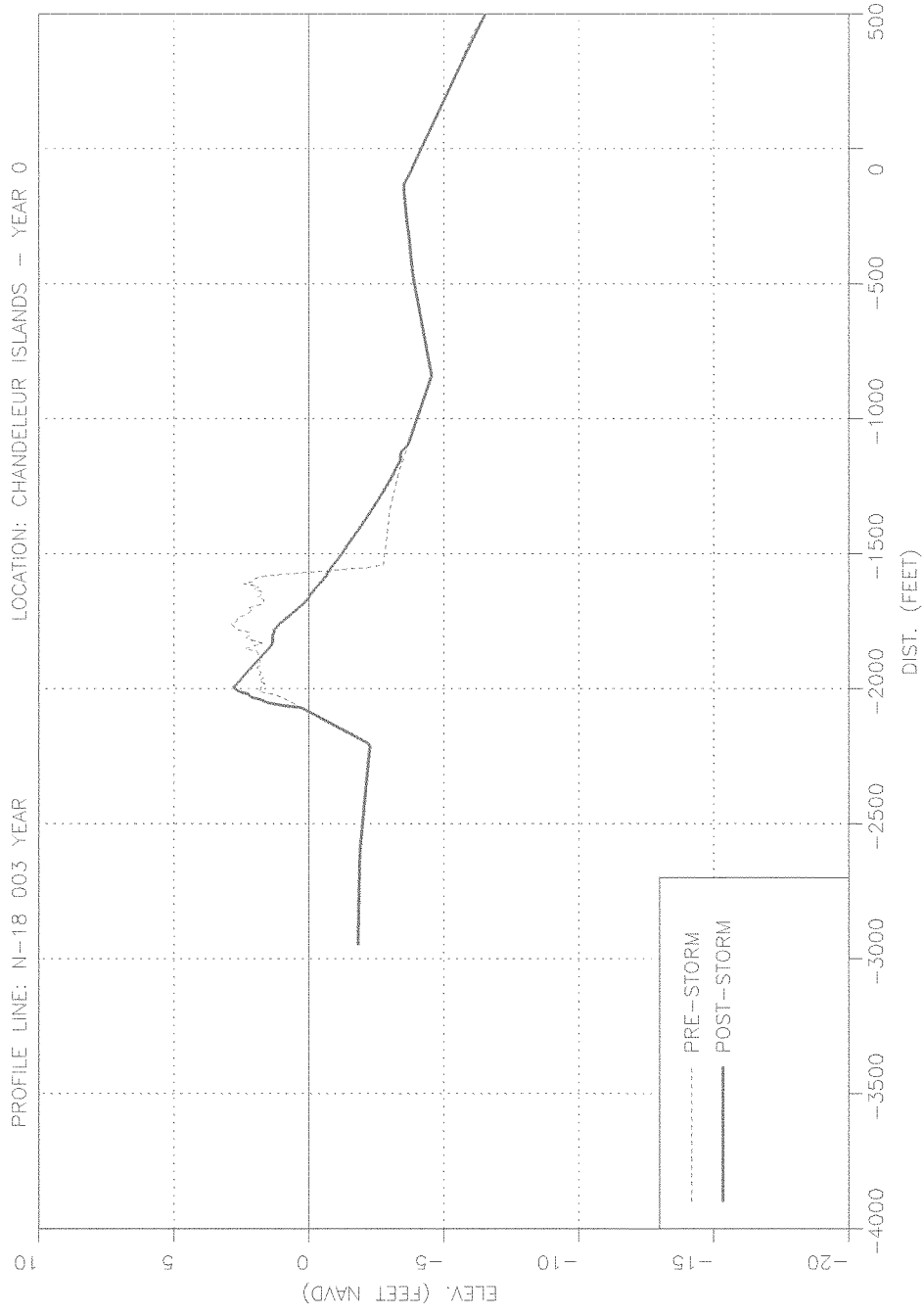

PROFILE LINE: S-11 020 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 0
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

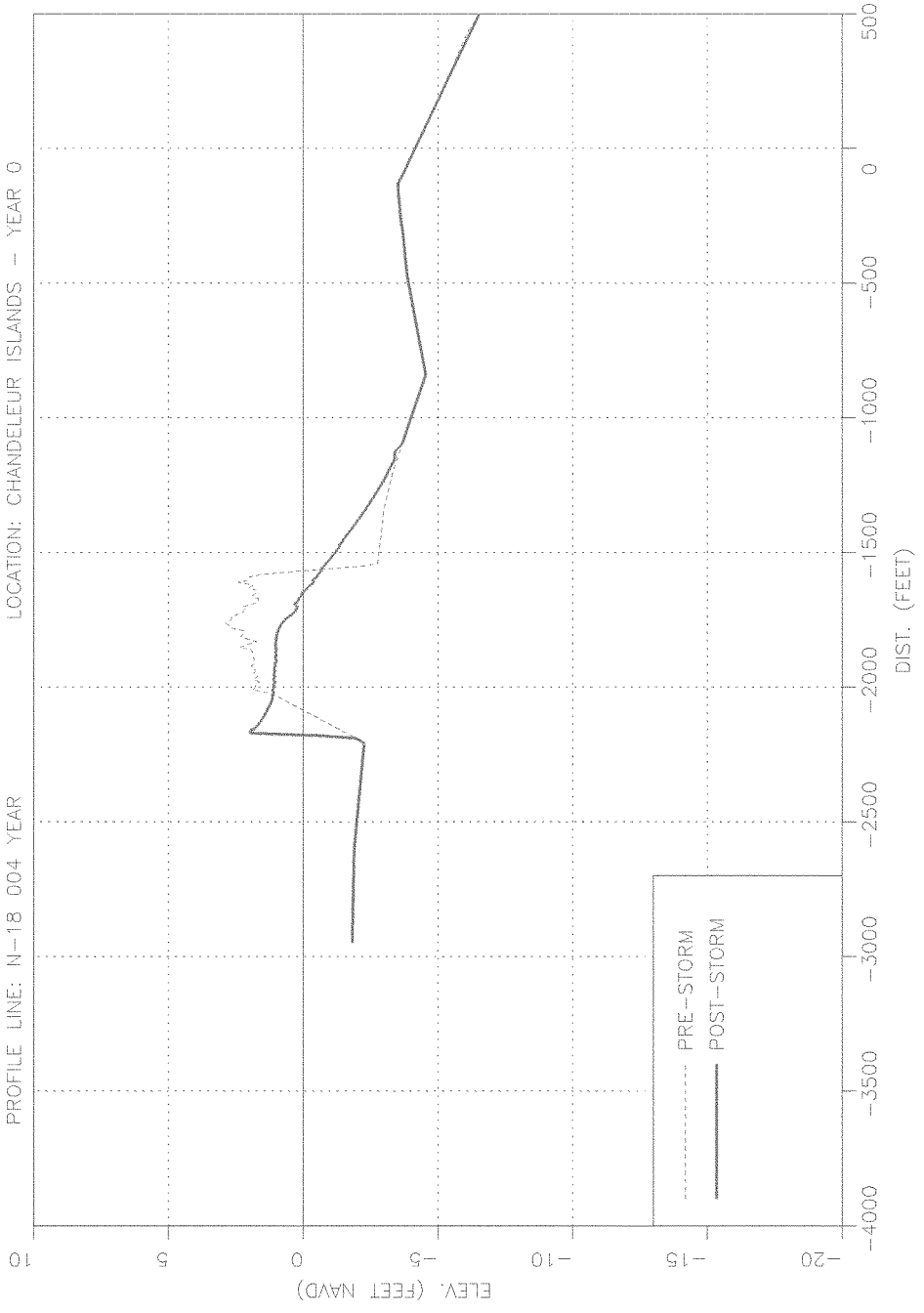

PROFILE LINE: S-11 050 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 0
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

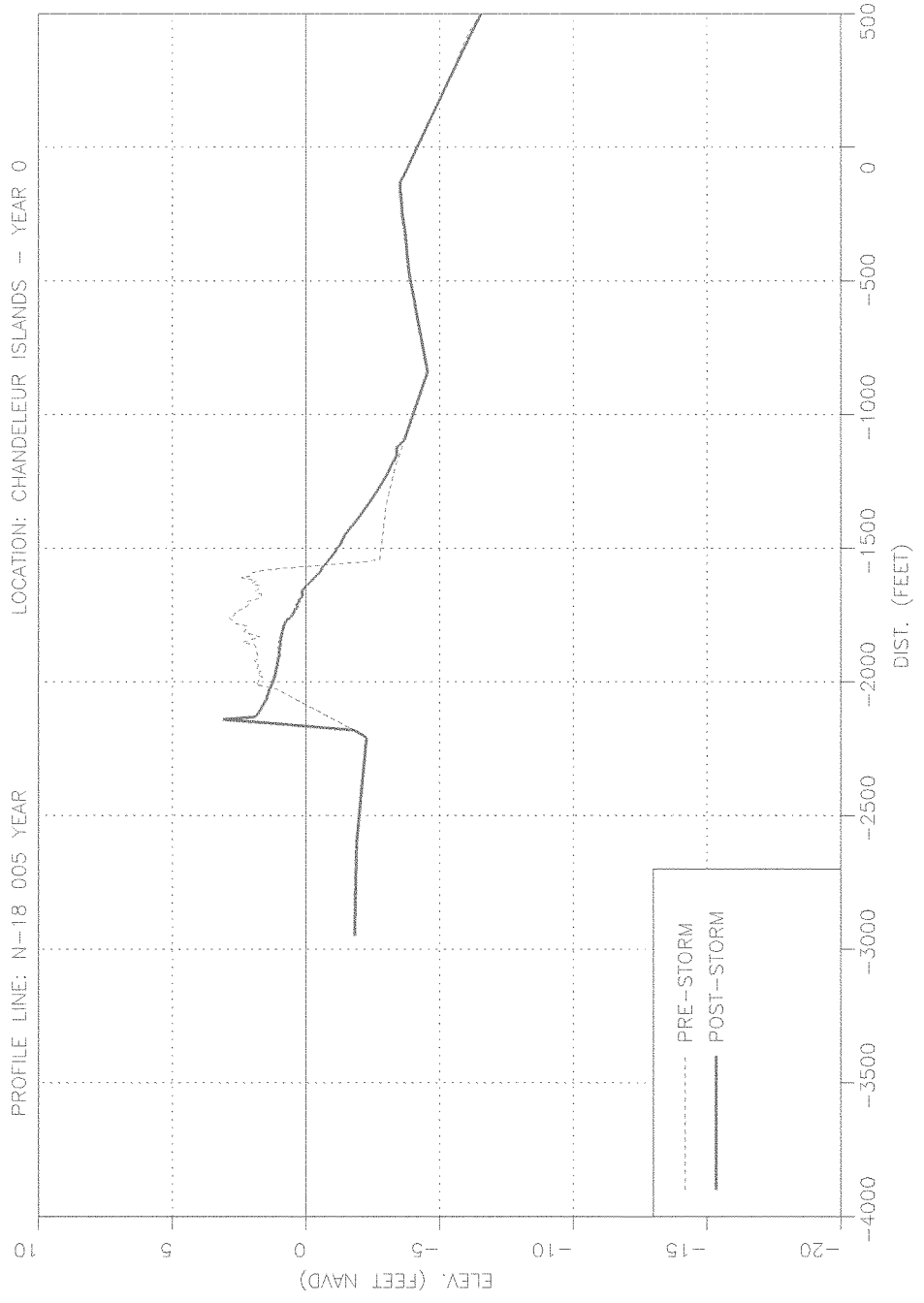

PROFILE LINE: S-11 100 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 0
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

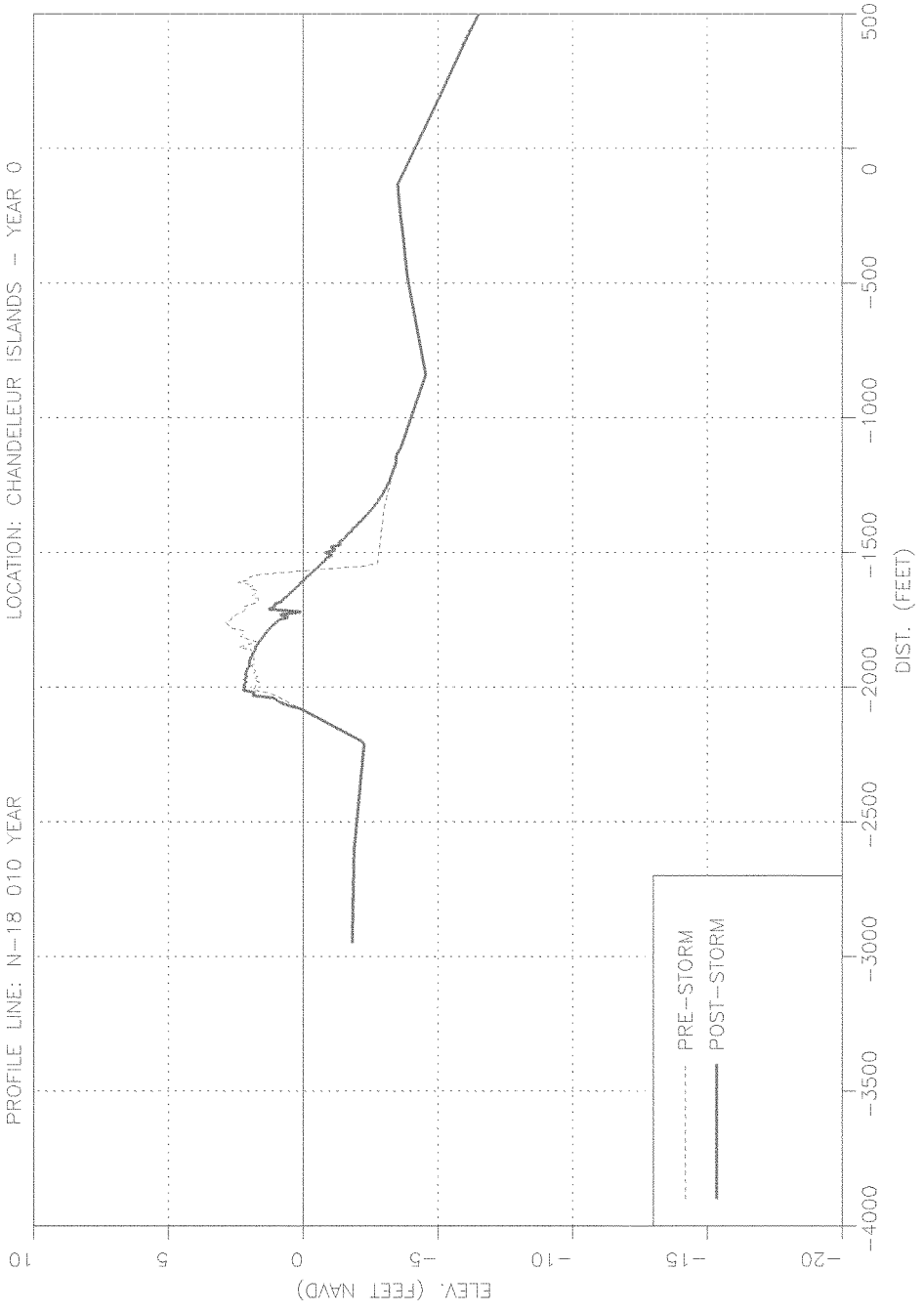

PROFILE LINE: N-18 001 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 0
ELEV. (FEET NAVD)
10
5
0
-5
-10
-15
-20
-4000
-3500
-3000
-2500
-2000
-1500
-1000
-500
0
500
DIST. (FEET)
PRE-STORM
POST-STORM

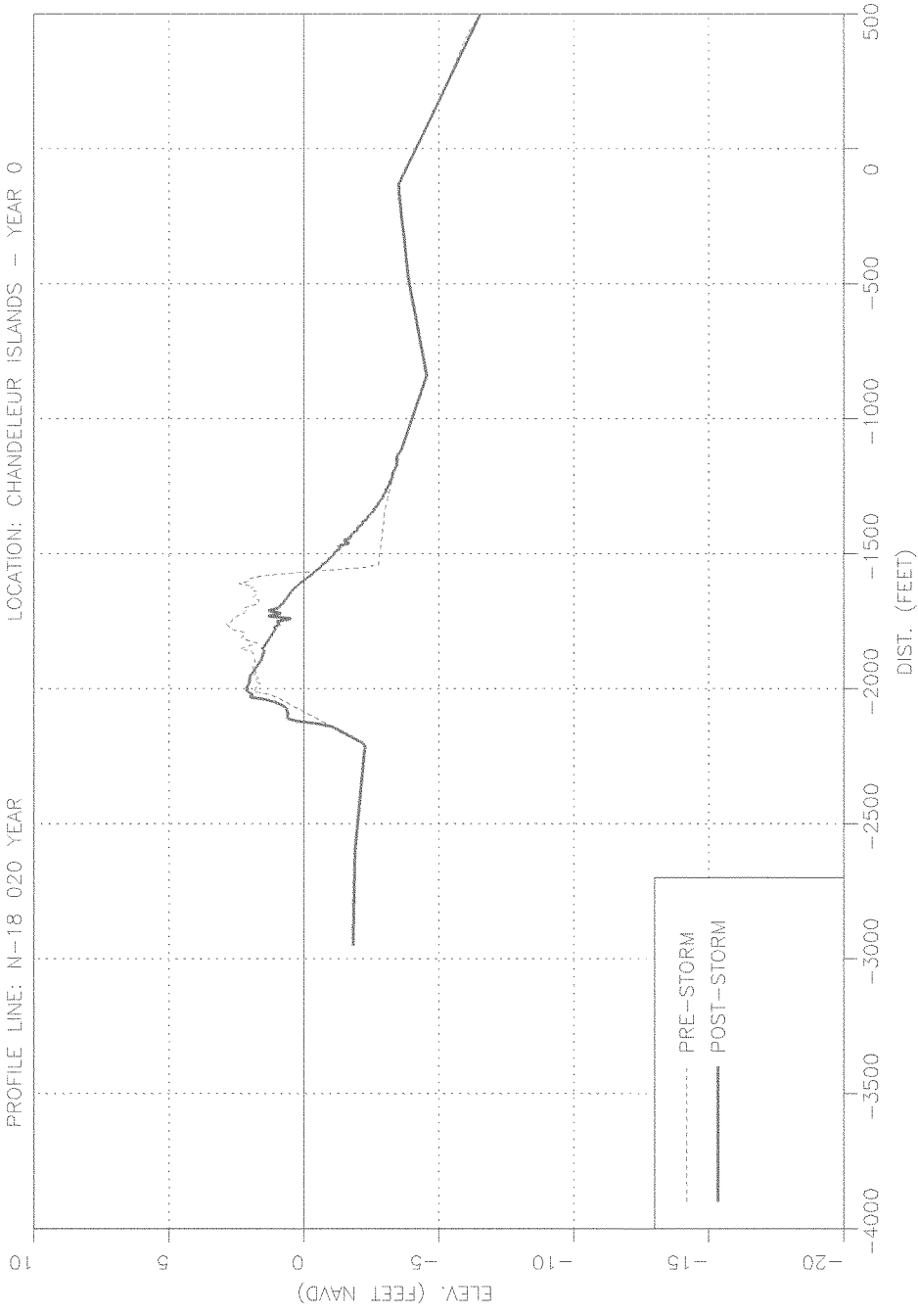

PROFILE LINE: N-18 002 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 0
PRE-STORM
POST-STORM
ELEV. (FEET NAVD)
DIST. (FEET)
10
5
0
-5
-10
-15
-20
-4000
-3500
-3000
-2500
-2000
-1500
-1000
-500
0
500

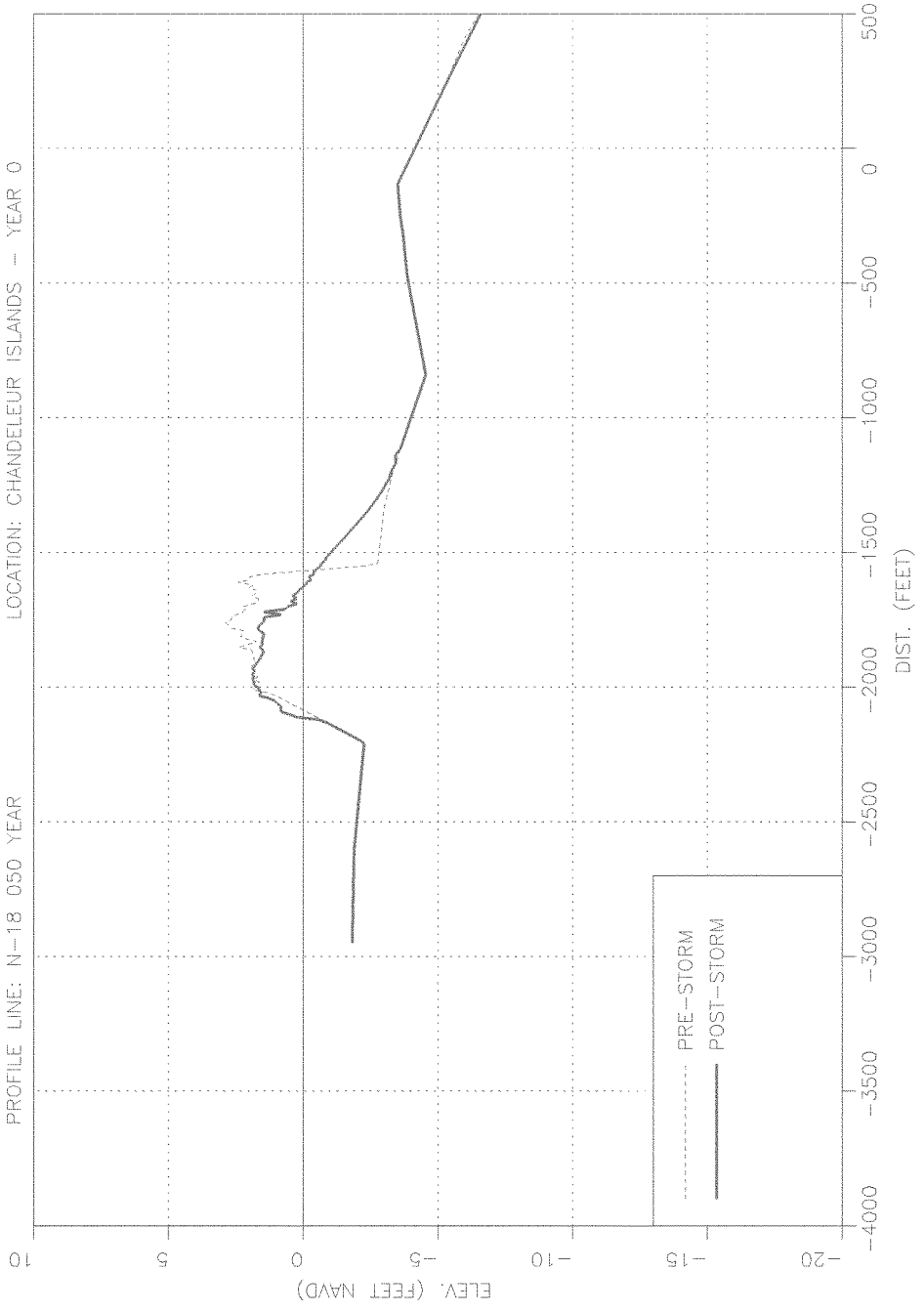

PROFILE LINE: N-18 003 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 0
ELEV. (FEET NAVD)
10
5
0
-5
-10
-15
-20
-4000
-3500
-3000
-2500
-2000
-1500
-1000
-500
0
500
DIST. (FEET)
PRE-STORM
POST-STORM

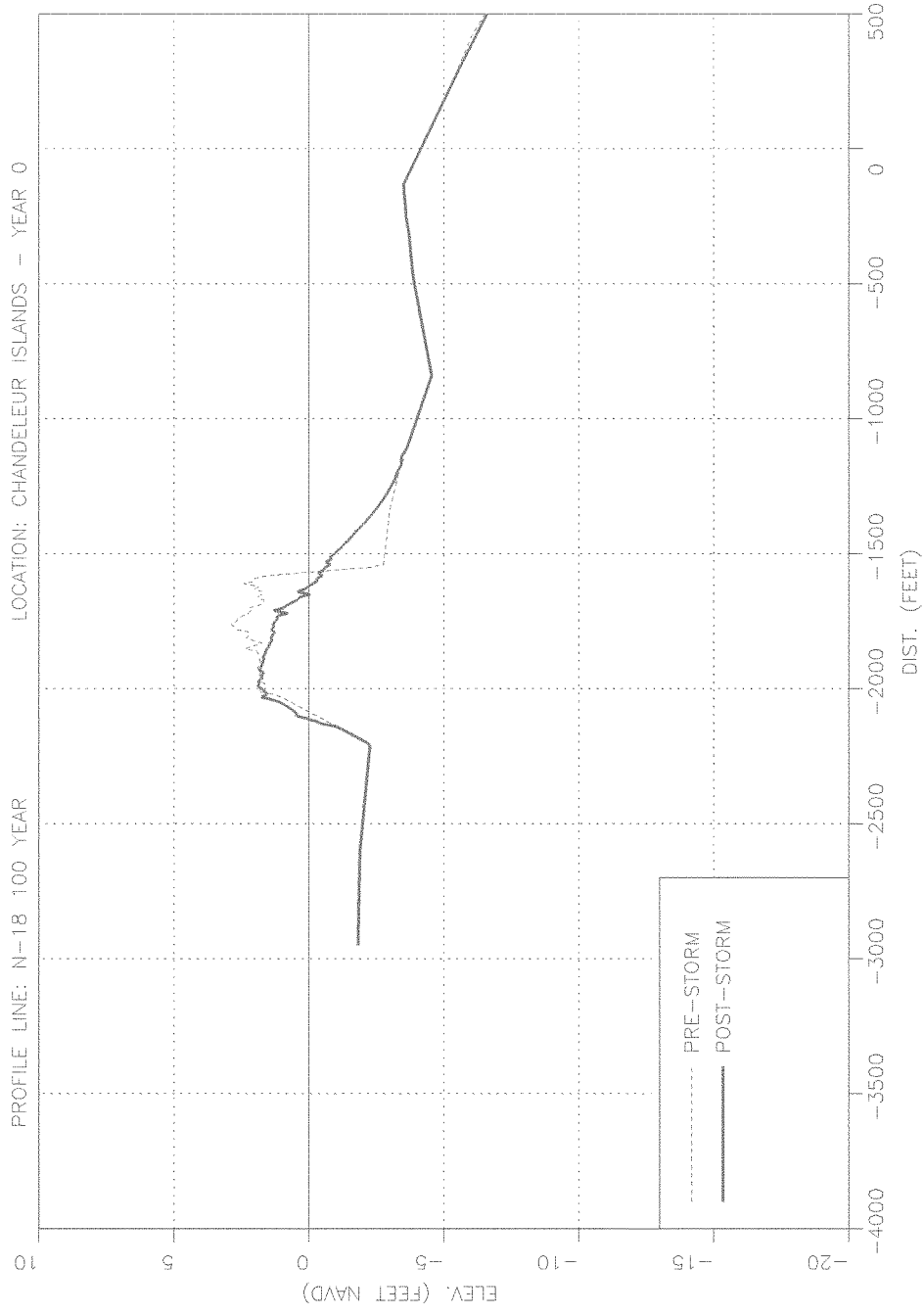

PROFILE LINE: N-18 004 YEAR
LOCATION: CHANDELEUR ISLANDS -- YEAR 0
PRE-STORM
POST-STORM
ELEV. (FEET NAVD)
DIST. (FEET)
10
5
0
-5
-10
-15
-20
-4000
-3500
-3000
-2500
-2000
-1500
-1000
-500
0
500

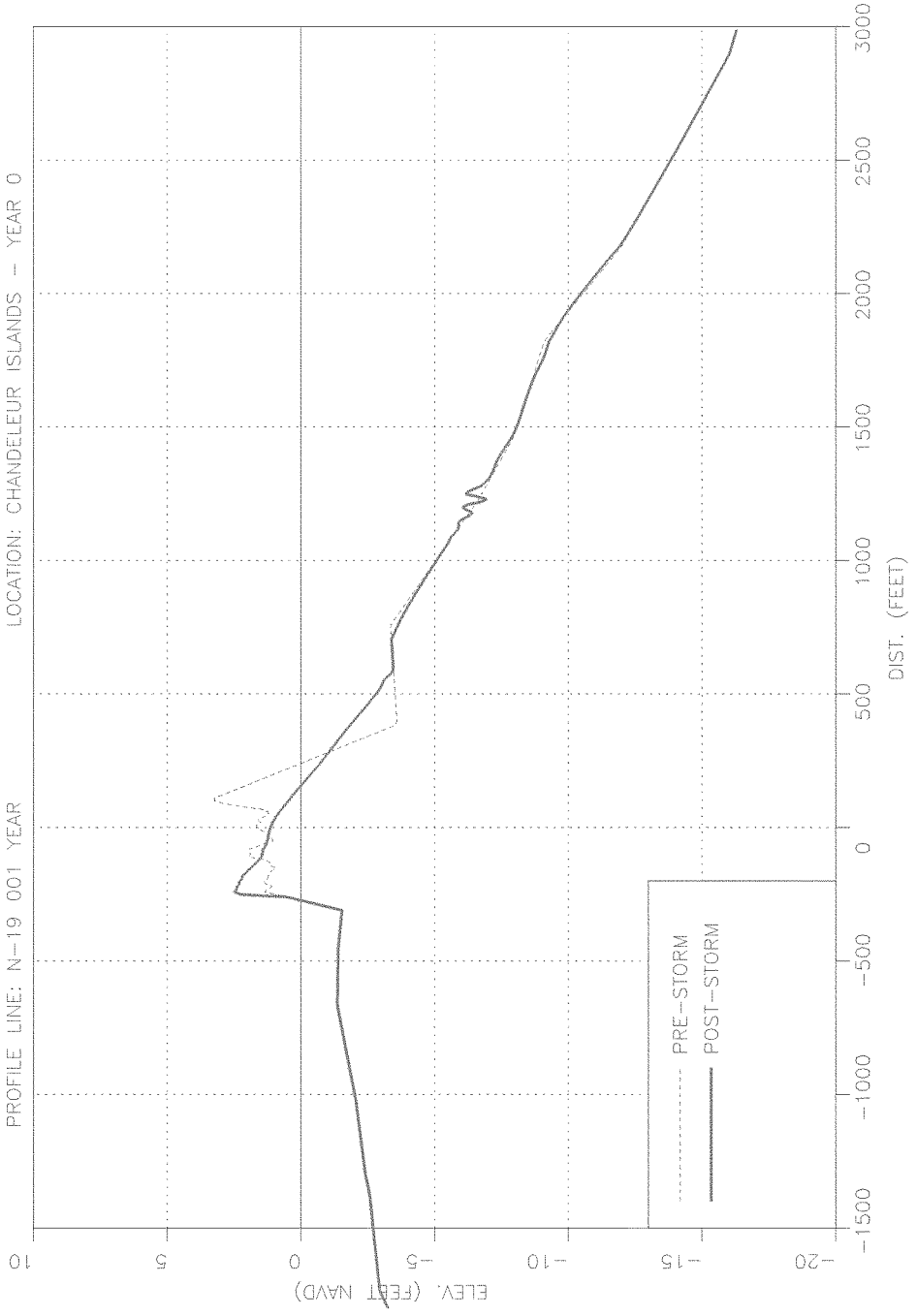

PROFILE LINE: N-18 005 YEAR
LOCATION: CHANDELEUR ISLANDS -- YEAR 0
PRE-STORM
POST-STORM
ELEV. (FEET NAVD)
DIST. (FEET)
10
5
0
-5
-10
-15
-20
-4000
-3500
-3000
-2500
-2000
-1500
-1000
-500
0
500

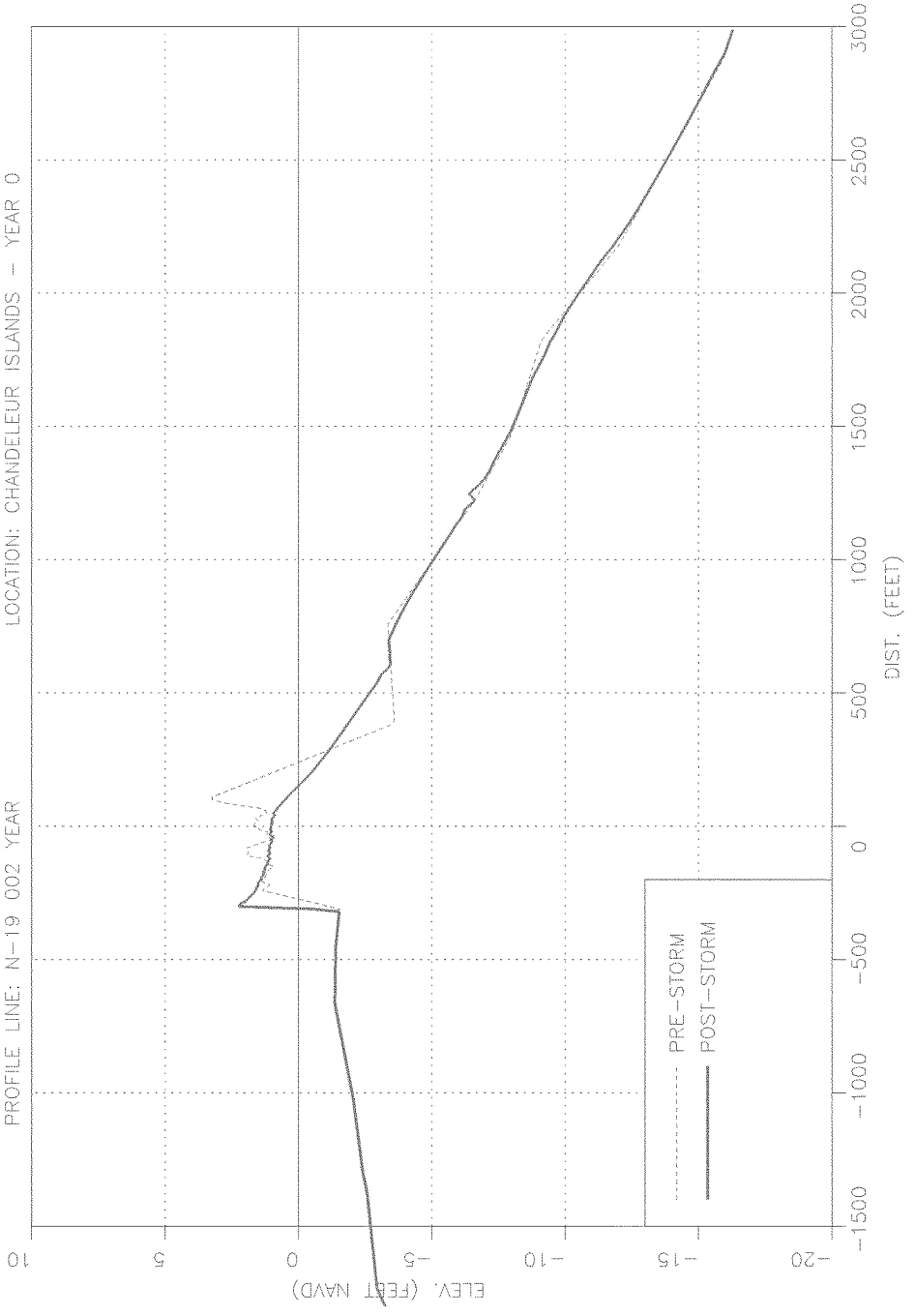

PROFILE LINE: N-18 010 YEAR
LOCATION: CHANDELEUR ISLANDS -- YEAR 0
PRE-STORM
POST-STORM
ELEV. (FEET NAVD)
DIST. (FEET)
10
5
0
-5
-10
-15
-20
-4000
-3500
-3000
-2500
-2000
-1500
-1000
-500
0
500

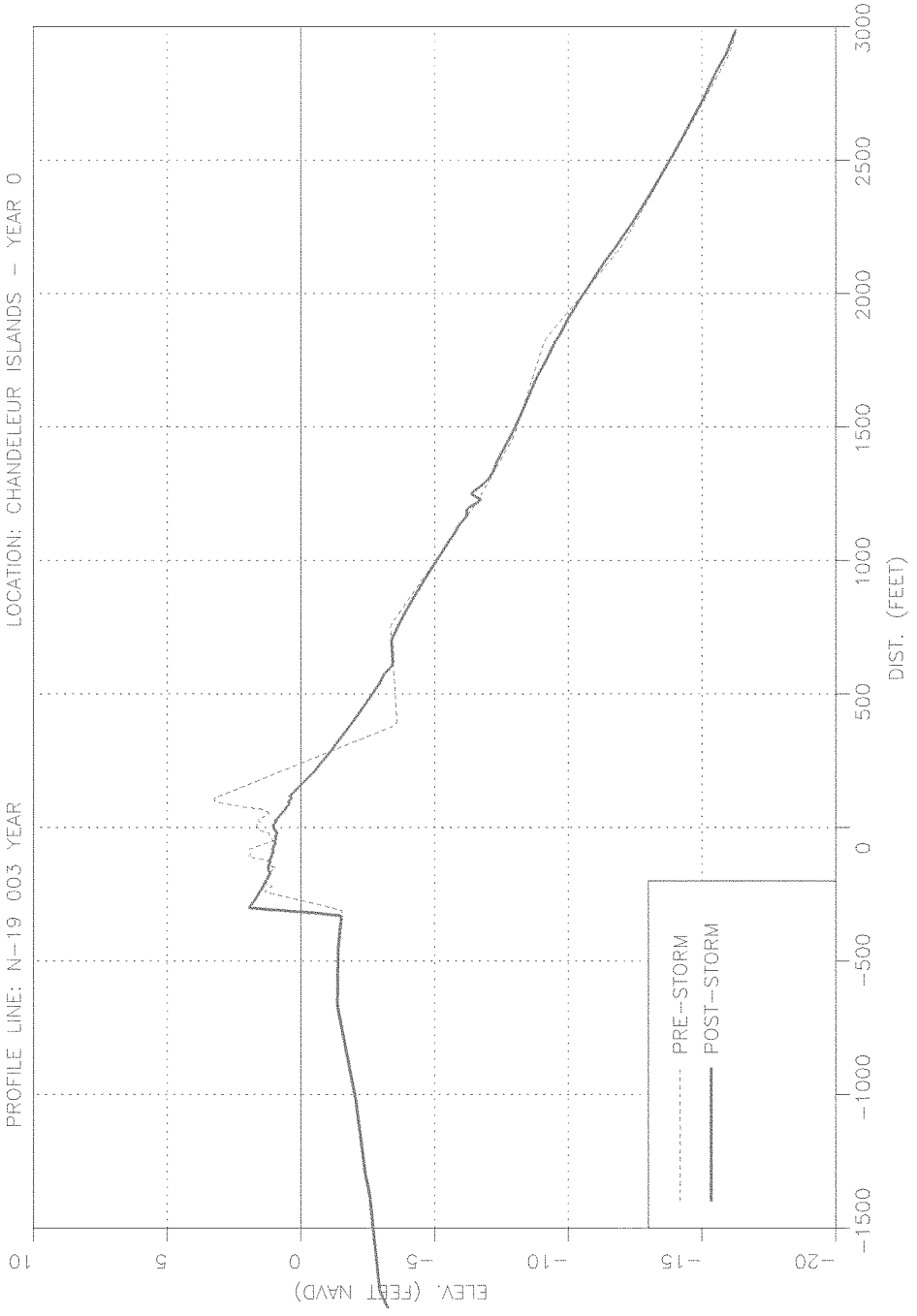

PROFILE LINE: N-18 020 YEAR
LOCATION: CHANDELEUR ISLANDS -- YEAR 0
ELEV. (FEET NAVD)
10
5
0
-5
-10
-15
-20
DIST. (FEET)
-4000
-3500
-3000
-2500
-2000
-1500
-1000
-500
0
500
PRE-STORM
POST-STORM

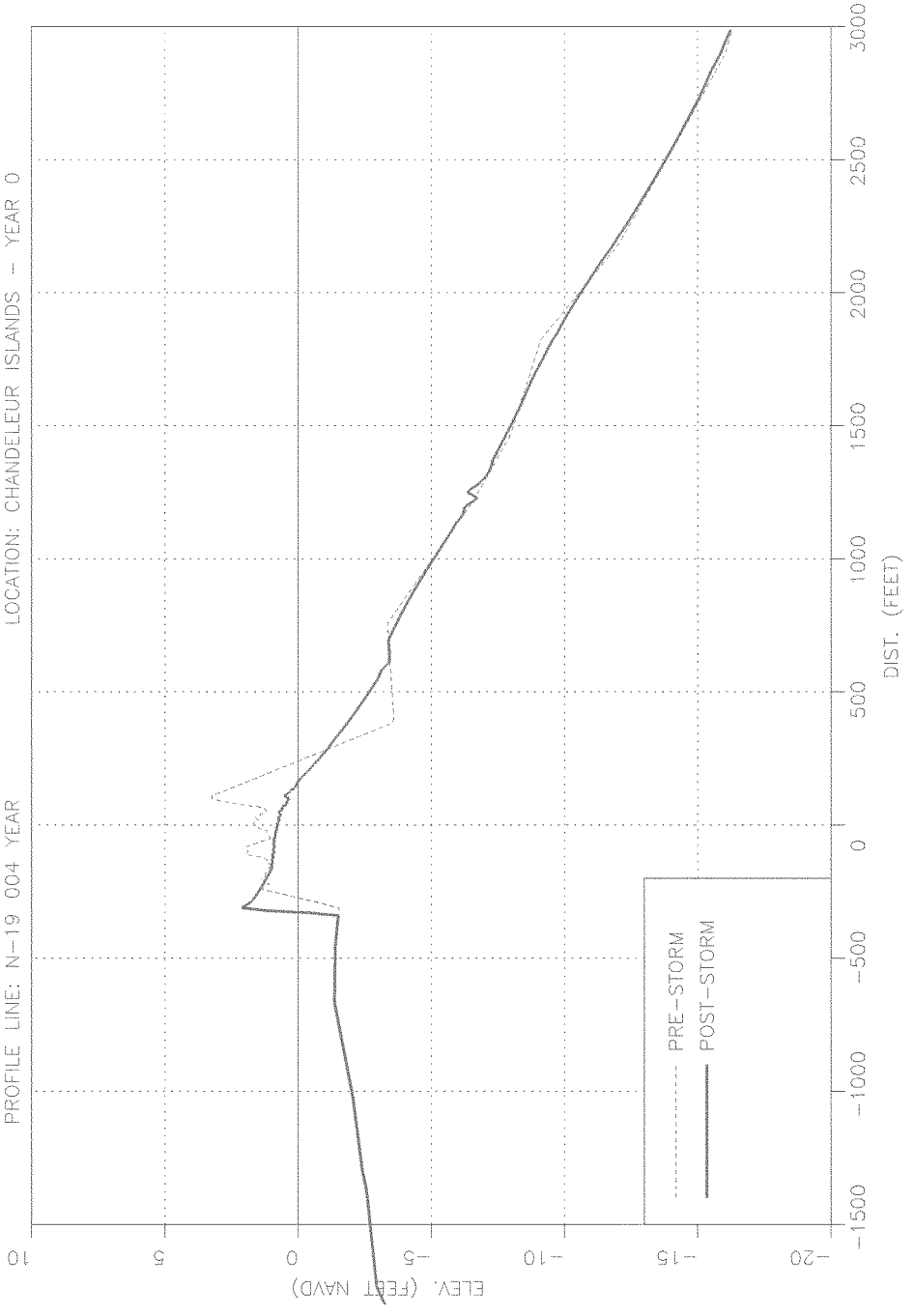

PROFILE LINE: N-18 050 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 0
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-4000
-3500
-3000
-2500
-2000
-1500
-1000
-500
0
500

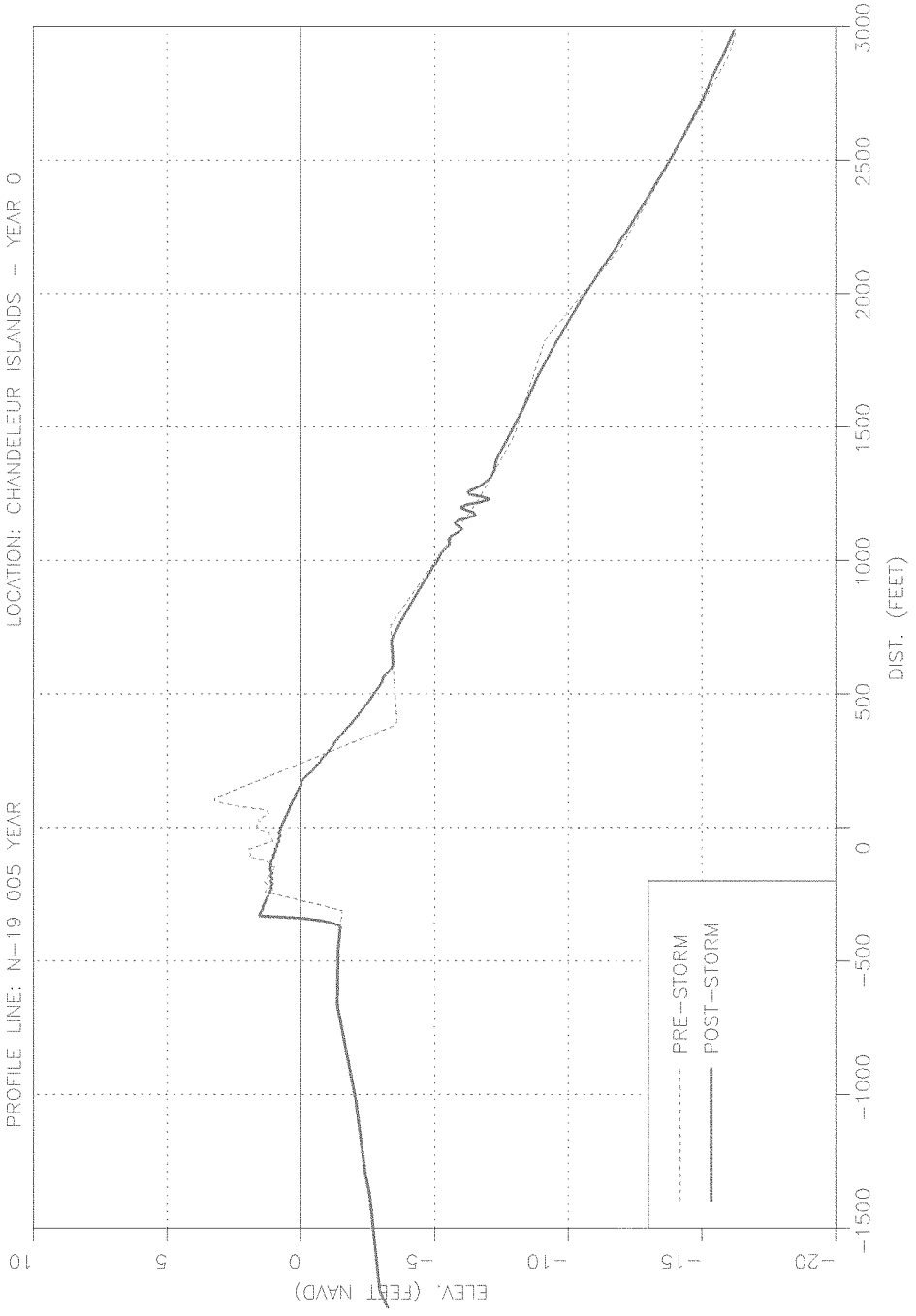

PROFILE LINE: N-18 100 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 0
ELEV. (FEET NAVD)
10
5
0
-5
-10
-15
-20
-4000
-3500
-3000
-2500
-2000
-1500
-1000
-500
0
500
DIST. (FEET)
PRE-STORM
POST-STORM

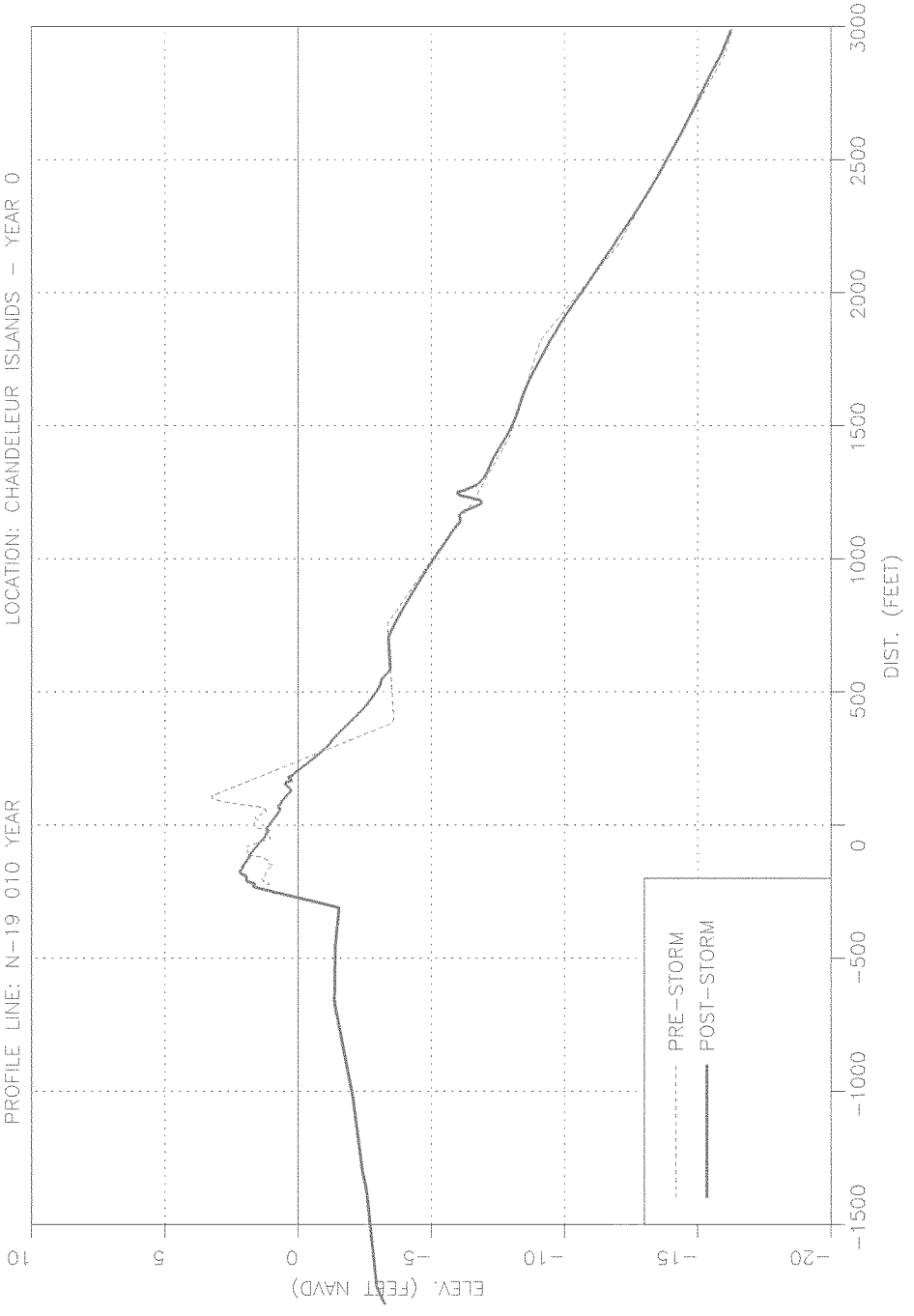

PROFILE LINE: N-19 001 YEAR
LOCATION: CHANDELEUR ISLANDS -- YEAR 0
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

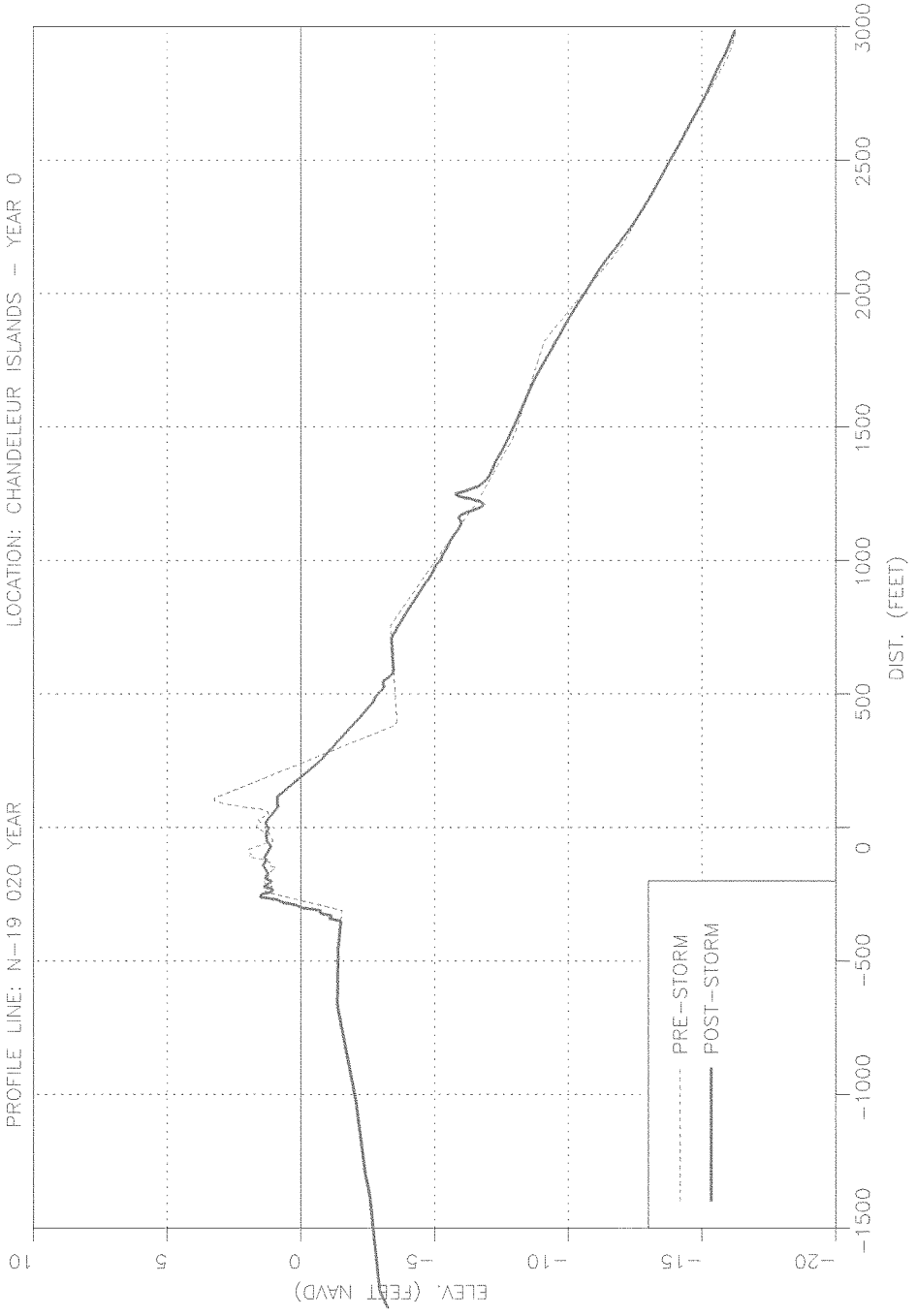

PROFILE LINE: N-19 002 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 0
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

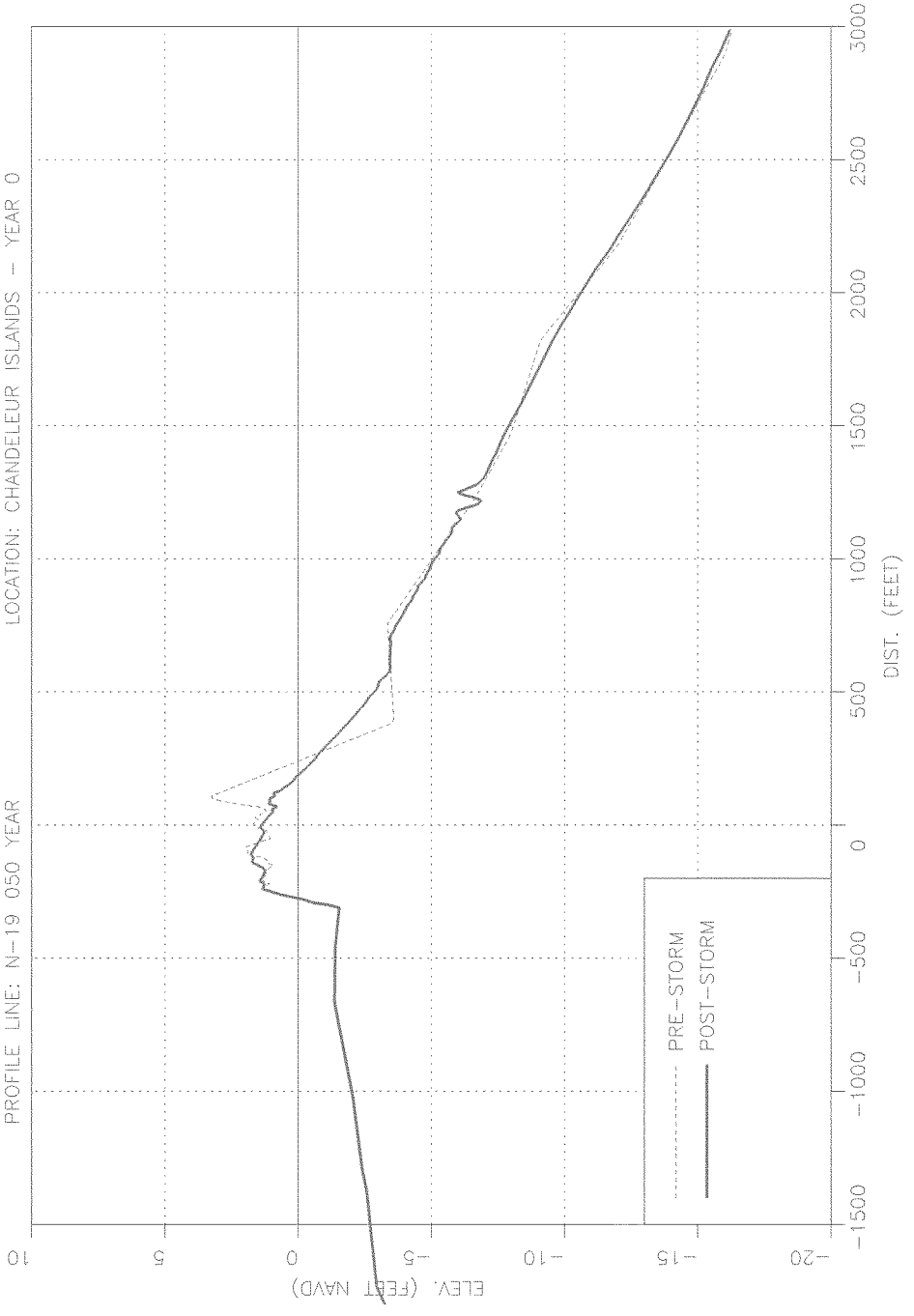

PROFILE LINE: N-19 003 YEAR
LOCATION: CHANDELEUR ISLANDS -- YEAR 0
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

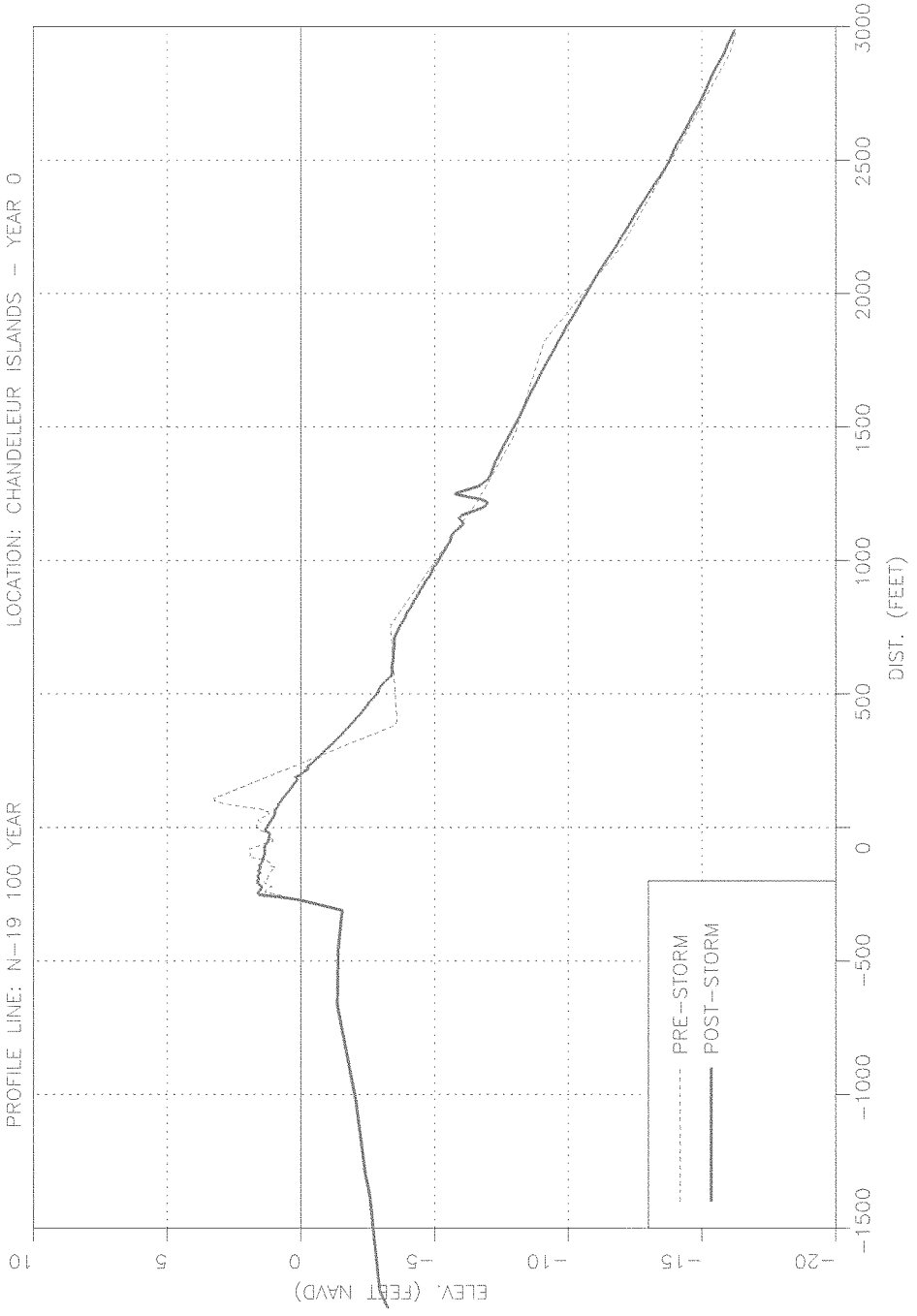

PROFILE LINE: N-19 004 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 0
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

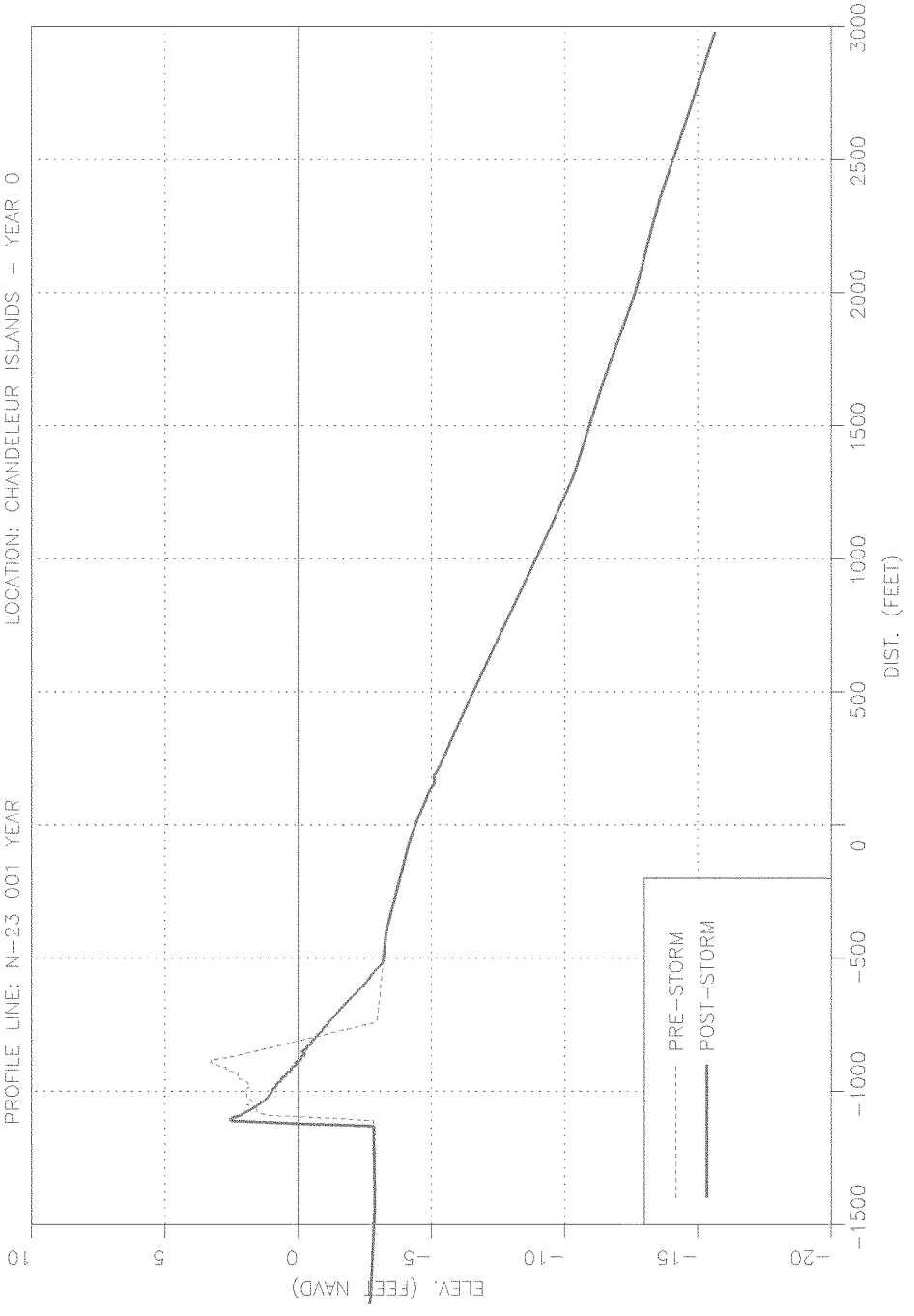

PROFILE LINE: N-19 005 YEAR
LOCATION: CHANDELEUR ISLANDS -- YEAR 0
PRE-STORM
POST-STORM
ELEV. (FEET NAVD)
DIST. (FEET)
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

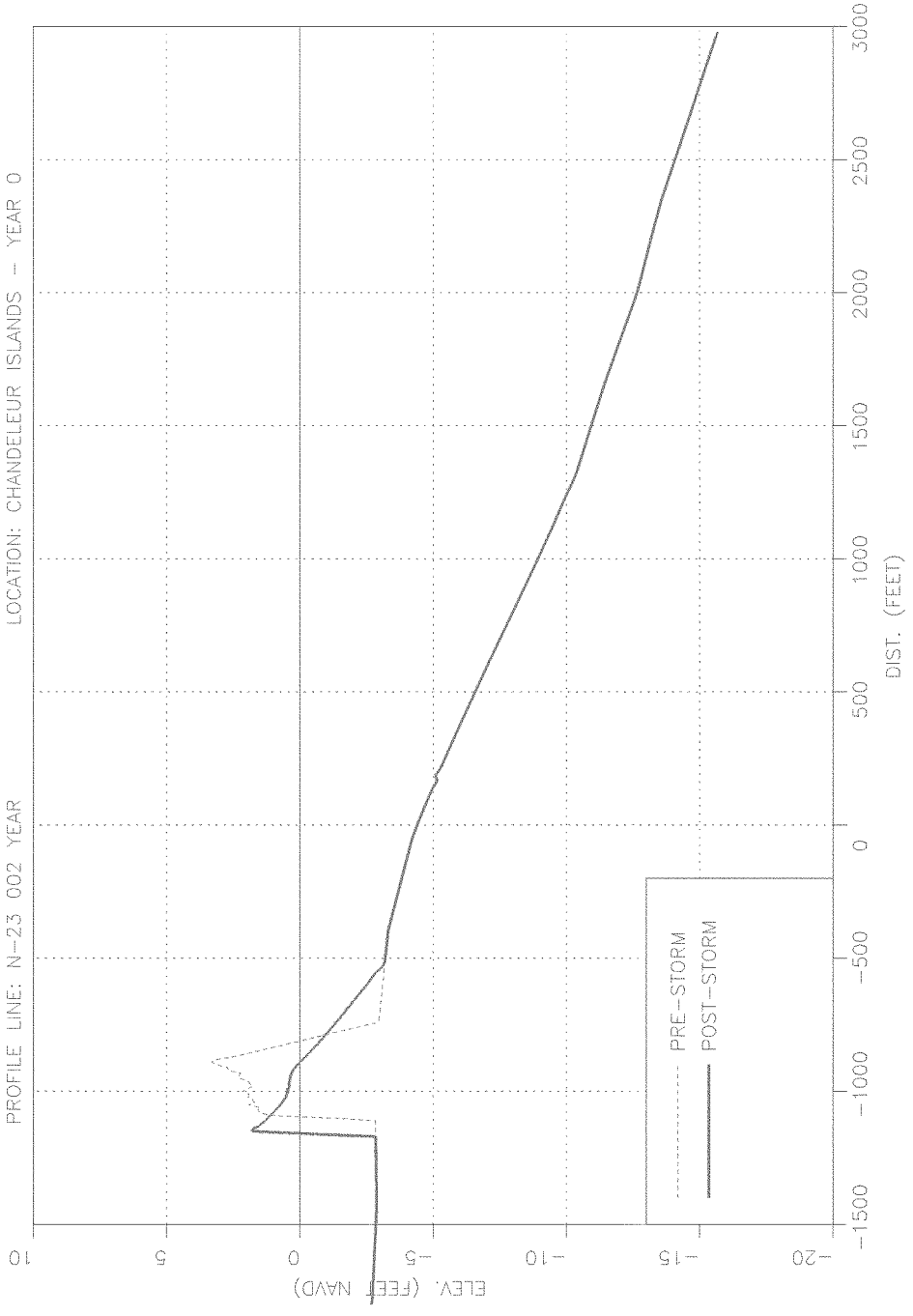

PROFILE LINE: N-19 010 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 0
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

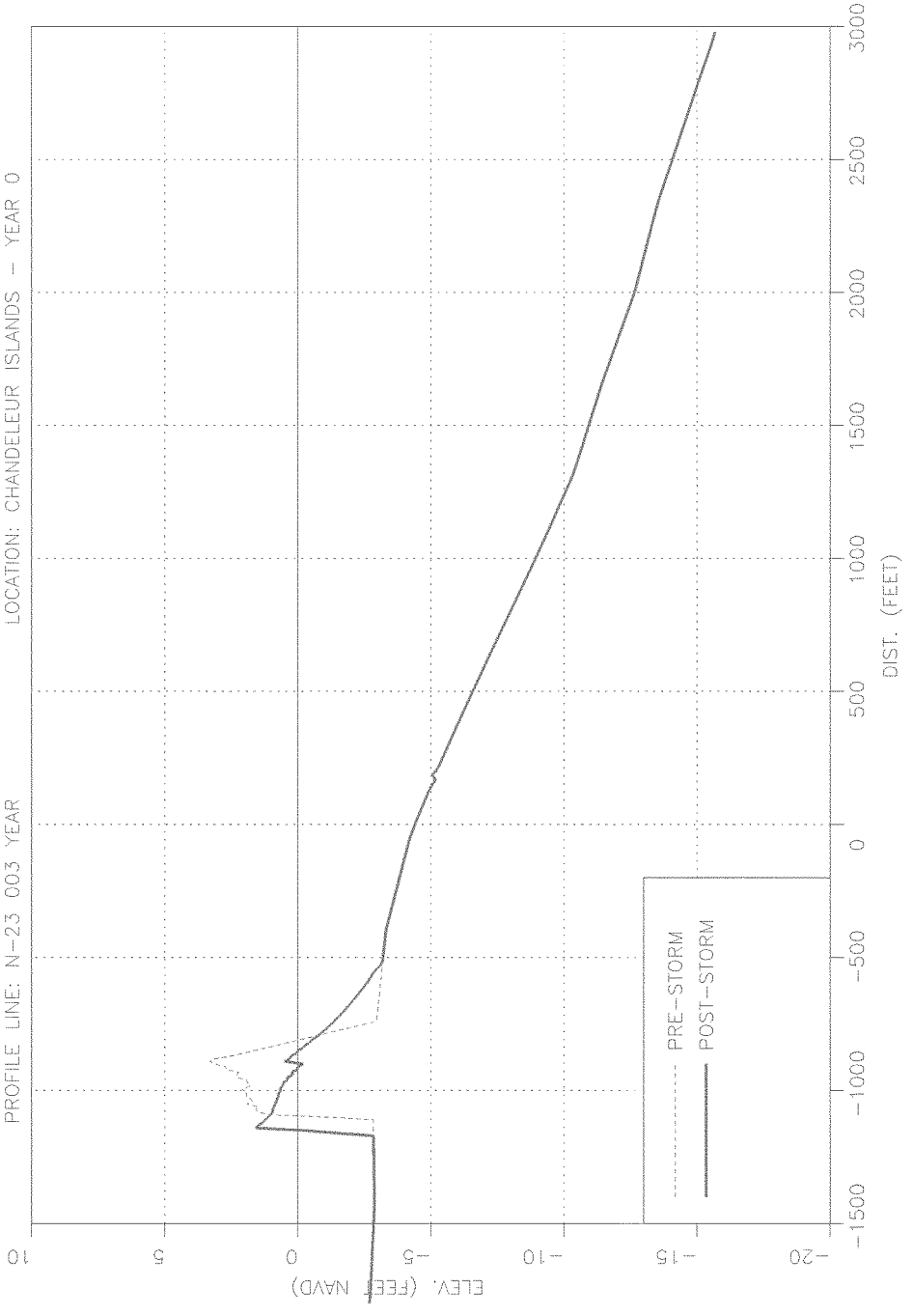

PROFILE LINE: N-19 020 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 0
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

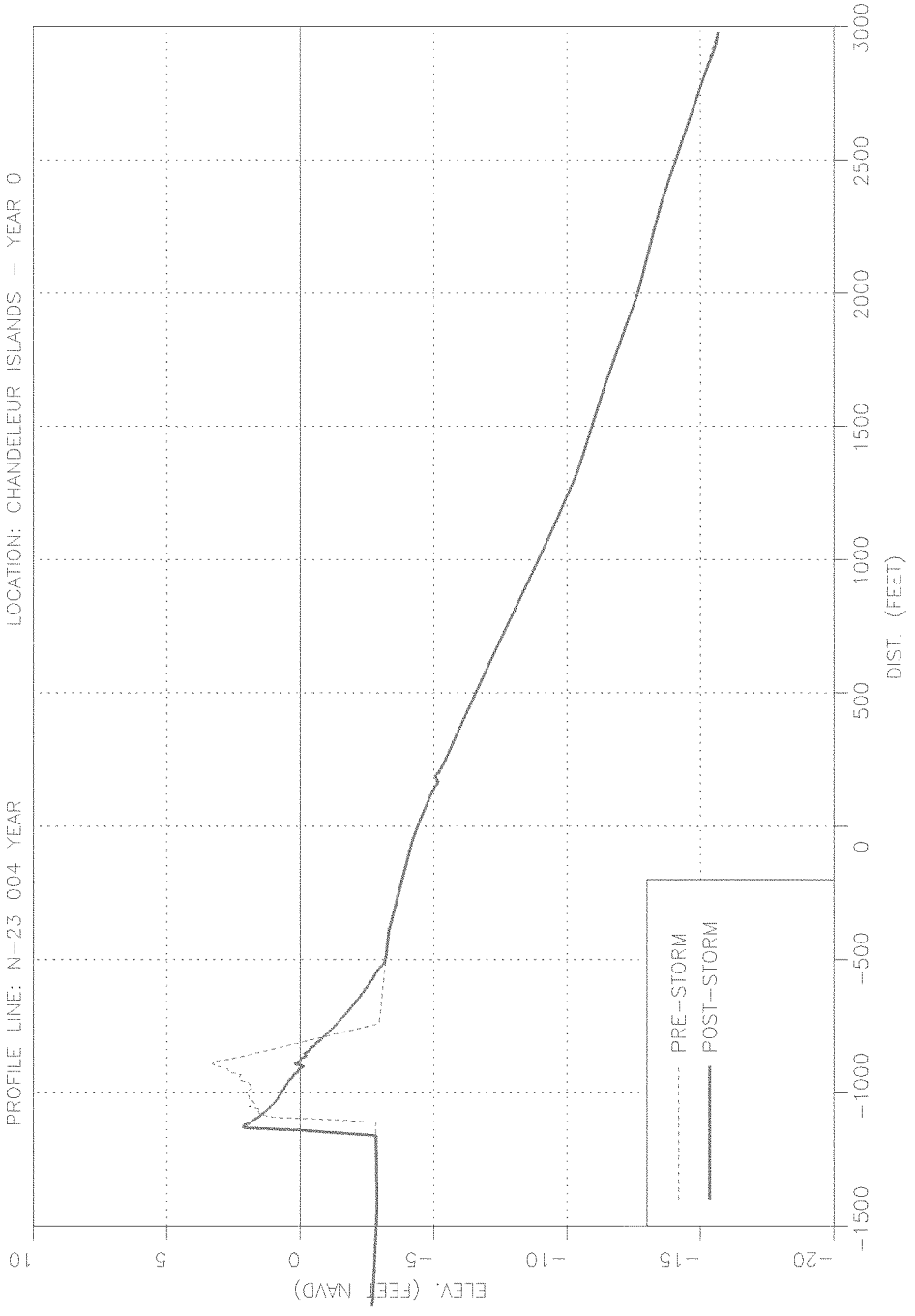

PROFILE LINE: N-19 050 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 0
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

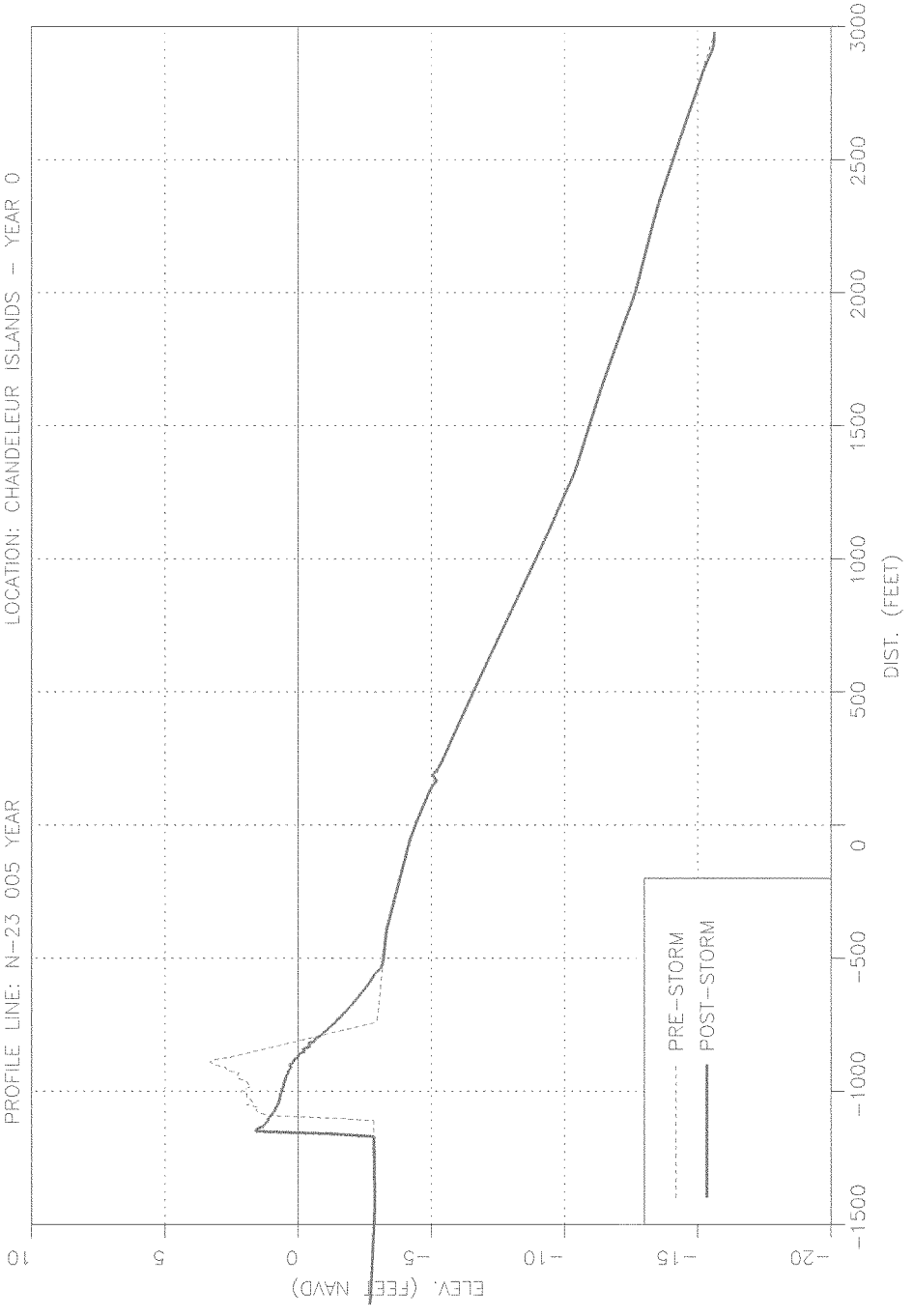

PROFILE LINE: N-19 100 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 0
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

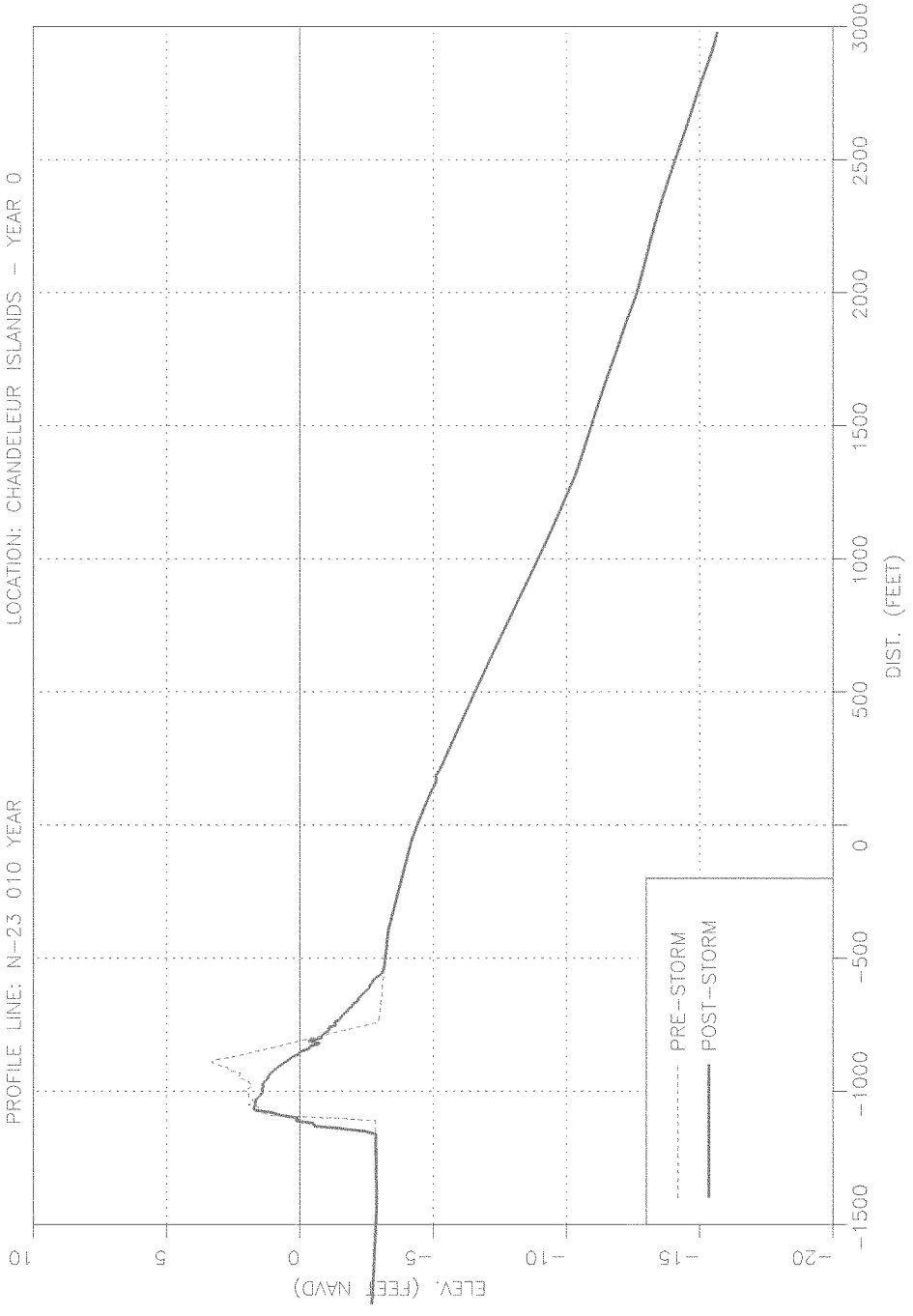

PROFILE LINE: N-23 001 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 0
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

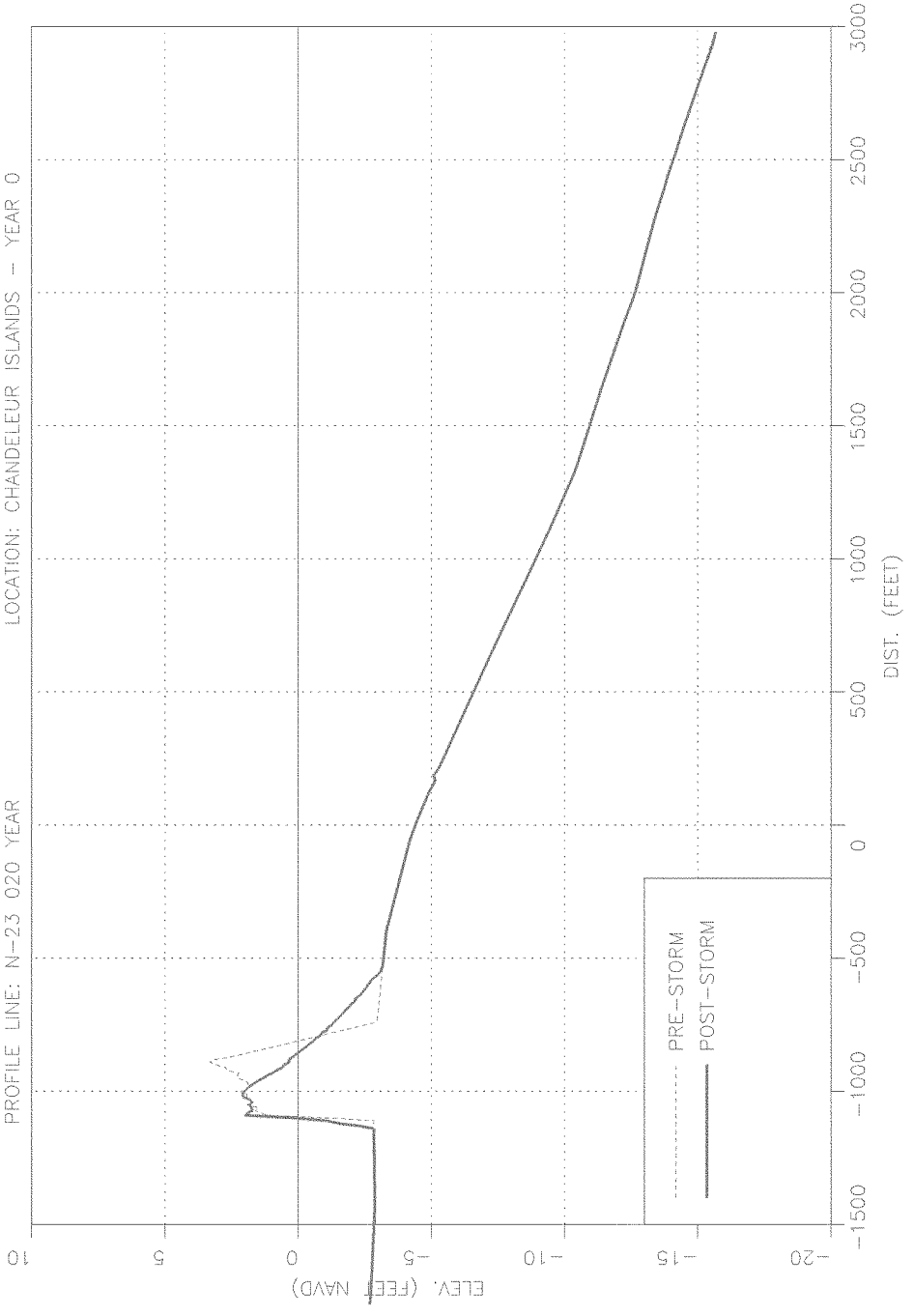

PROFILE LINE: N-23 002 YEAR
LOCATION: CHANDELEUR ISLANDS -- YEAR 0
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

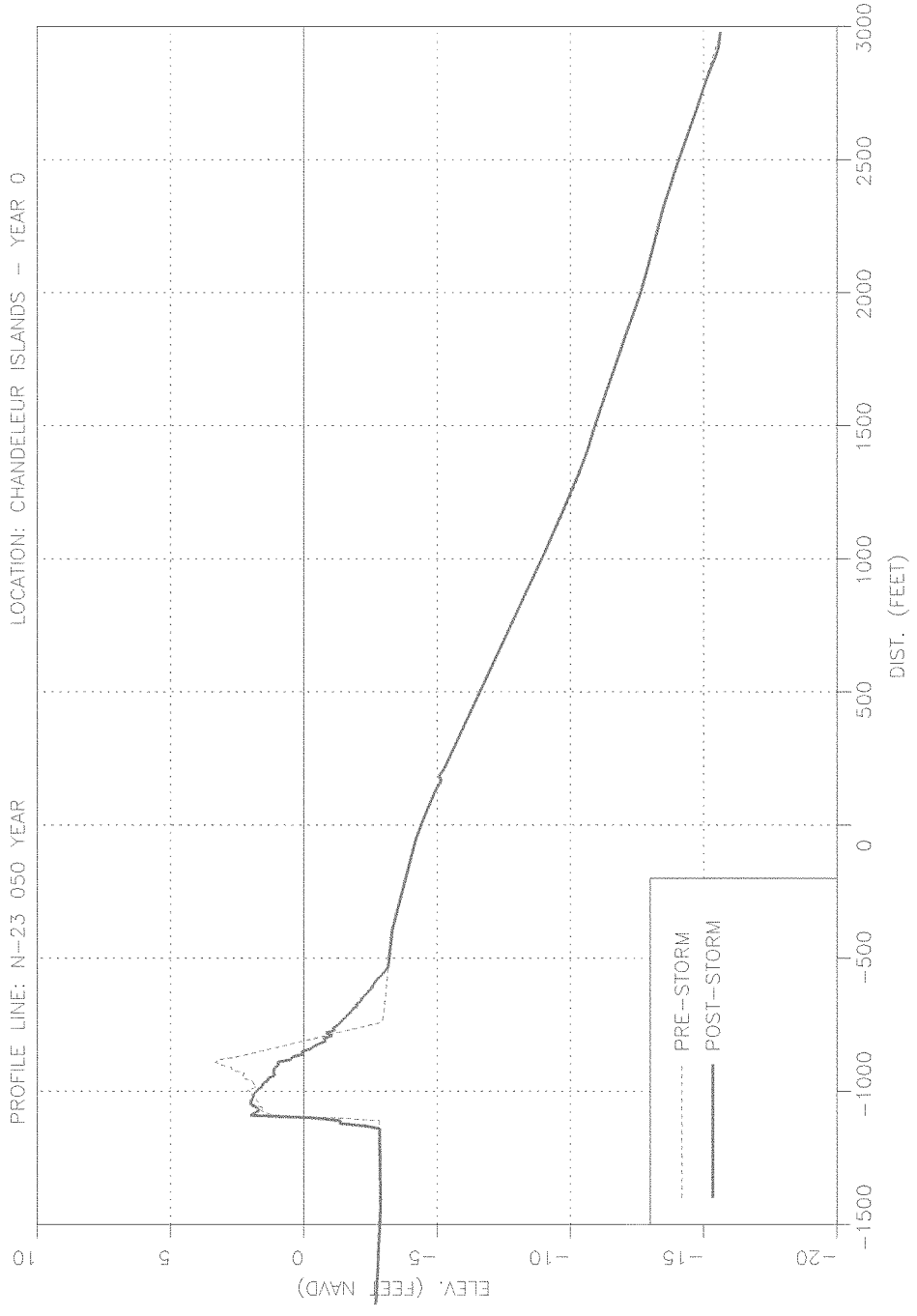

PROFILE LINE: N-23 003 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 0
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

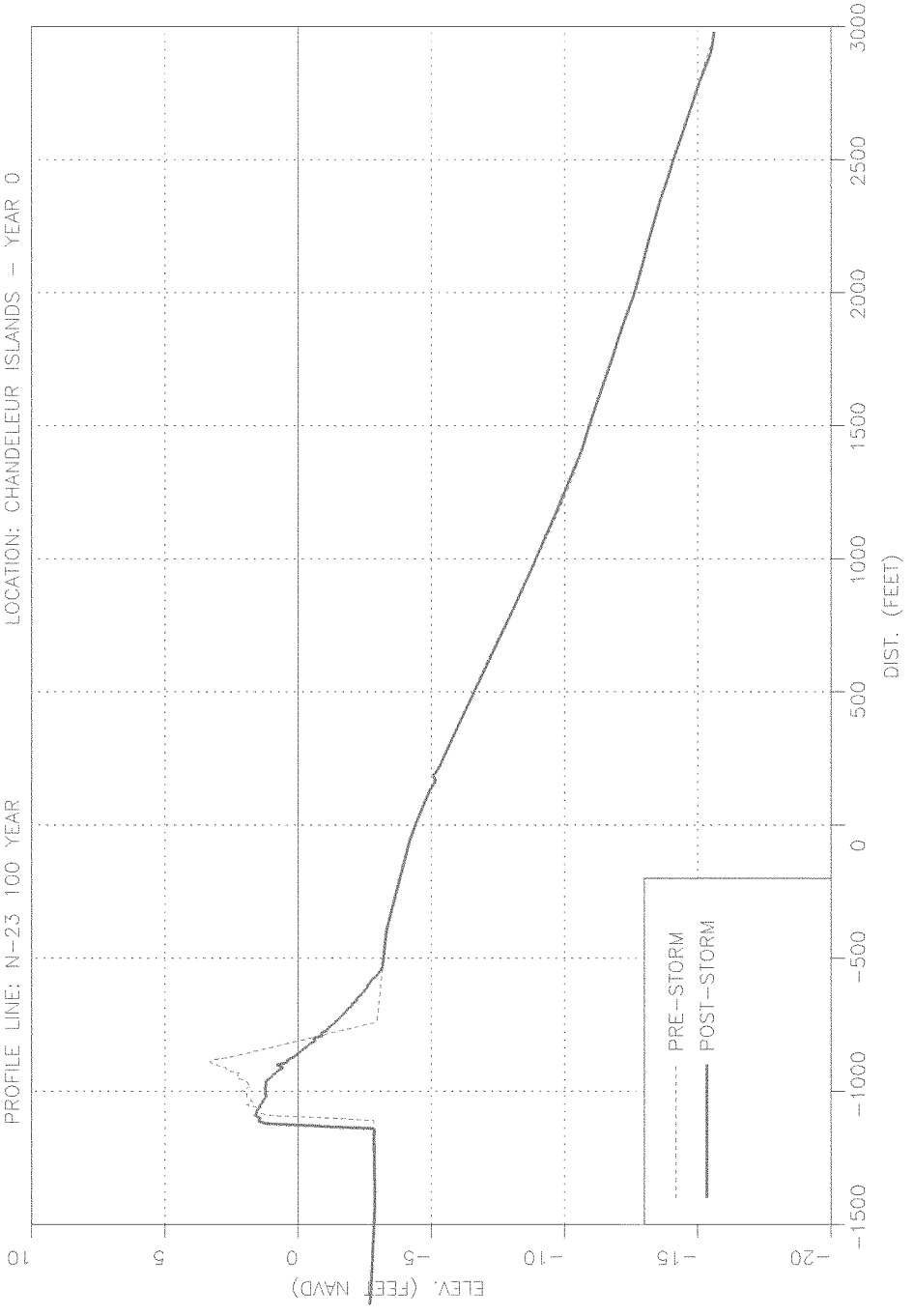

PROFILE LINE: N-23 004 YEAR
LOCATION: CHANDELEUR ISLANDS -- YEAR 0
PRE-STORM
POST-STORM
ELEV. (FEET NAVD)
DIST. (FEET)
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

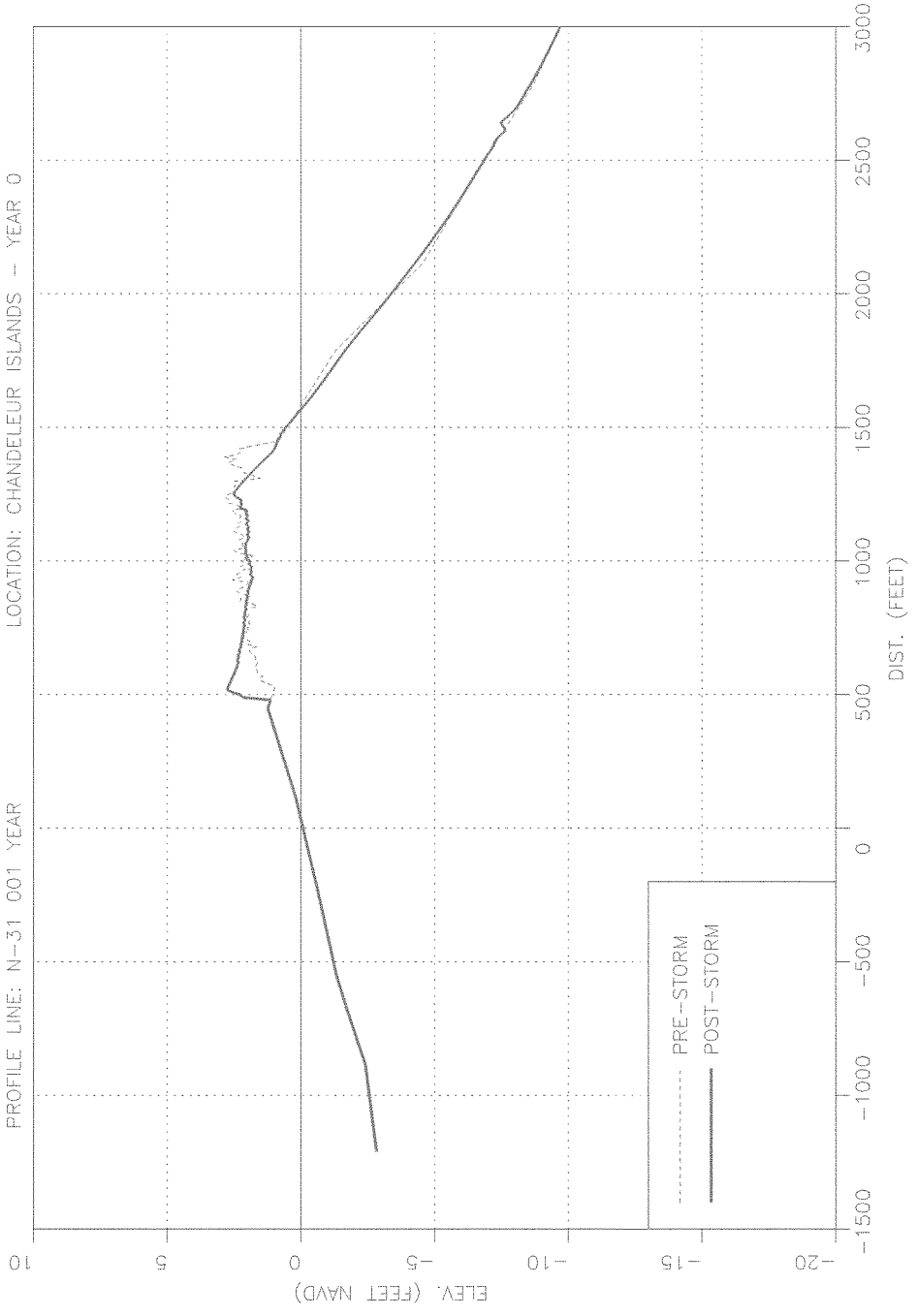

PROFILE LINE: N-23 005 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 0
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

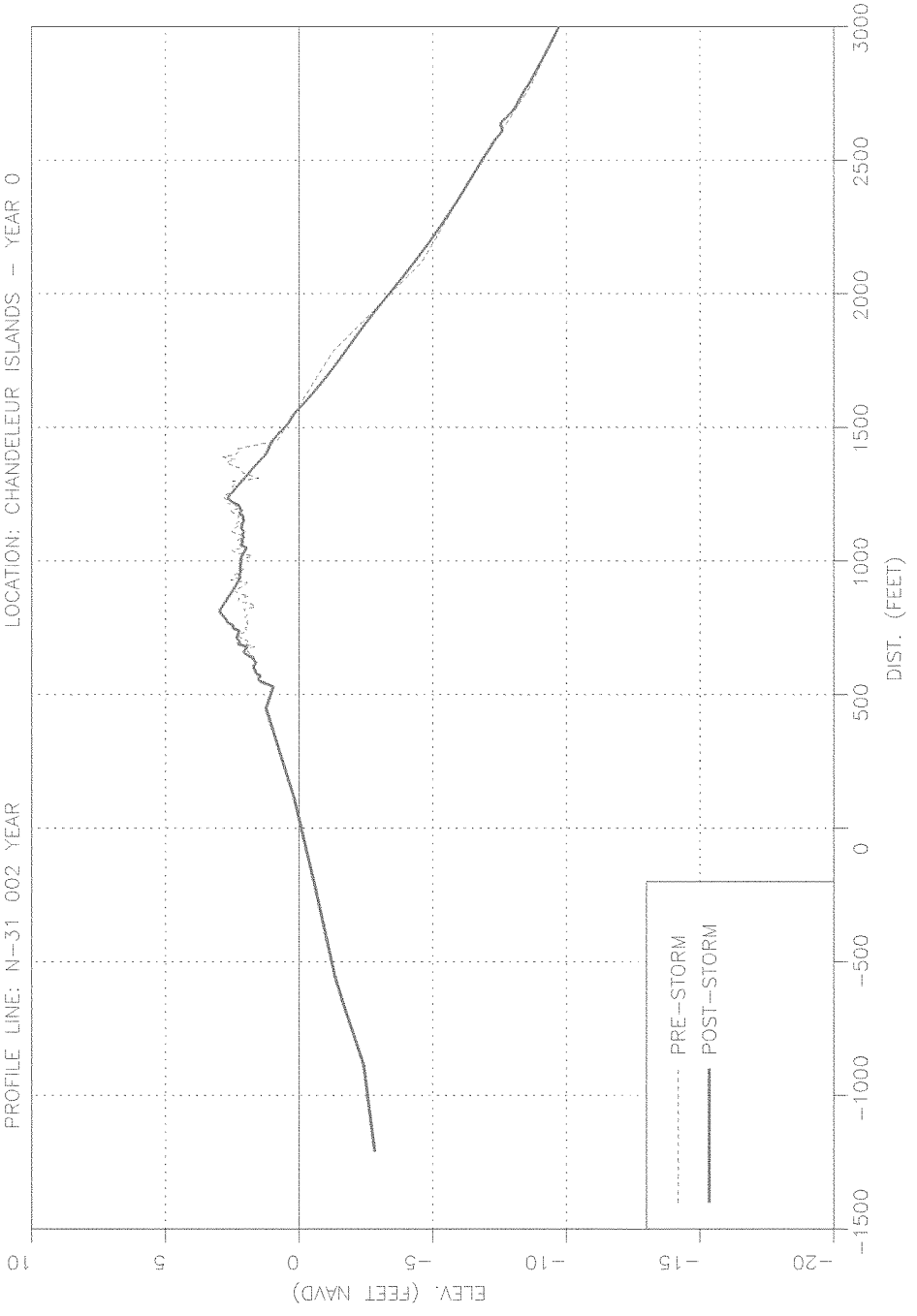

PROFILE LINE: N-23 010 YEAR
LOCATION: CHANDELEUR ISLANDS -- YEAR 0
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

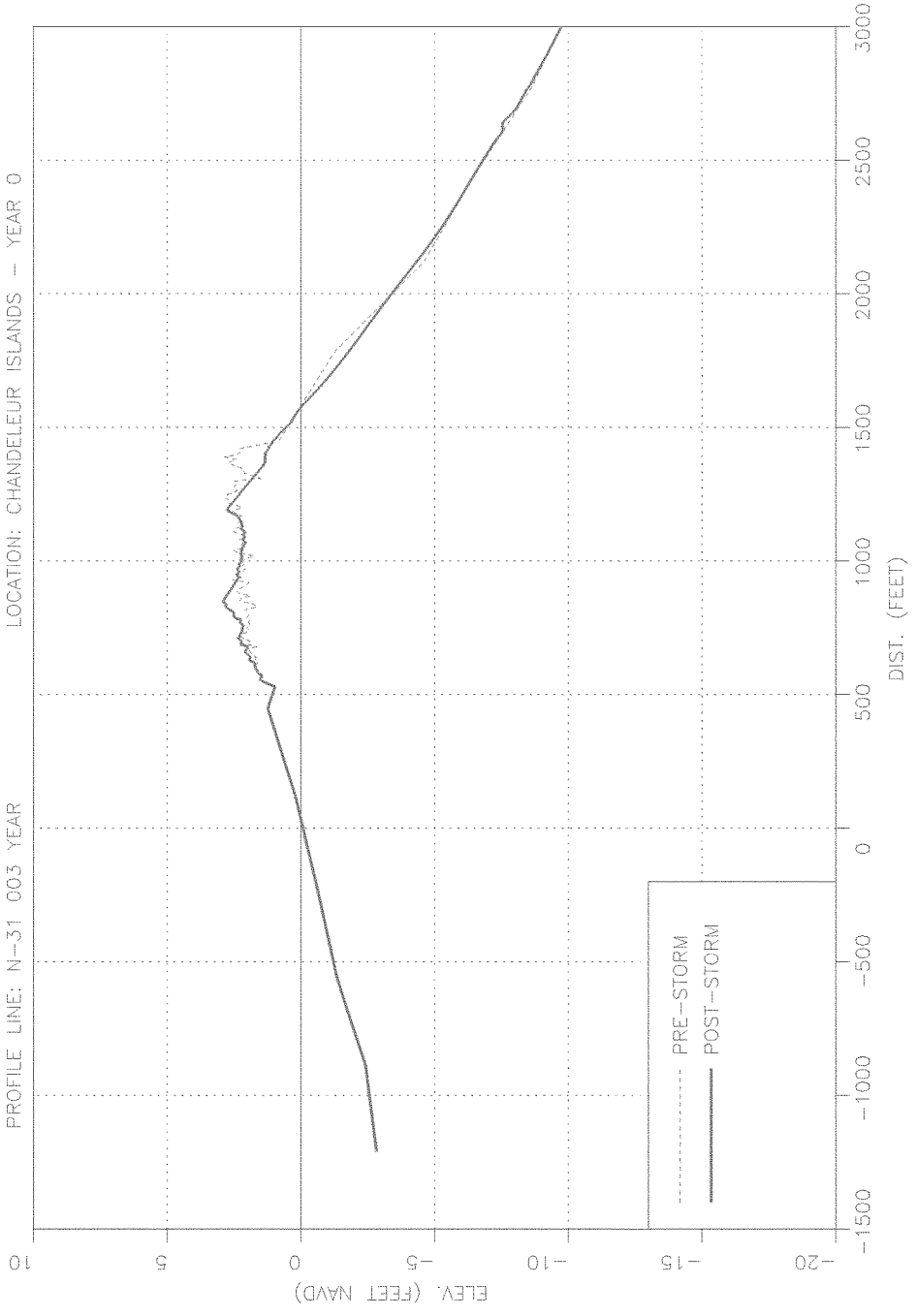

PROFILE LINE: N-23 020 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 0
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

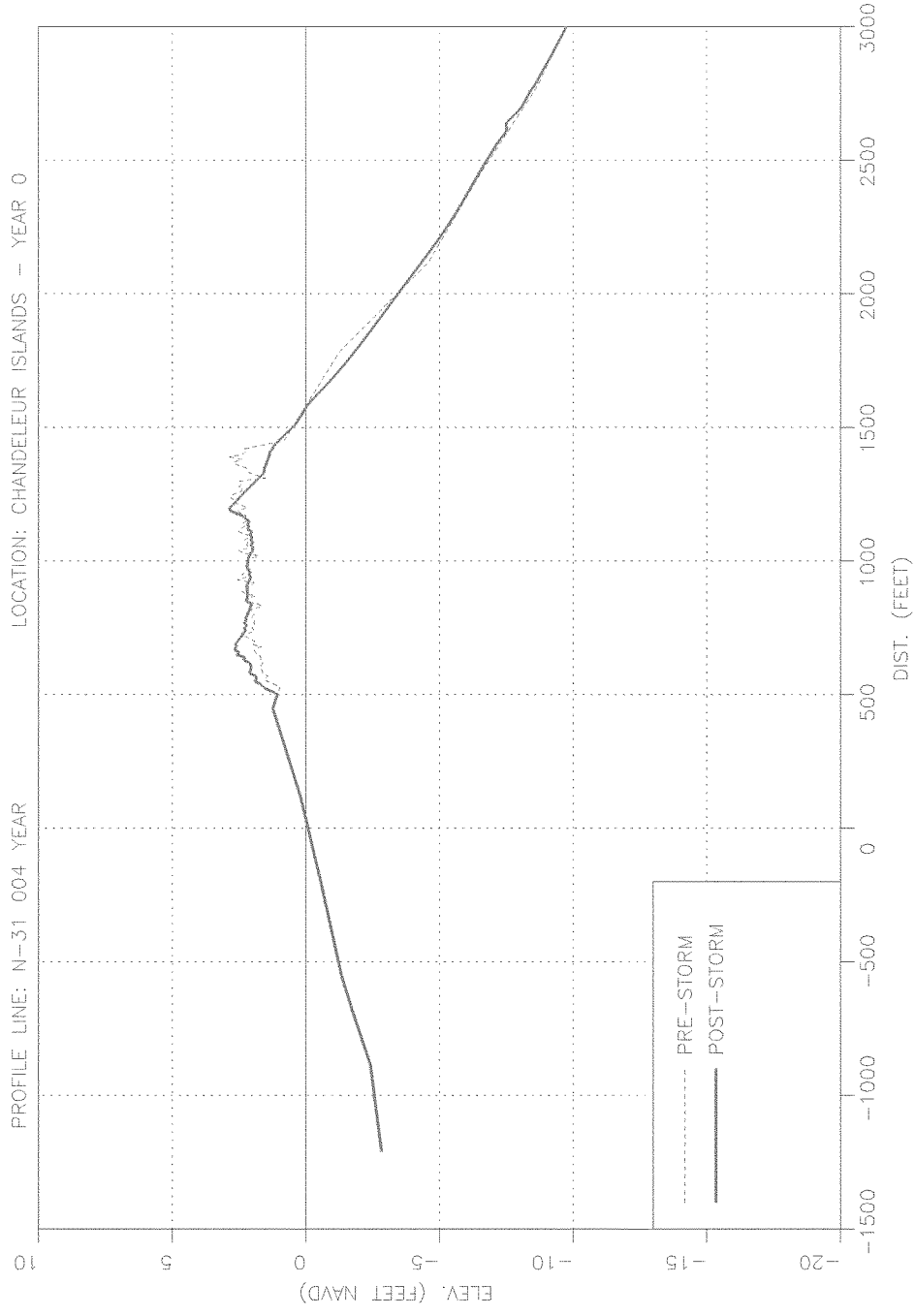

PROFILE LINE: N-23 050 YEAR
LOCATION: CHANDELEUR ISLANDS -- YEAR 0
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

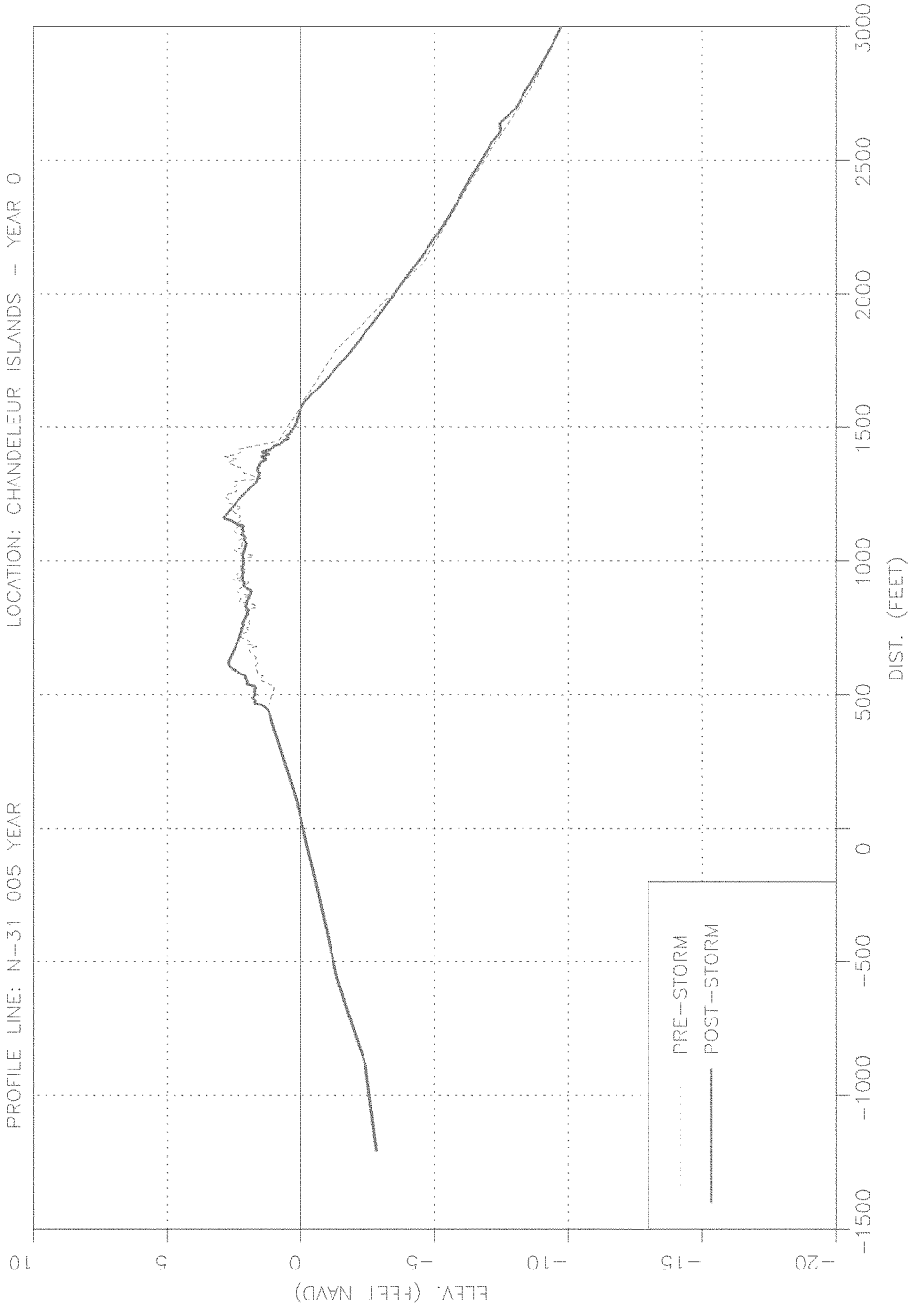

PROFILE LINE: N-23 100 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 0
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

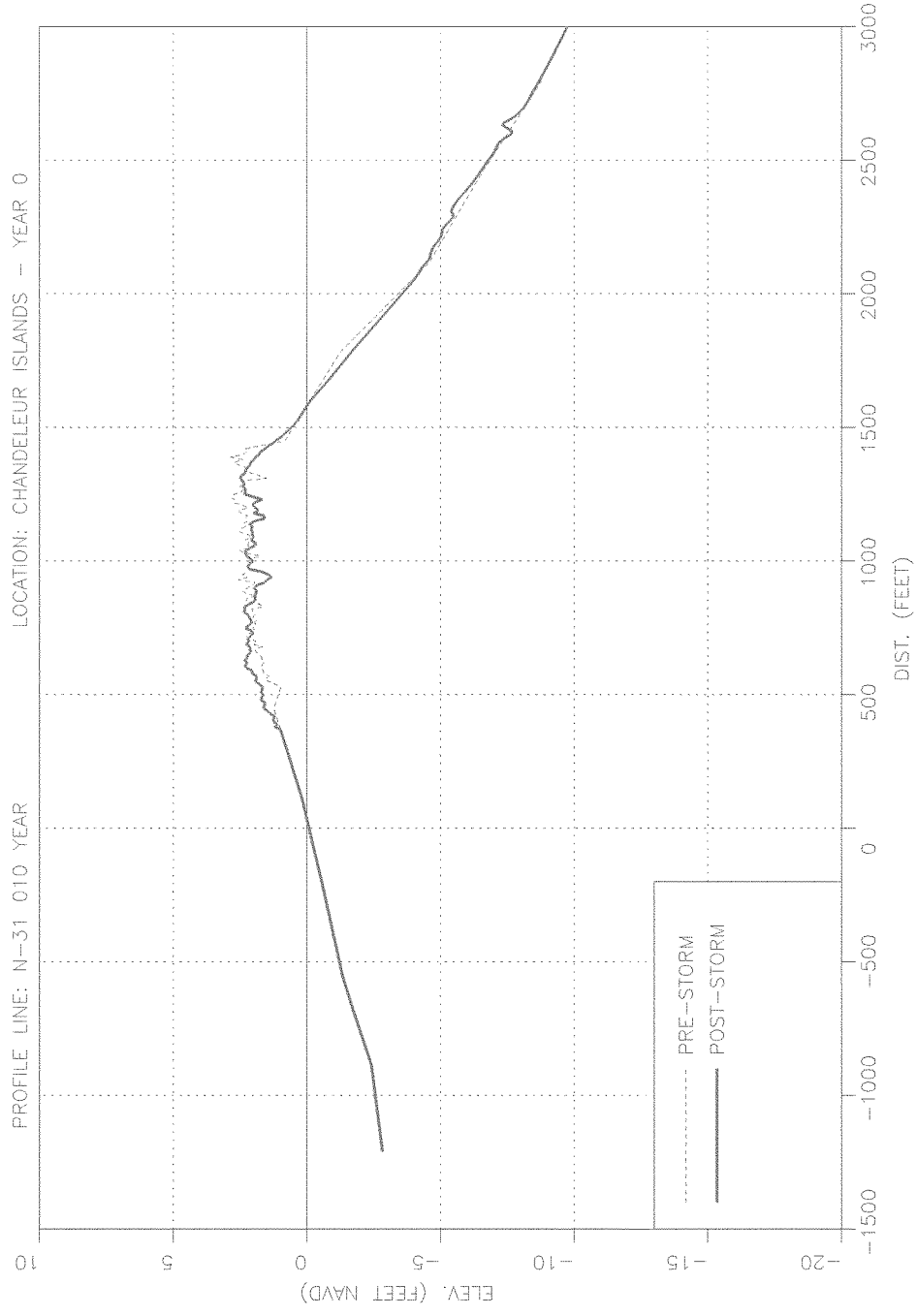

PROFILE LINE: N-31 001 YEAR
LOCATION: CHANDELEUR ISLANDS -- YEAR 0
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

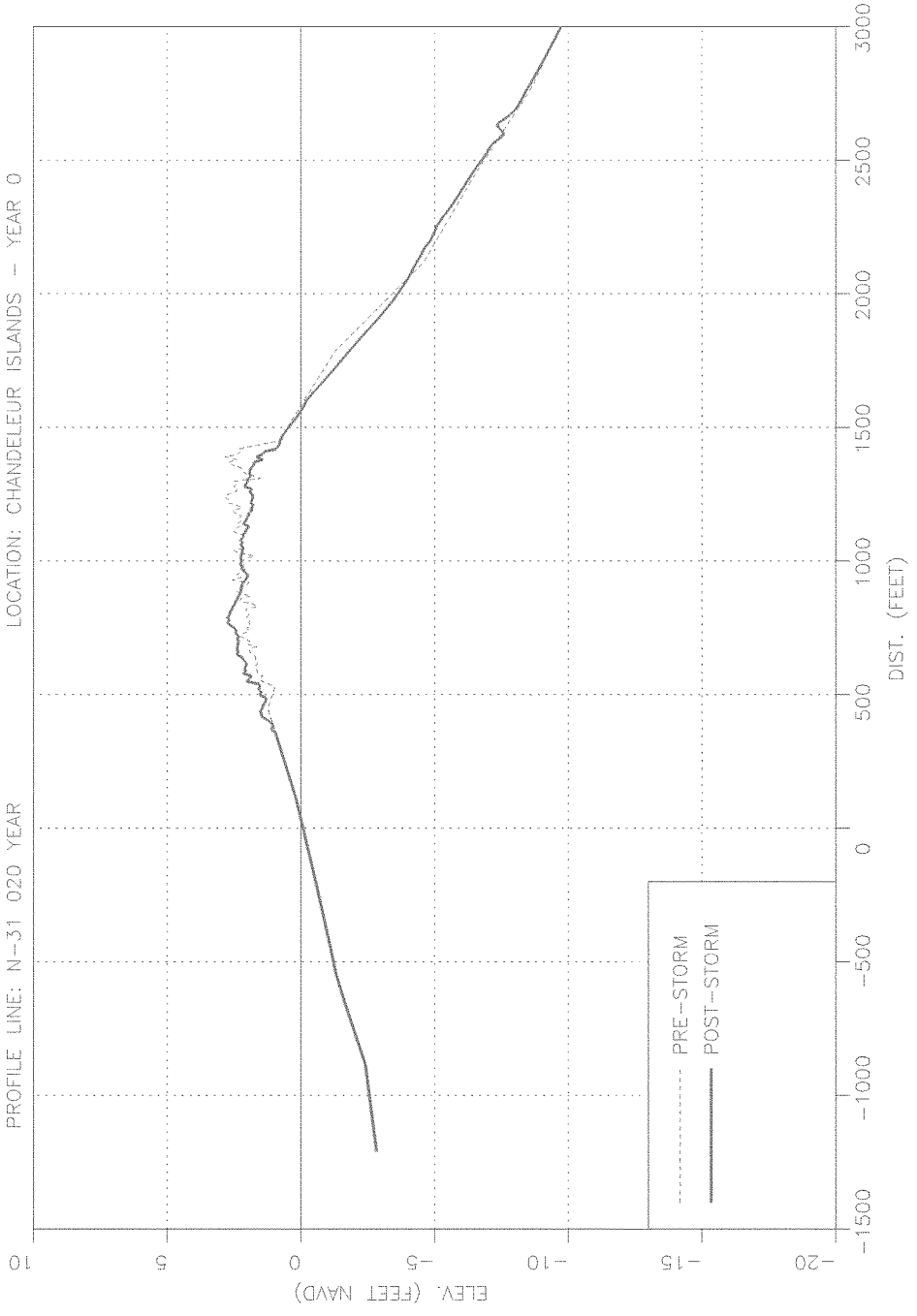

PROFILE LINE: N-31 002 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 0
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

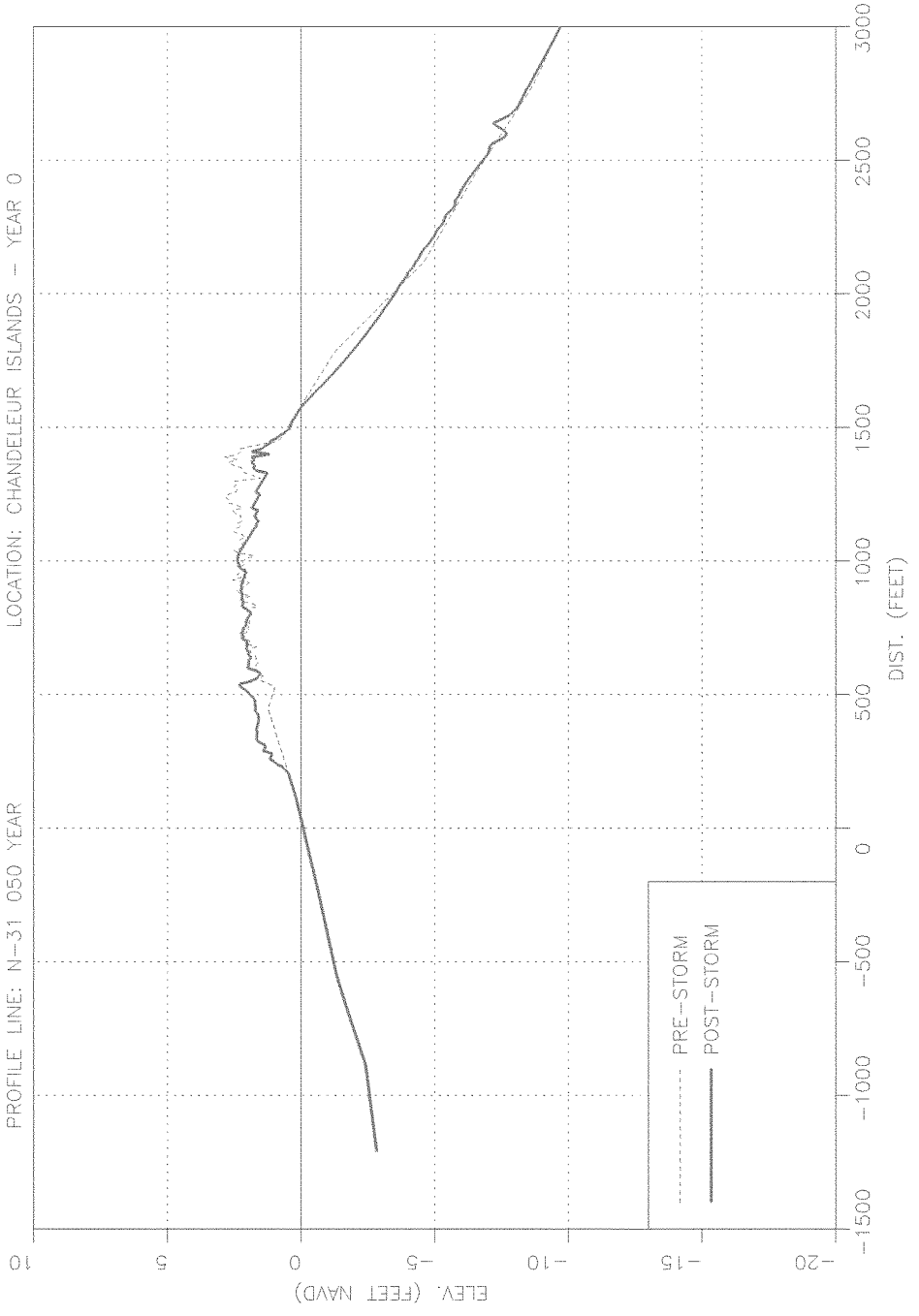

PROFILE LINE: N-31 003 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 0
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

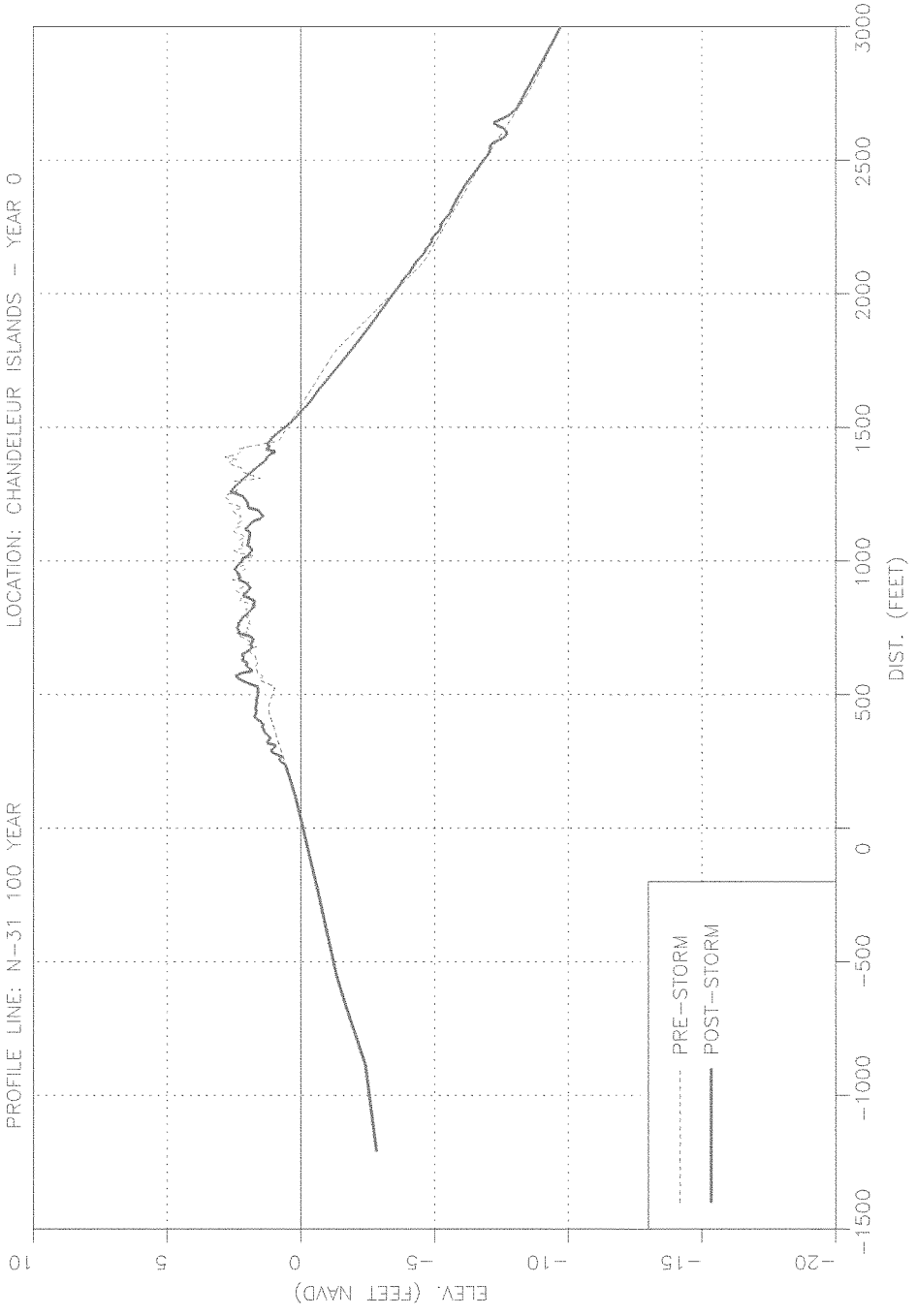

PROFILE LINE: N-31 004 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 0
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

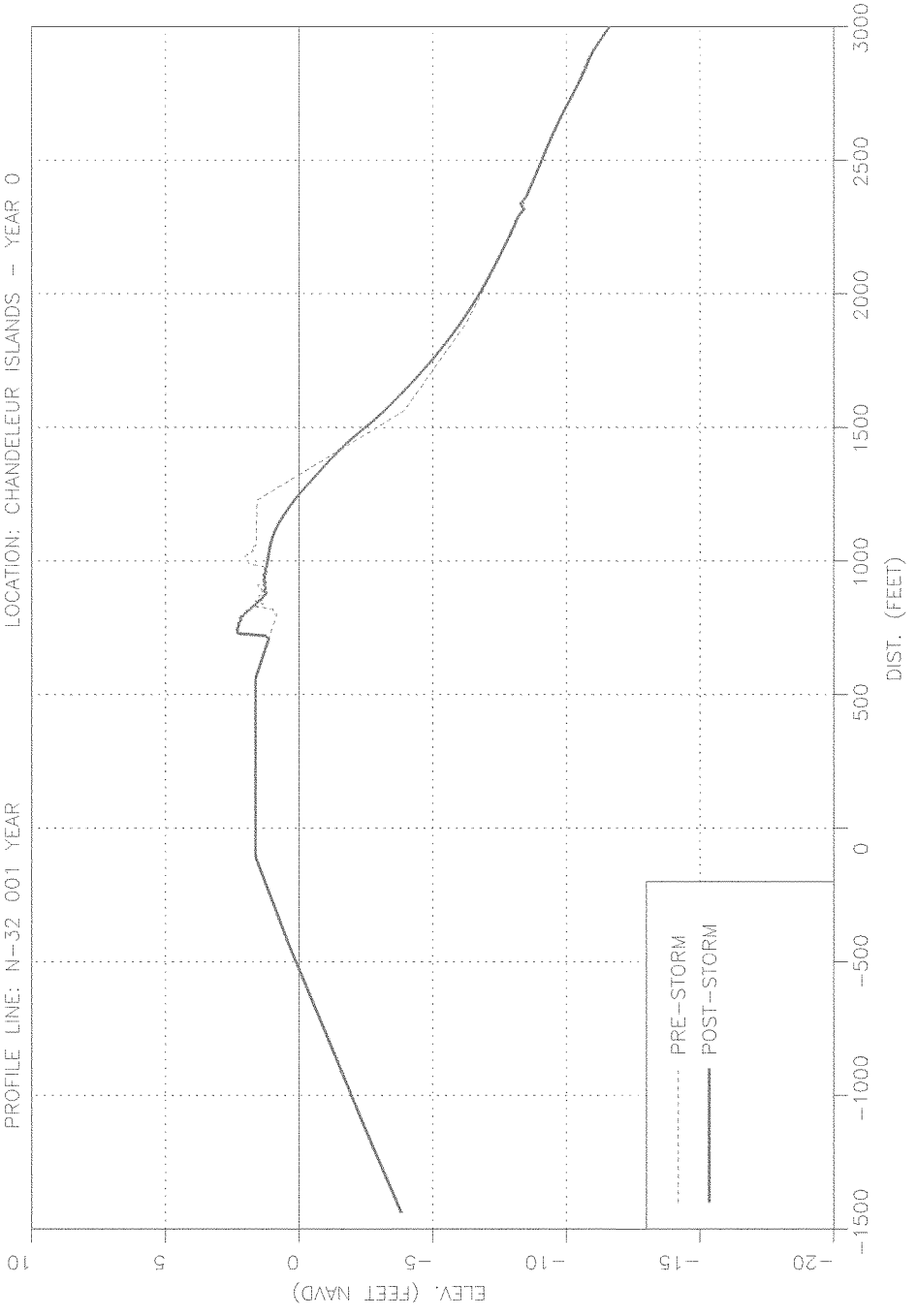

PROFILE LINE: N-31 005 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 0
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000


PROFILE LINE: N-31 010 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 0
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

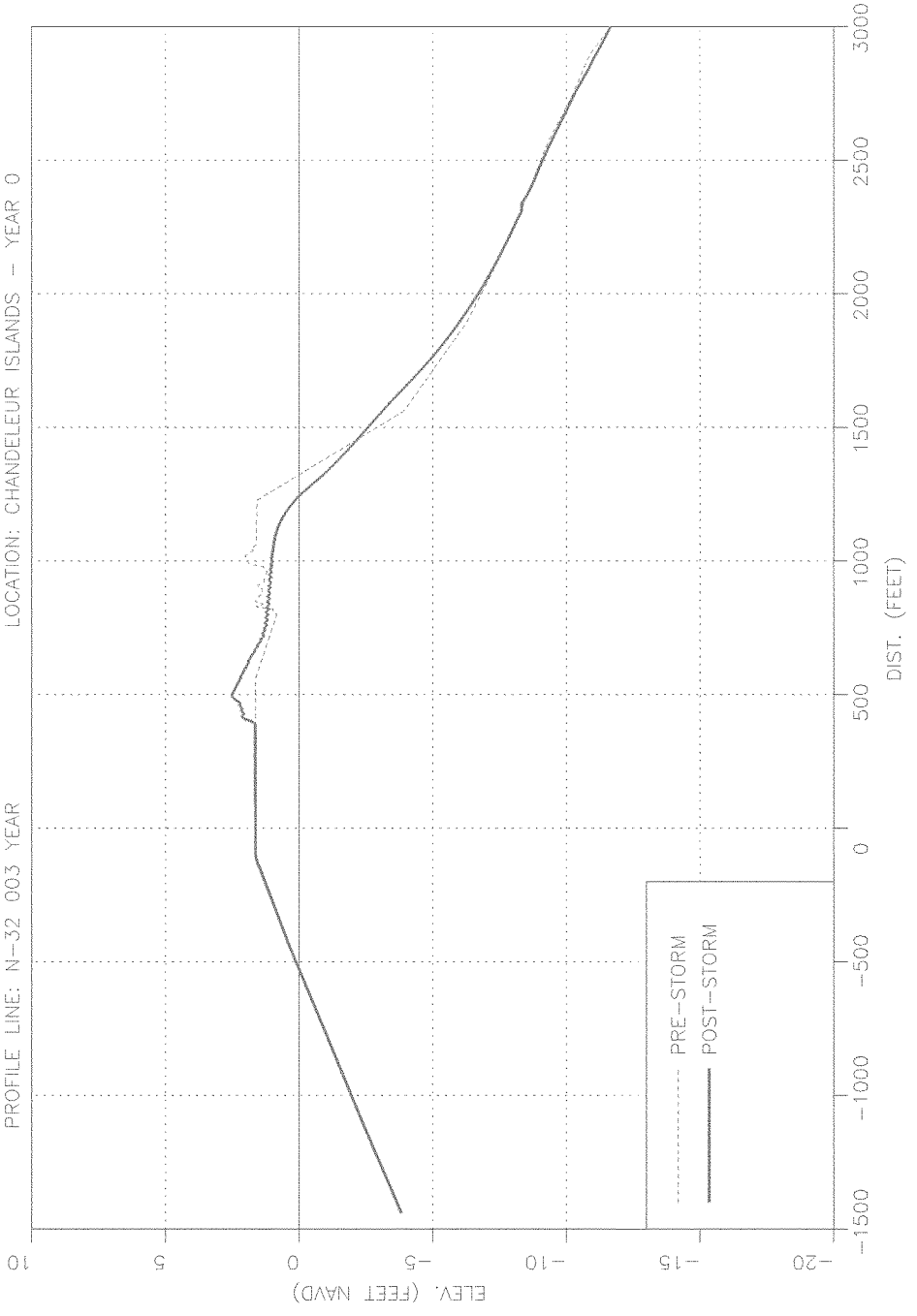

PROFILE LINE: N-31 020 YEAR
LOCATION: CHANDELEUR ISLANDS -- YEAR 0
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

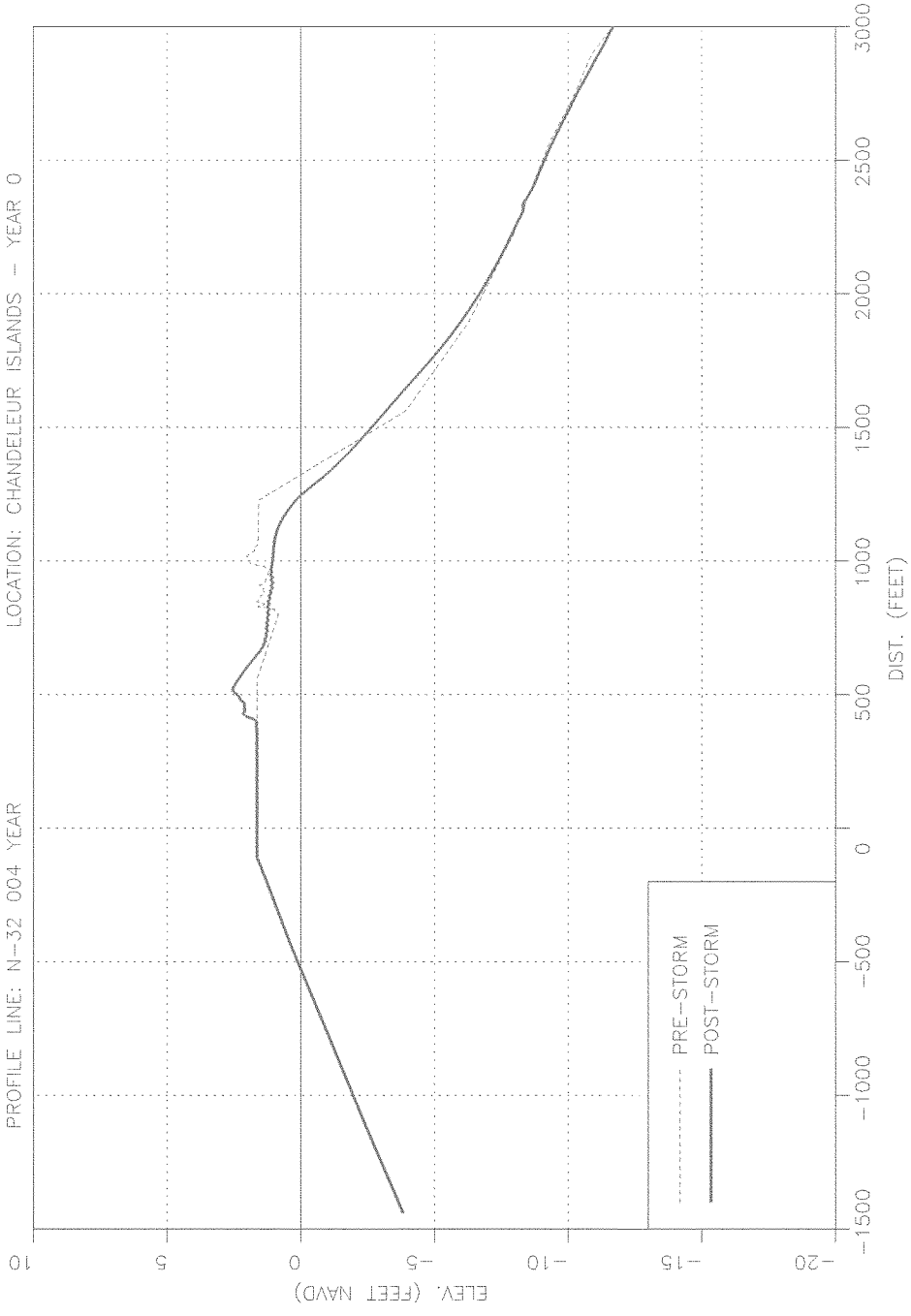

PROFILE LINE: N-31 050 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 0
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

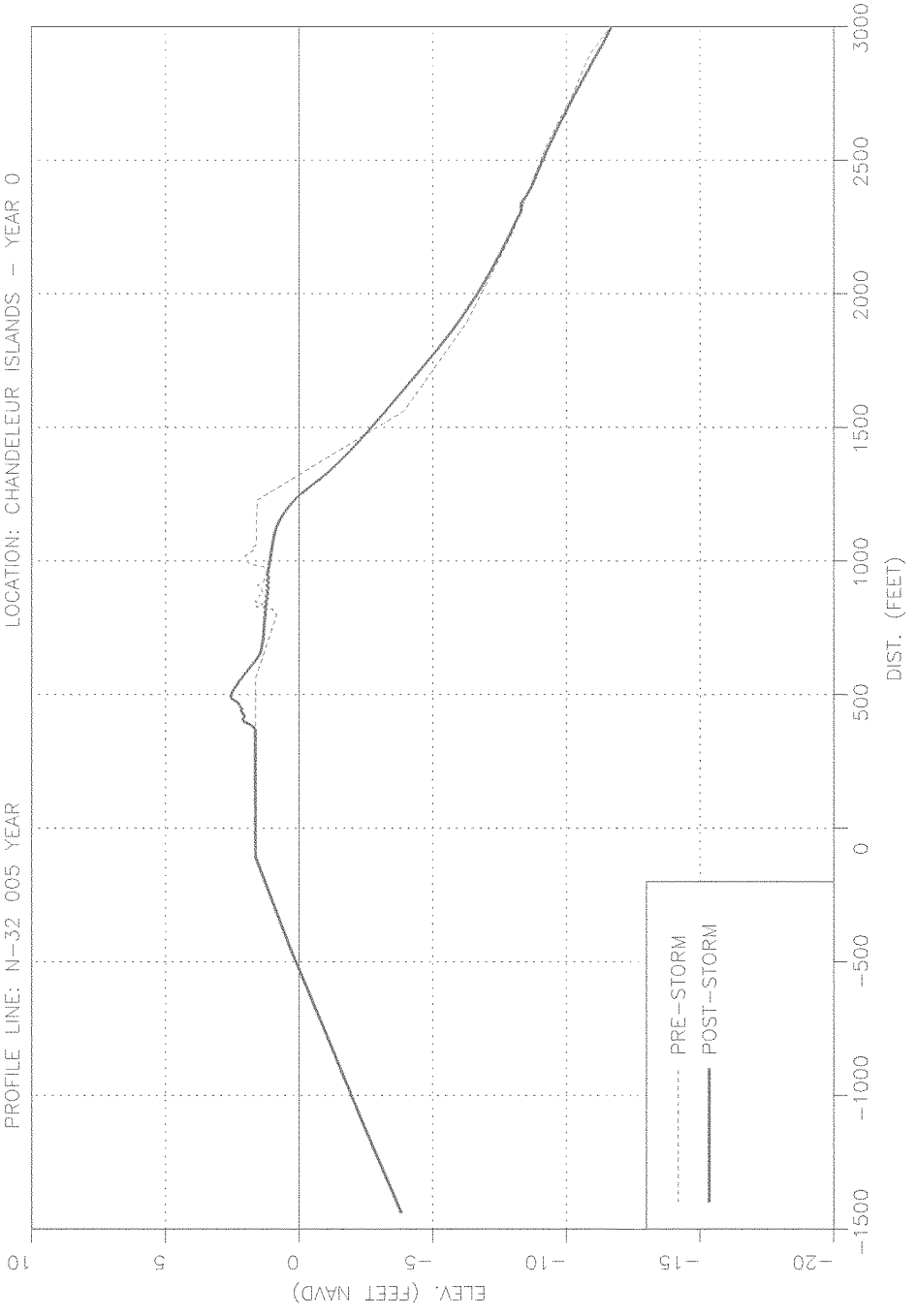

PROFILE LINE: N-31 100 YEAR
LOCATION: CHANDELEUR ISLANDS -- YEAR 0
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

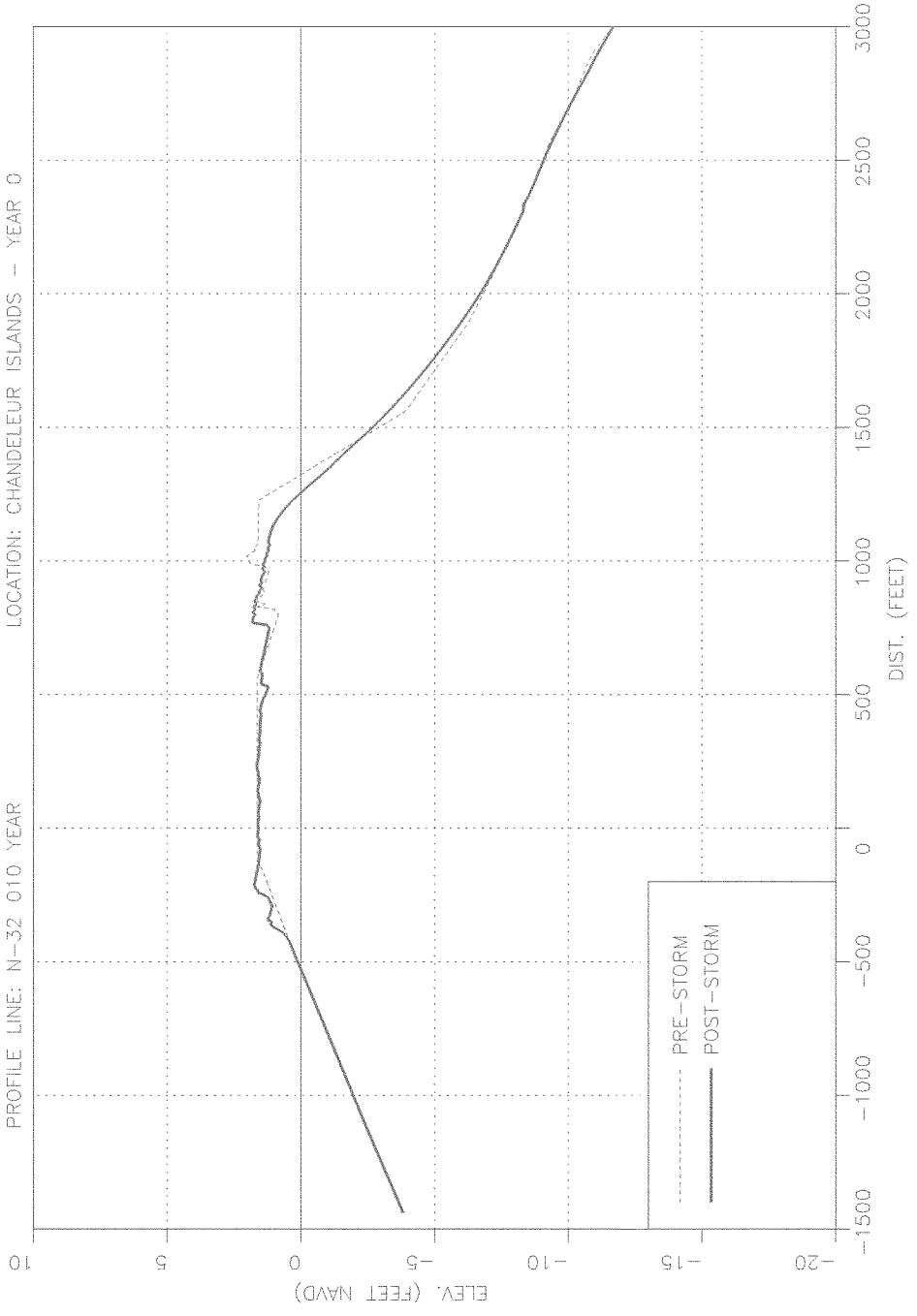

PROFILE LINE: N-32 001 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 0
PRE-STORM
POST-STORM
ELEV. (FEET NAVD)
DIST. (FEET)
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

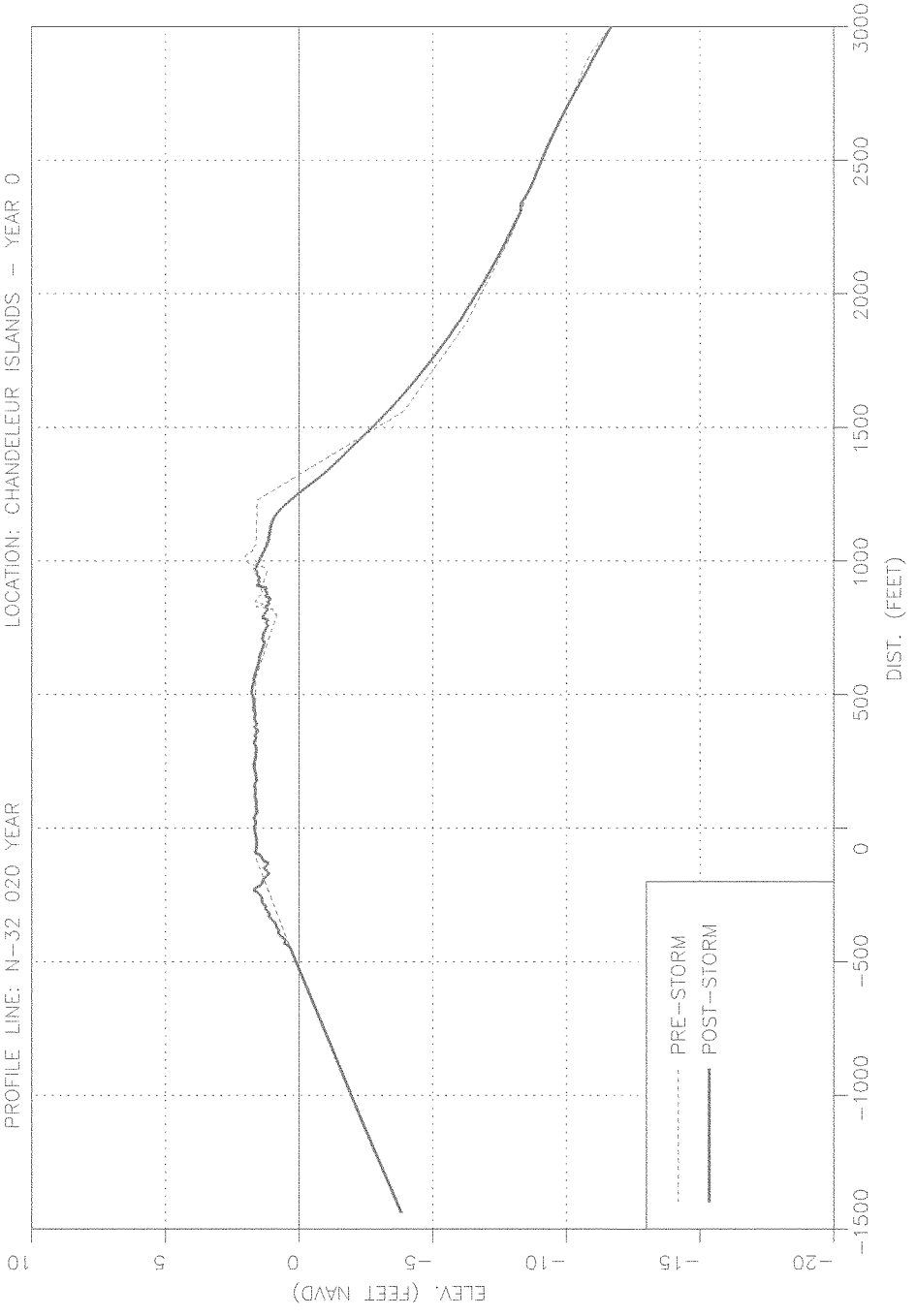

PROFILE LINE: N-32 002 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 0
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

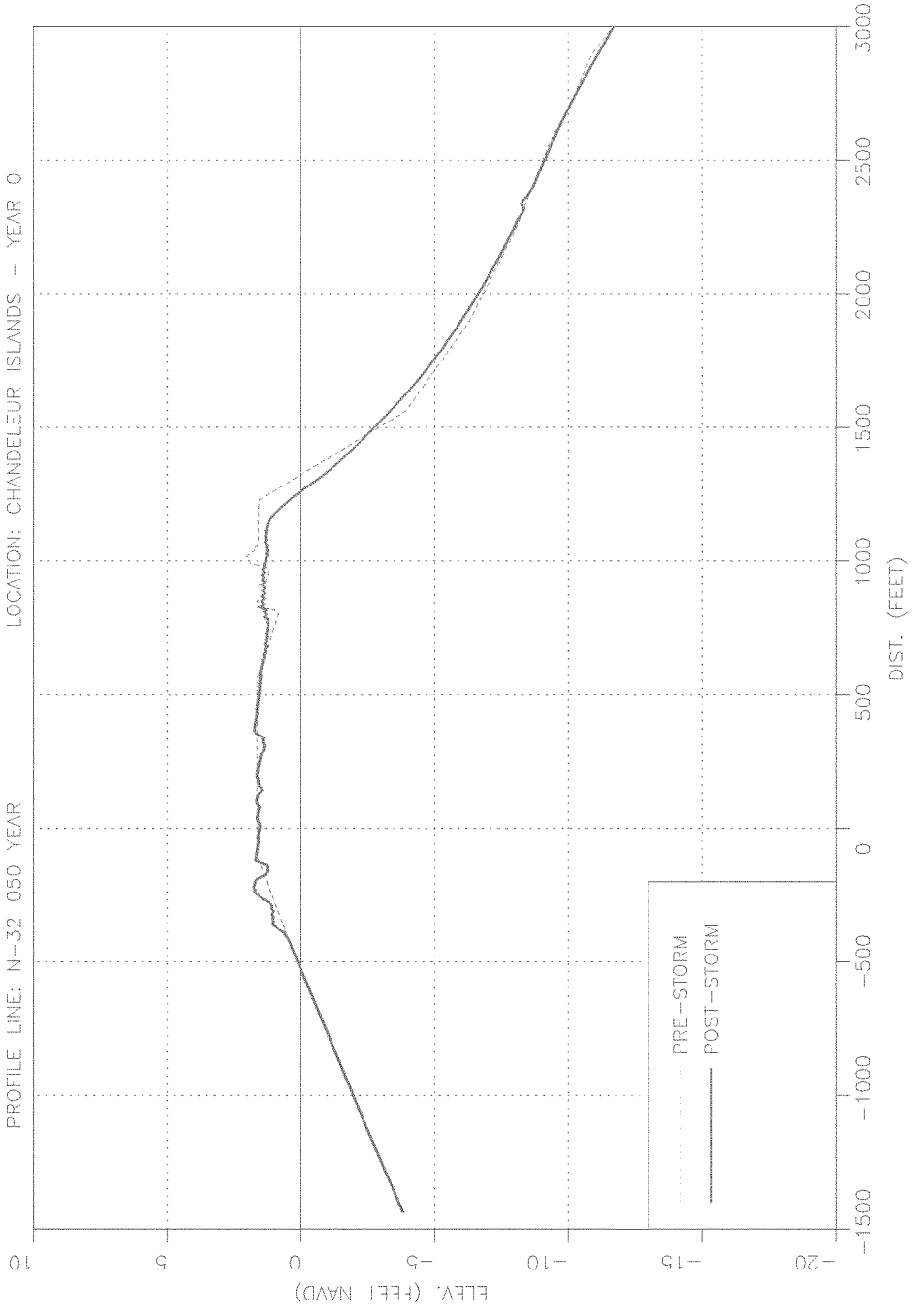

PROFILE LINE: N-32 003 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 0
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

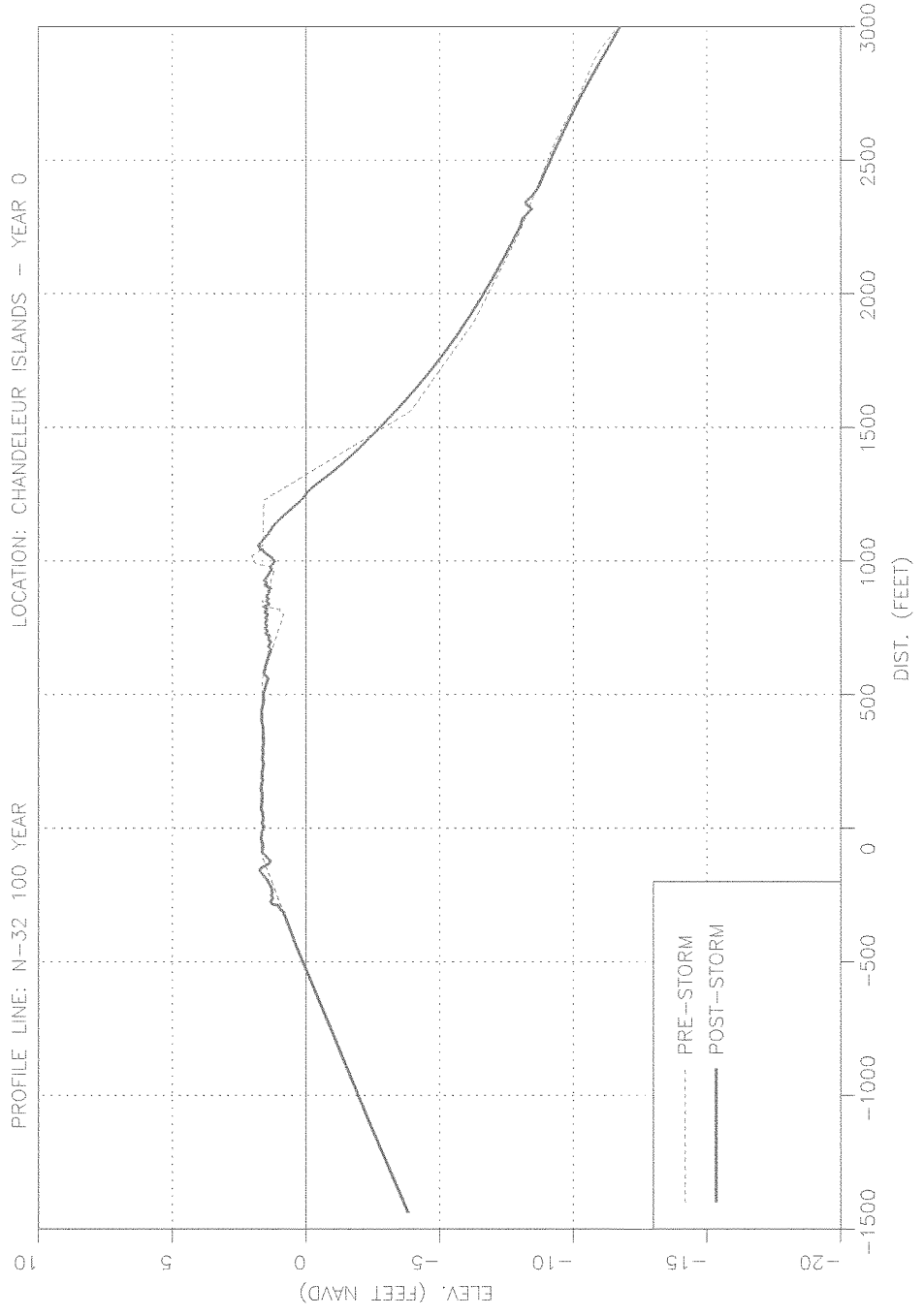

PROFILE LINE: N-32 004 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 0
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

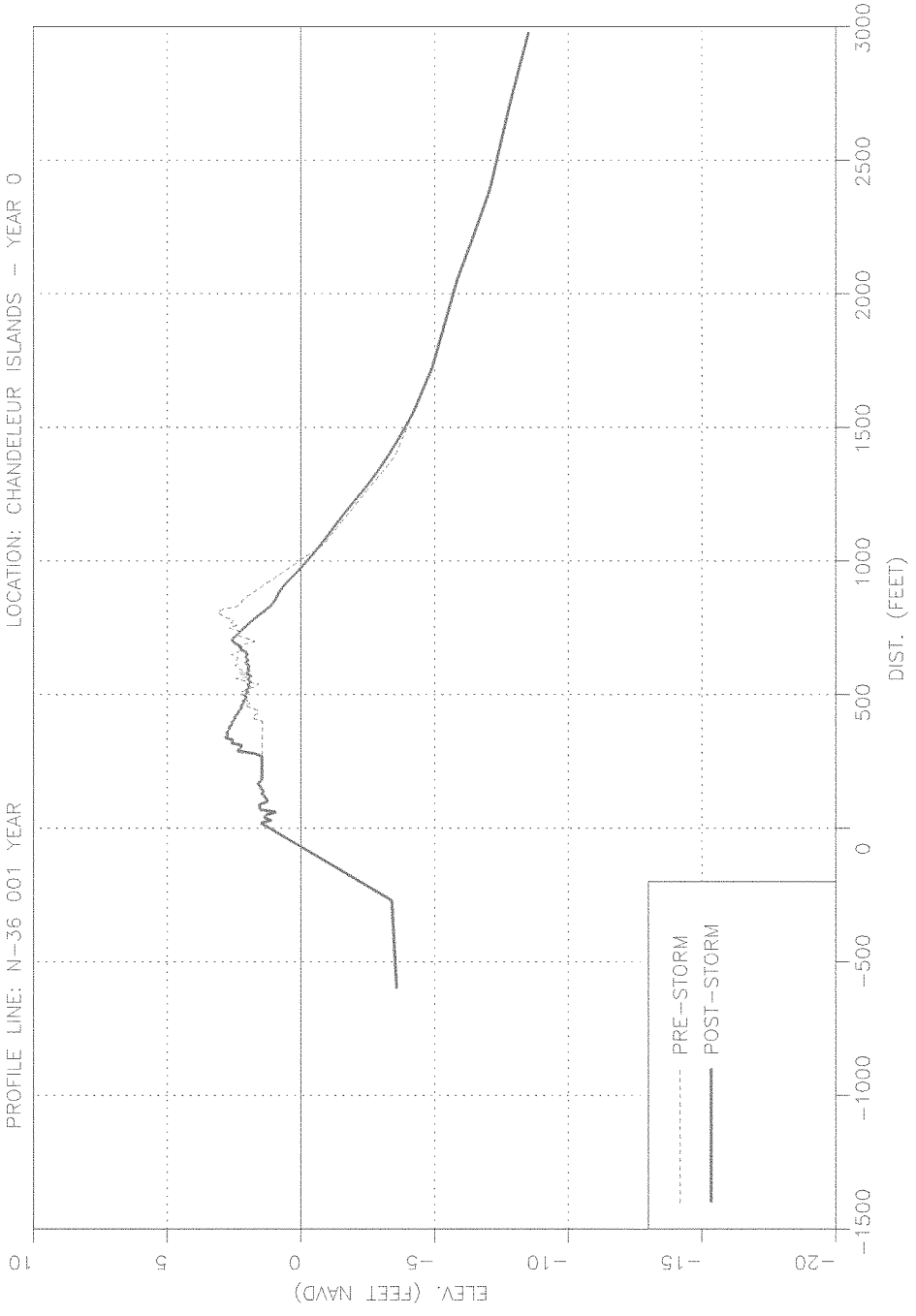

PROFILE LINE: N-32 005 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 0
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

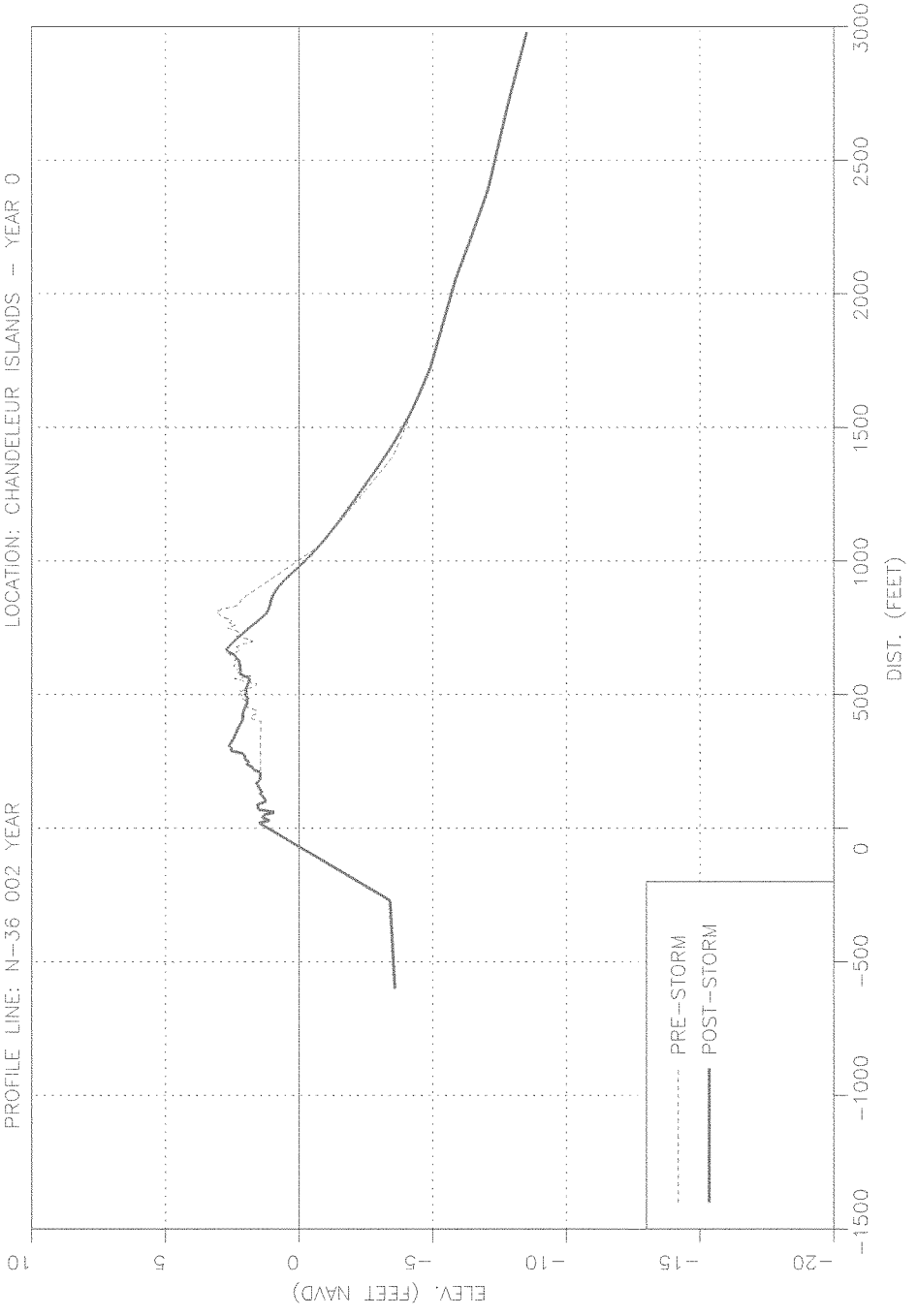

PROFILE LINE: N-32 010 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 0
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

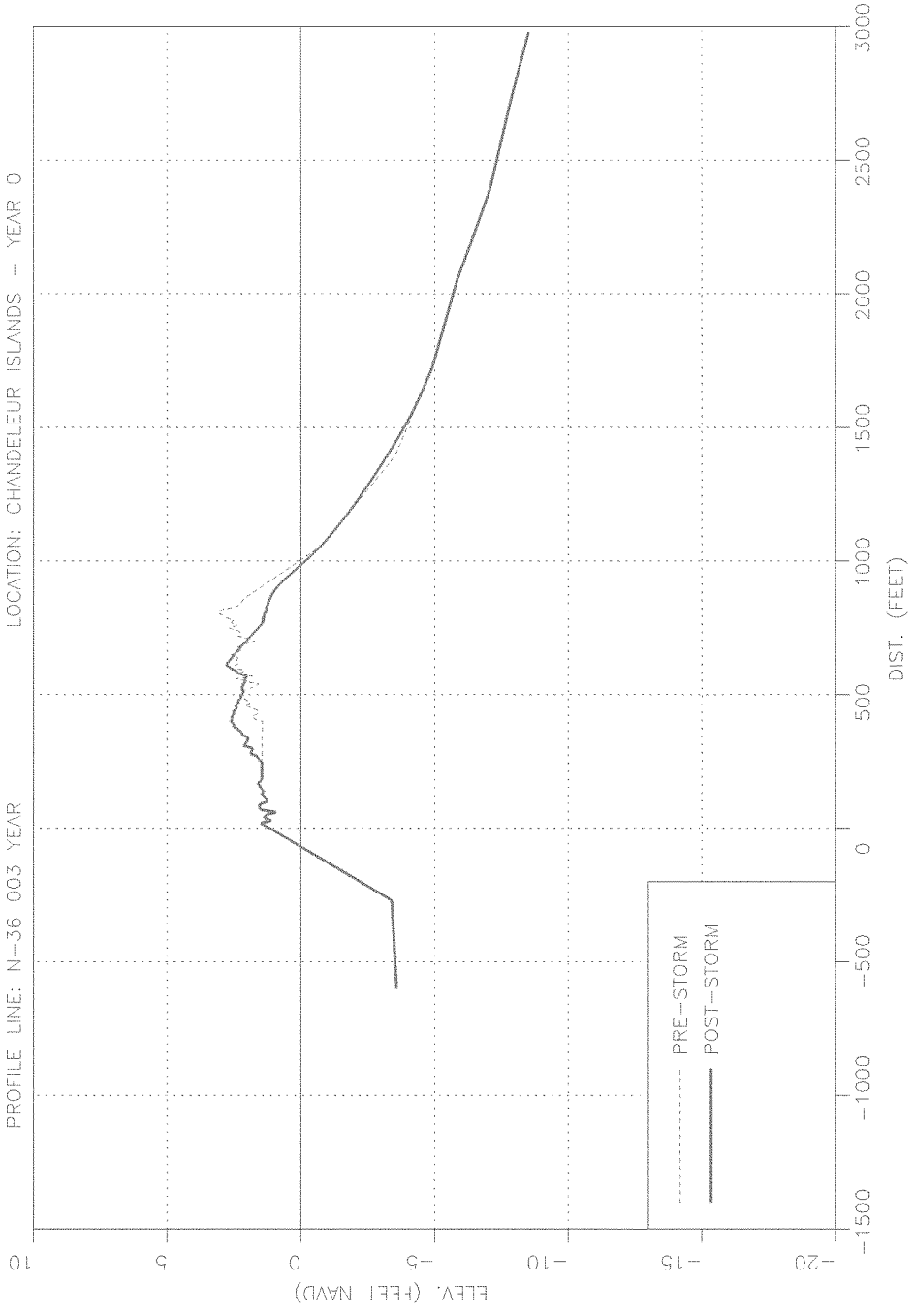

PROFILE LINE: N-32 020 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 0
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

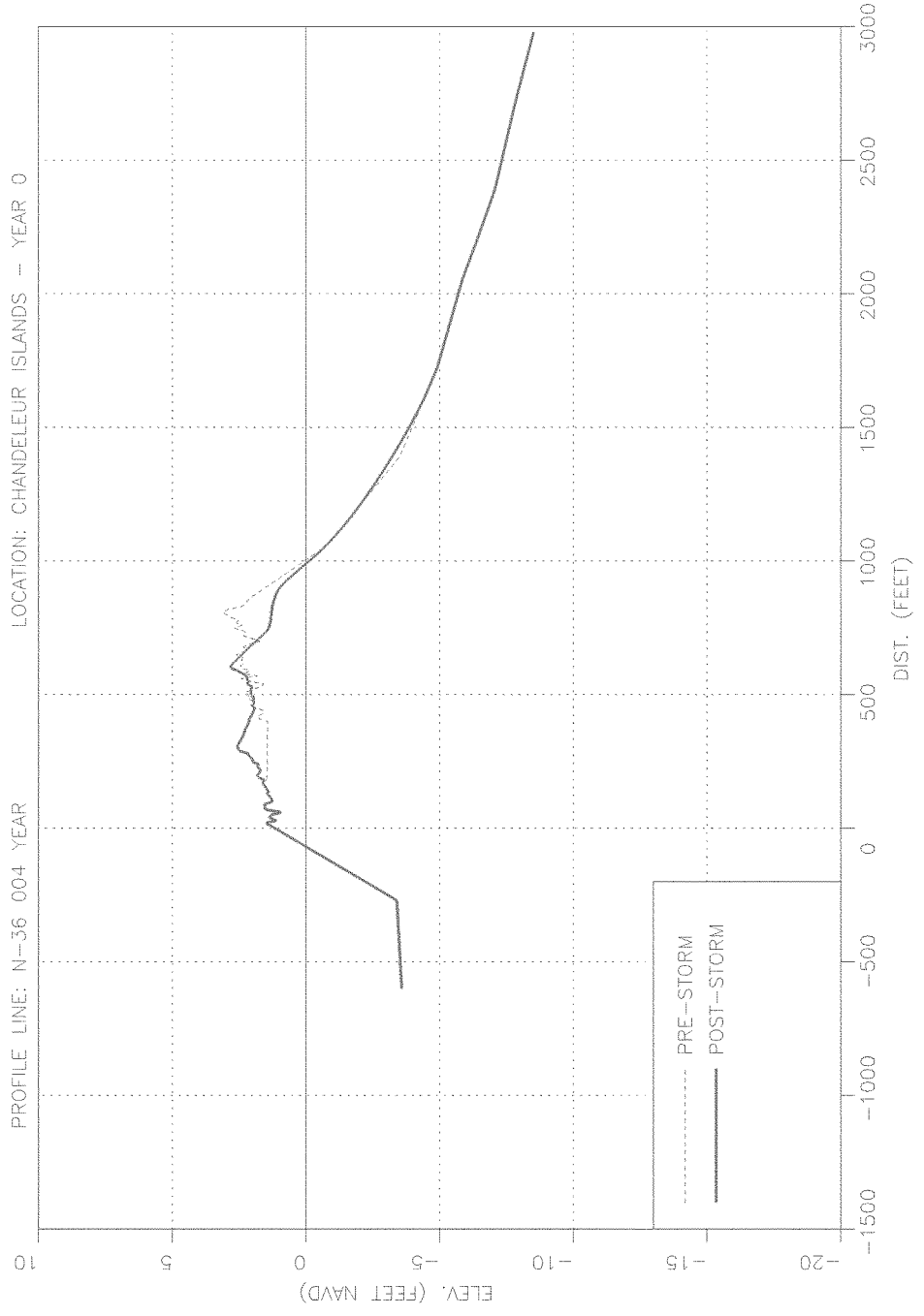

PROFILE LINE: N-32 050 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 0
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

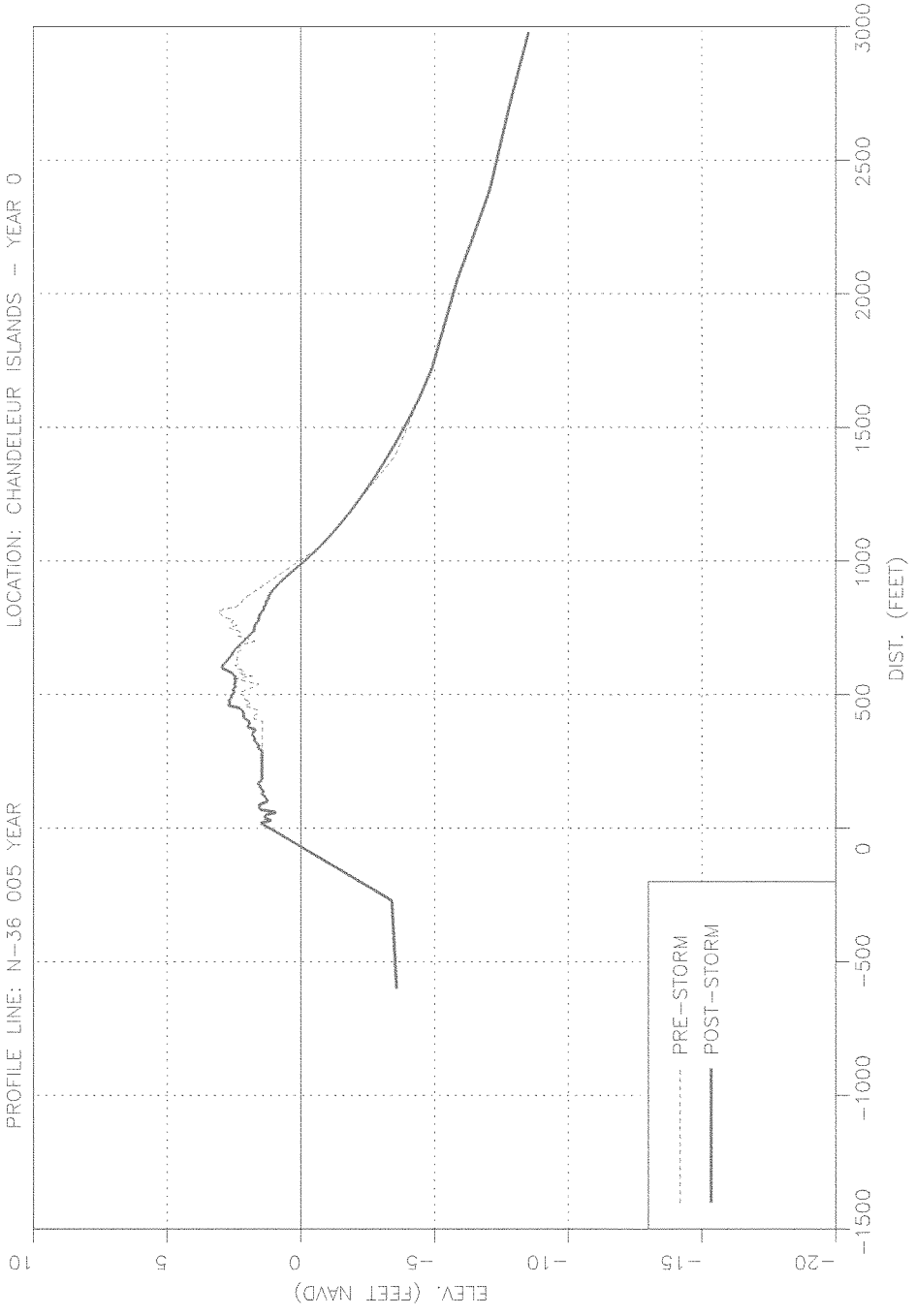

PROFILE LINE: N-32 100 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 0
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

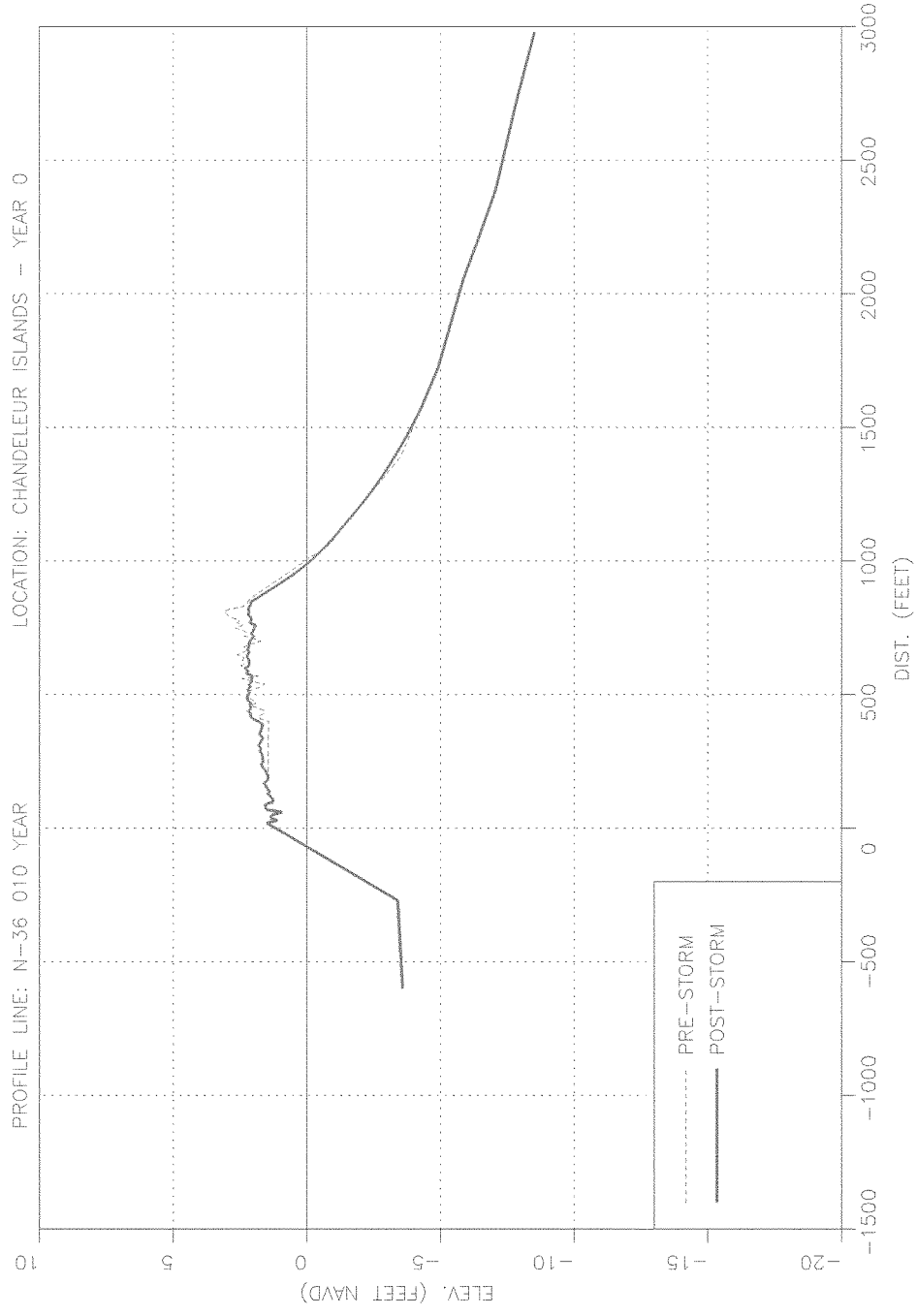

PROFILE LINE: N-36 001 YEAR
LOCATION: CHANDELEUR ISLANDS -- YEAR 0
ELEV. (FEET NAVD)
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000
DIST. (FEET)
PRE-STORM
POST-STORM

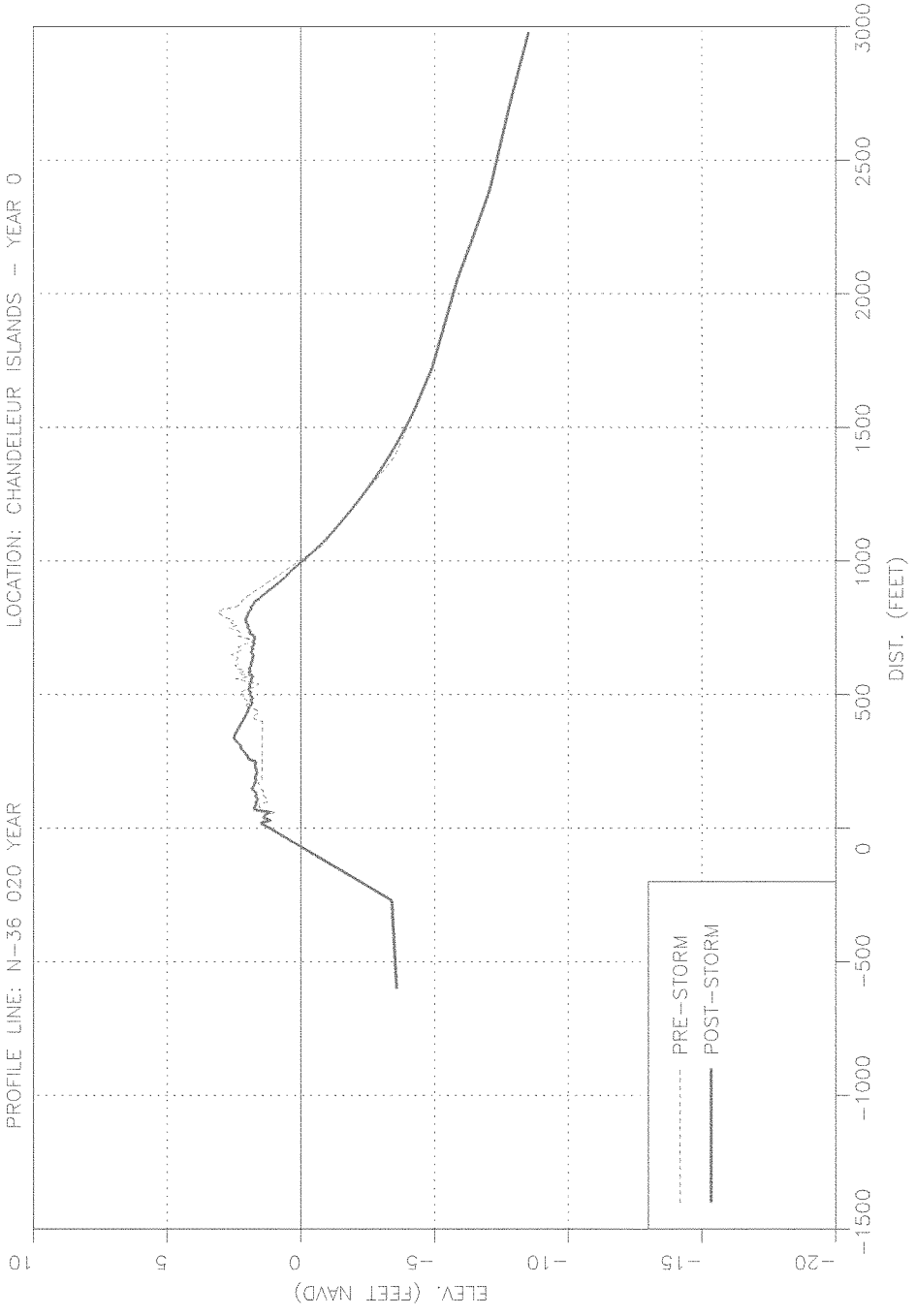

PROFILE LINE: N-36 002 YEAR
LOCATION: CHANDELEUR ISLANDS -- YEAR 0
PRE-STORM
POST-STORM
ELEV. (FEET NAVD)
DIST. (FEET)
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

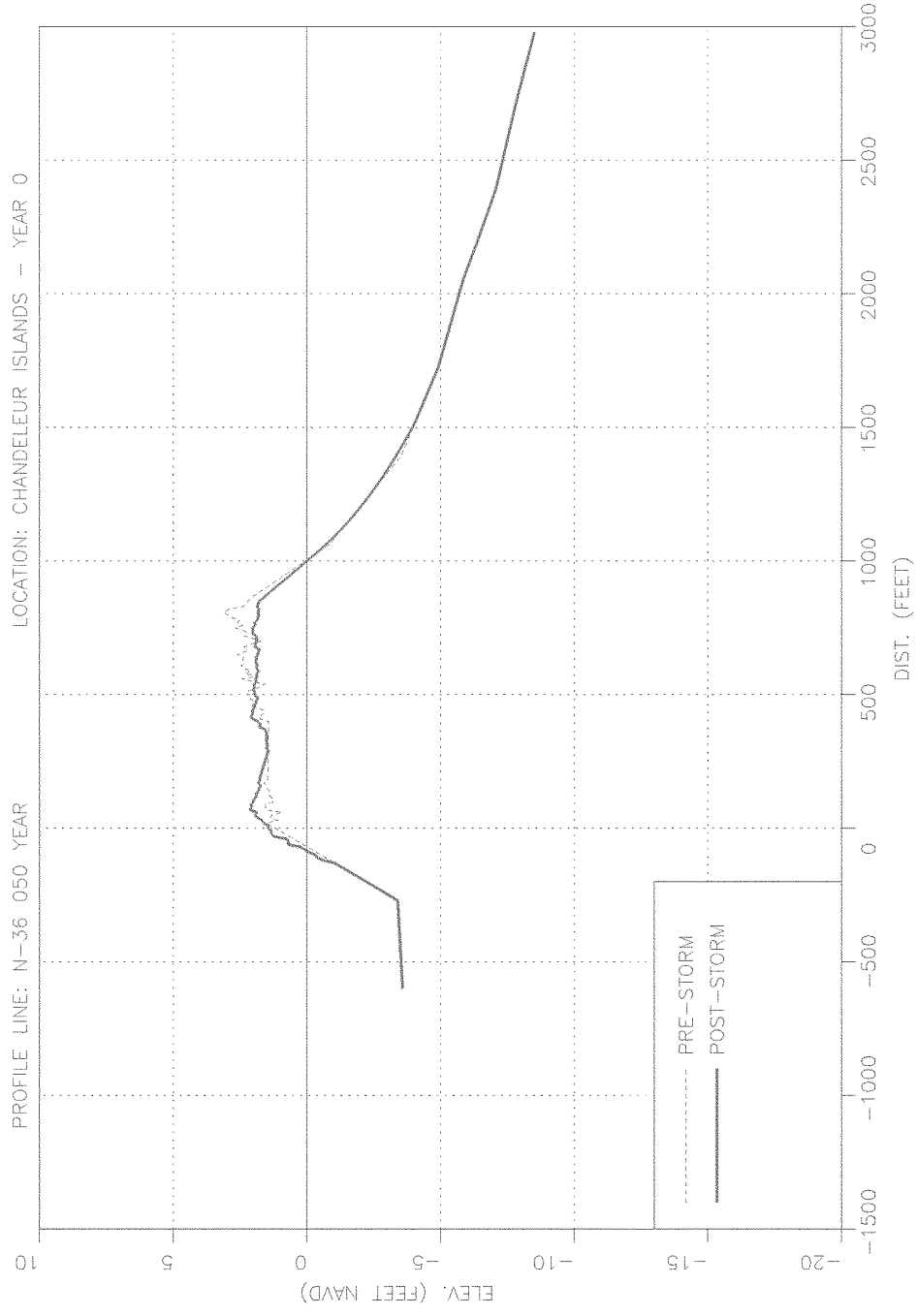

PROFILE LINE: N-36 003 YEAR
LOCATION: CHANDELEUR ISLANDS -- YEAR 0
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

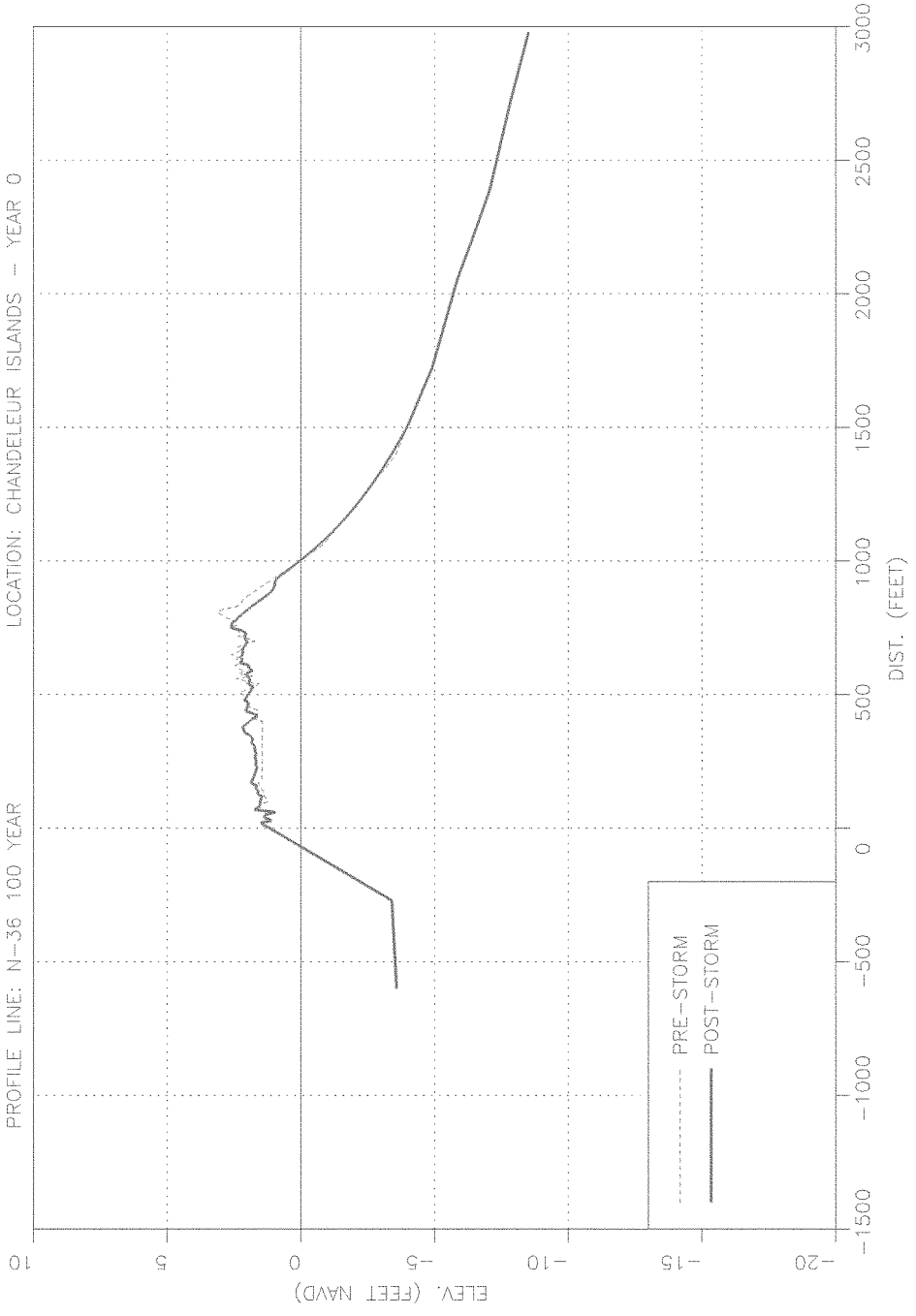

PROFILE LINE: N-36 004 YEAR
LOCATION: CHANDELEUR ISLANDS -- YEAR 0
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

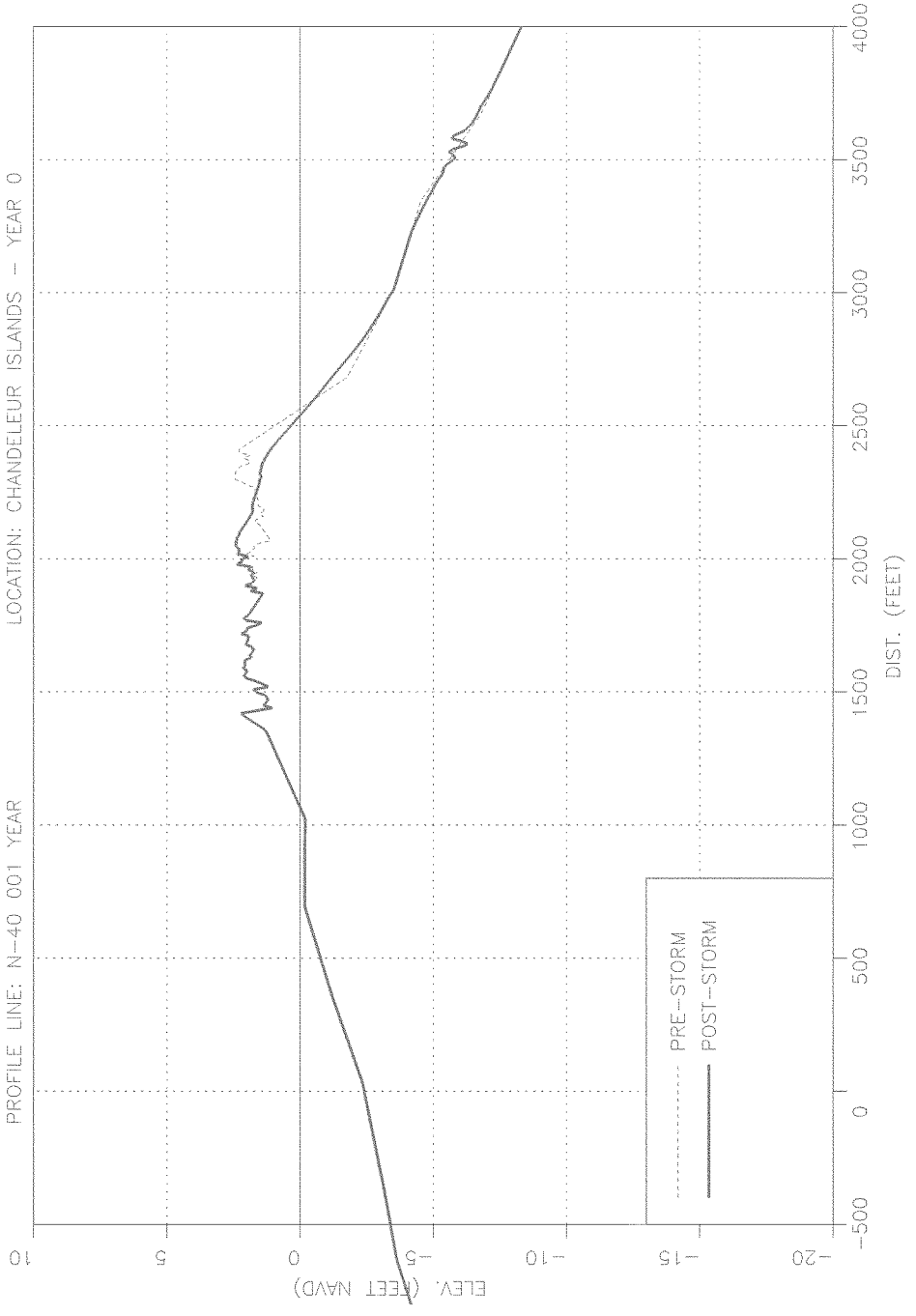

PROFILE LINE: N-36 005 YEAR
LOCATION: CHANDELEUR ISLANDS -- YEAR 0
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

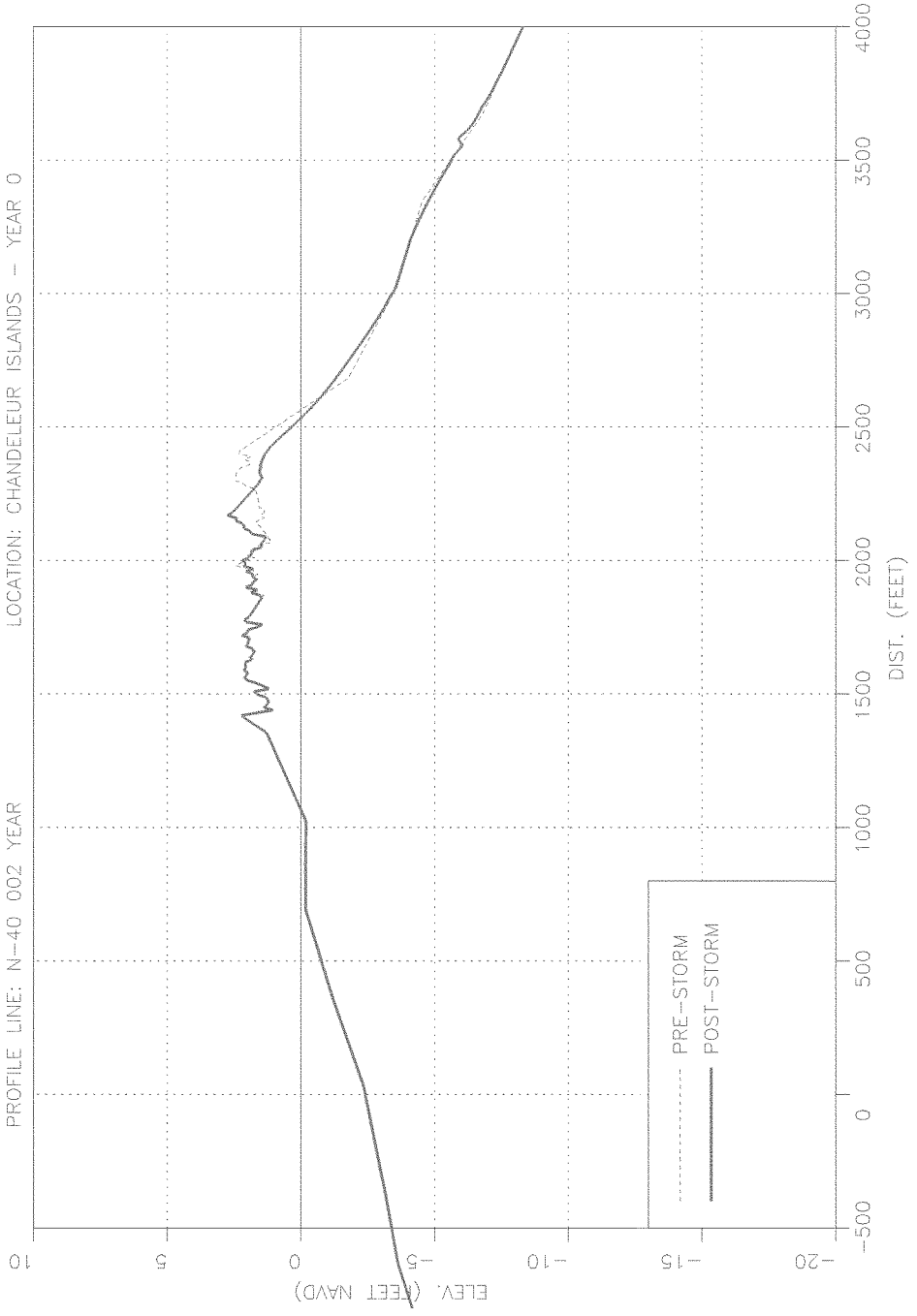

PROFILE LINE: N-36 010 YEAR
LOCATION: CHANDELEUR ISLANDS -- YEAR 0
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

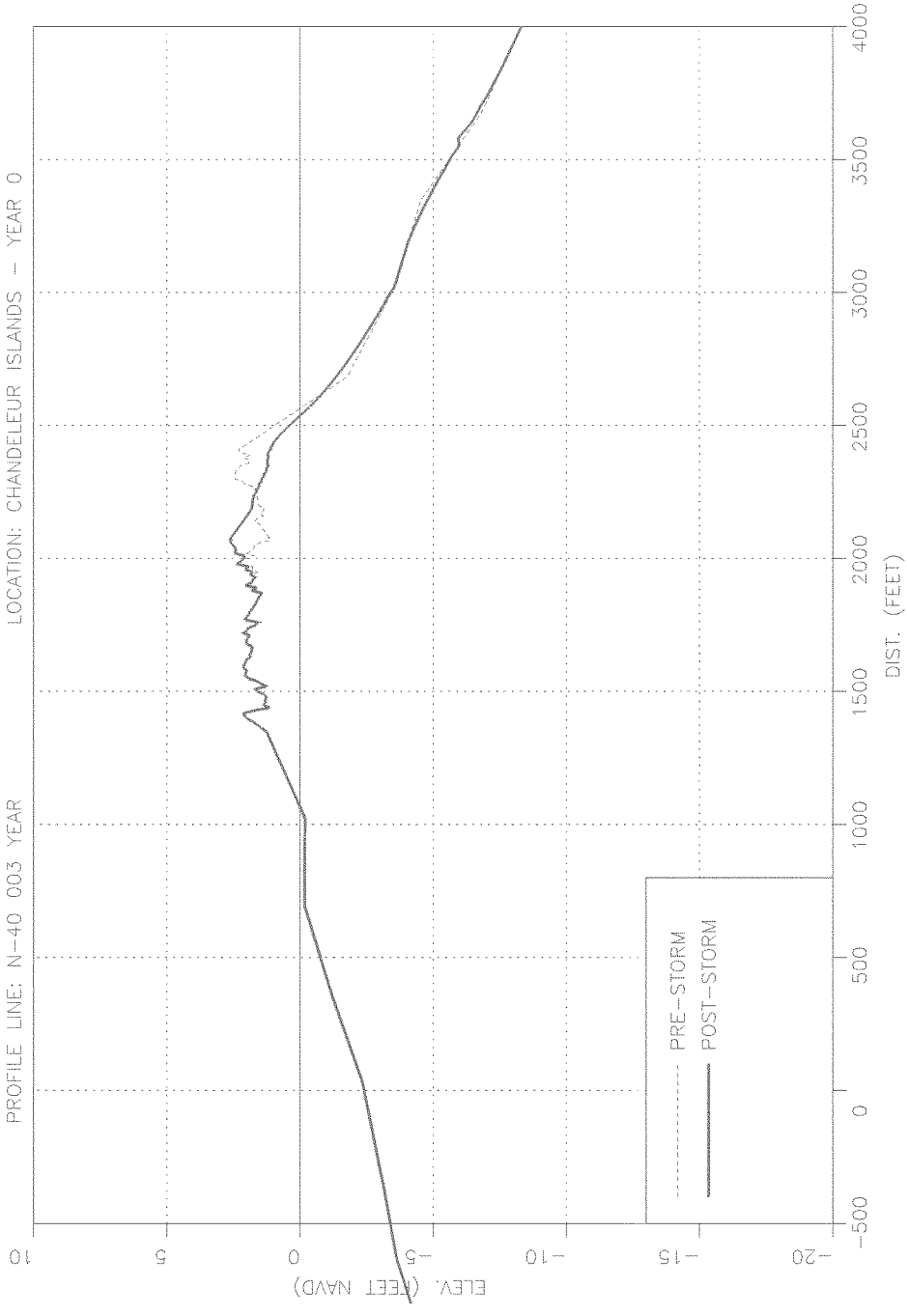

PROFILE LINE: N-36 020 YEAR
LOCATION: CHANDELEUR ISLANDS -- YEAR 0
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

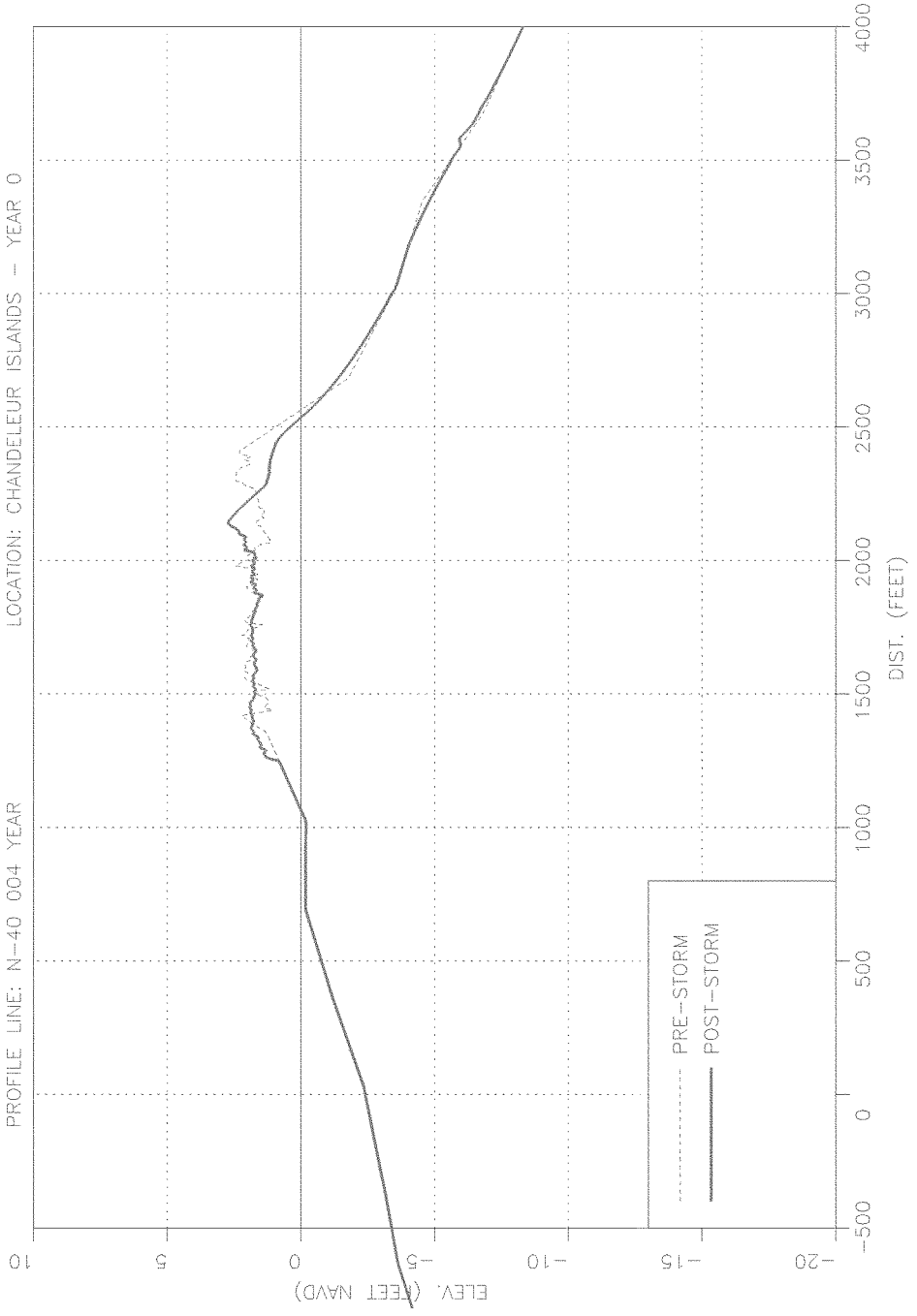

PROFILE LINE: N-36 050 YEAR
LOCATION: CHANDELEUR ISLANDS -- YEAR 0
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

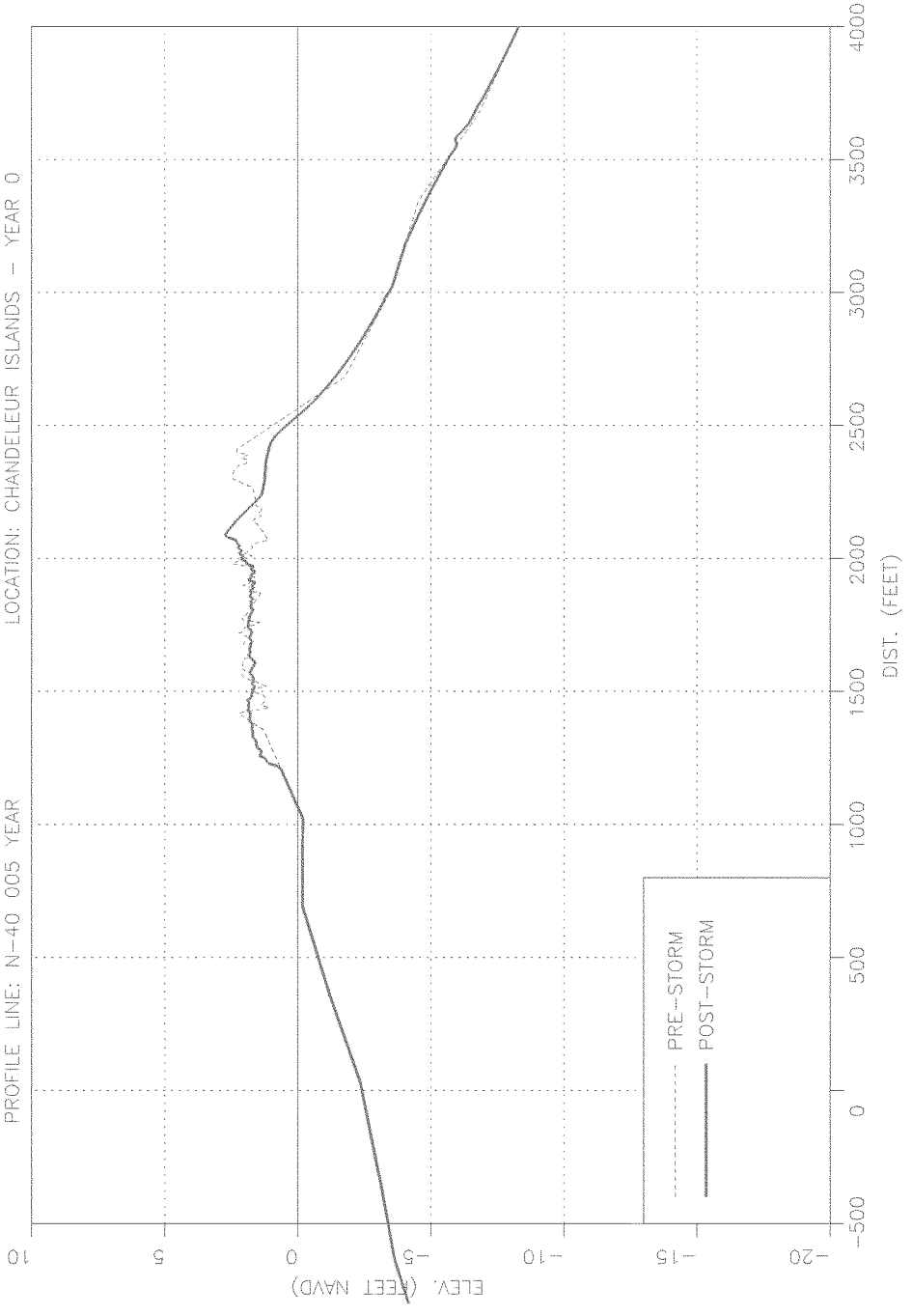

PROFILE LINE: N-36 100 YEAR
LOCATION: CHANDELEUR ISLANDS -- YEAR 0
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

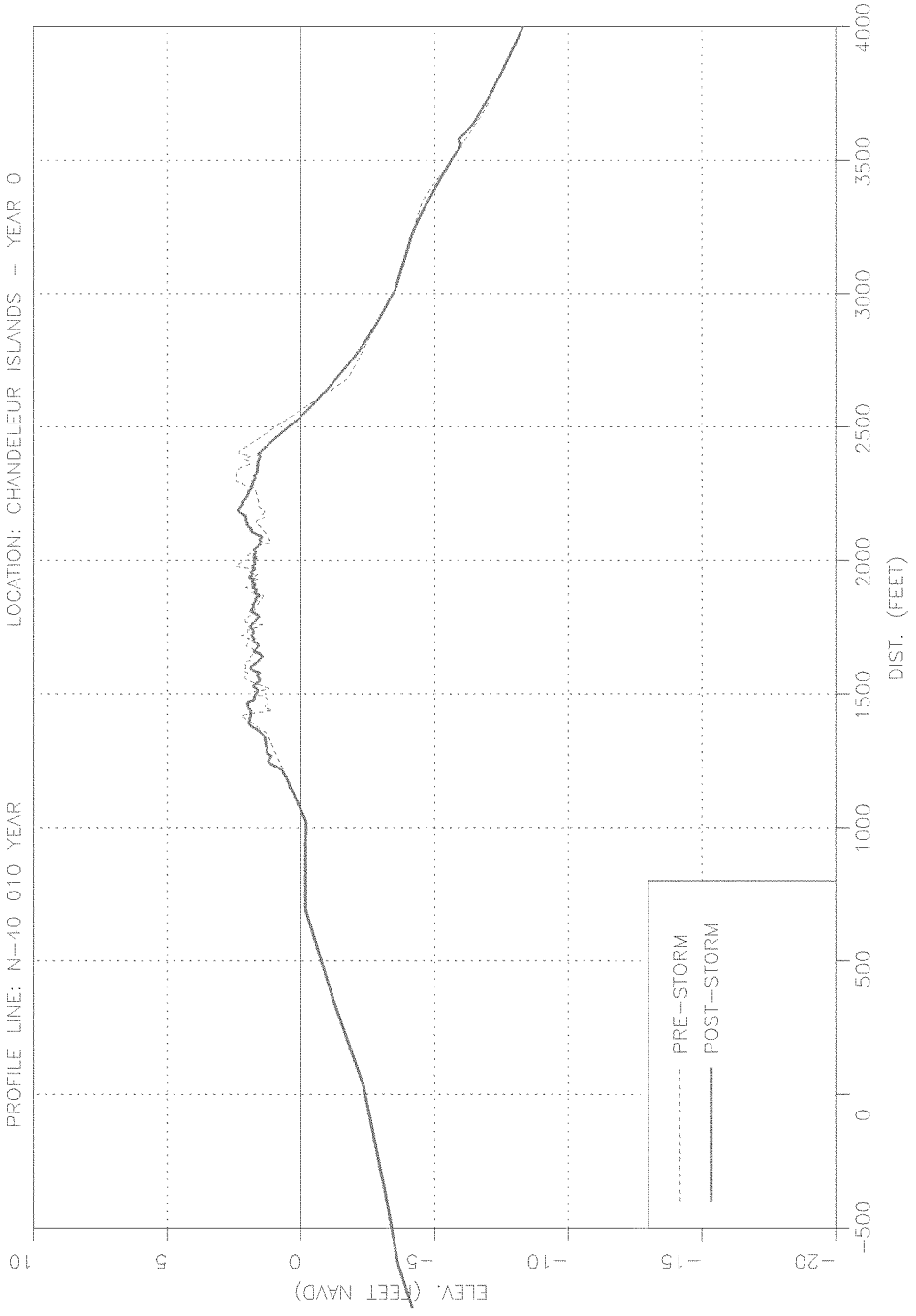

PROFILE LINE: N-40 001 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 0
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

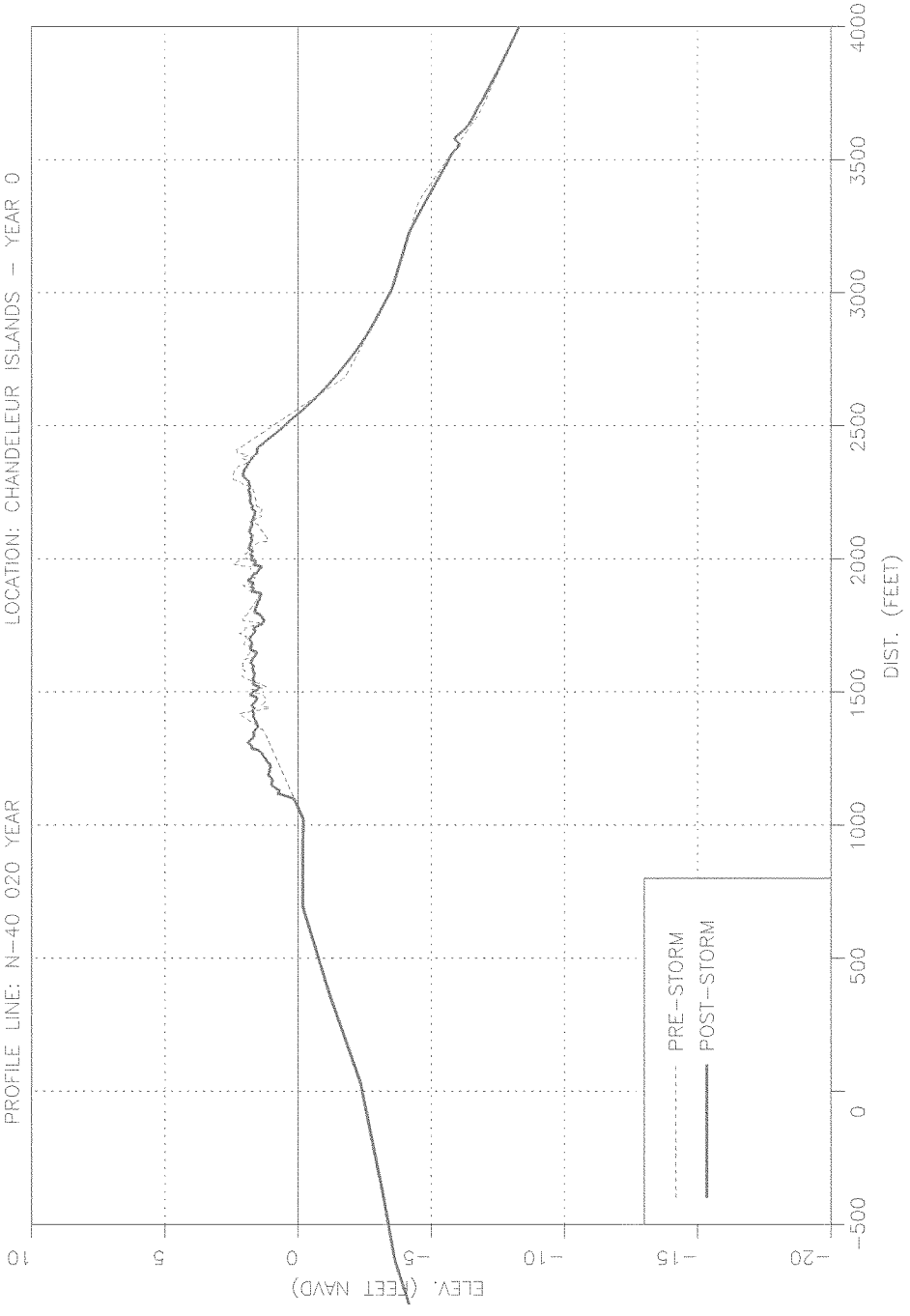

PROFILE LINE: N-40 002 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 0
PRE-STORM
POST-STORM
ELEV. (FEET NAVD)
DIST. (FEET)
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

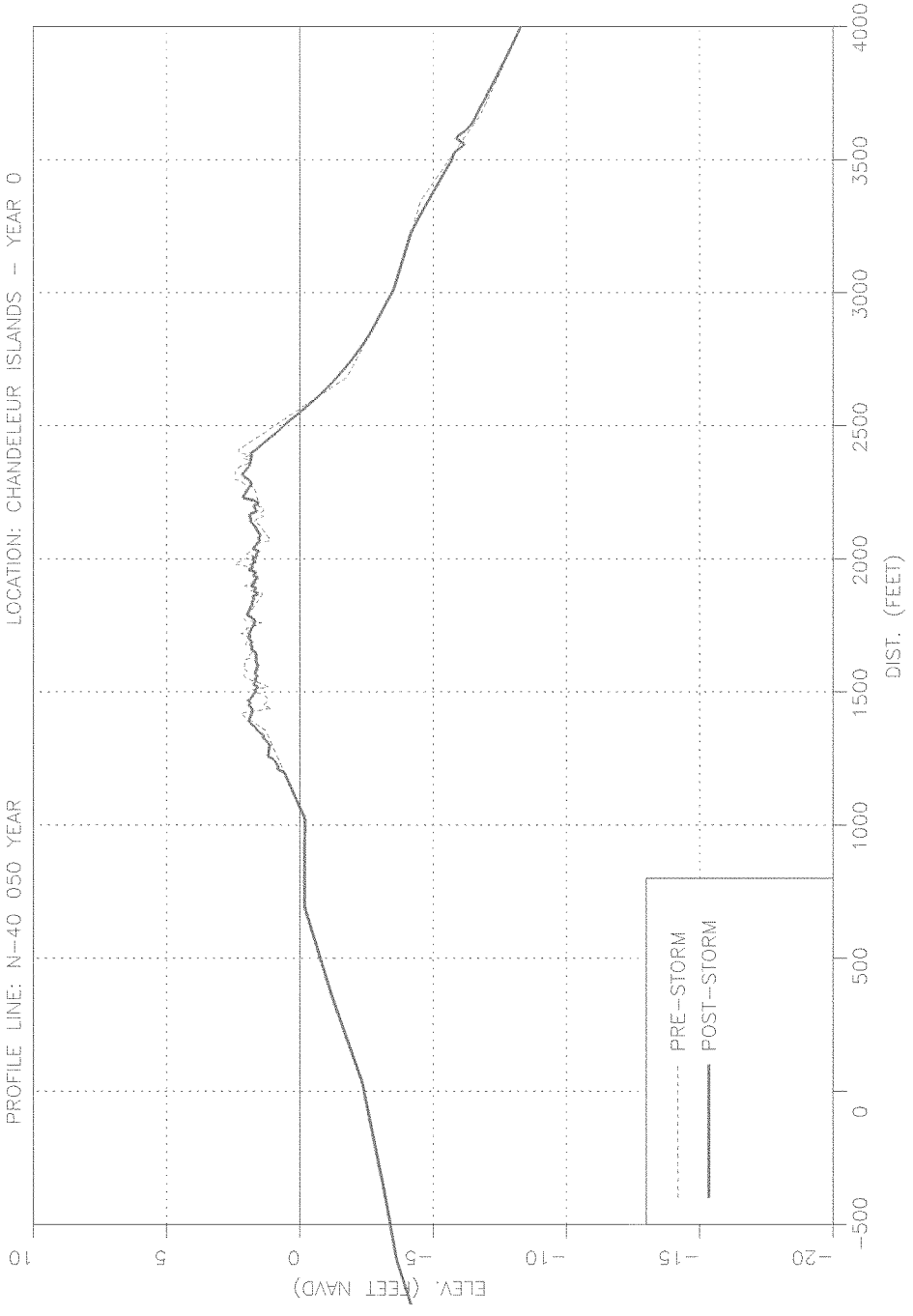

PROFILE LINE: N-40 003 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 0
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

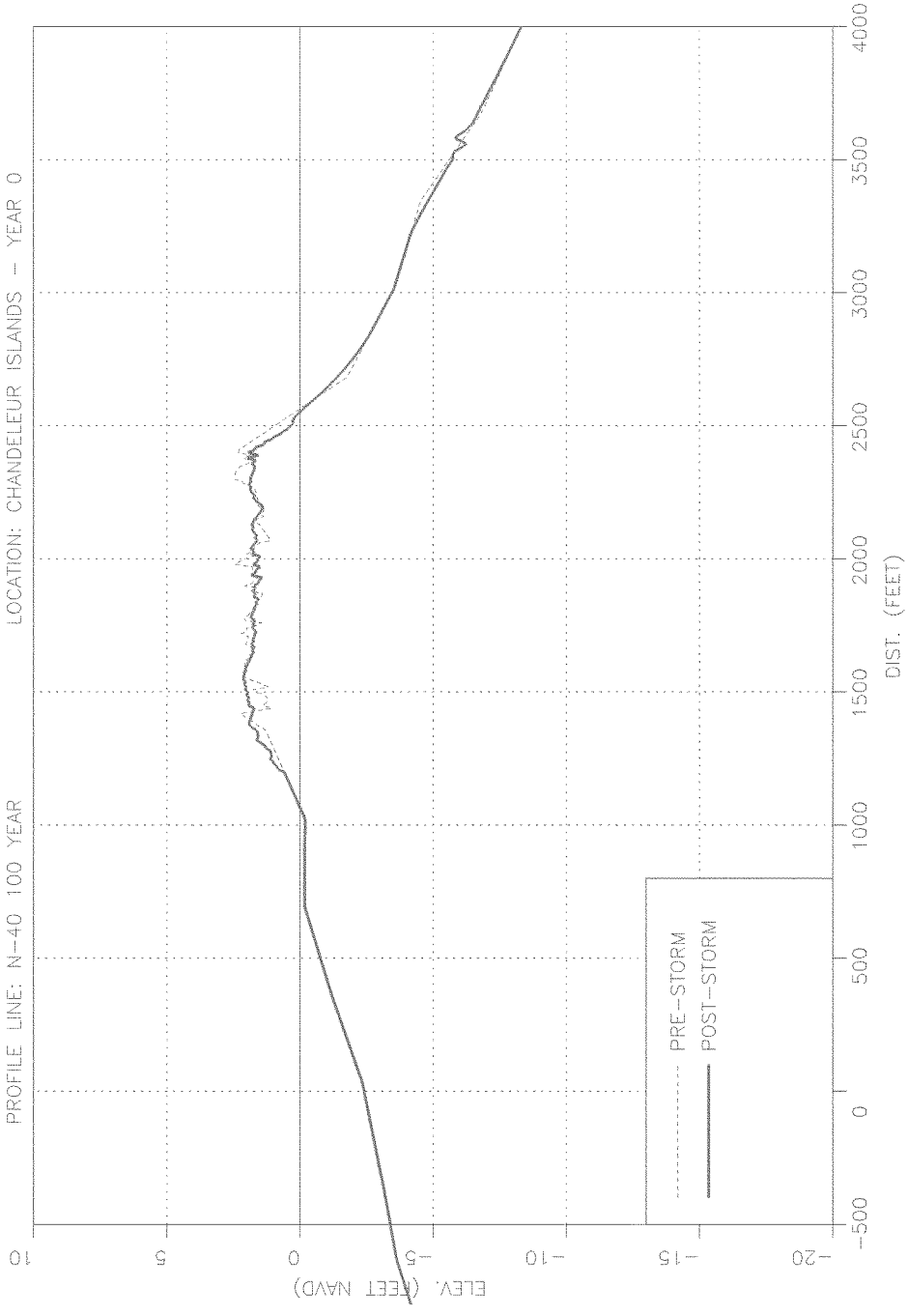

PROFILE LINE: N-40 004 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 0
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

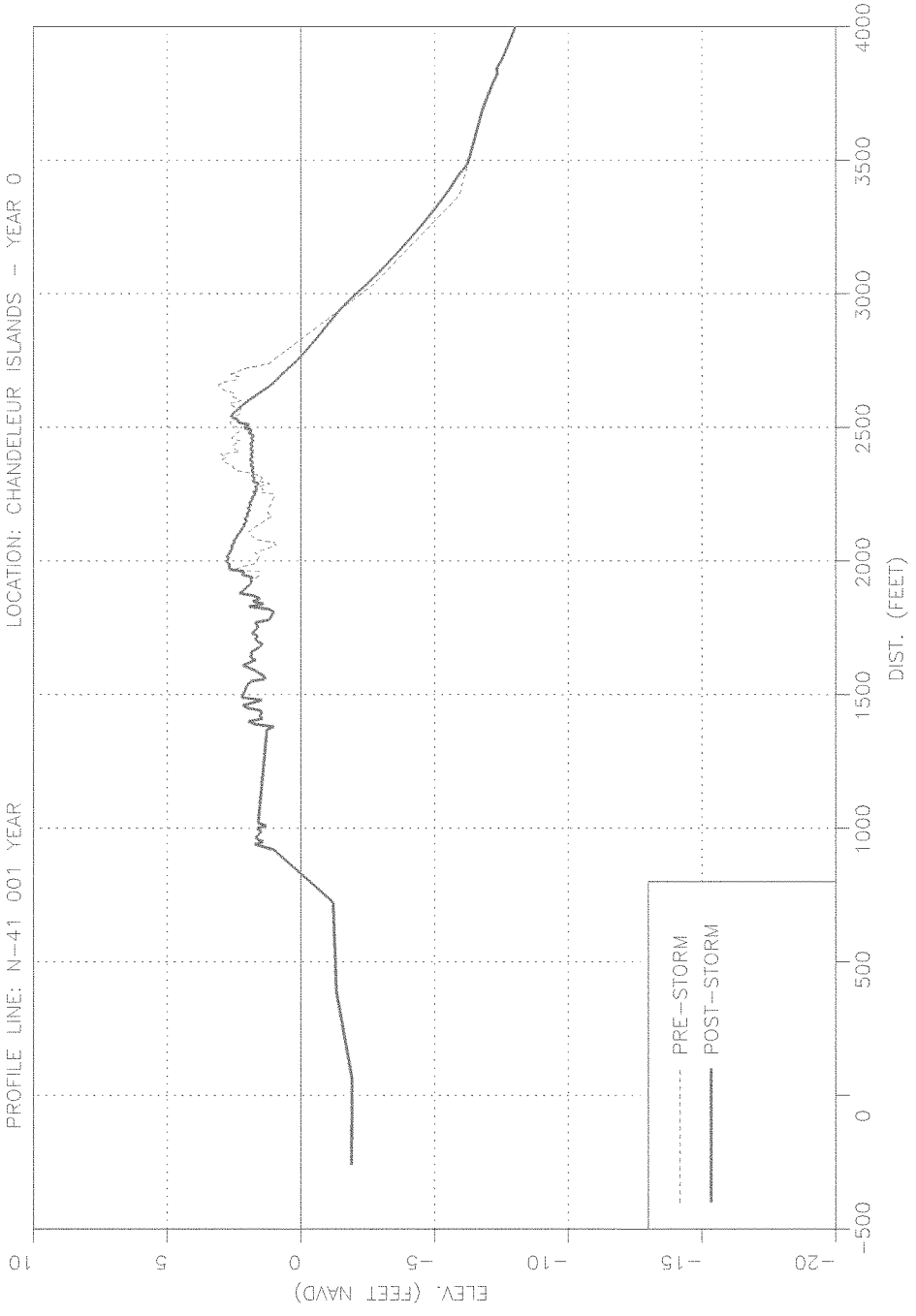

PROFILE LINE: N-40 005 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 0
ELEV. (FEET NAVD)
DIST. (FEET)
PRE--STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

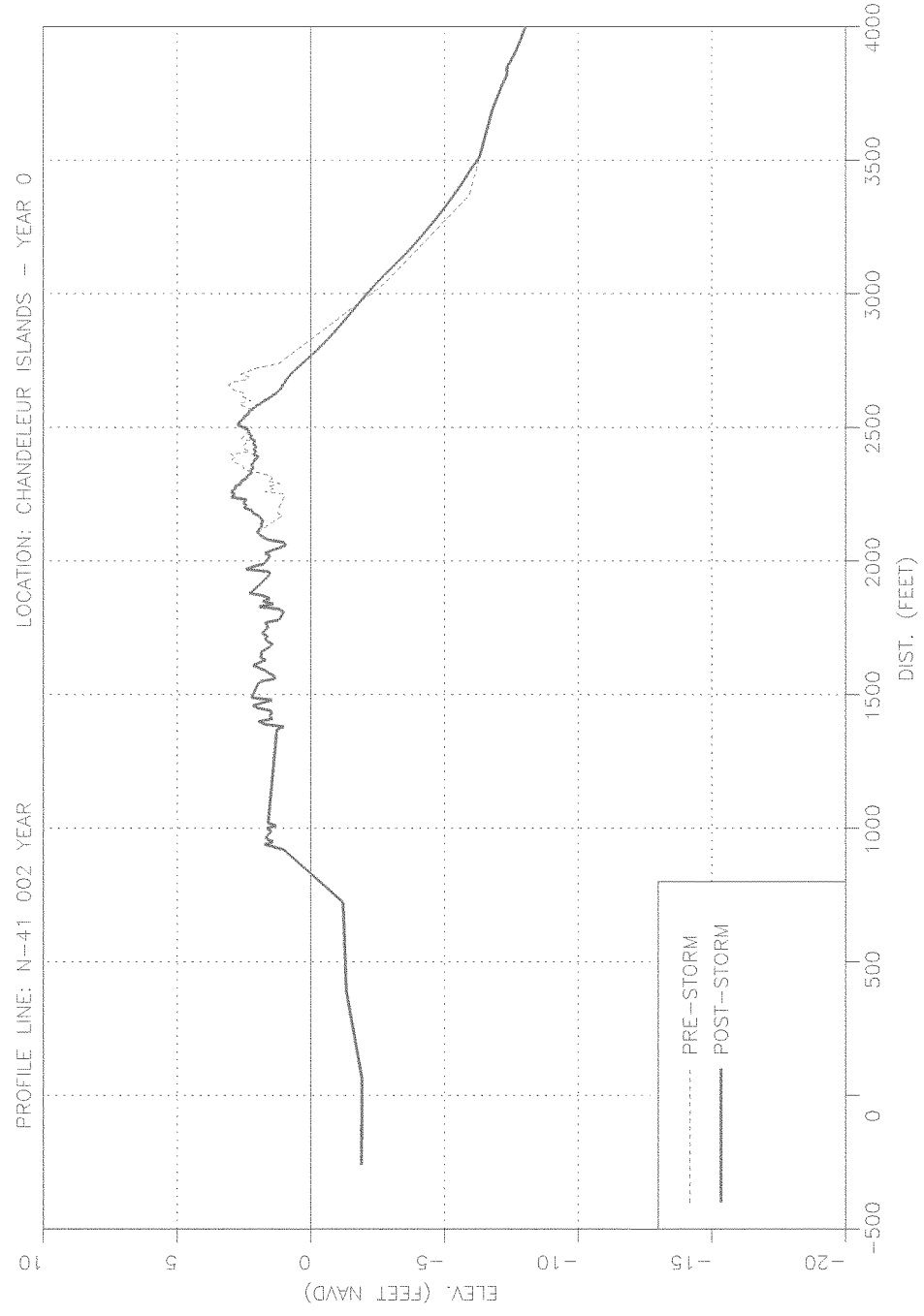

PROFILE LINE: N-40 010 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 0
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

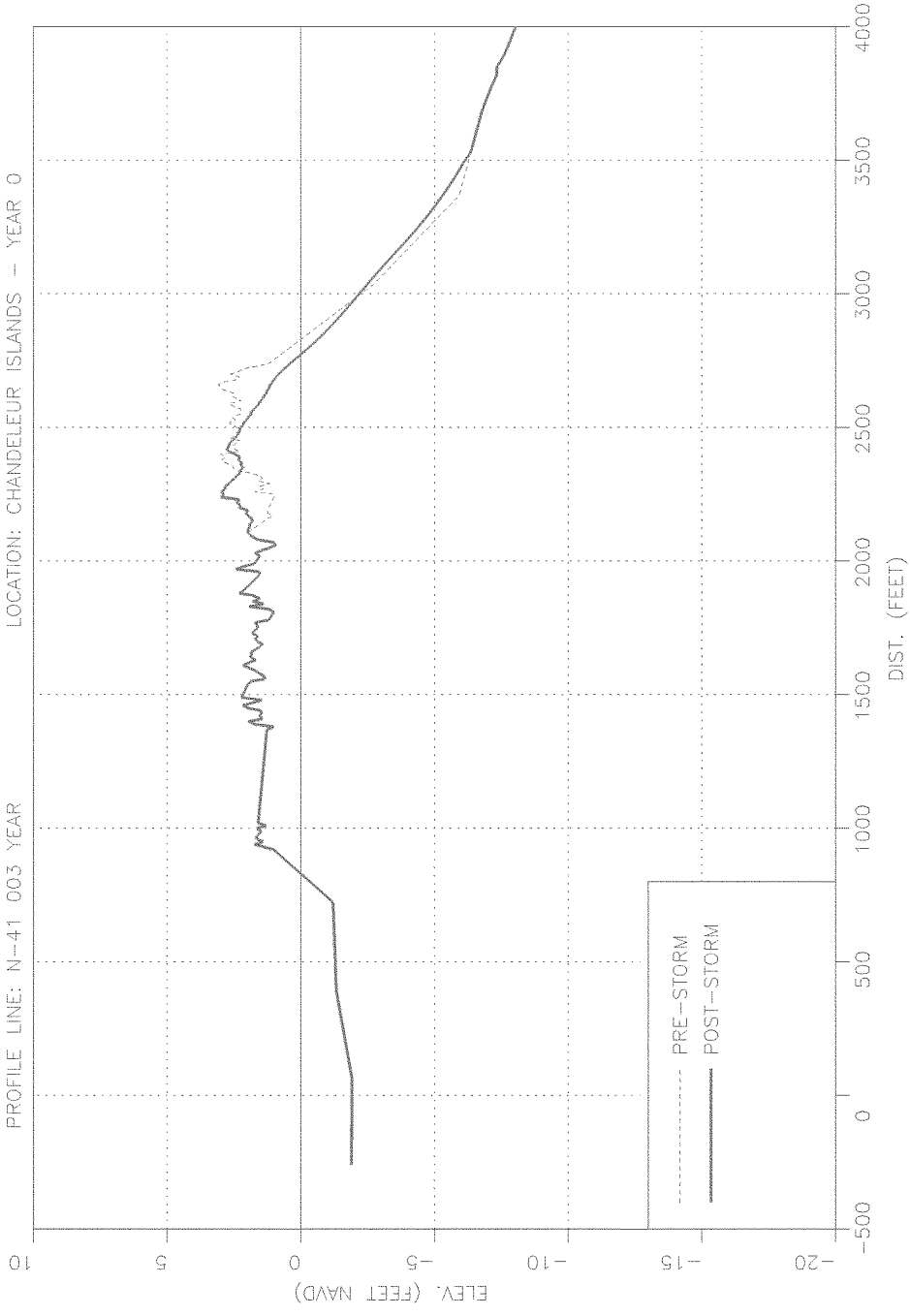

PROFILE LINE: N-40 020 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 0
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

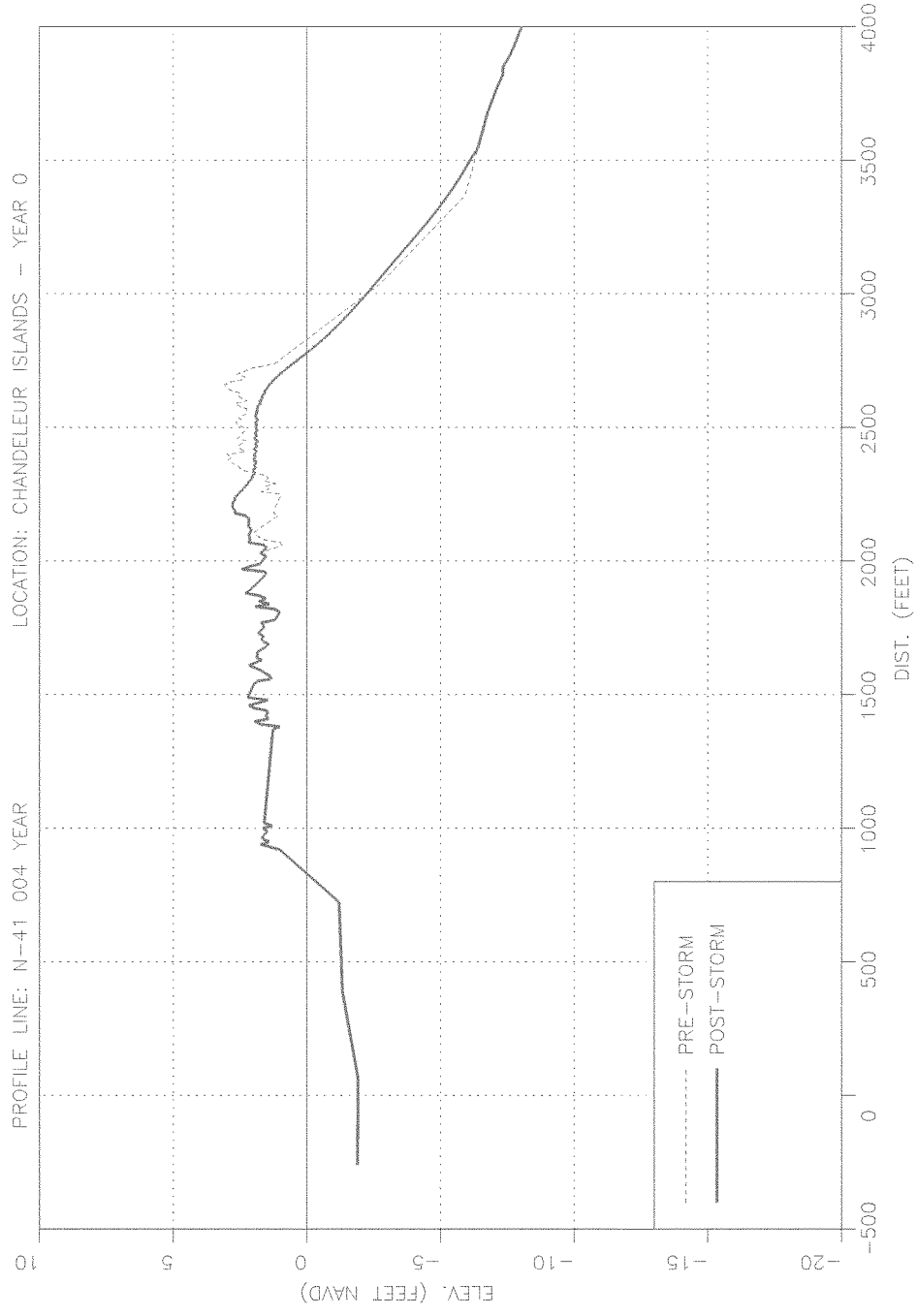

PROFILE LINE: N-40 050 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 0
PRE-STORM
POST-STORM
ELEV. (FEET NAVD)
DIST. (FEET)
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

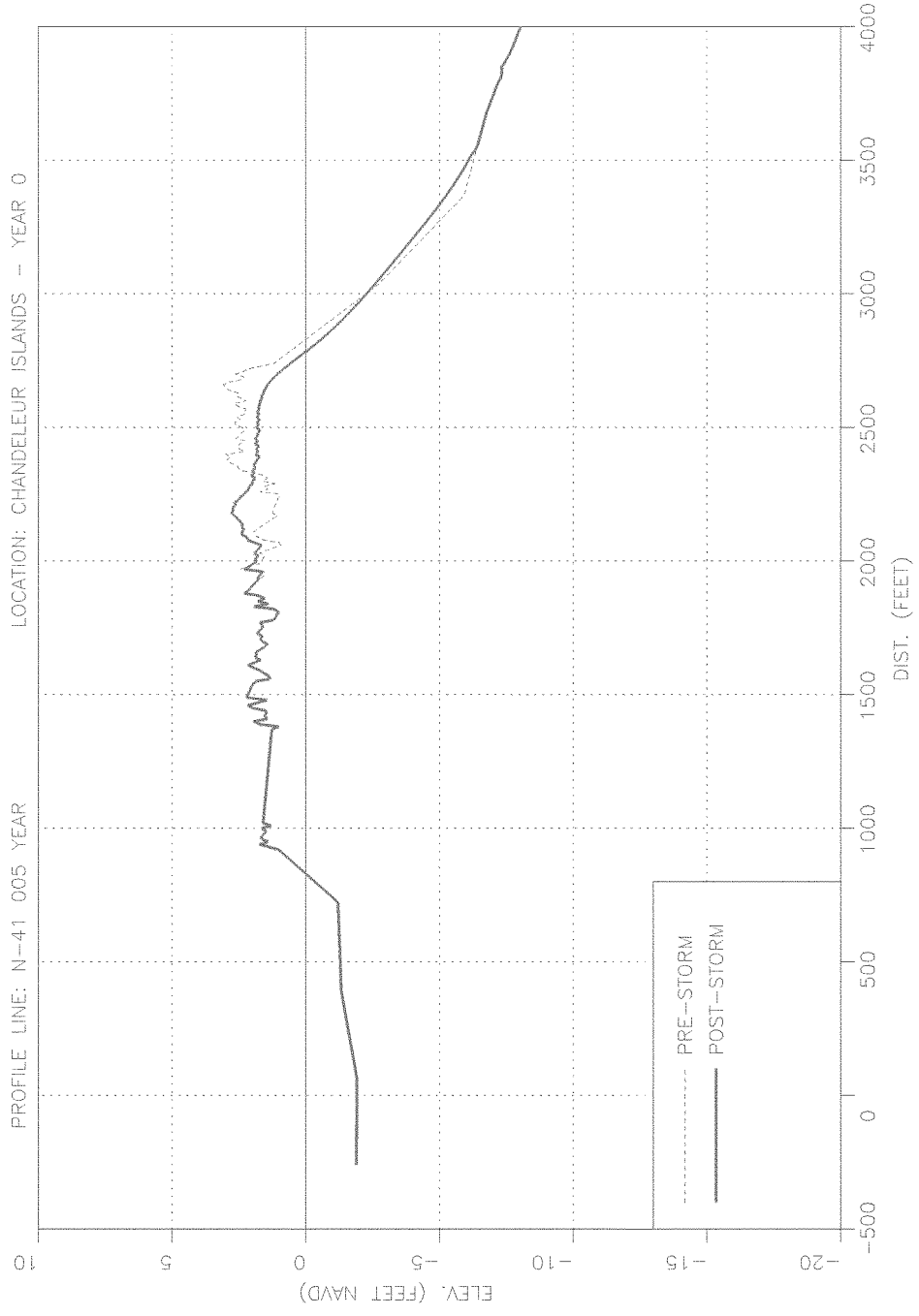

PROFILE LINE: N-40 100 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 0
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

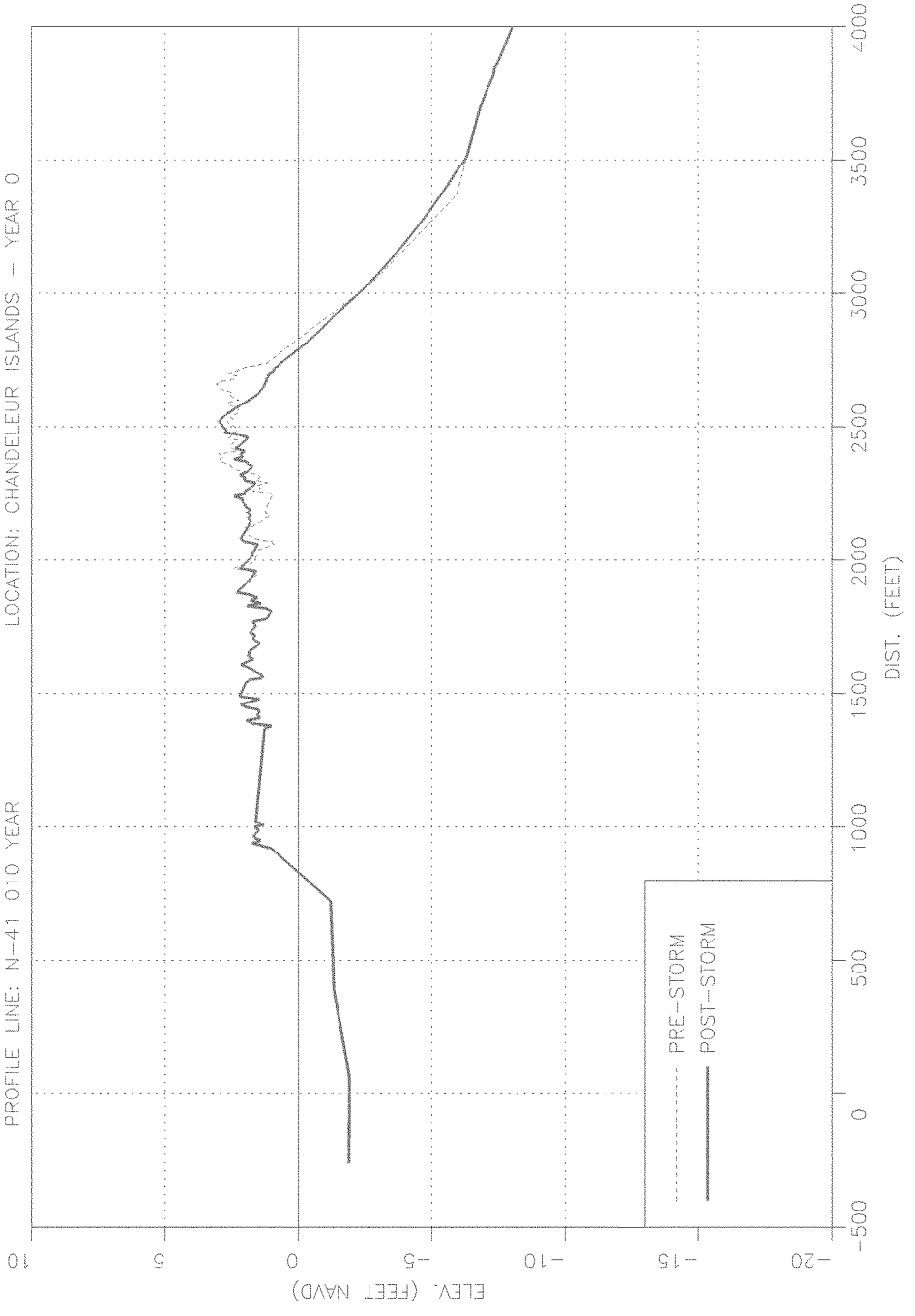

PROFILE LINE: N-41 001 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 0
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

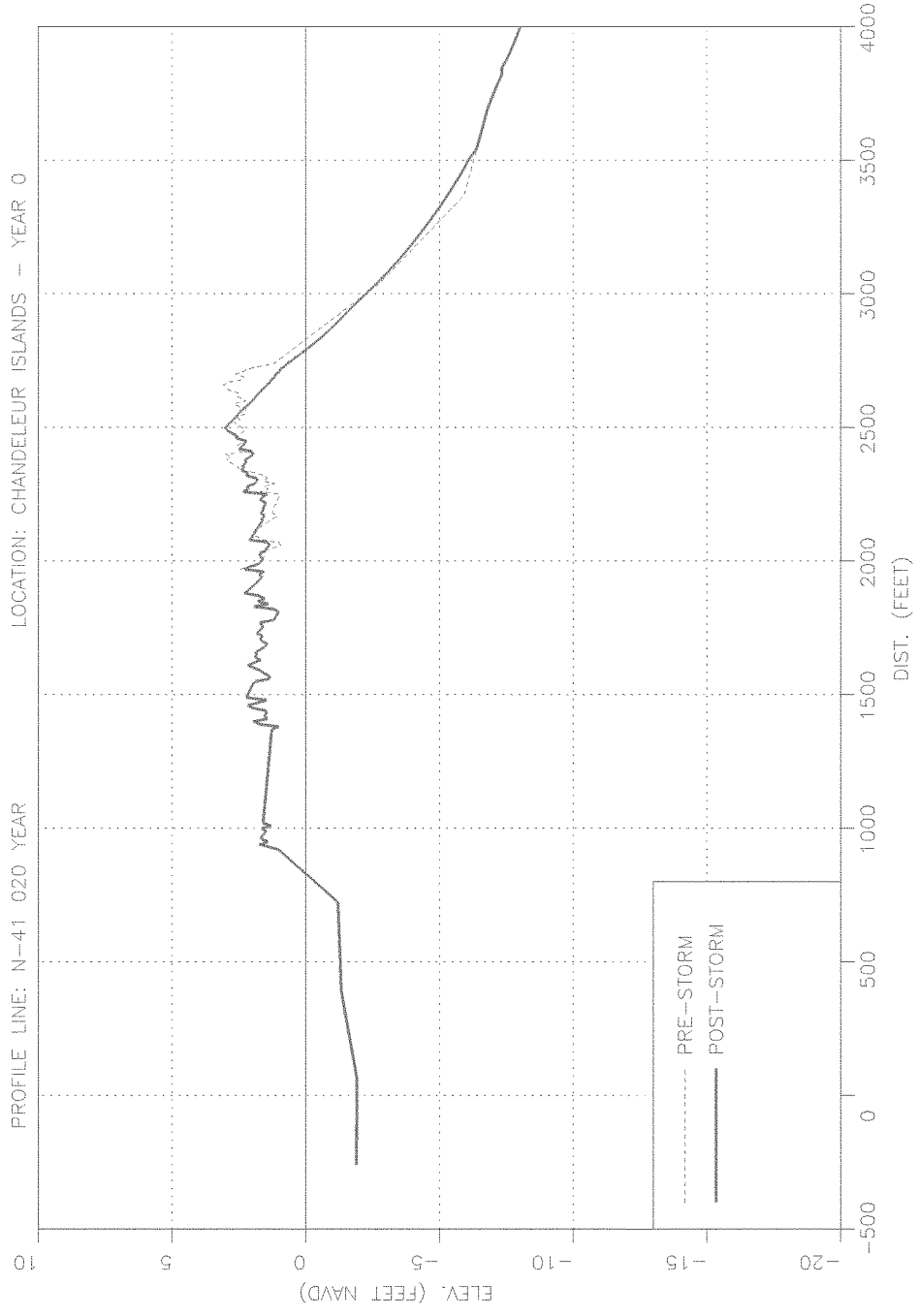

PROFILE LINE: N-41 002 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 0
PRE-STORM
POST-STORM
ELEV. (FEET NAVD)
DIST. (FEET)
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

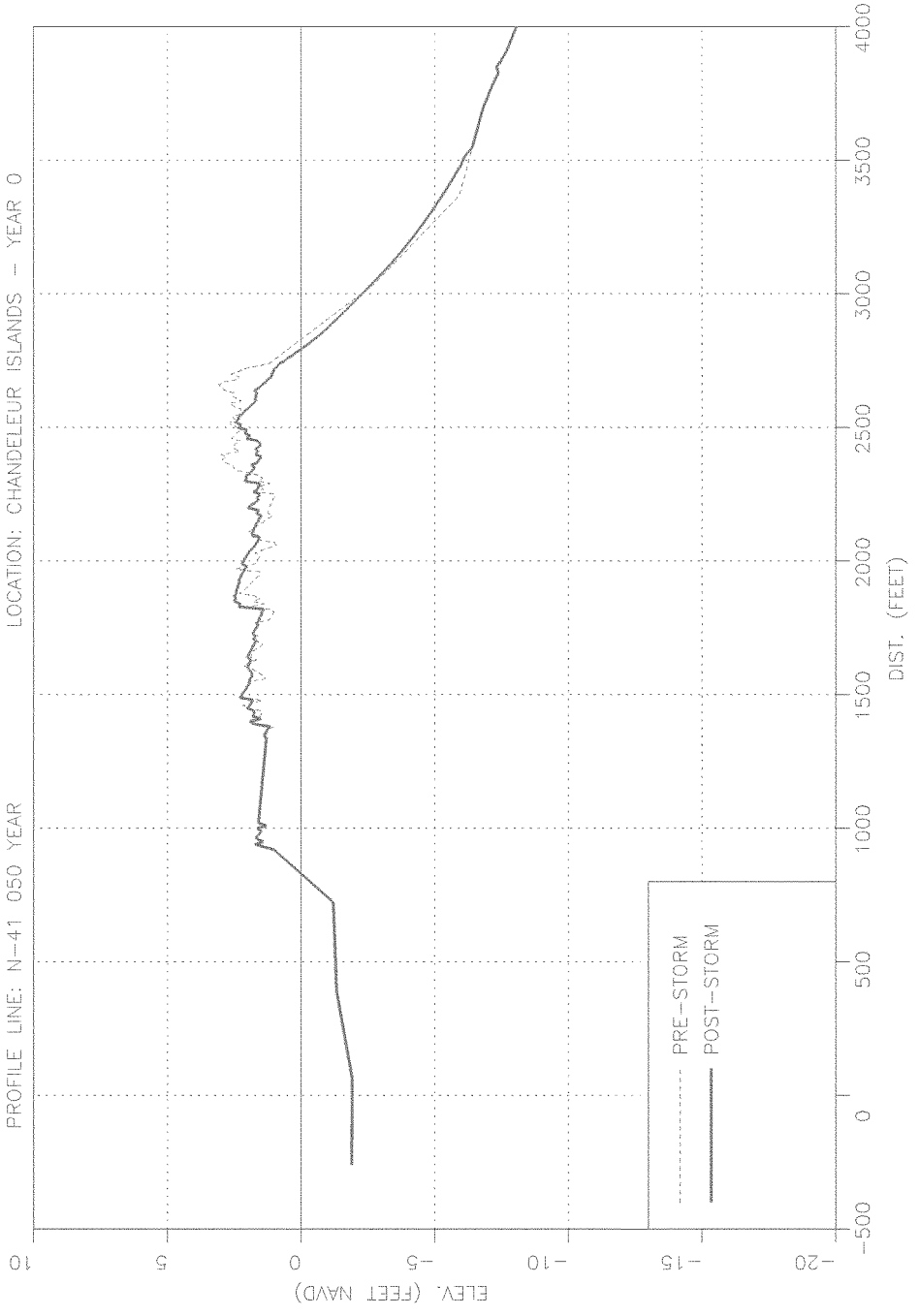

PROFILE LINE: N-41 003 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 0
ELEV. (FEET NAVD)
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000
DIST. (FEET)
PRE-STORM
POST-STORM

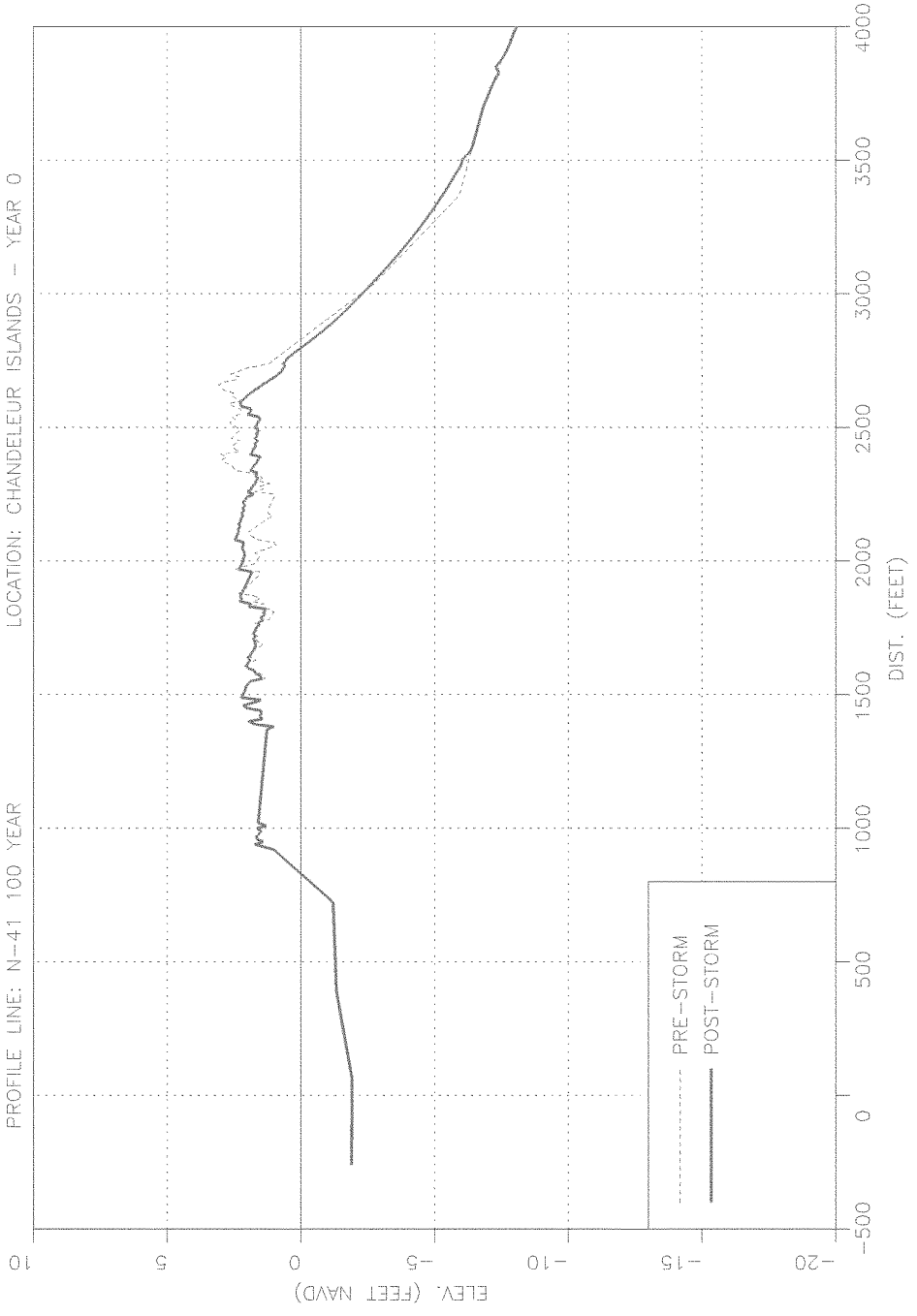

PROFILE LINE: N-41 004 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 0
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

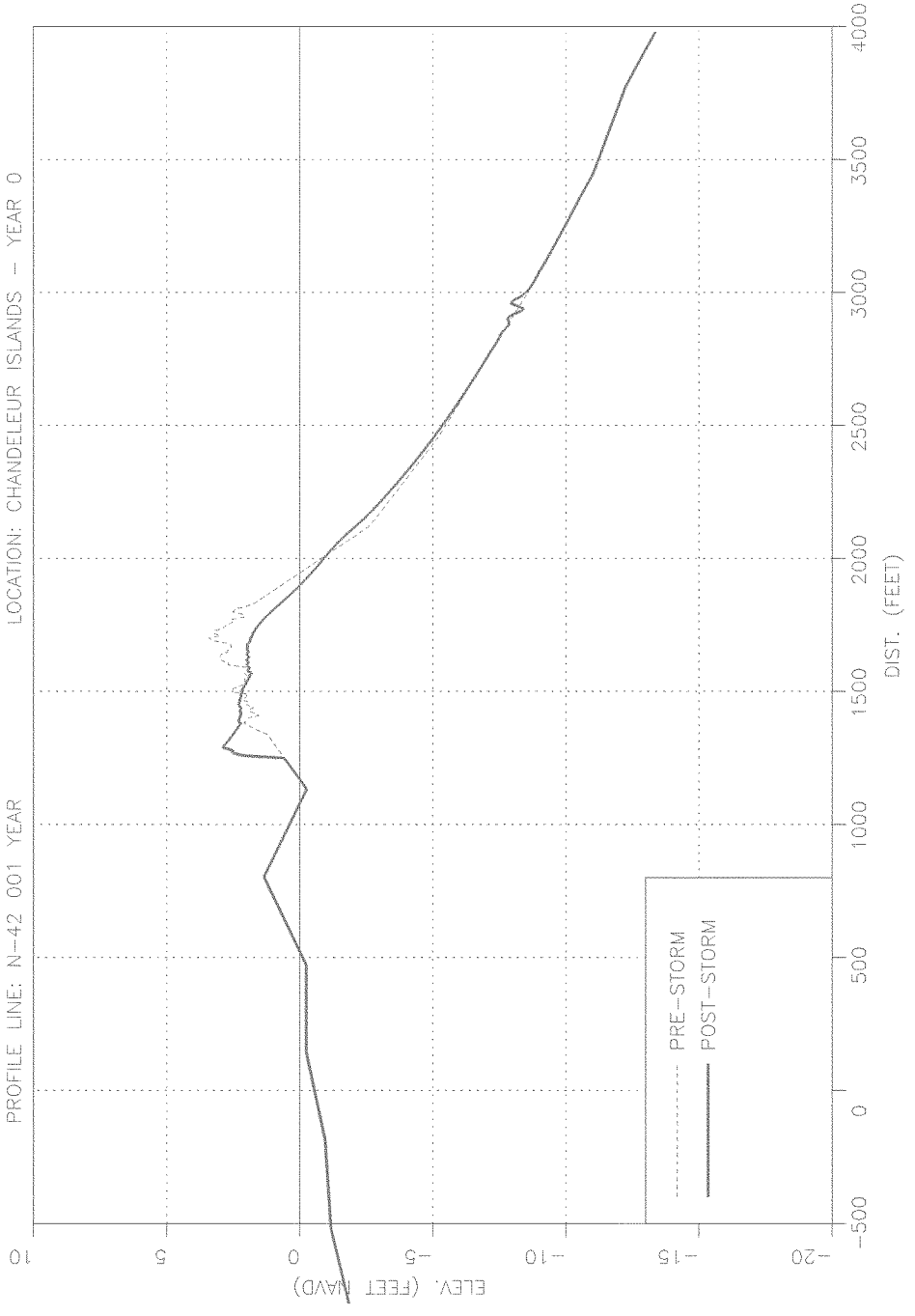

PROFILE LINE: N-41 005 YEAR
LOCATION: CHANDELEUR ISLANDS -- YEAR 0
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

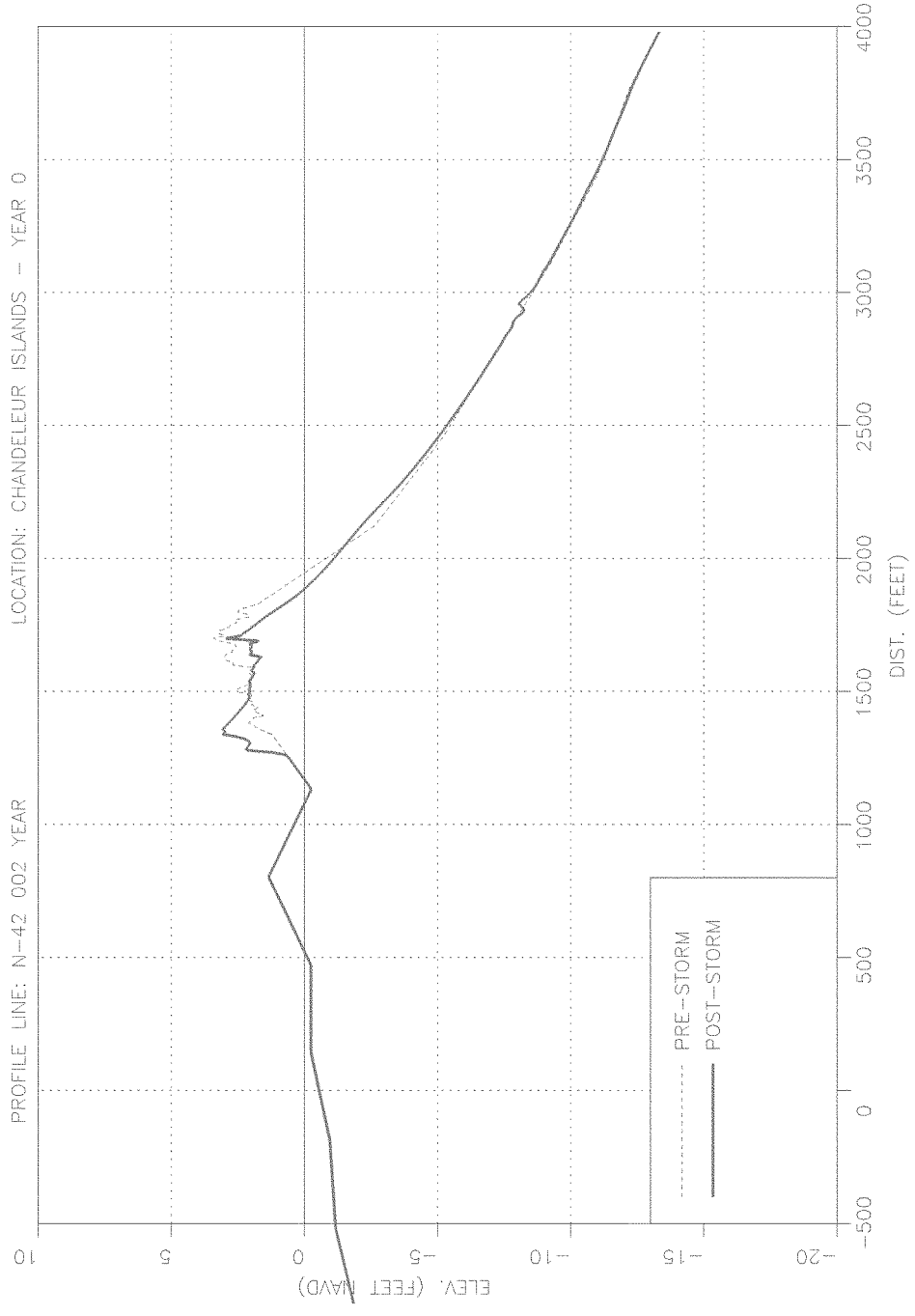

PROFILE LINE: N-41 010 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 0
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

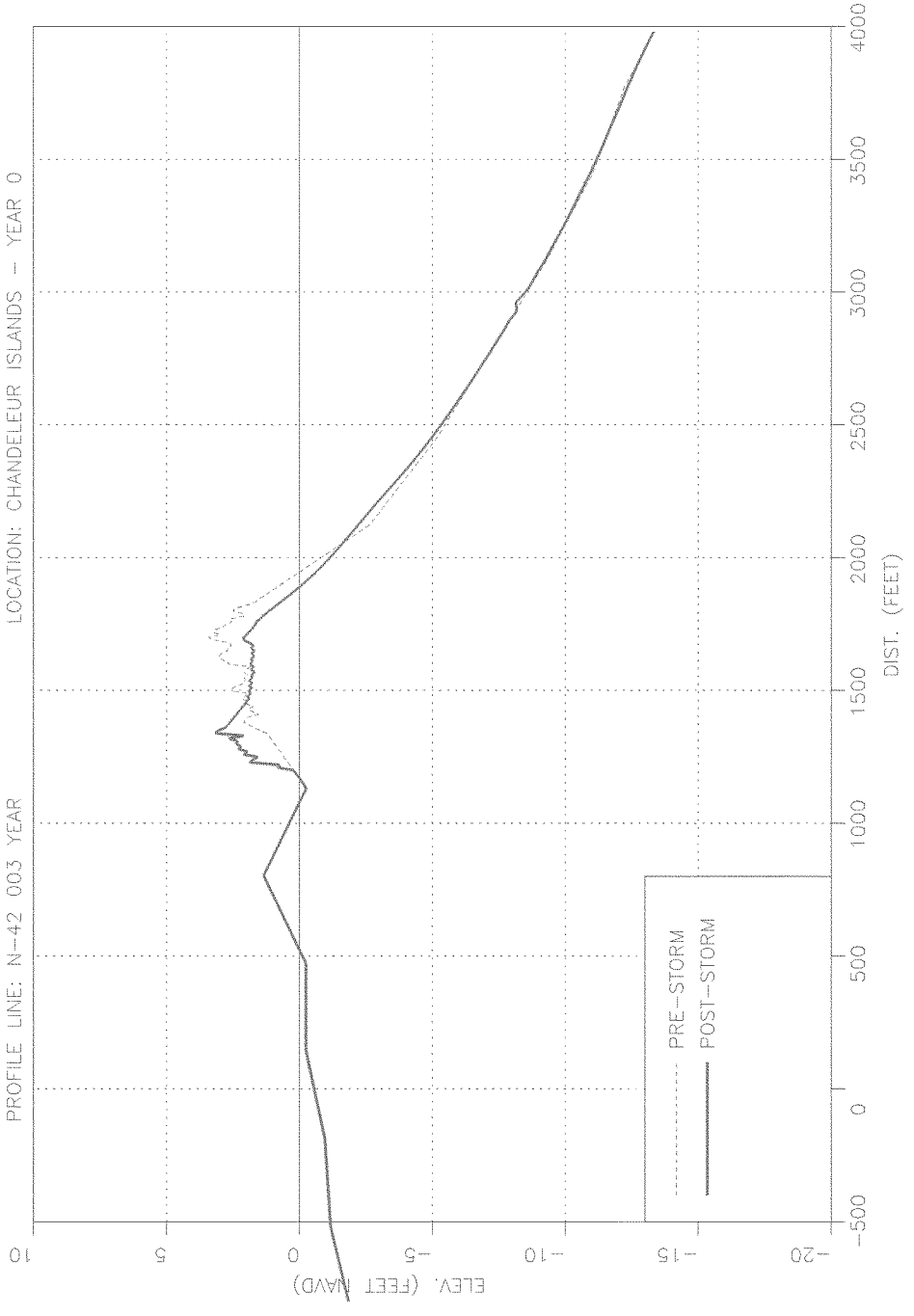

PROFILE LINE: N-41 020 YEAR
LOCATION: CHANDELEUR ISLANDS -- YEAR 0
PRE-STORM
POST-STORM
ELEV. (FEET NAVD)
DIST. (FEET)
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

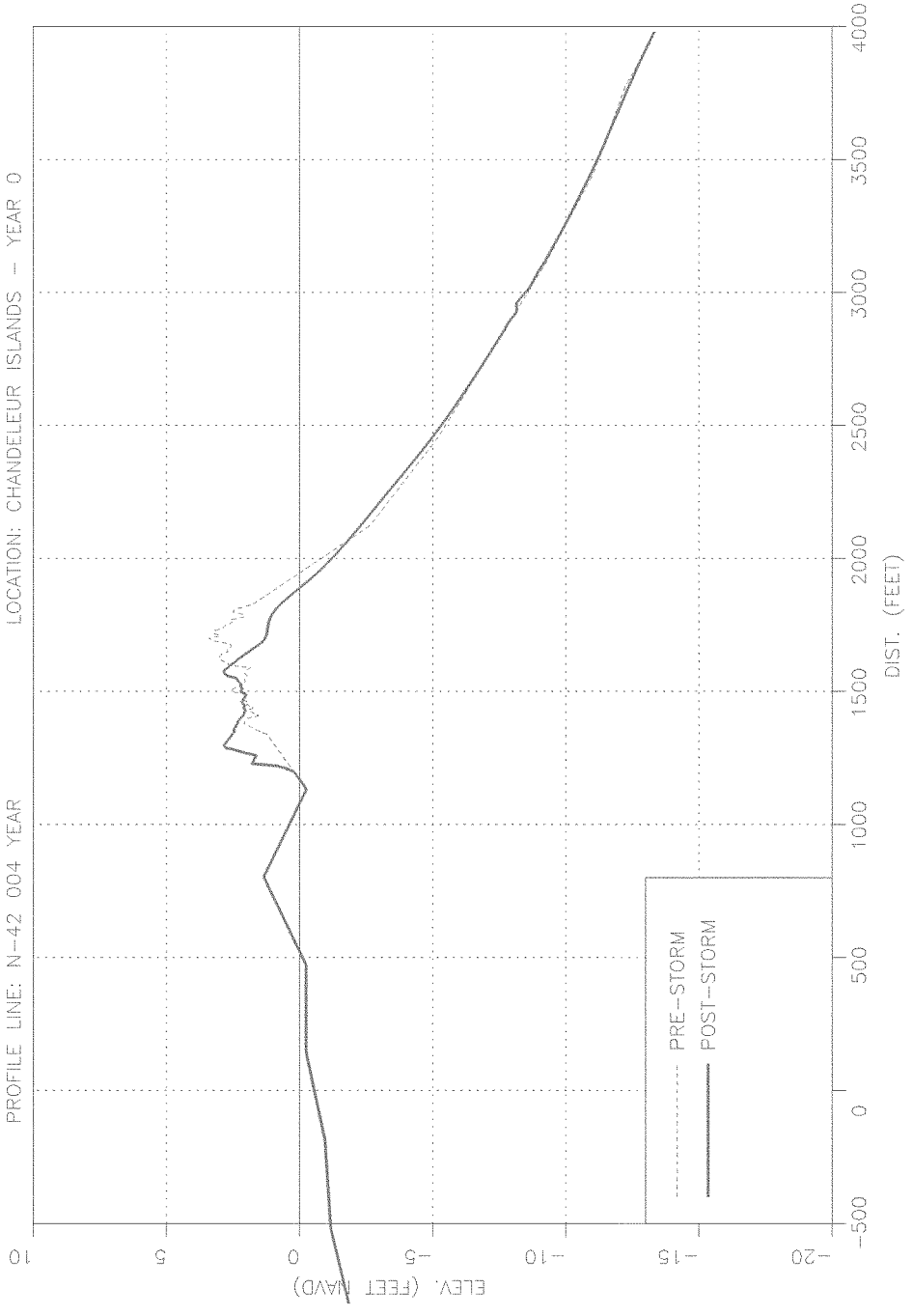

PROFILE LINE: N-41 050 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 0
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

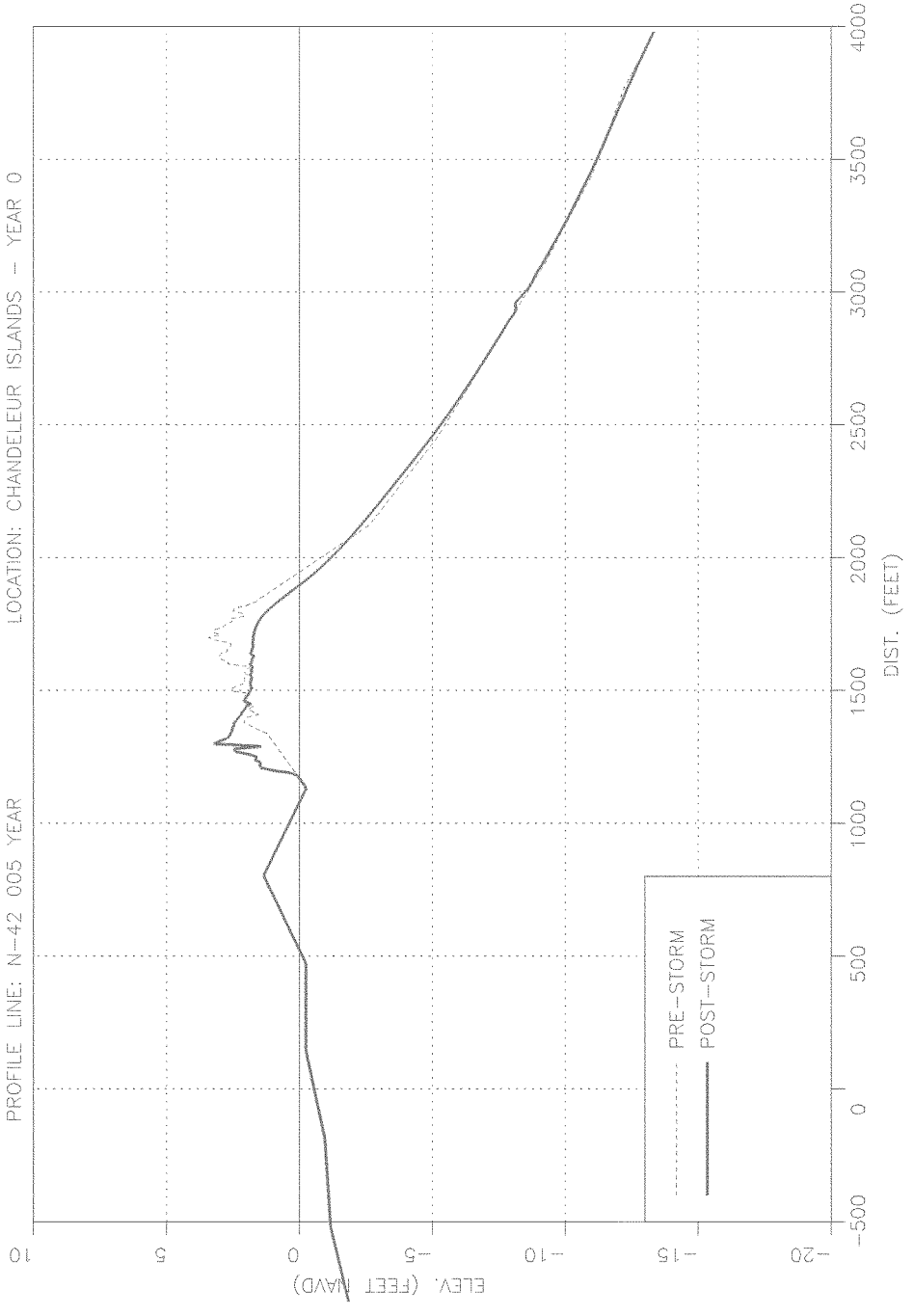

PROFILE LINE: N-41 100 YEAR
LOCATION: CHANDELEUR ISLANDS -- YEAR 0
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

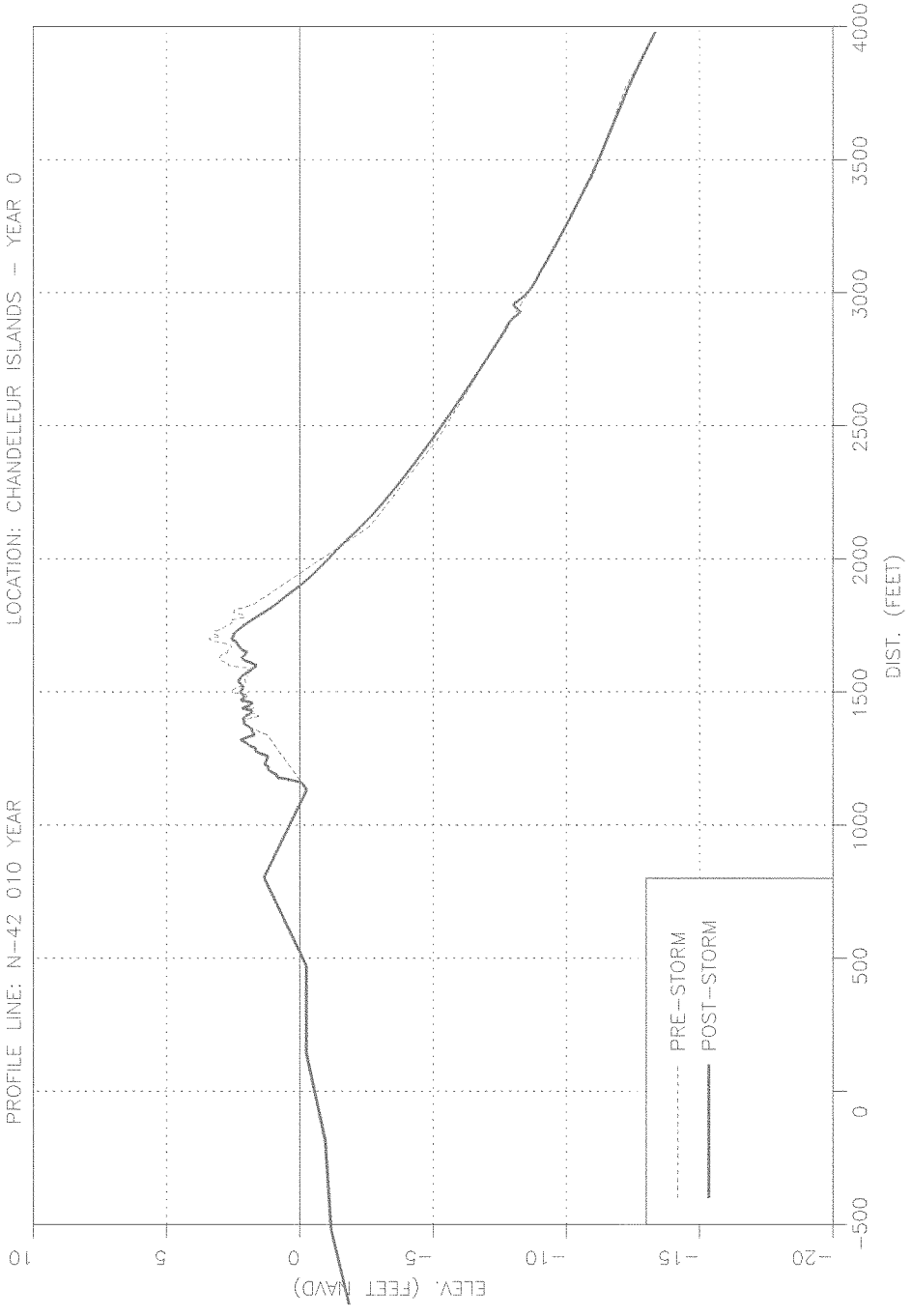

PROFILE LINE: N-42 001 YEAR
LOCATION: CHANDELEUR ISLANDS -- YEAR 0
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

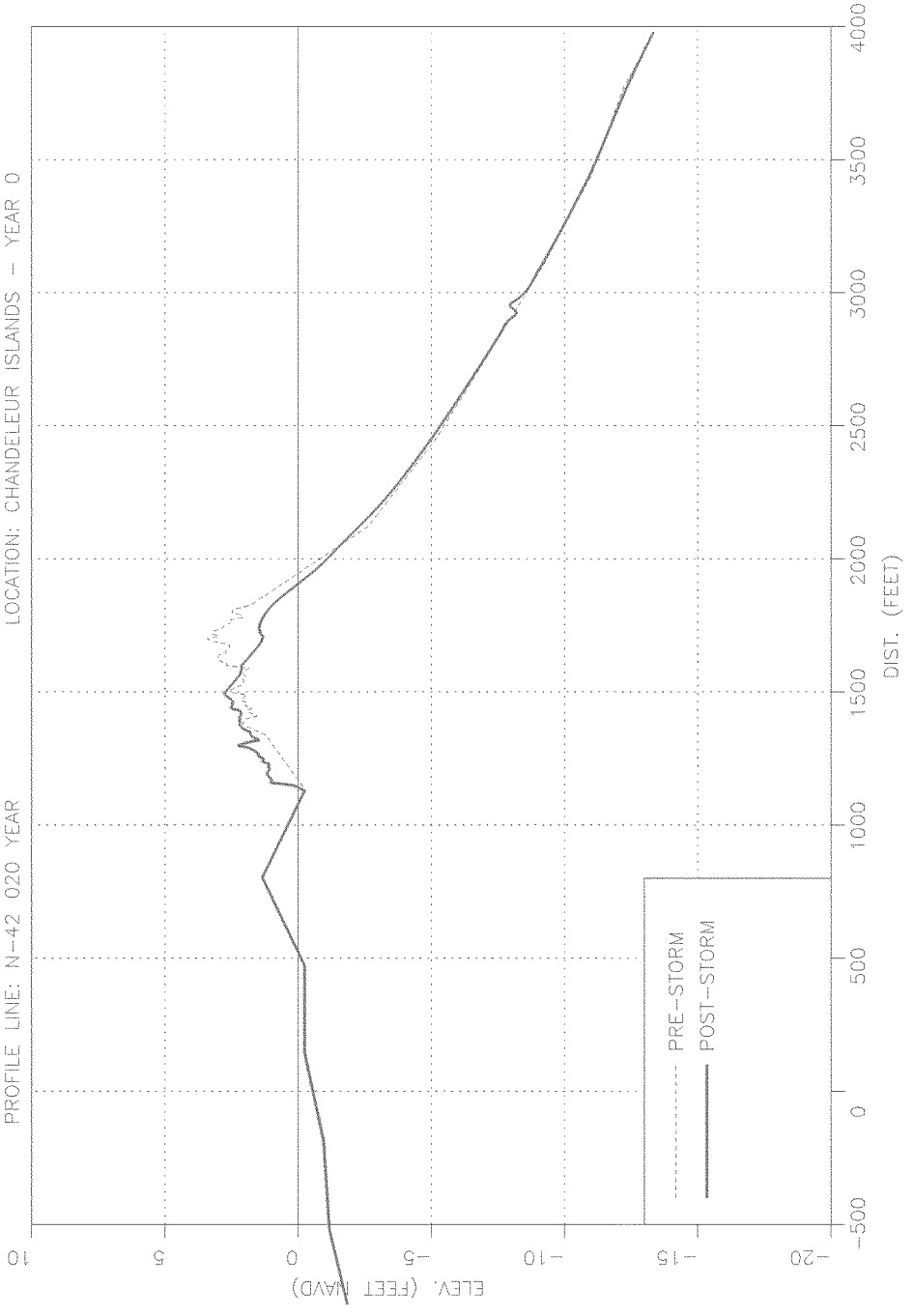

PROFILE LINE: N-42 002 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 0
ELEV. (FEET NAVD)
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000
DIST. (FEET)
PRE-STORM
POST-STORM

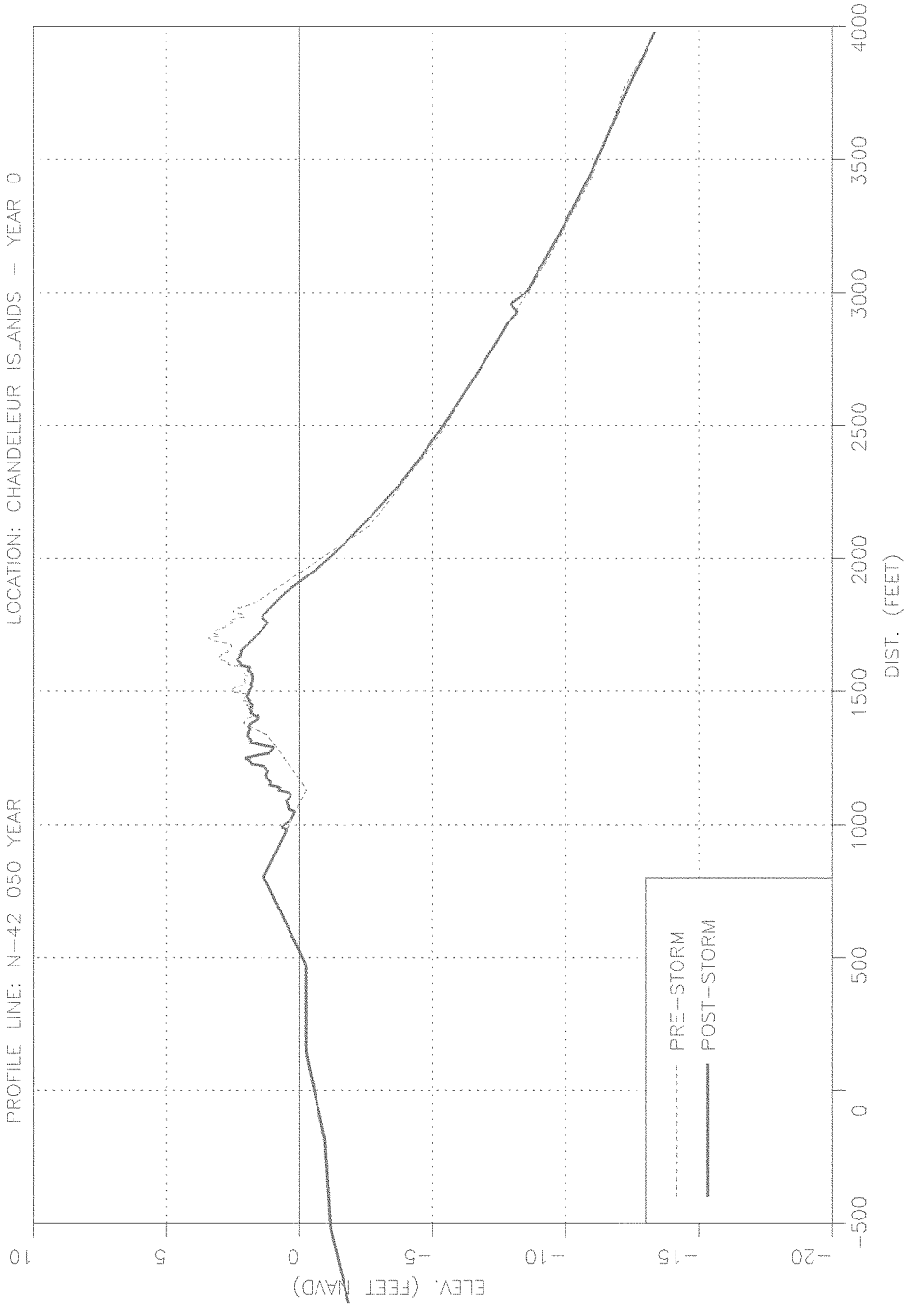

PROFILE LINE: N-42 003 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 0
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

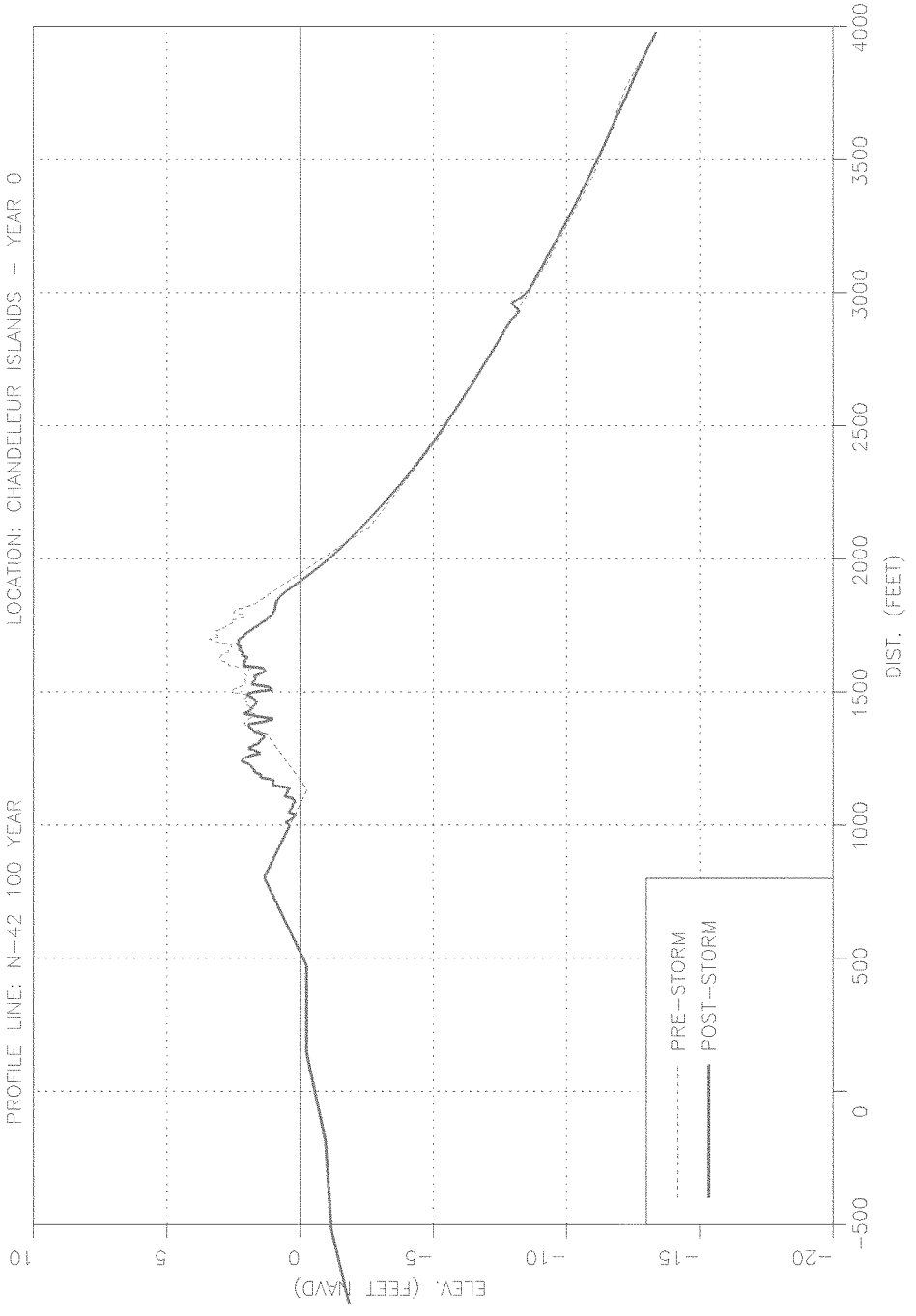

PROFILE LINE: N-42 004 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 0
PRE-STORM
POST-STORM
ELEV. (FEET NAVD)
DIST. (FEET)
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

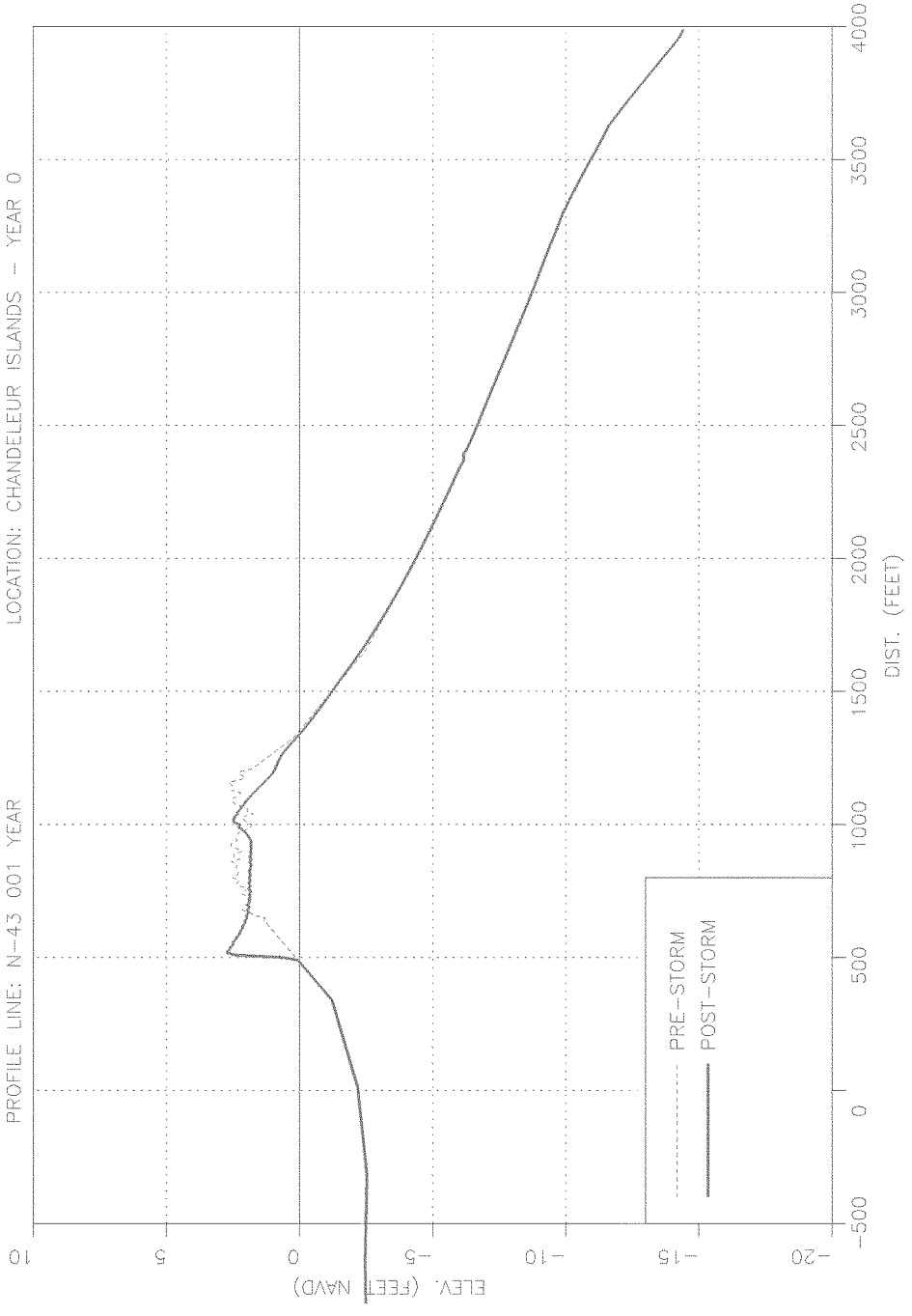

PROFILE LINE: N-42 005 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 0
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

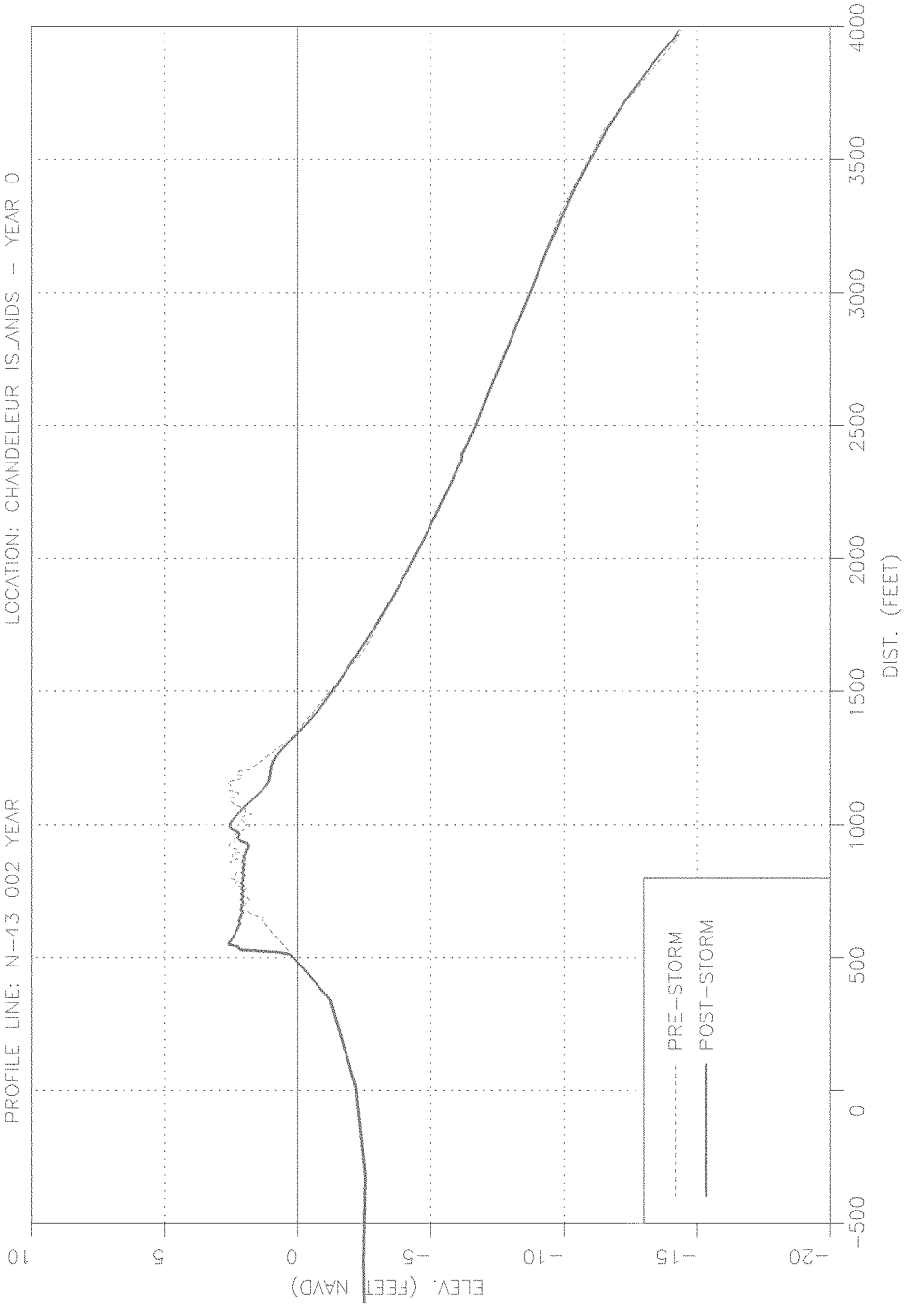

PROFILE LINE: N-42 010 YEAR
LOCATION: CHANDELEUR ISLANDS -- YEAR 0
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

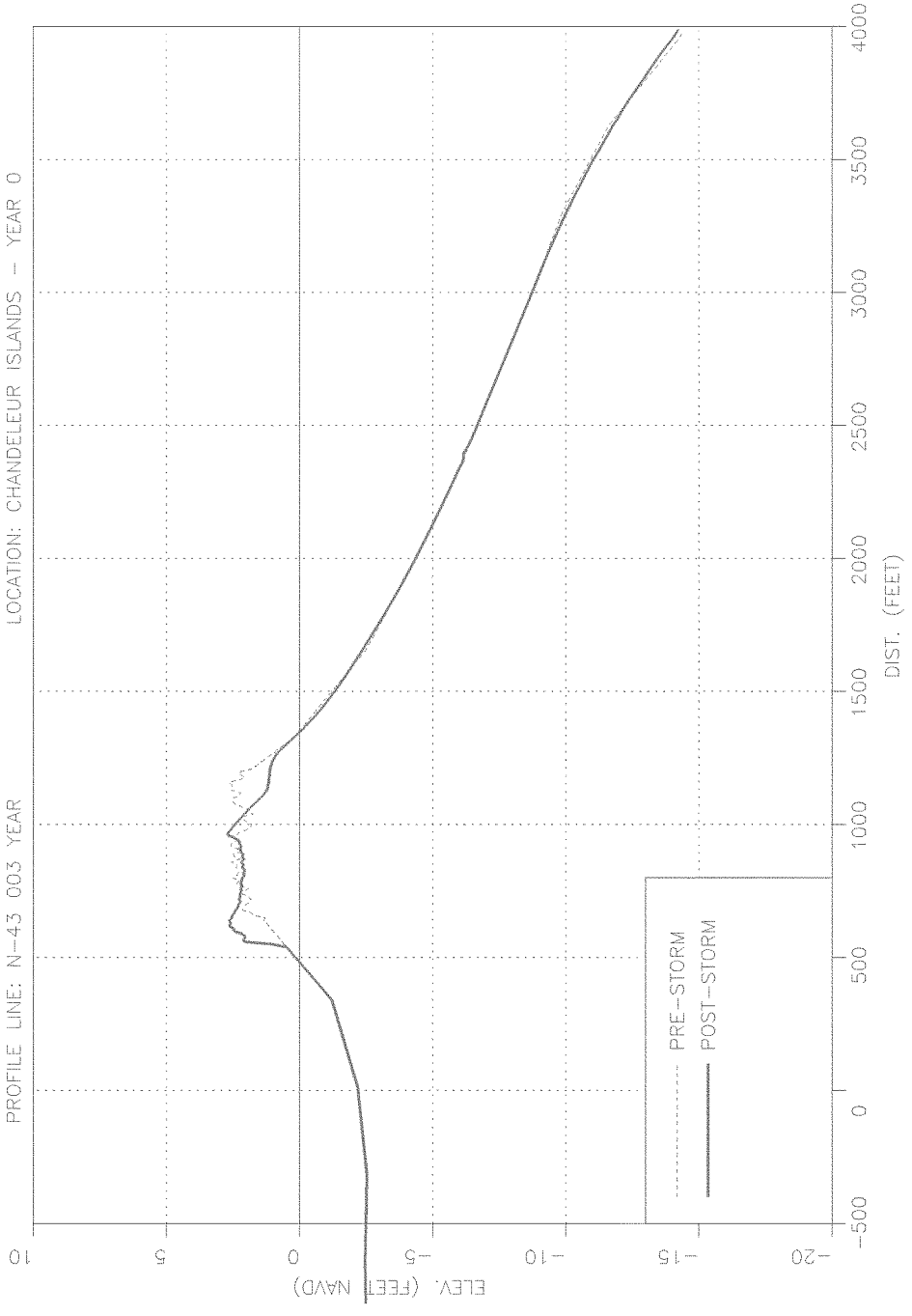

PROFILE LINE: N-42 020 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 0
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

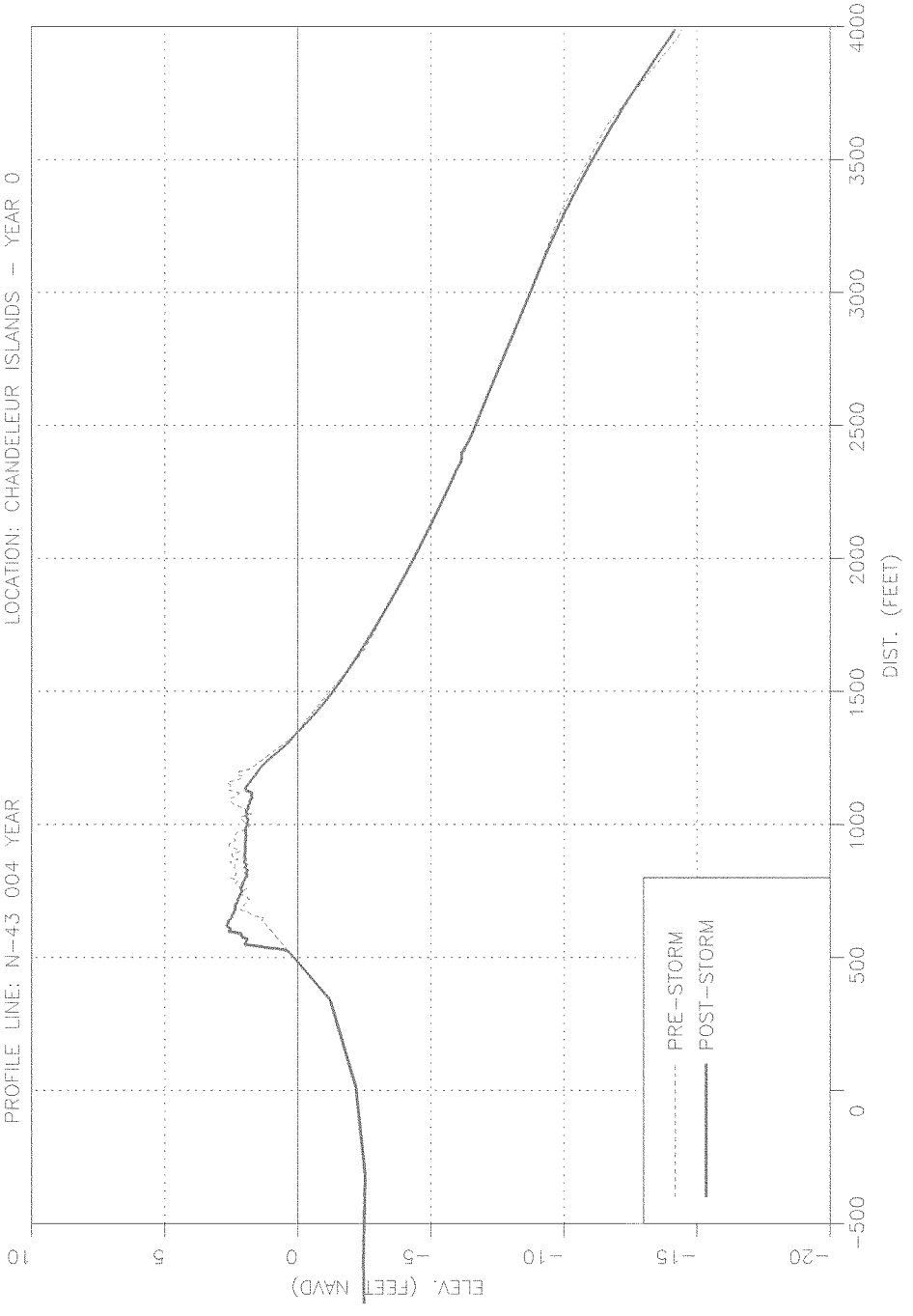

PROFILE LINE: N-42 050 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 0
PRE-STORM
POST-STORM
ELEV. (FEET NAVD)
DIST. (FEET)
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

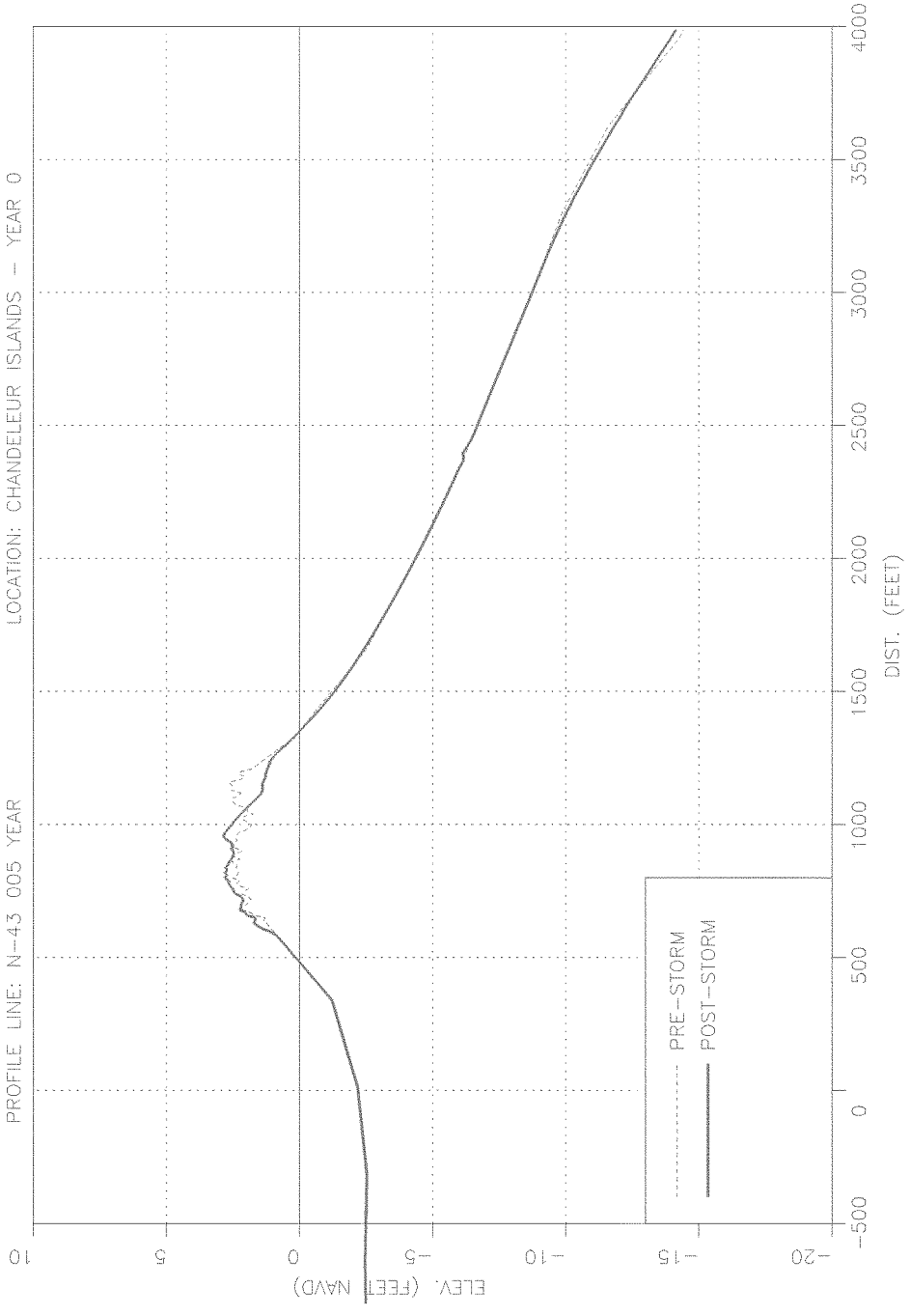

PROFILE LINE: N-42 100 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 0
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

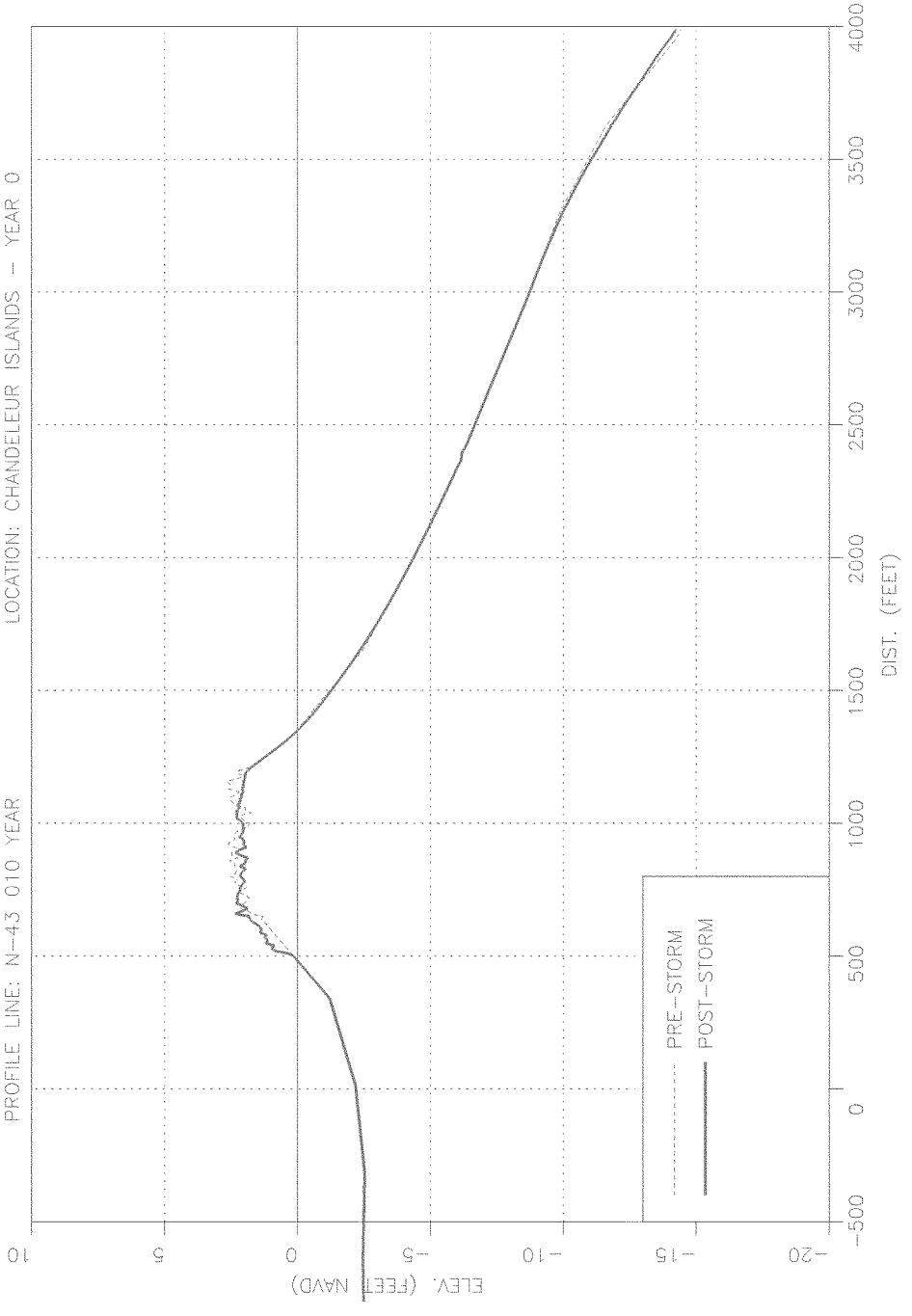

PROFILE LINE: N-43 001 YEAR
LOCATION: CHANDELEUR ISLANDS -- YEAR 0
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

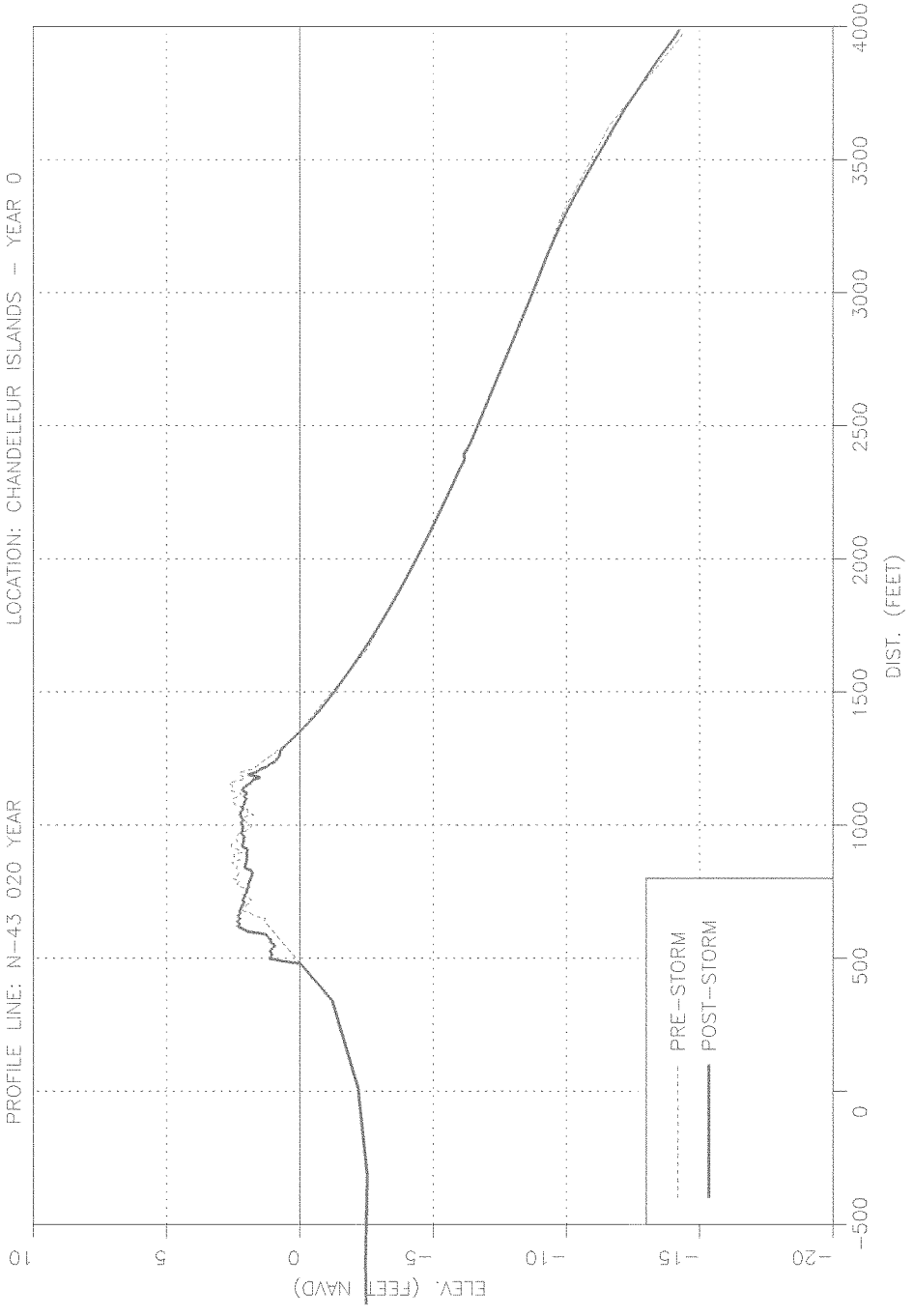

PROFILE LINE: N-43 002 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 0
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

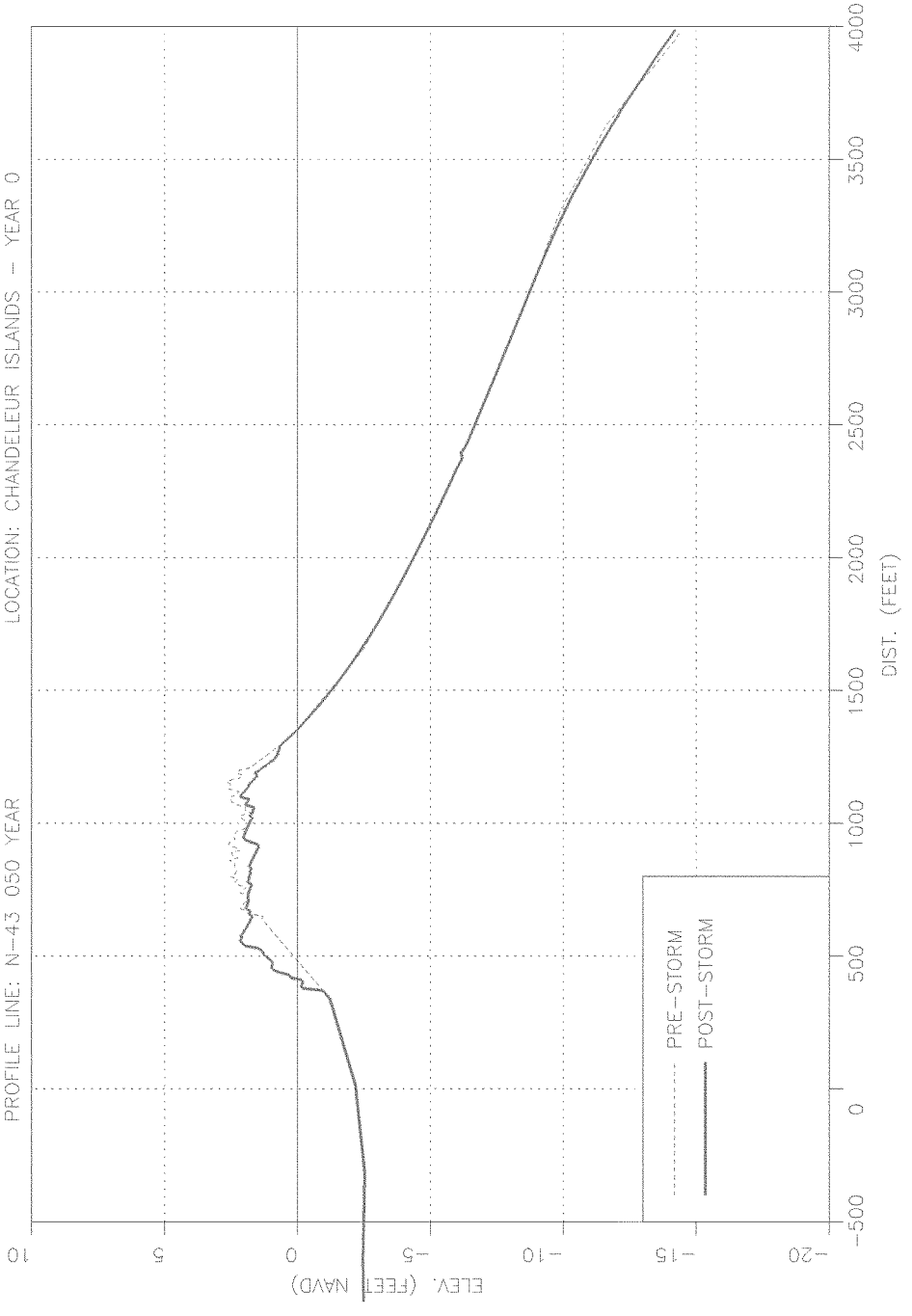

PROFILE LINE: N-43 003 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 0
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

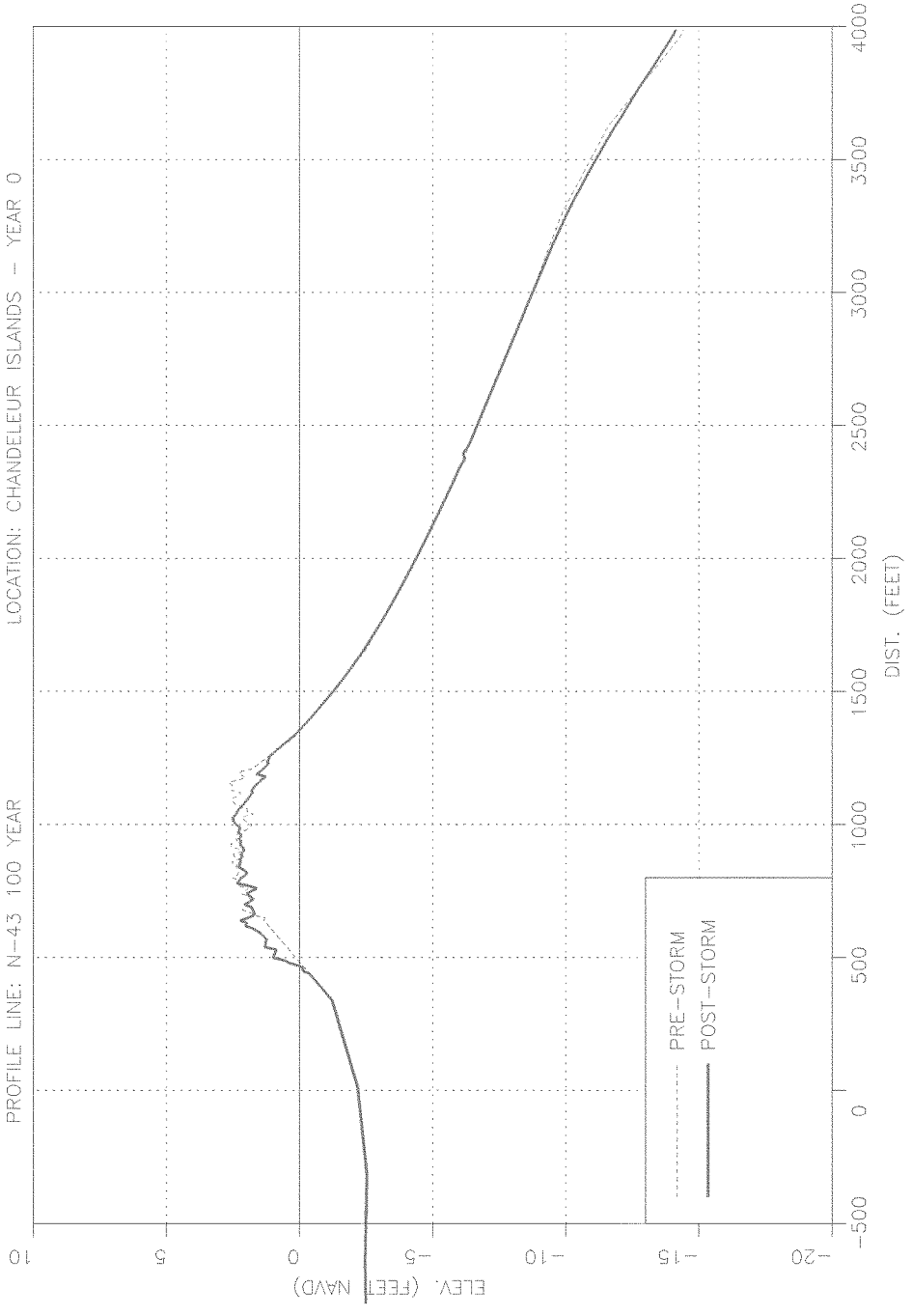

PROFILE LINE: N-43 004 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 0
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

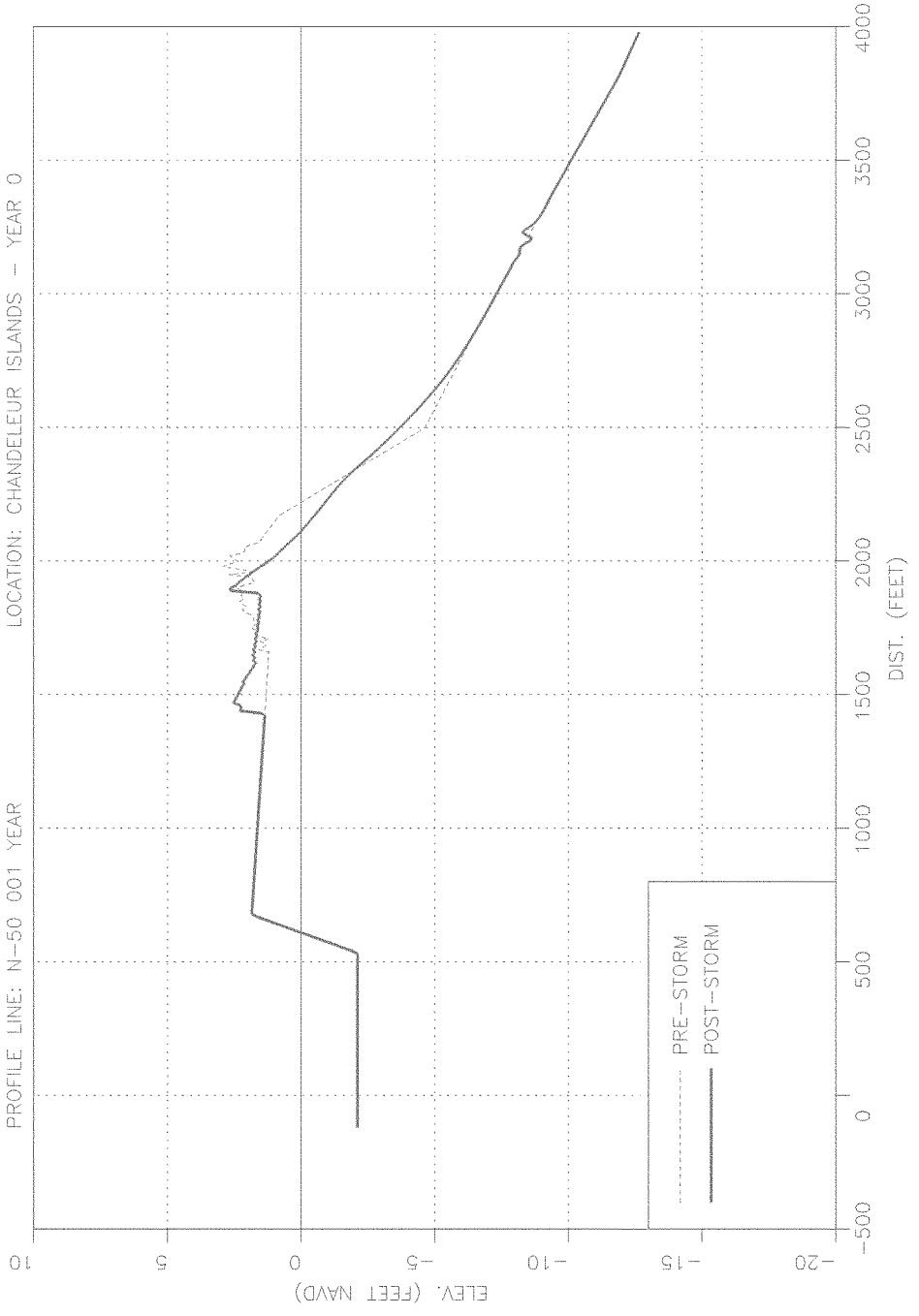

PROFILE LINE: N-43 005 YEAR
LOCATION: CHANDELEUR ISLANDS -- YEAR 0
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

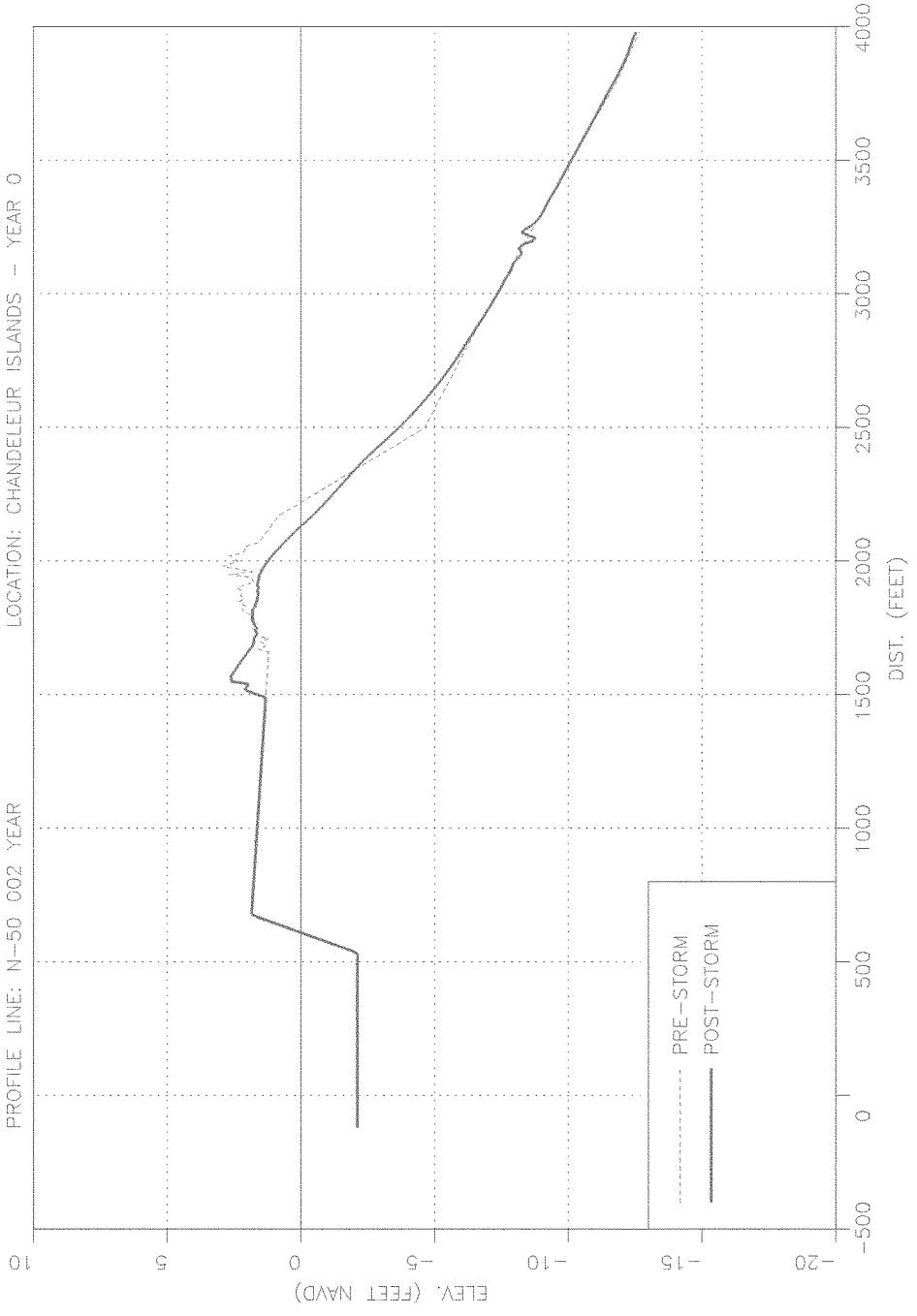

PROFILE LINE: N-43 010 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 0
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

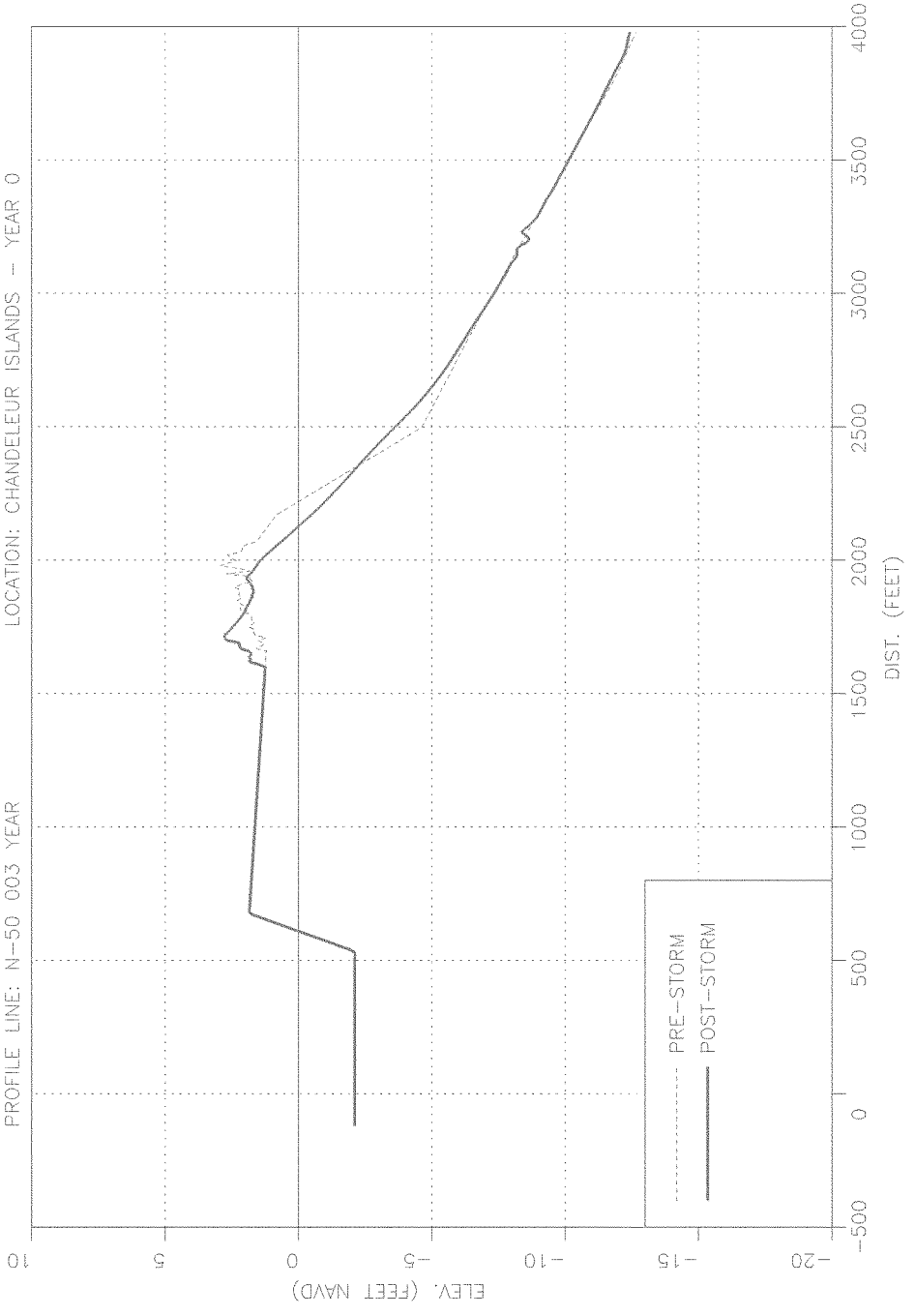

PROFILE LINE: N-43 020 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 0
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

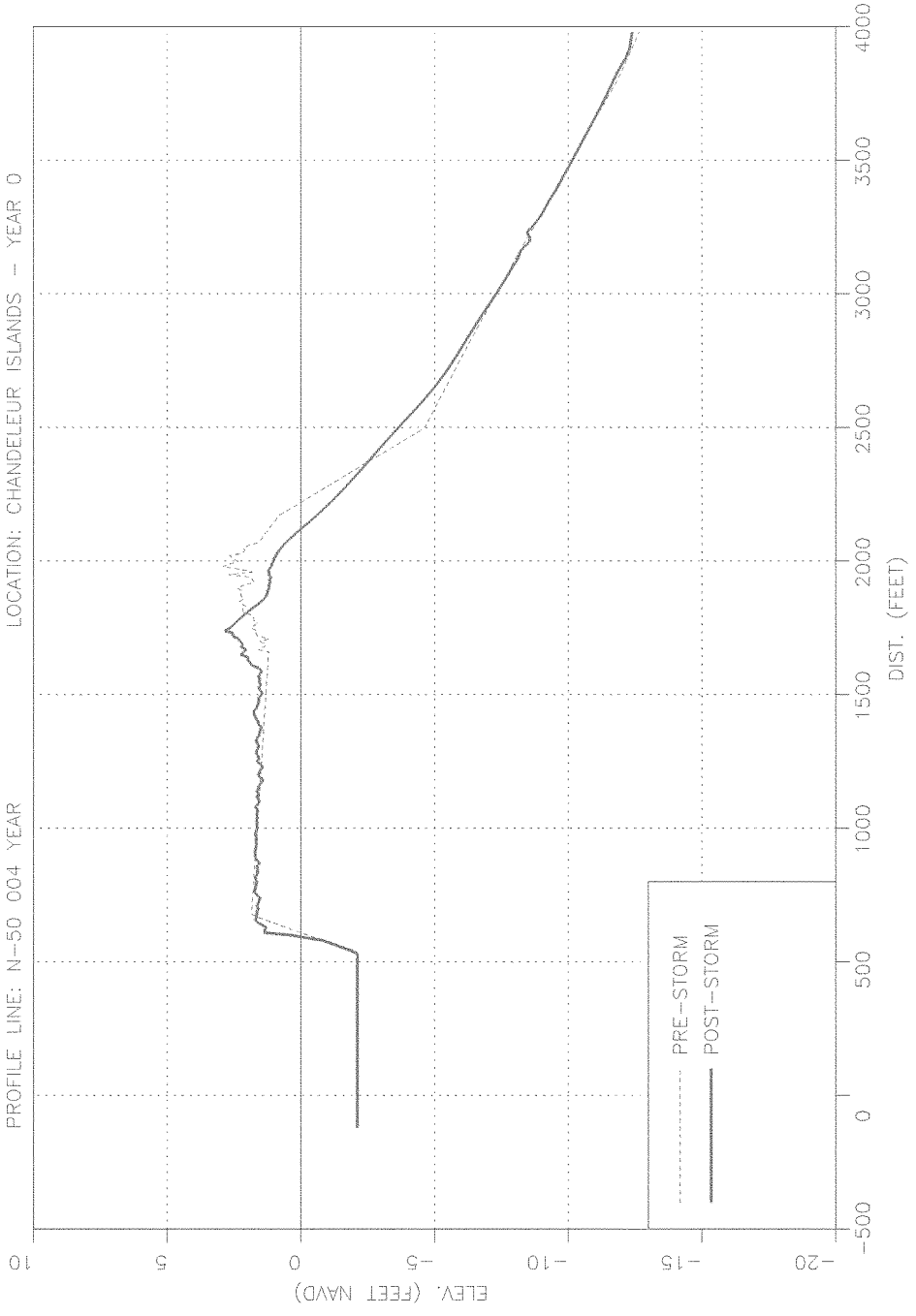

PROFILE LINE: N-43 050 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 0
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

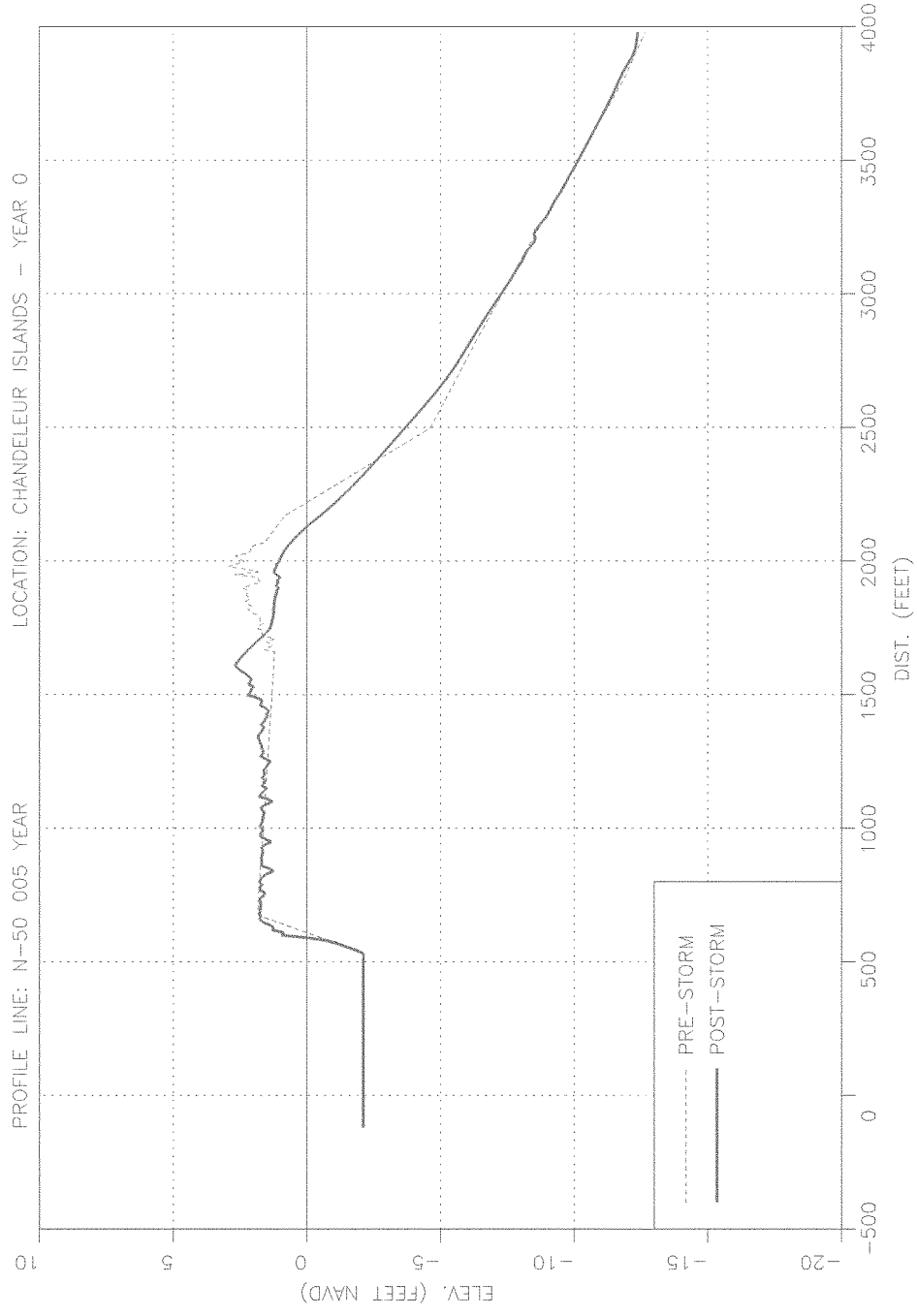

PROFILE LINE: N-43 100 YEAR
LOCATION: CHANDELEUR ISLANDS -- YEAR 0
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

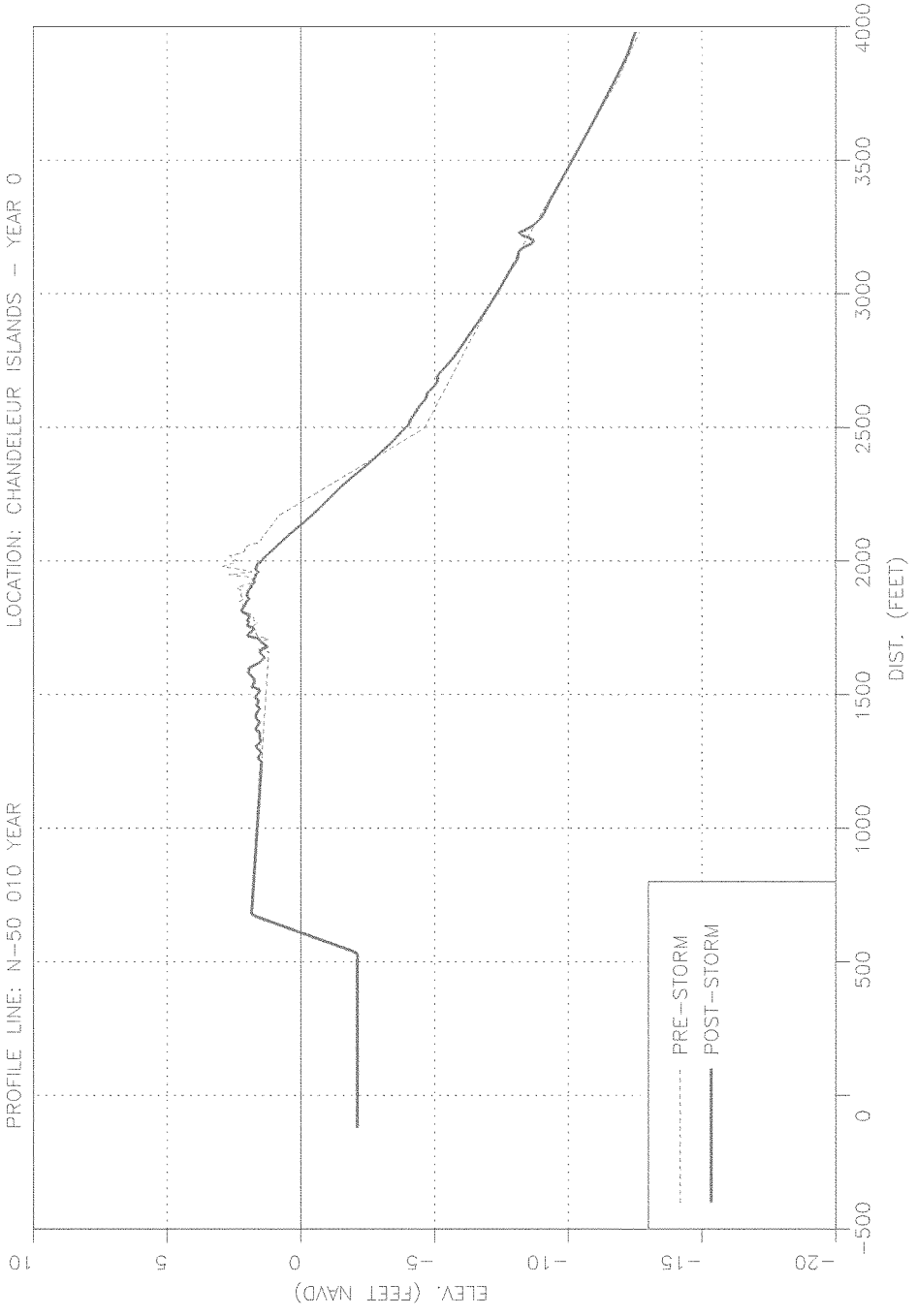

PROFILE LINE: N-50 001 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 0
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

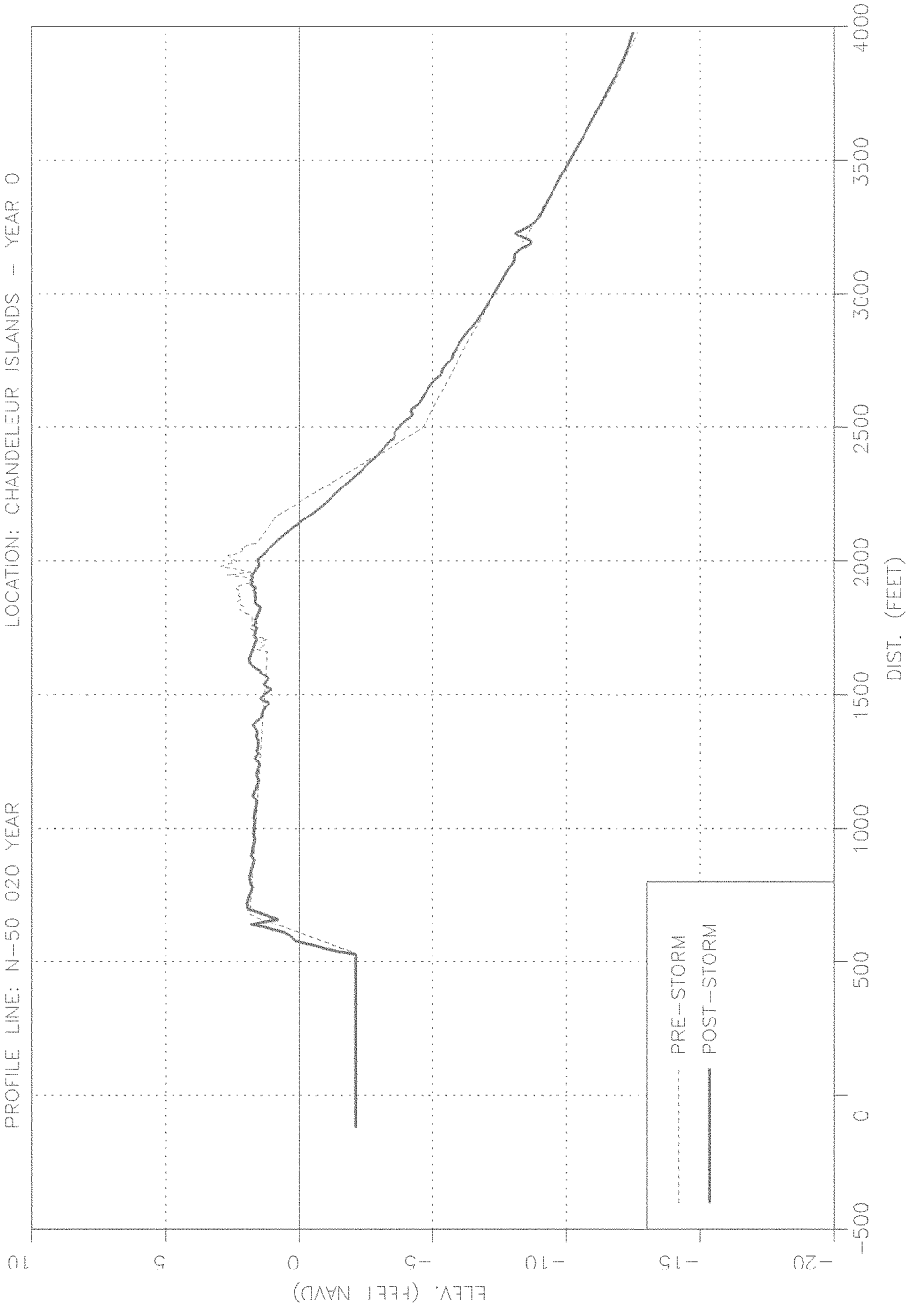

PROFILE LINE: N-50 002 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 0
PRE-STORM
POST-STORM
ELEV. (FEET NAVD)
DIST. (FEET)
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

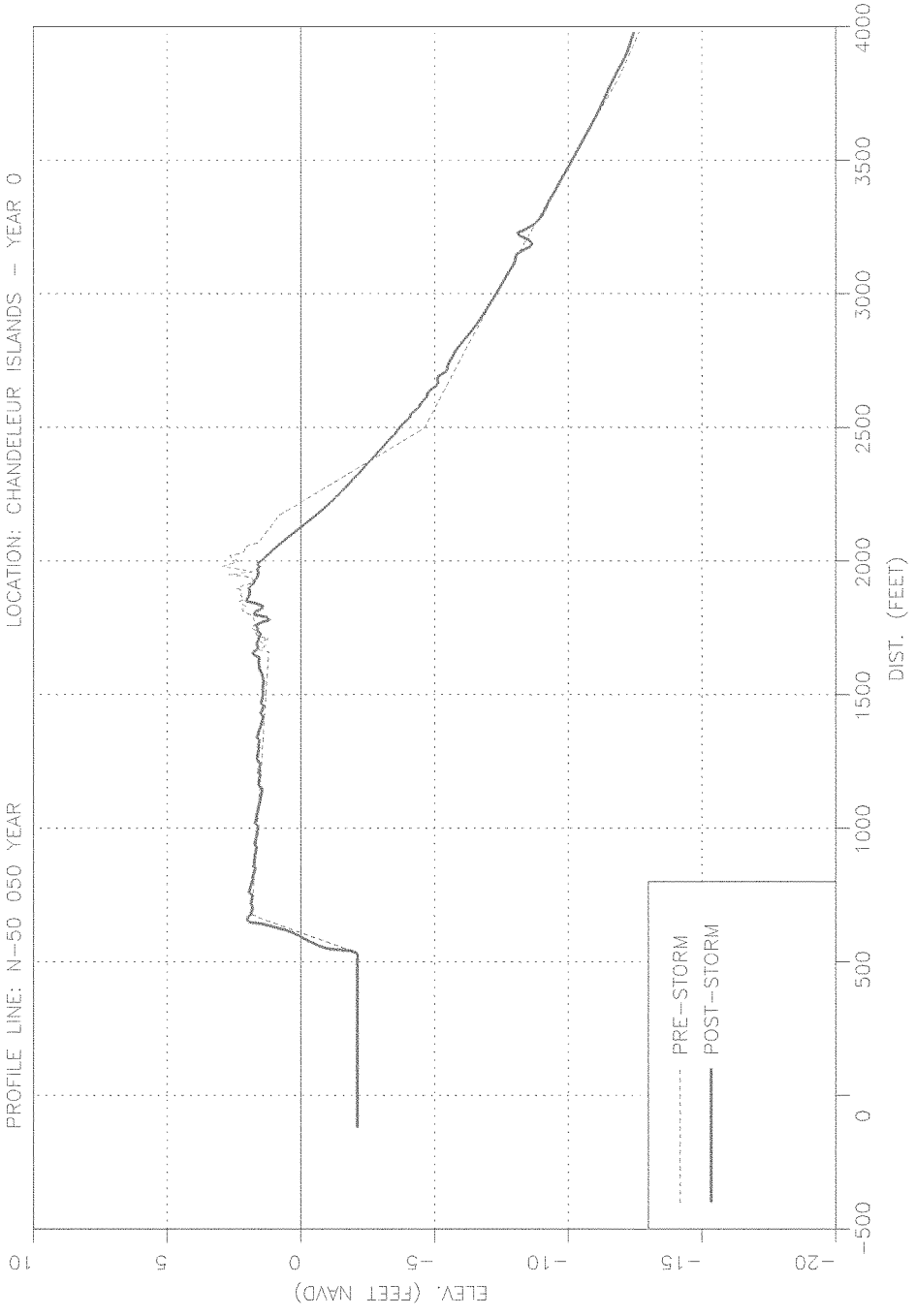

PROFILE LINE: N-50 003 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 0
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

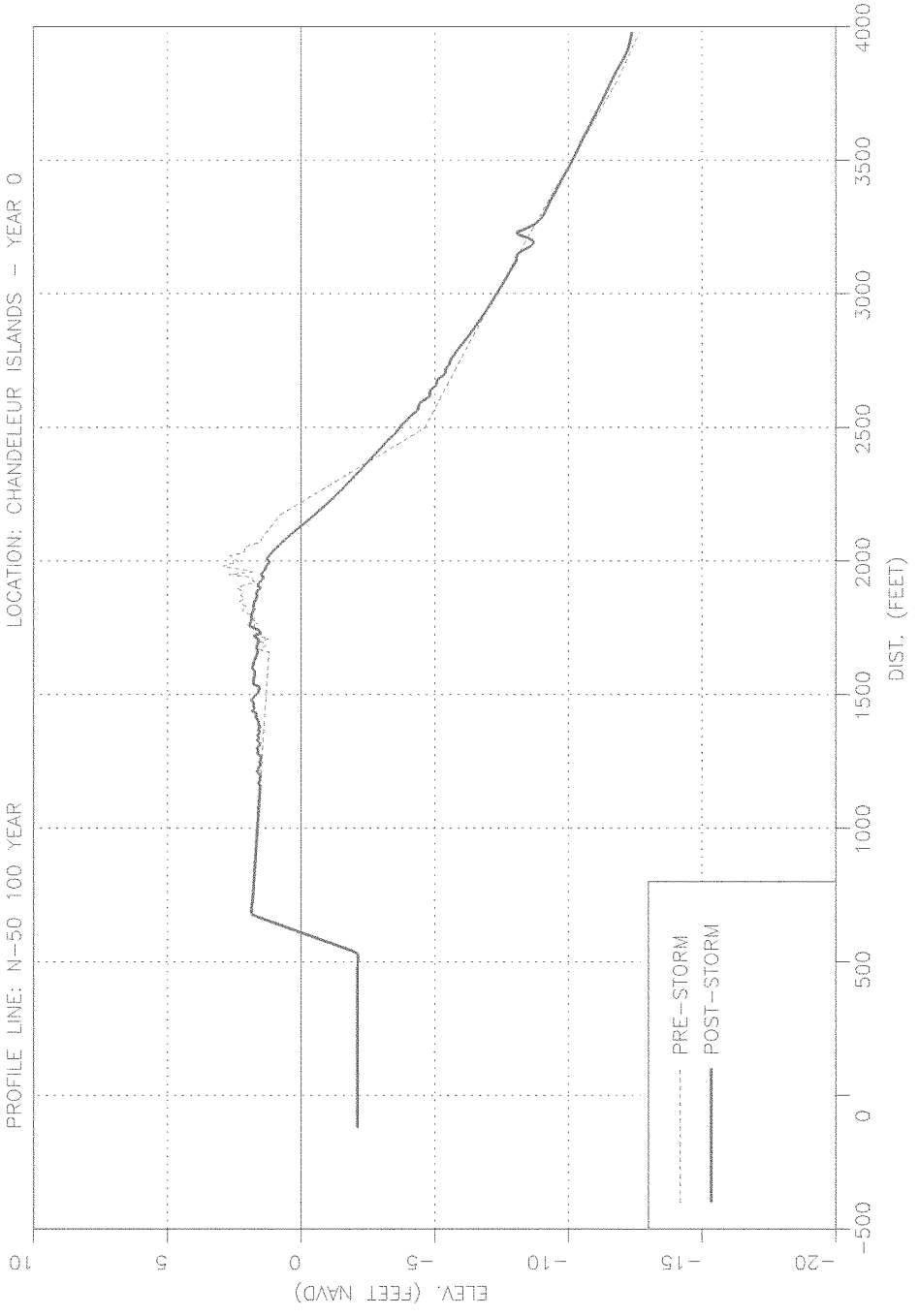

PROFILE LINE: N-50 004 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 0
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

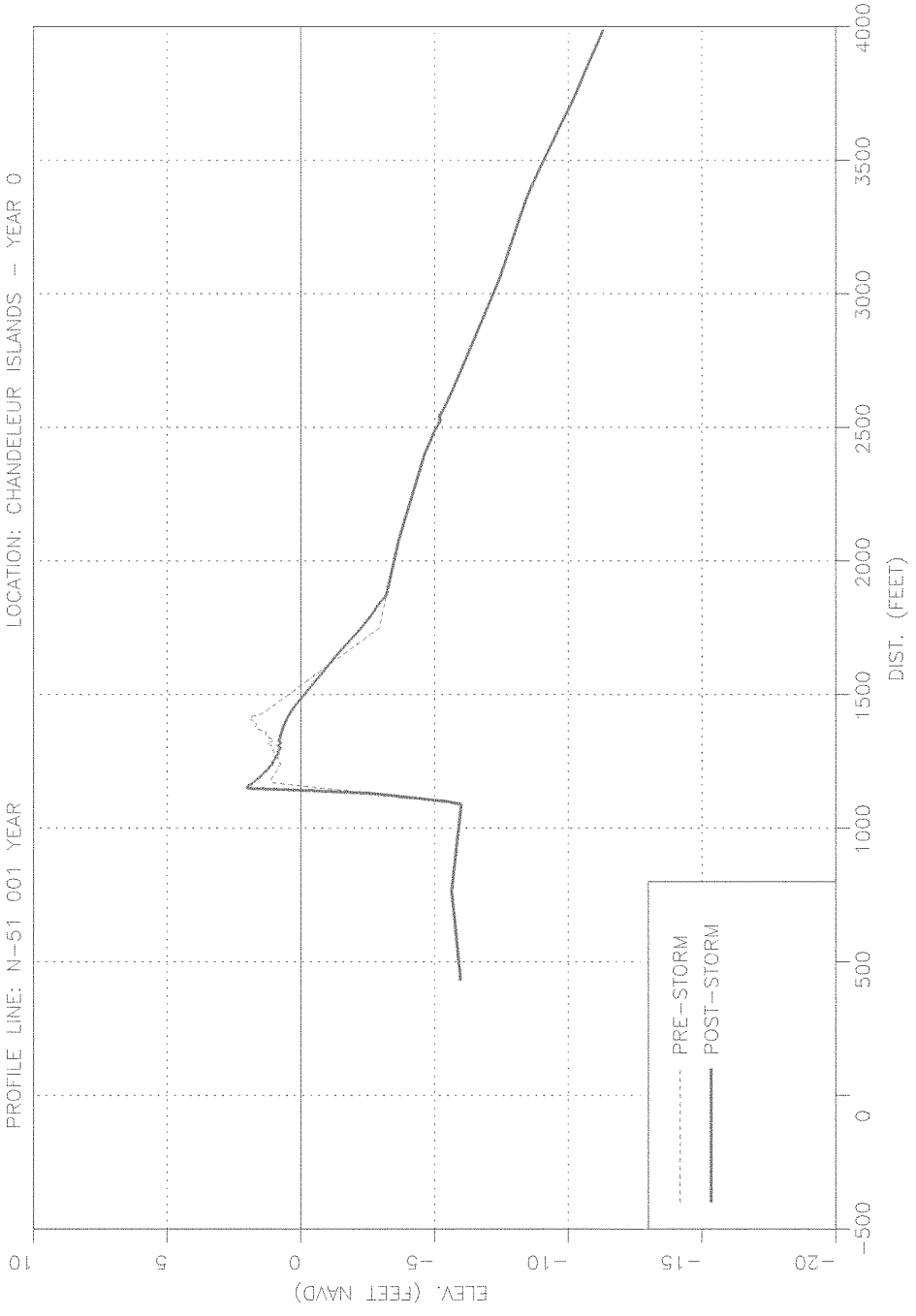

PROFILE LINE: N-50 005 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 0
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

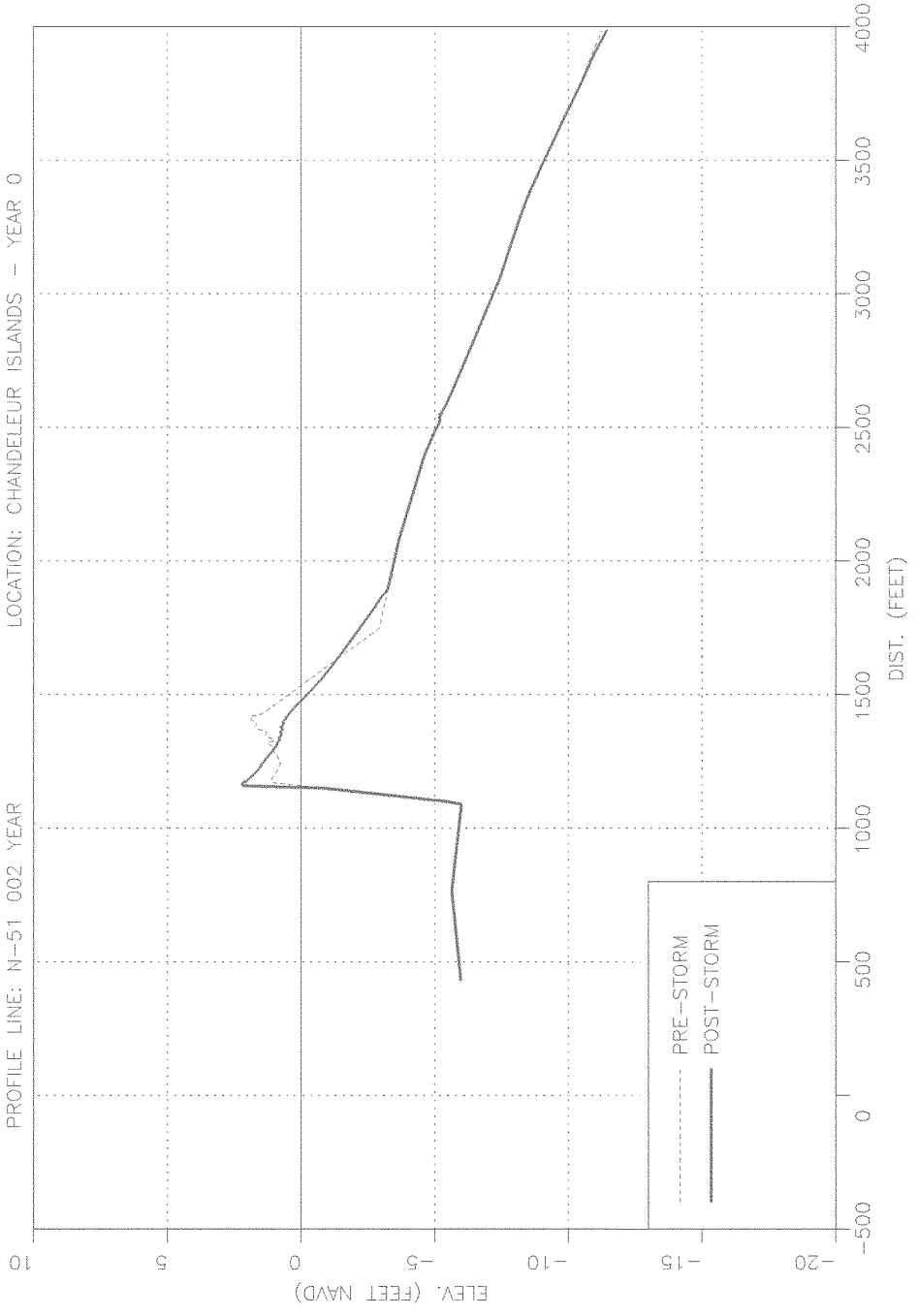

PROFILE LINE: N-50 010 YEAR
LOCATION: CHANDELEUR ISLANDS -- YEAR 0
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

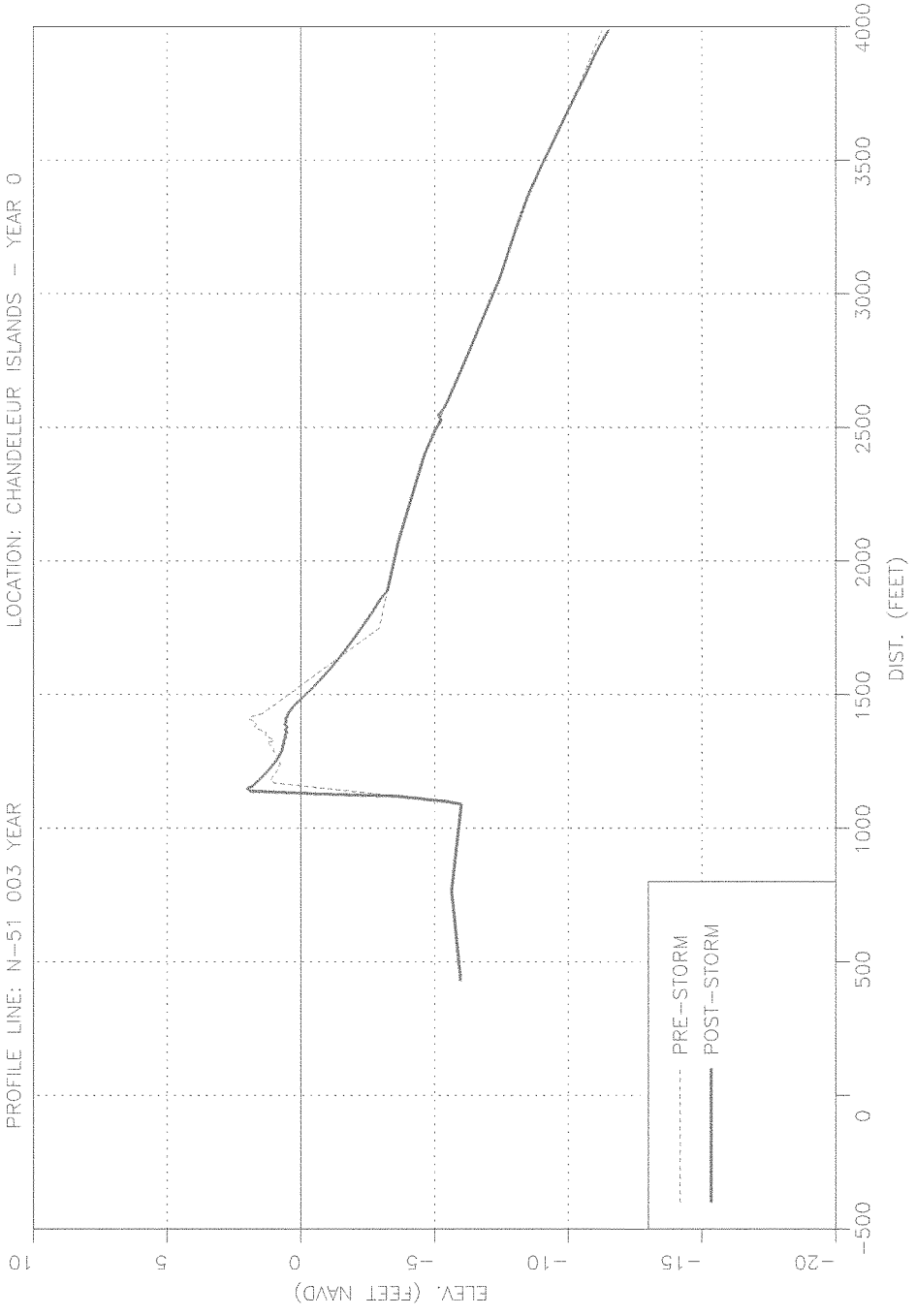

PROFILE LINE: N-50 020 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 0
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

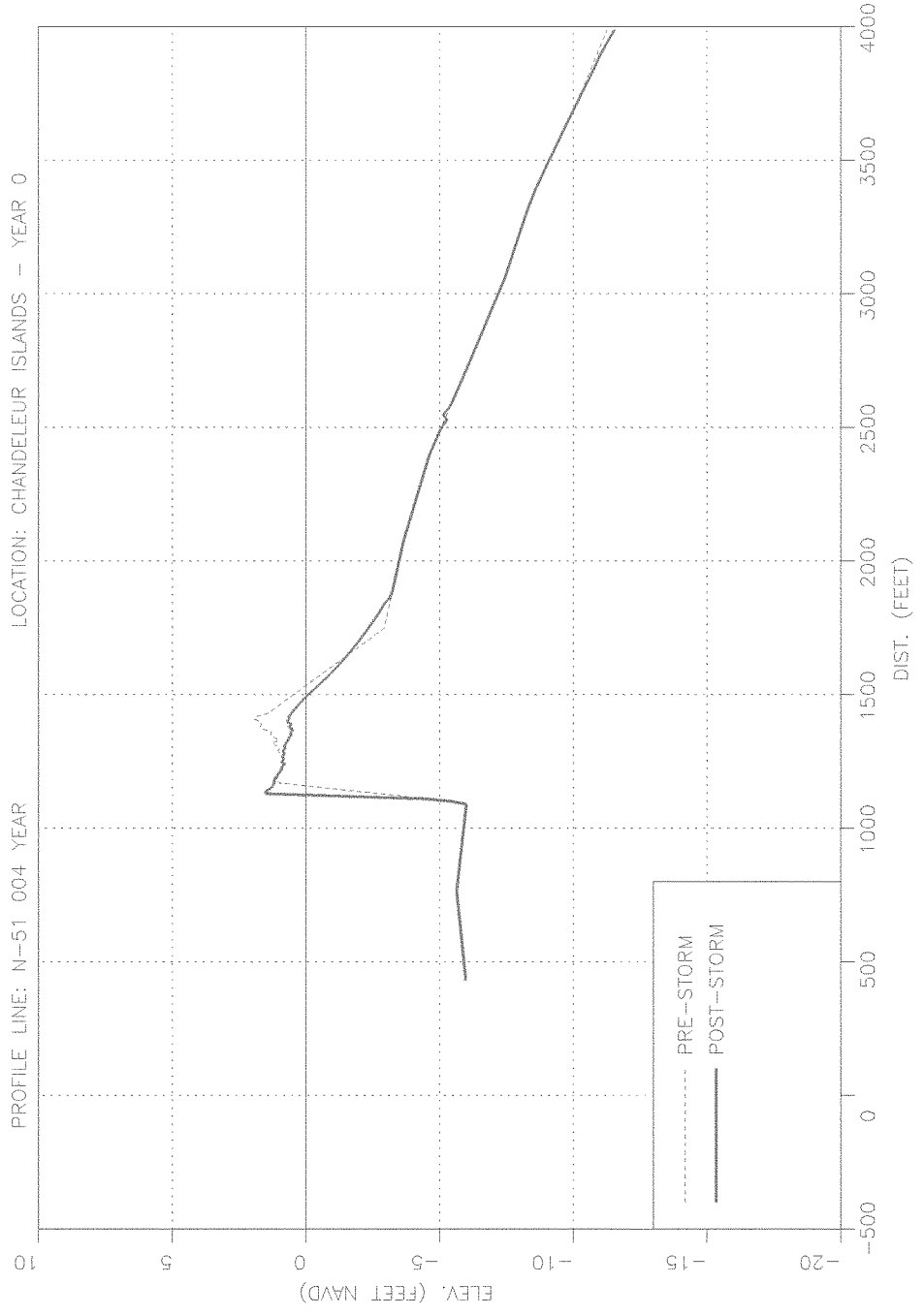

PROFILE LINE: N-50 050 YEAR
LOCATION: CHANDELEUR ISLANDS -- YEAR 0
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000


PROFILE LINE: N-50 100 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 0
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000


PROFILE LINE: N-51 001 YEAR
LOCATION: CHANDELEUR ISLANDS -- YEAR 0
PRE-STORM
POST-STORM
ELEV. (FEET NAVD)
DIST. (FEET)
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

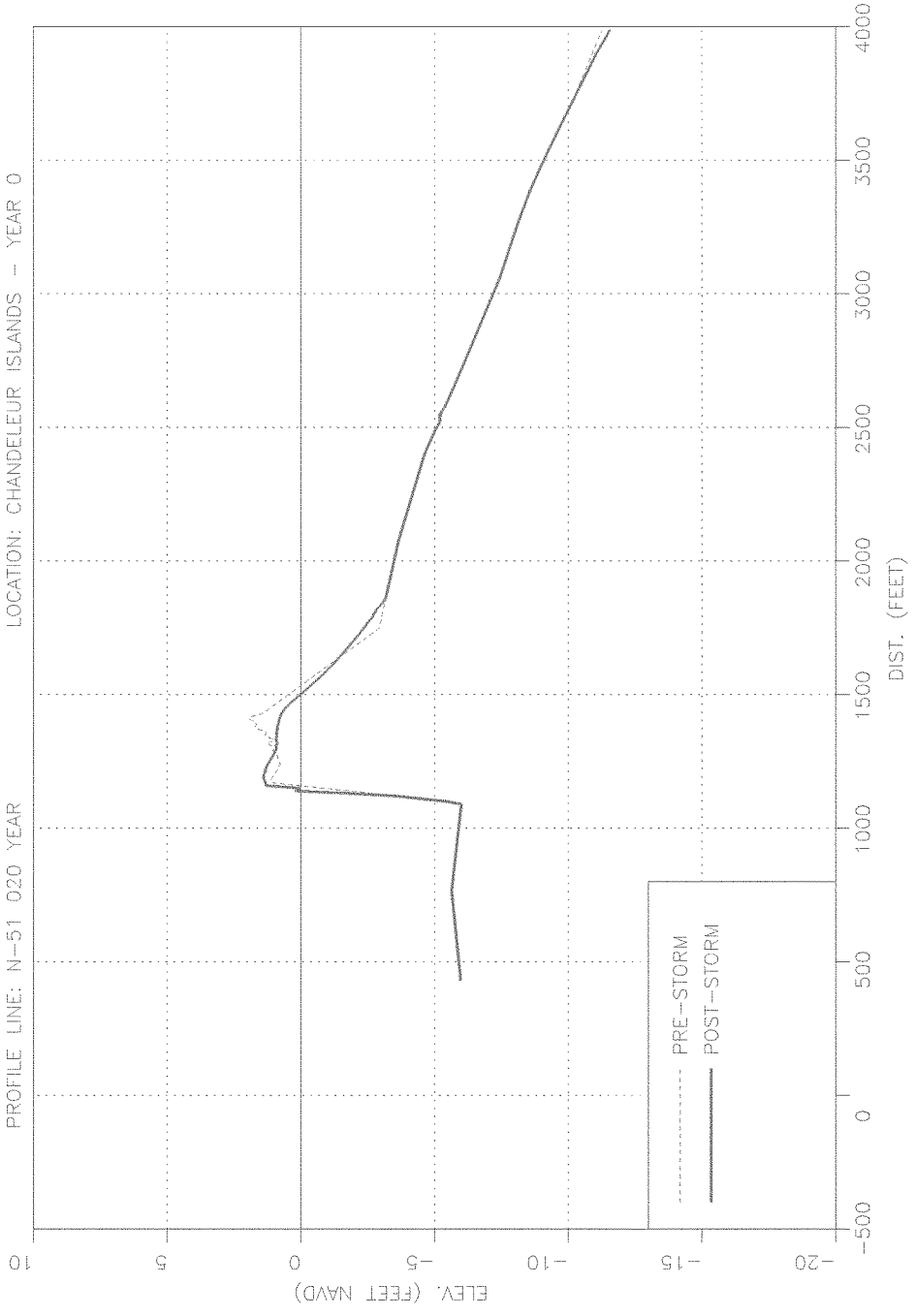

PROFILE LINE: N-51 002 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 0
PRE-STORM
POST-STORM
ELEV. (FEET NAVD)
DIST. (FEET)
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

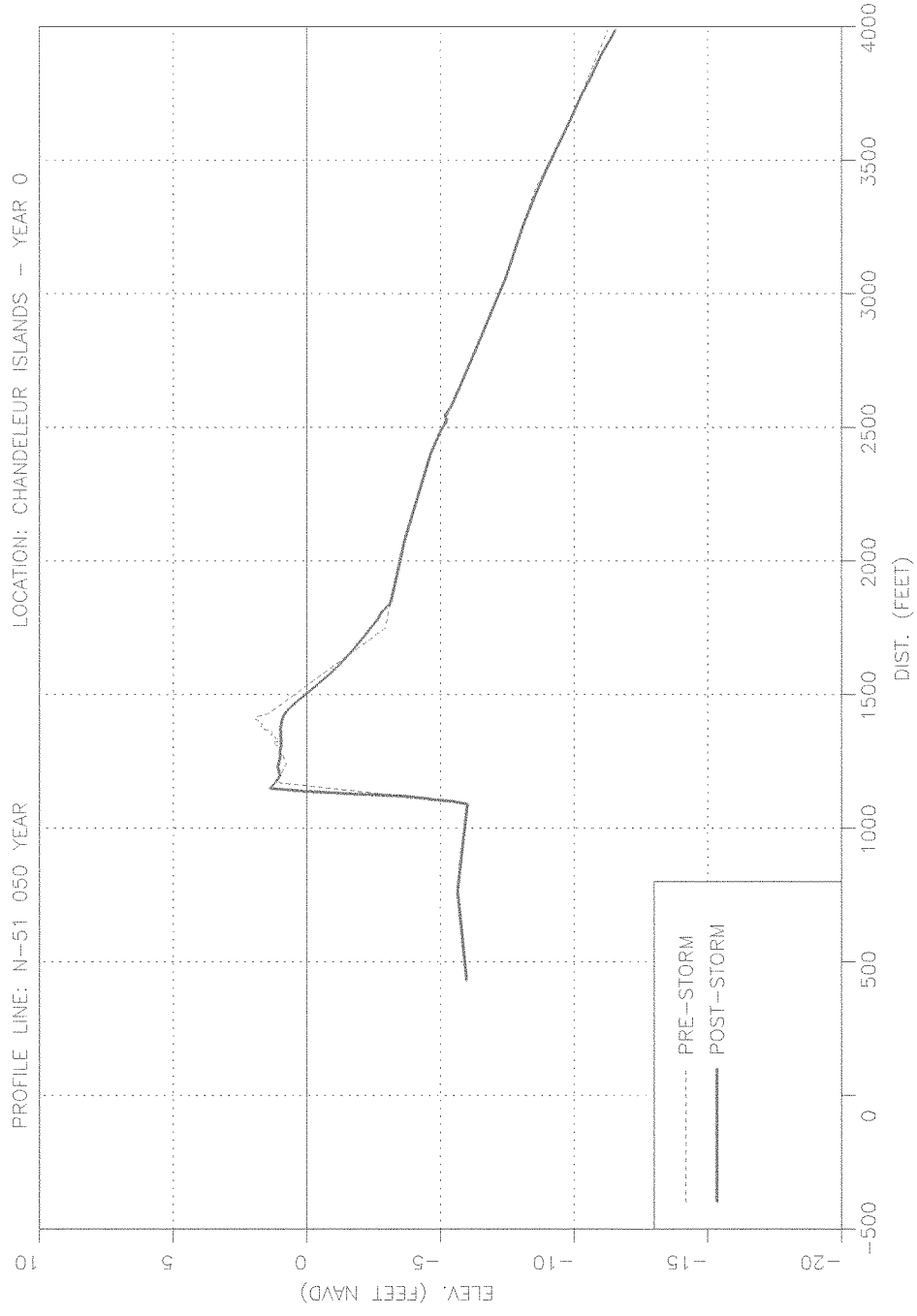

PROFILE LINE: N-51 003 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 0
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

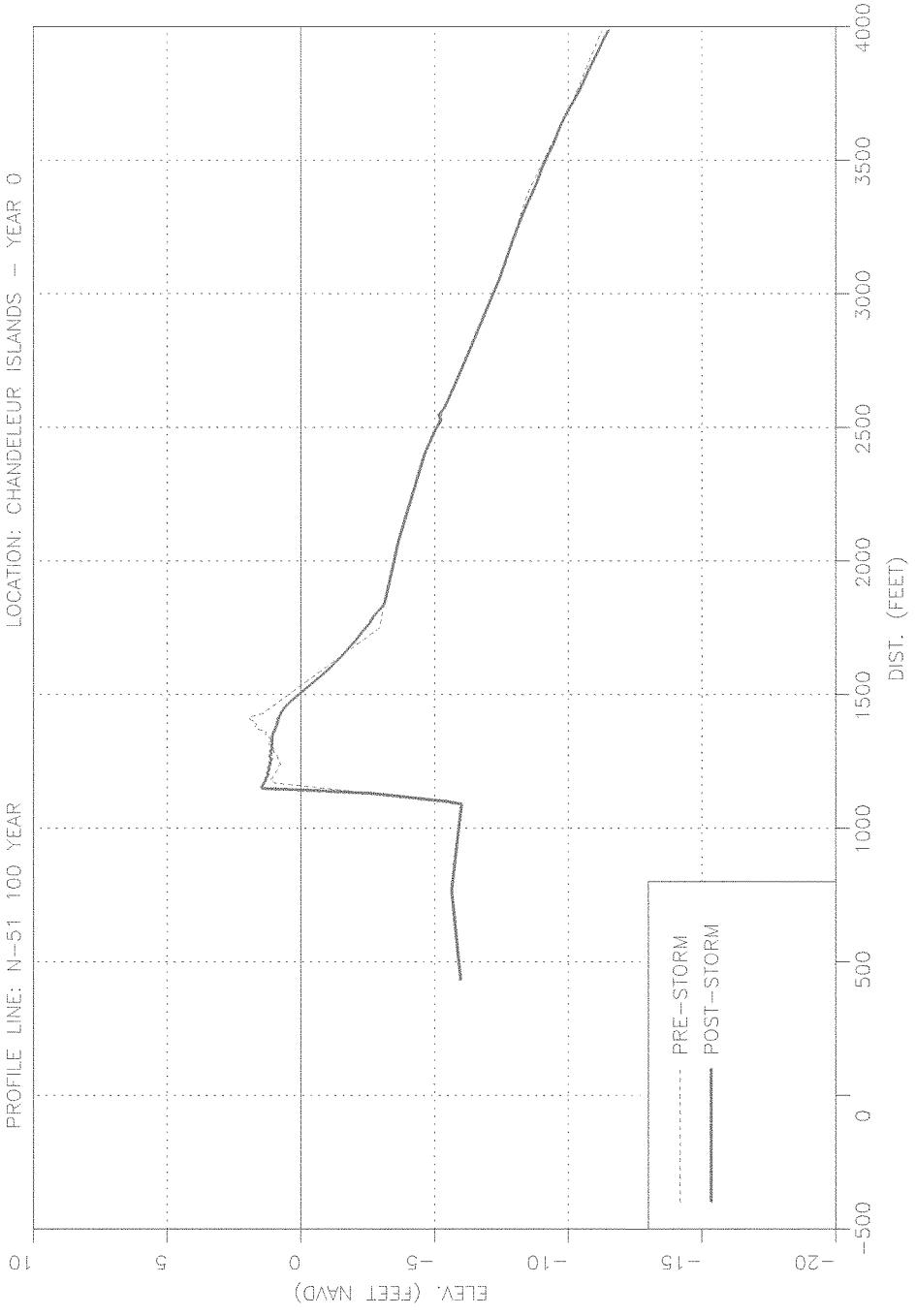

PROFILE LINE: N-51 004 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 0
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

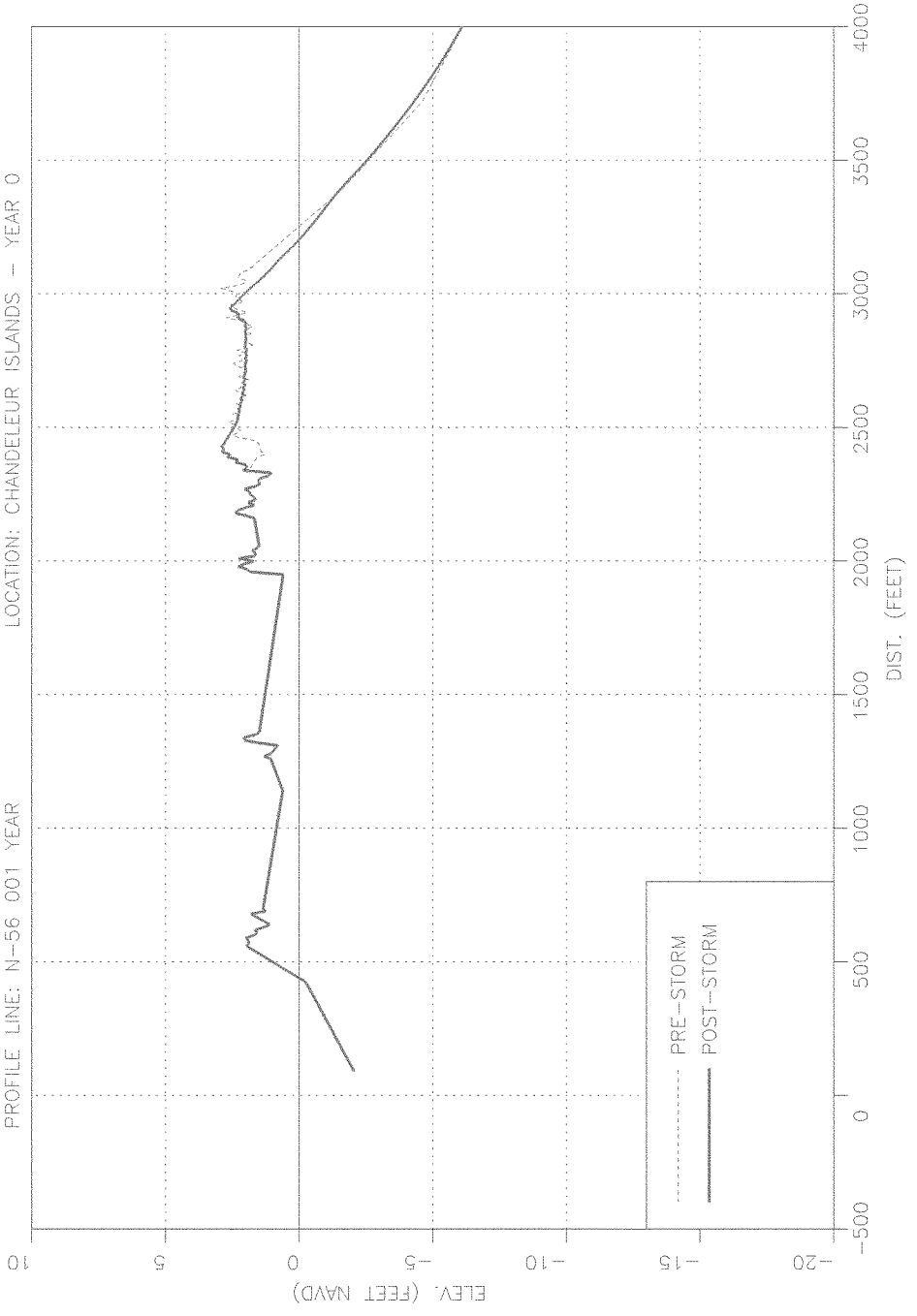

PROFILE LINE: N-51 005 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 0
PRE-STORM
POST-STORM
ELEV. (FEET NAVD)
DIST. (FEET)
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

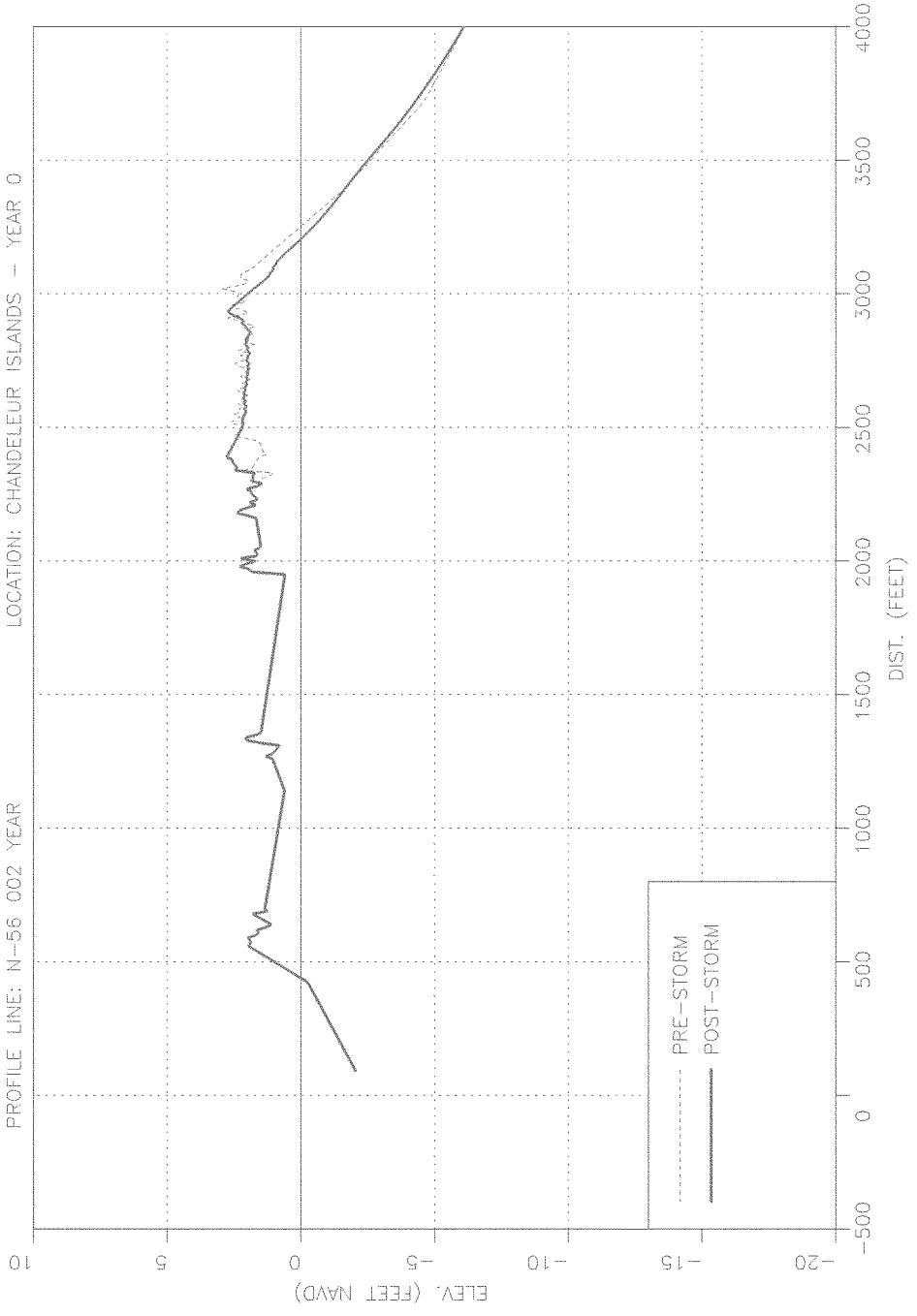

PROFILE LINE: N-51 010 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 0
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

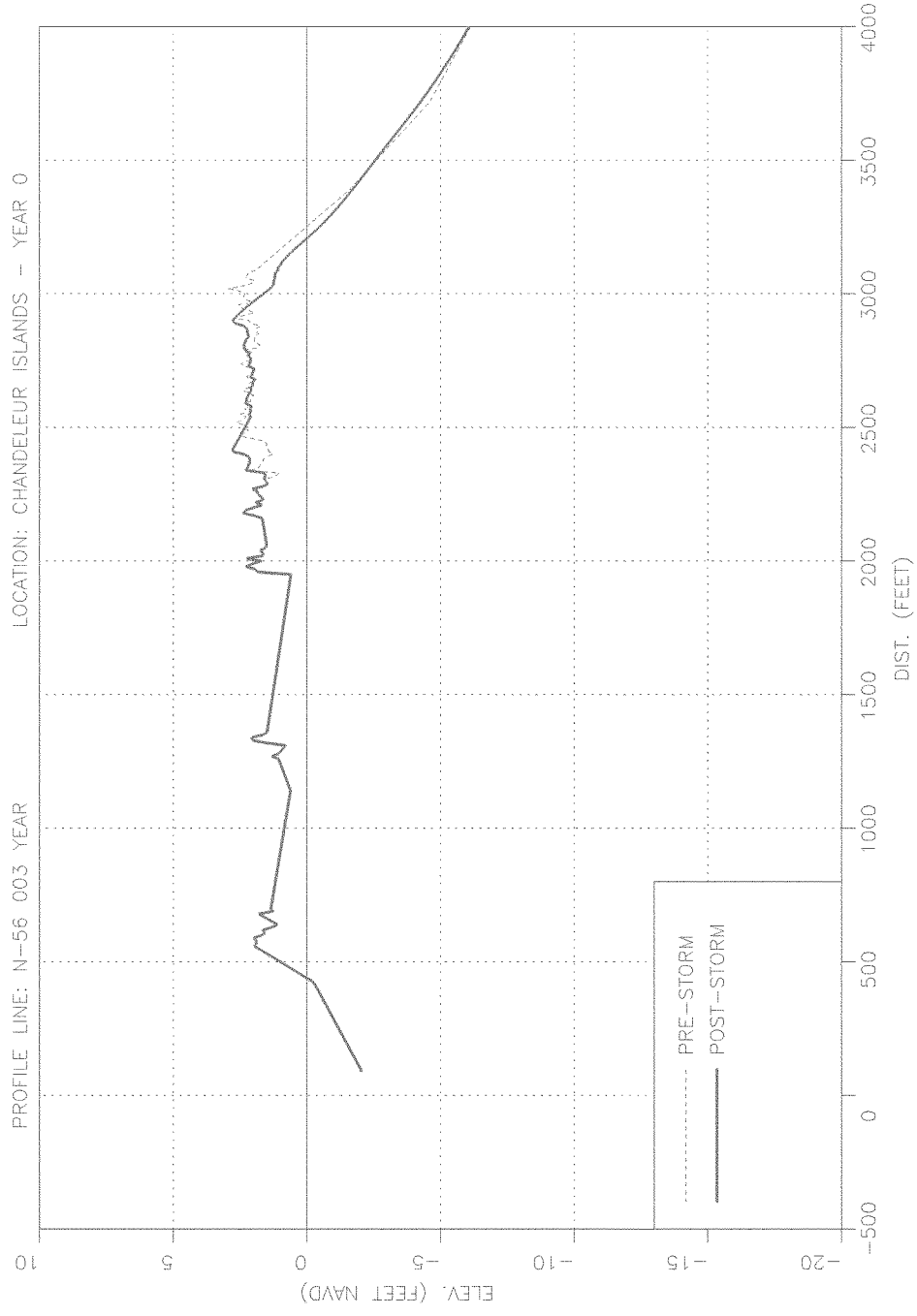

PROFILE LINE: N-51 020 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 0
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

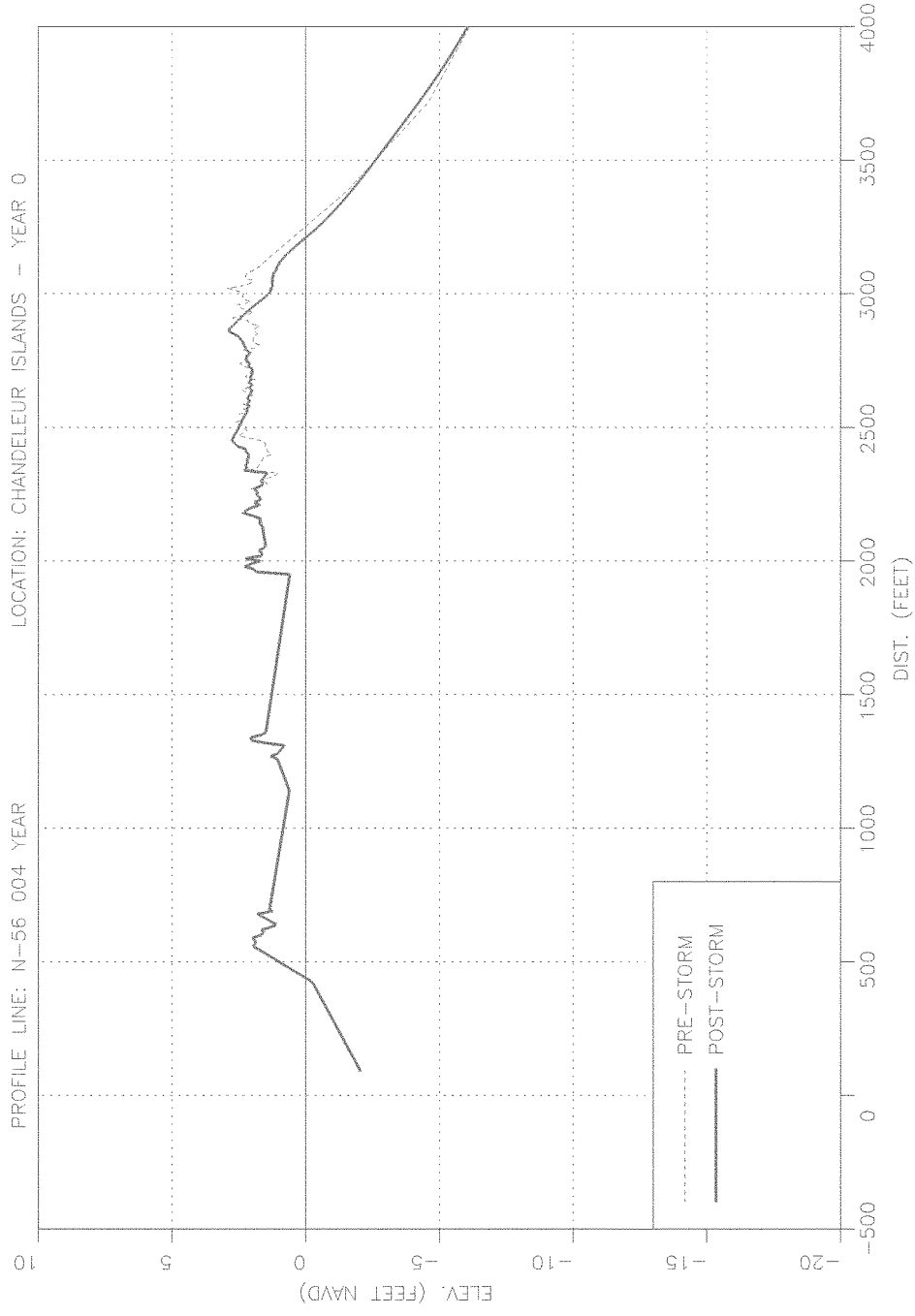

PROFILE LINE: N-51 050 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 0
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

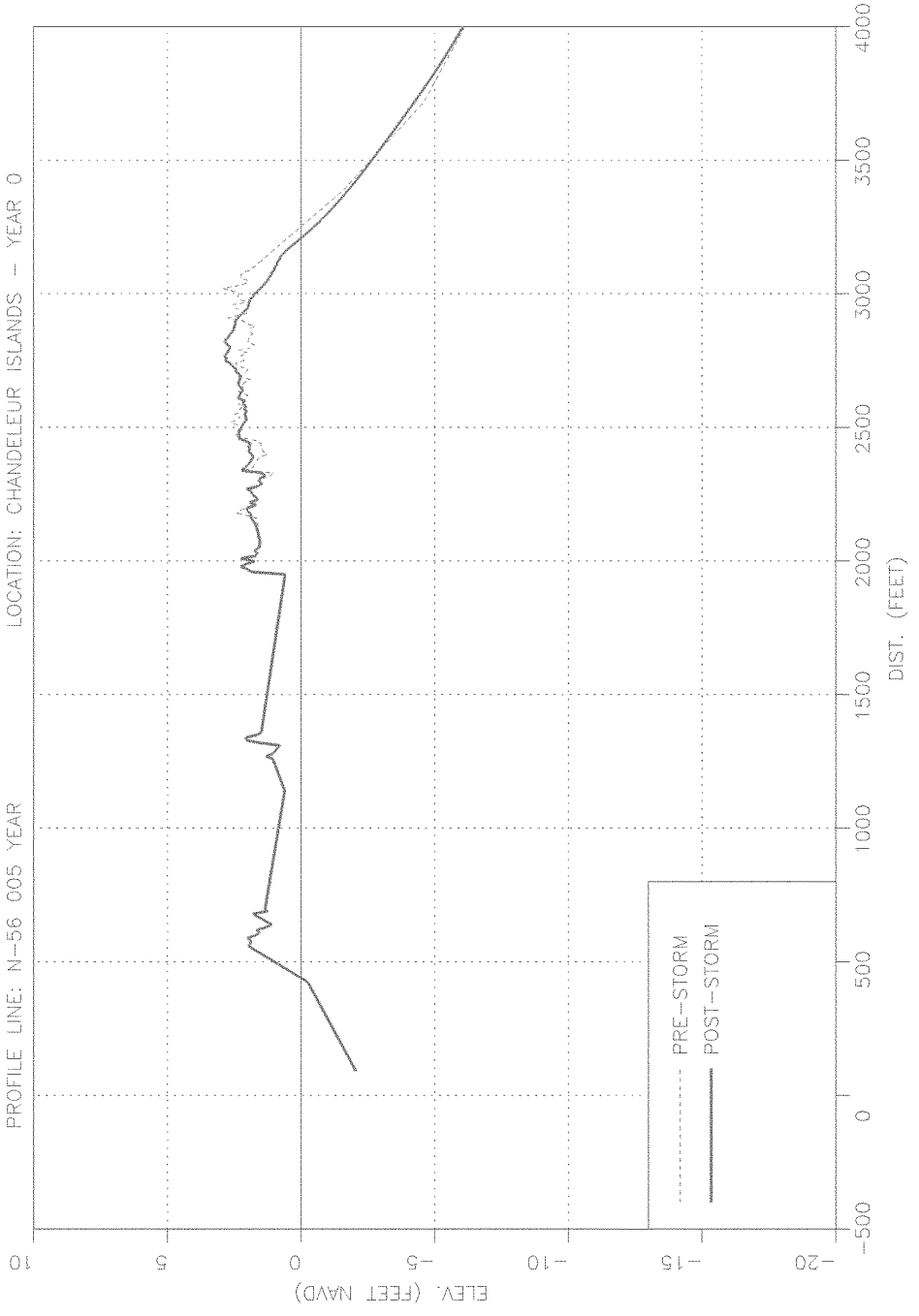

PROFILE LINE: N-51 100 YEAR
LOCATION: CHANDELEUR ISLANDS -- YEAR 0
ELEV. (FEET NAVD)
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000
DIST. (FEET)
PRE-STORM
POST-STORM

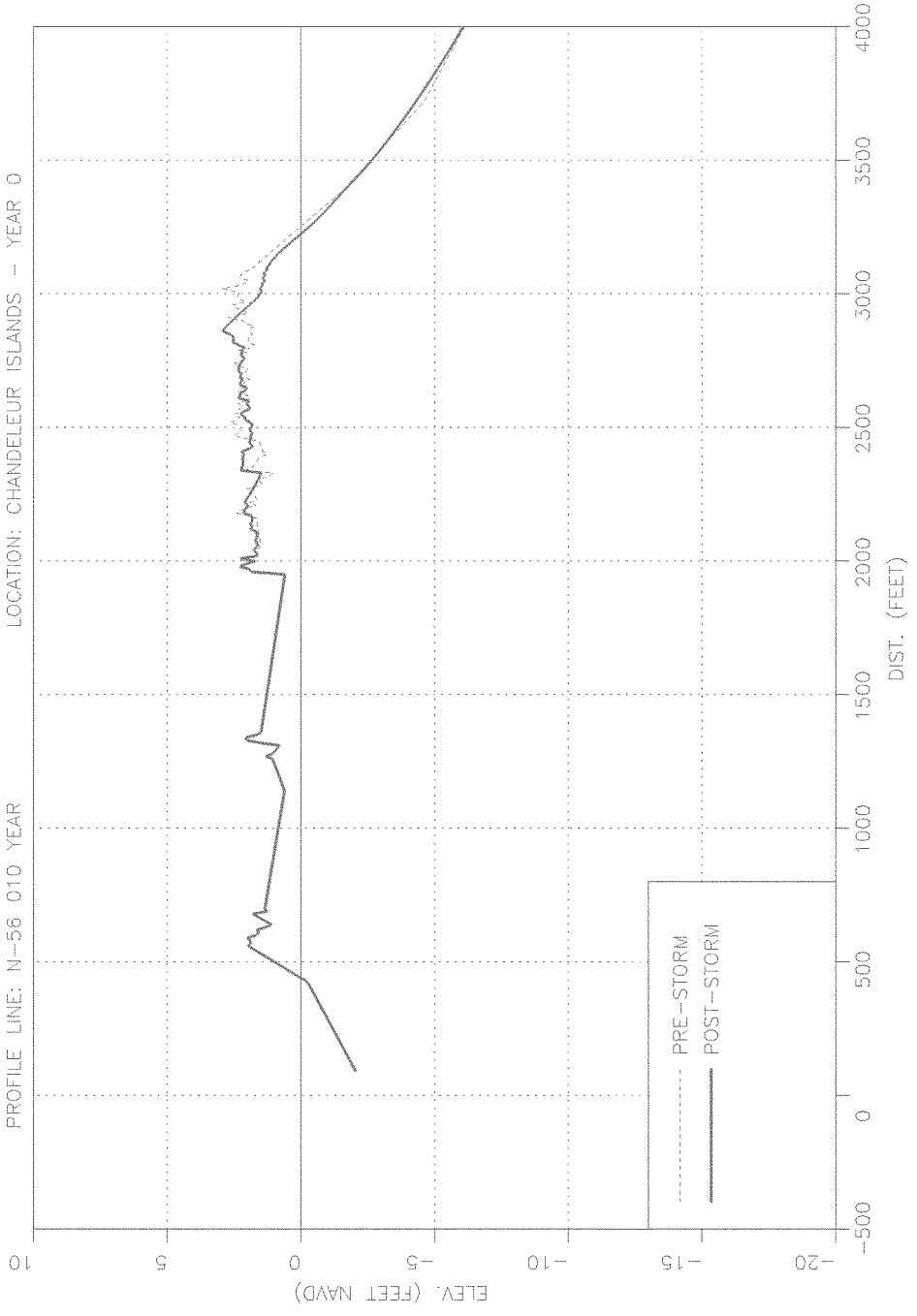

PROFILE LINE: N-56 001 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 0
PRE-STORM
POST-STORM
ELEV. (FEET NAVD)
DIST. (FEET)
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

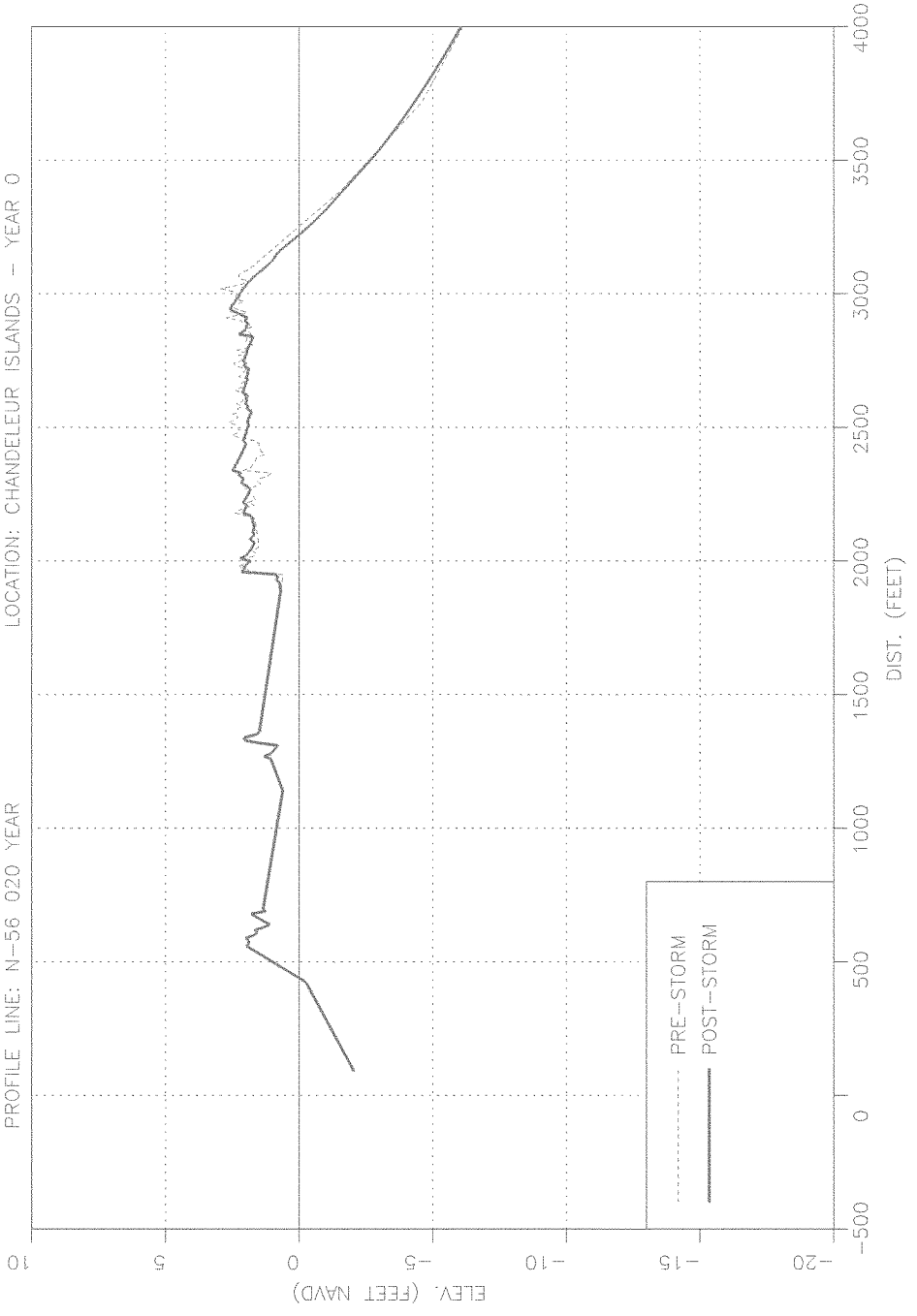

PROFILE LINE: N-56 002 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 0
PRE-STORM
POST-STORM
ELEV. (FEET NAVD)
DIST. (FEET)
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

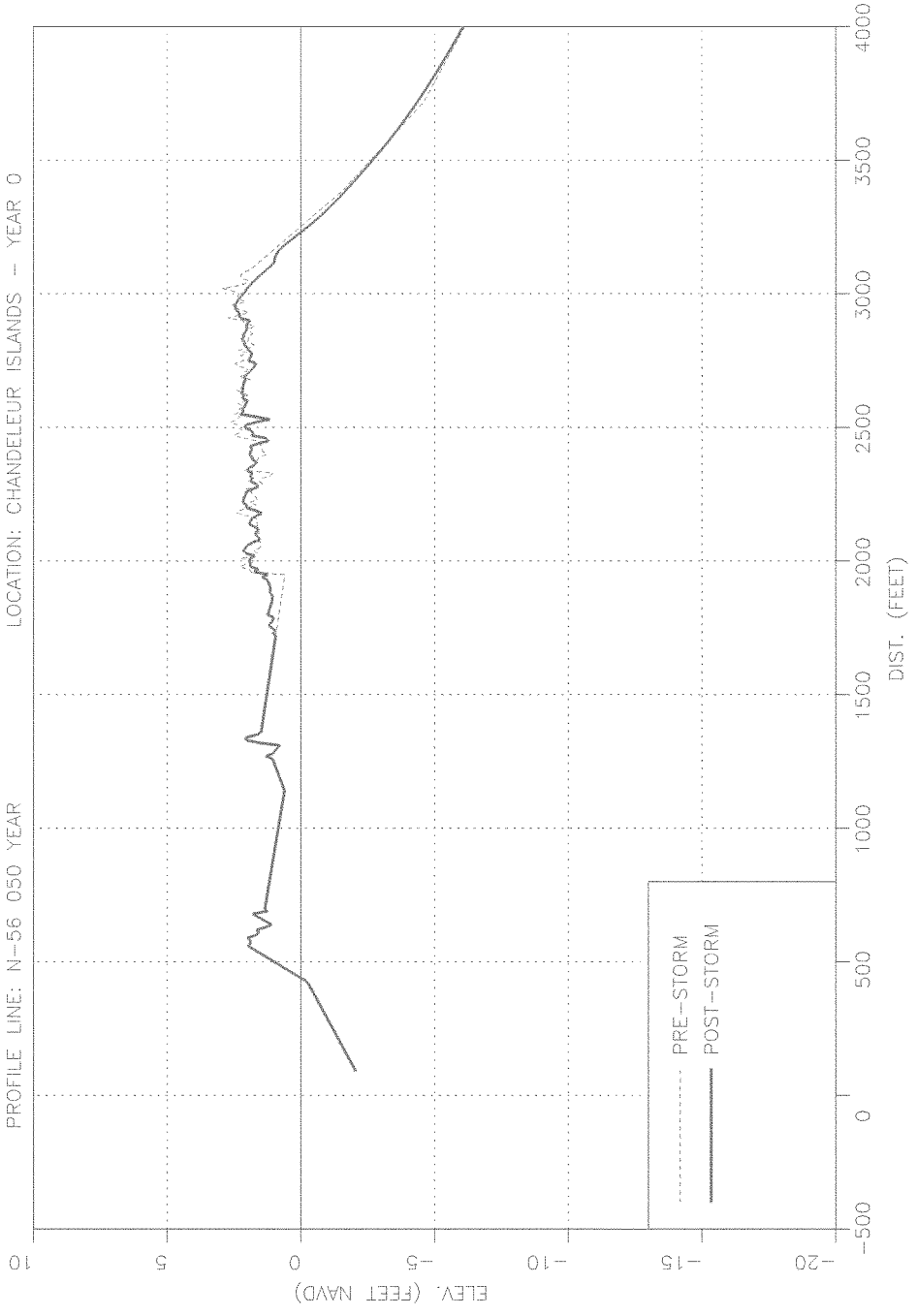

PROFILE LINE: N-56 003 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 0
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

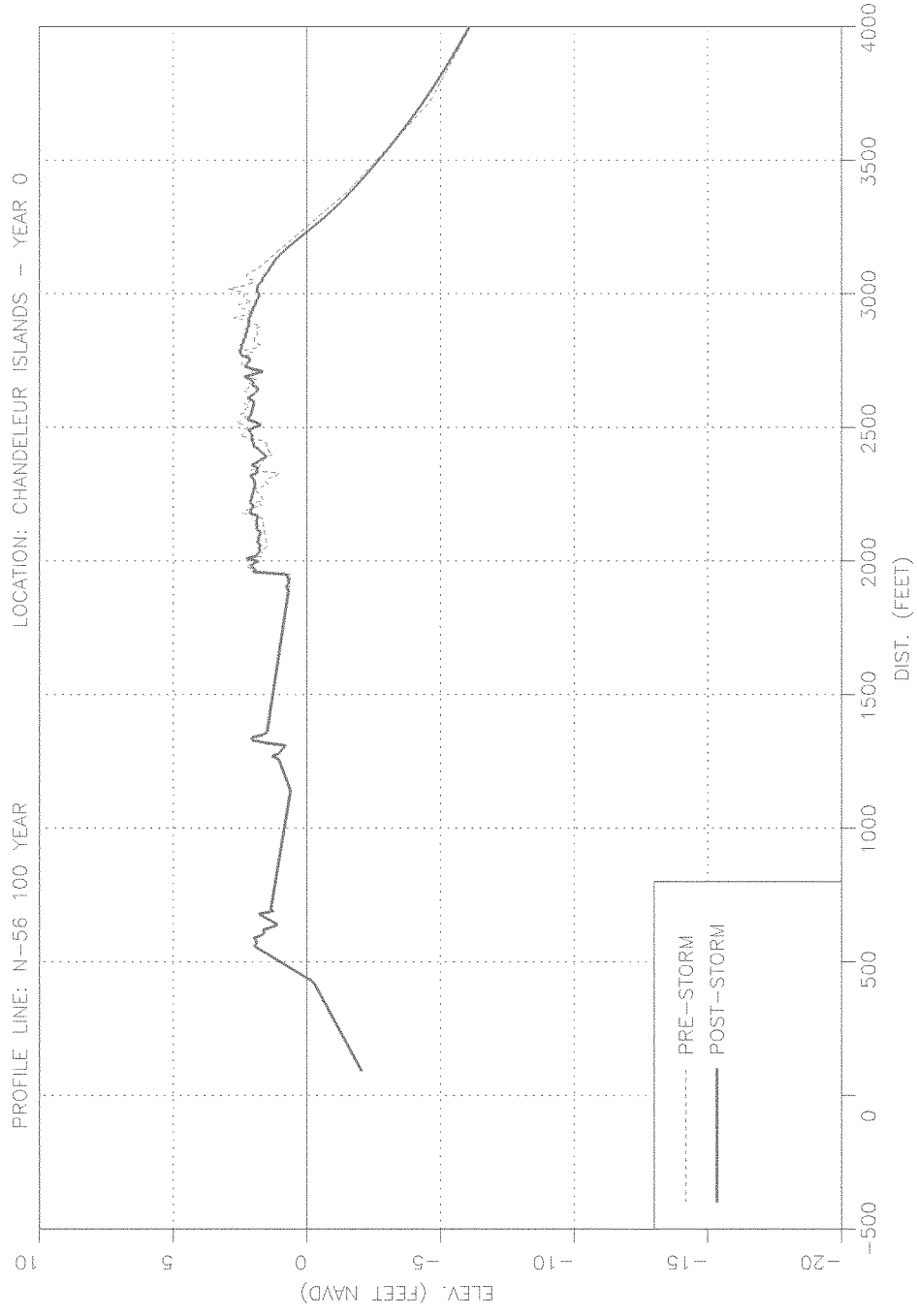

PROFILE LINE: N-56 004 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 0
PRE-STORM
POST-STORM
ELEV. (FEET NAVD)
DIST. (FEET)
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

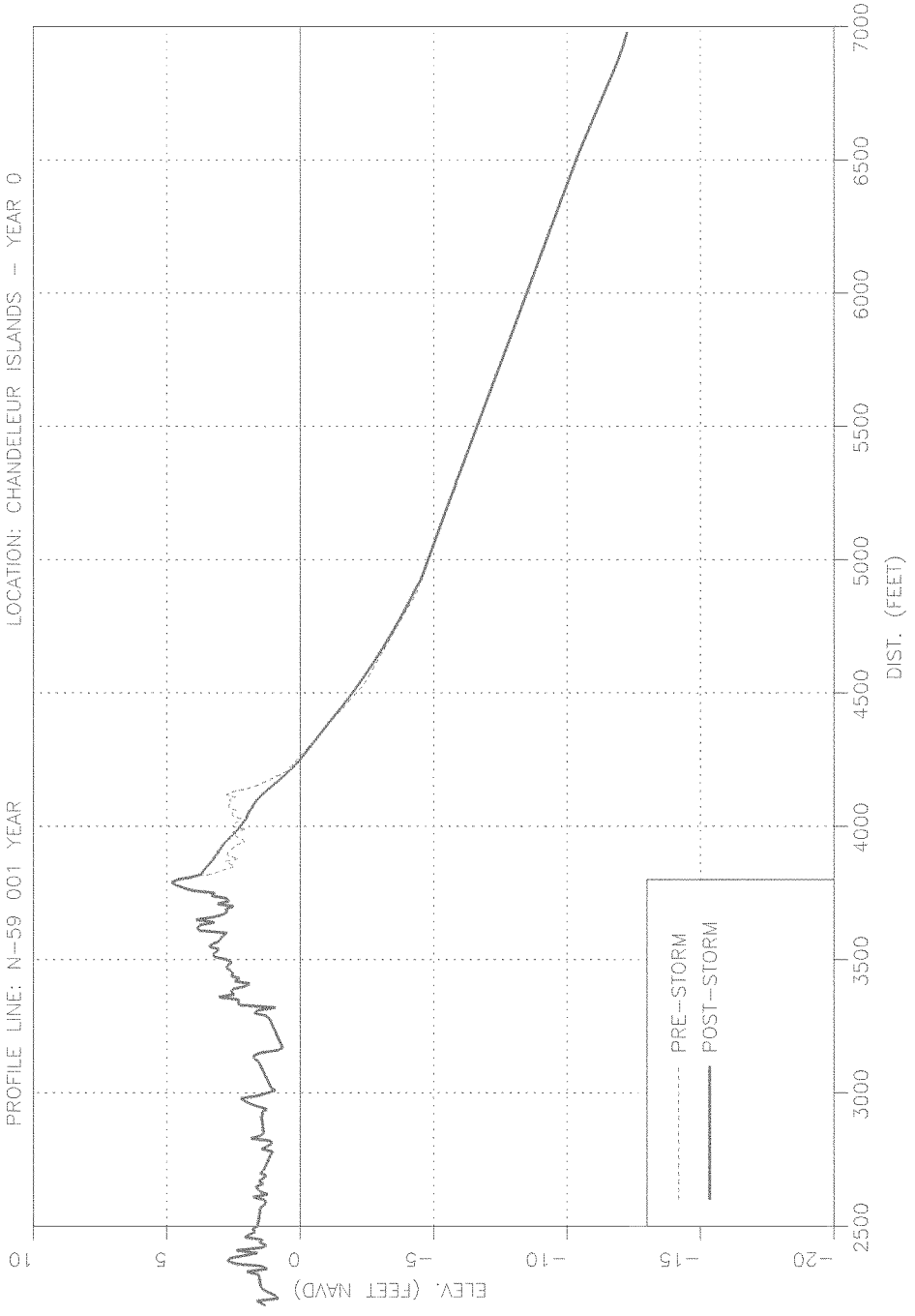

PROFILE LINE: N-56 005 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 0
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

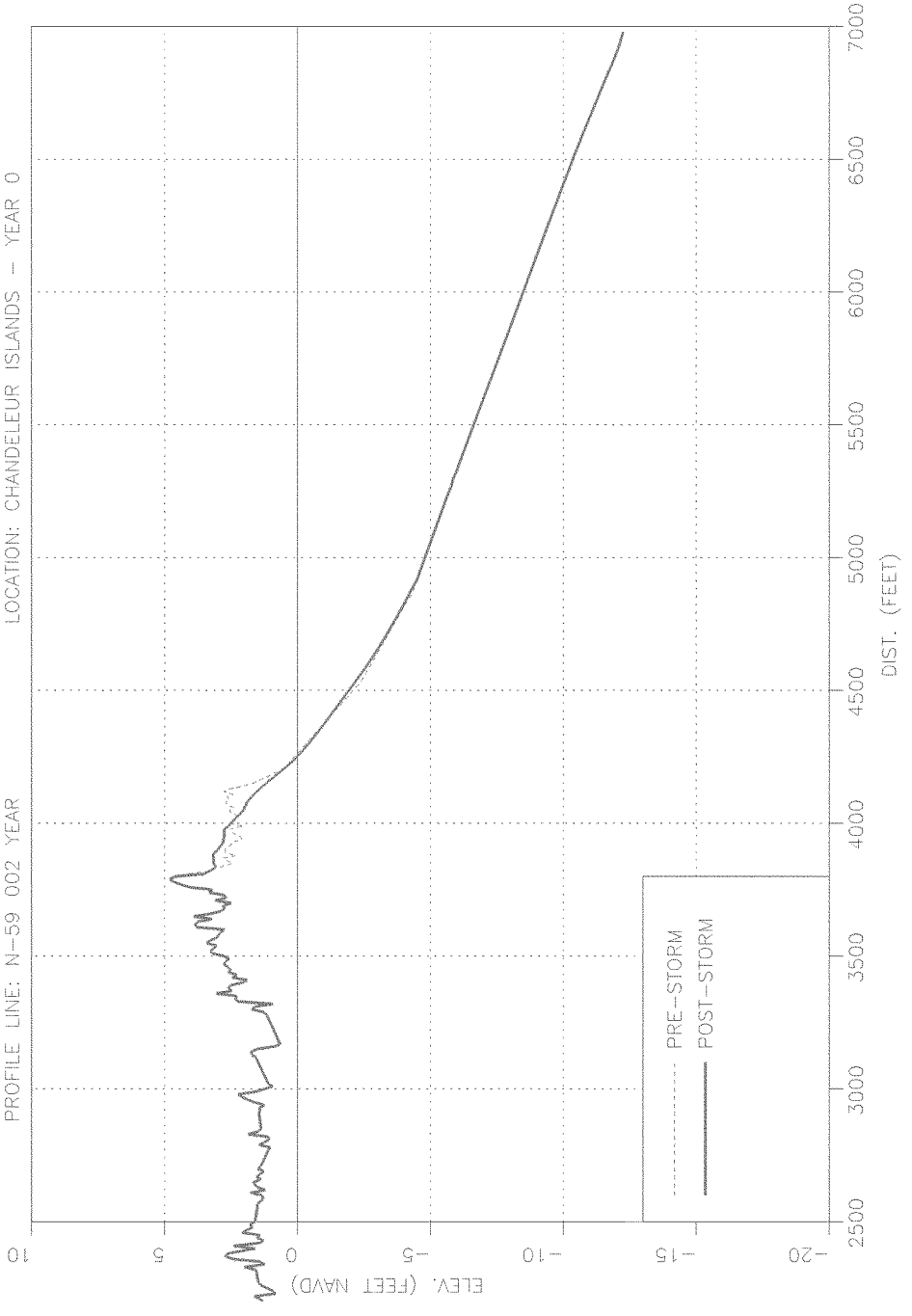

PROFILE LINE: N-56 010 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 0
PRE-STORM
POST-STORM
ELEV. (FEET NAVD)
DIST. (FEET)
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

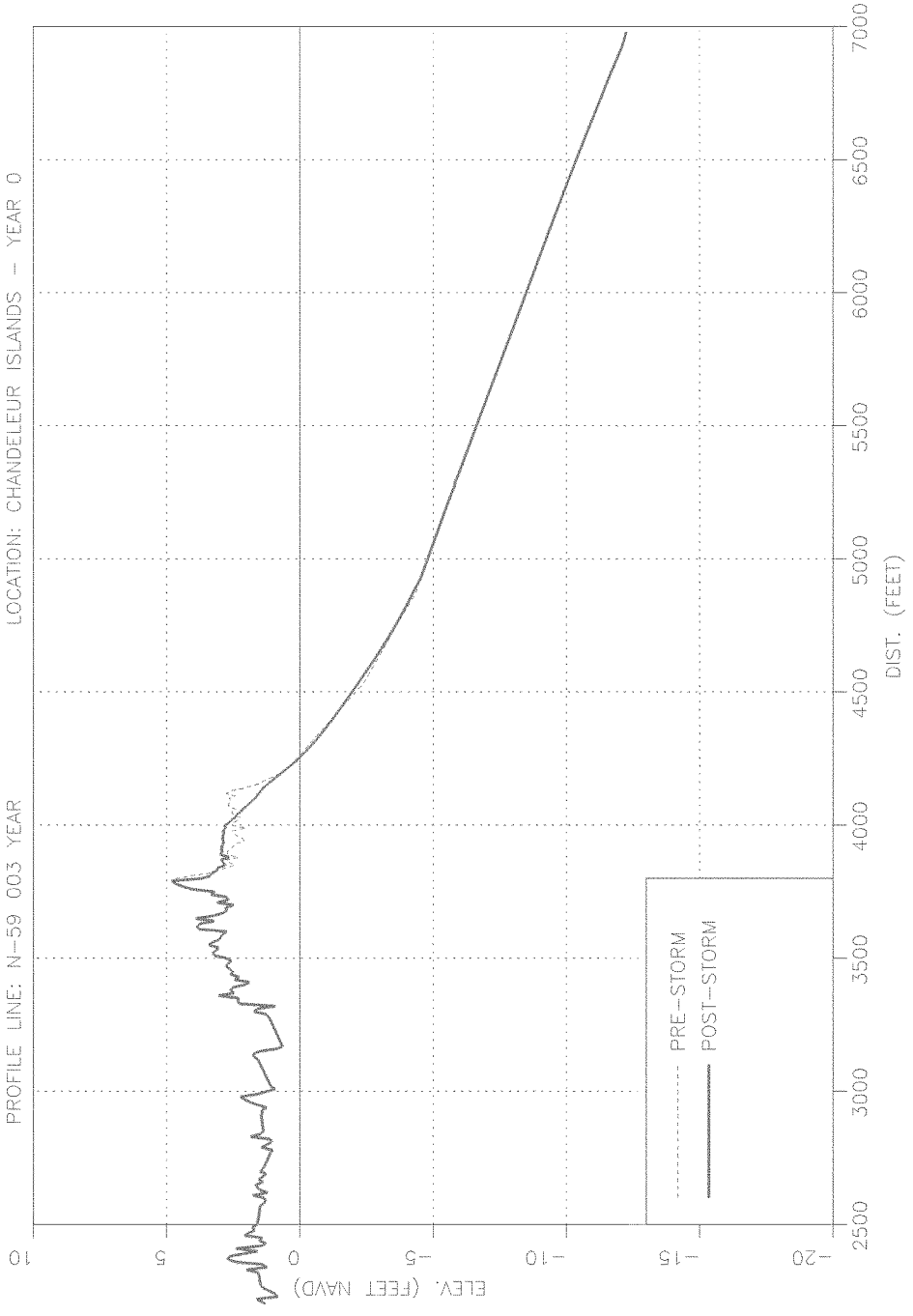

PROFILE LINE: N-56 020 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 0
PRE-STORM
POST-STORM
ELEV. (FEET NAVD)
DIST. (FEET)
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

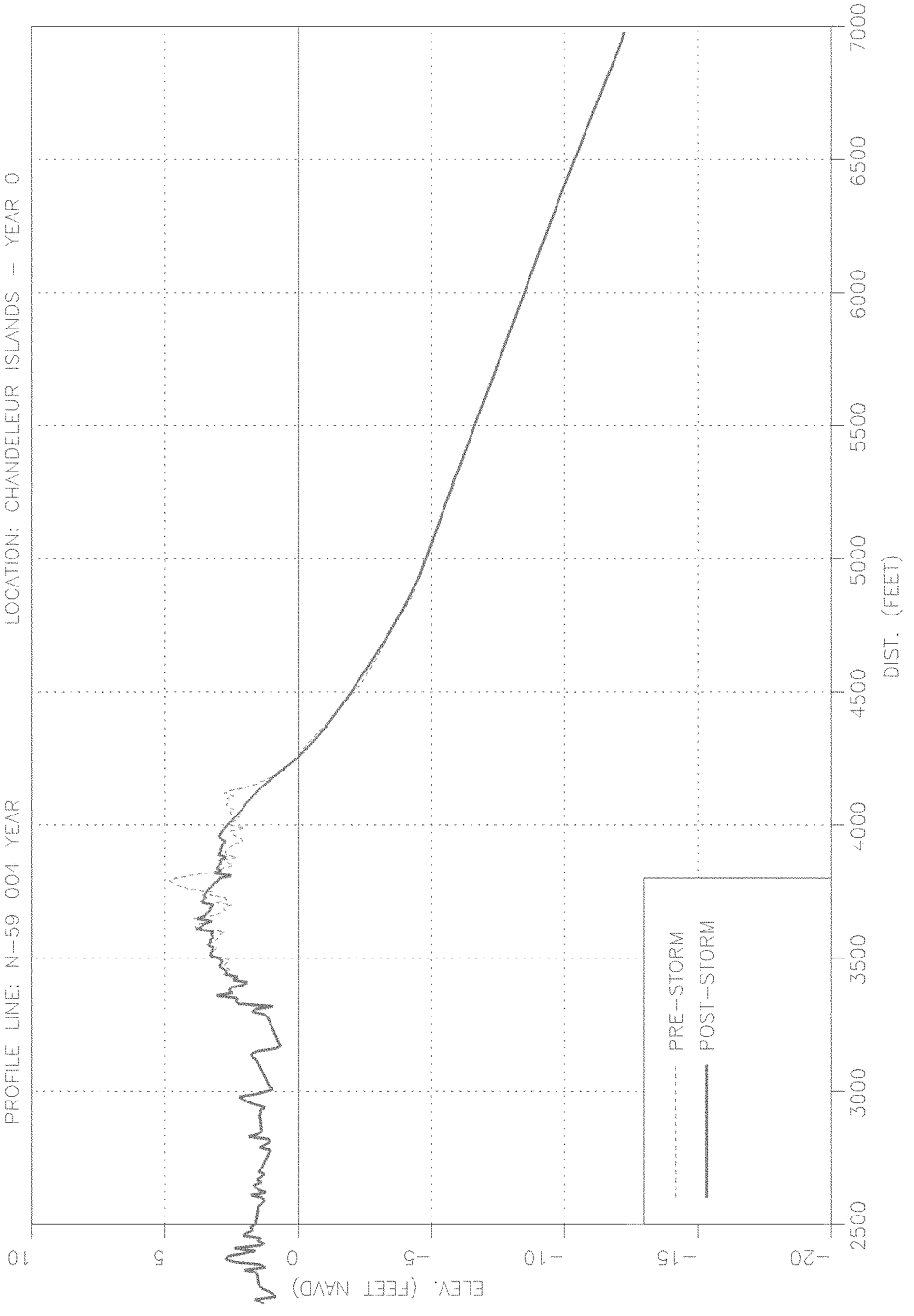

PROFILE LINE: N-56 050 YEAR
LOCATION: CHANDELEUR ISLANDS -- YEAR 0
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

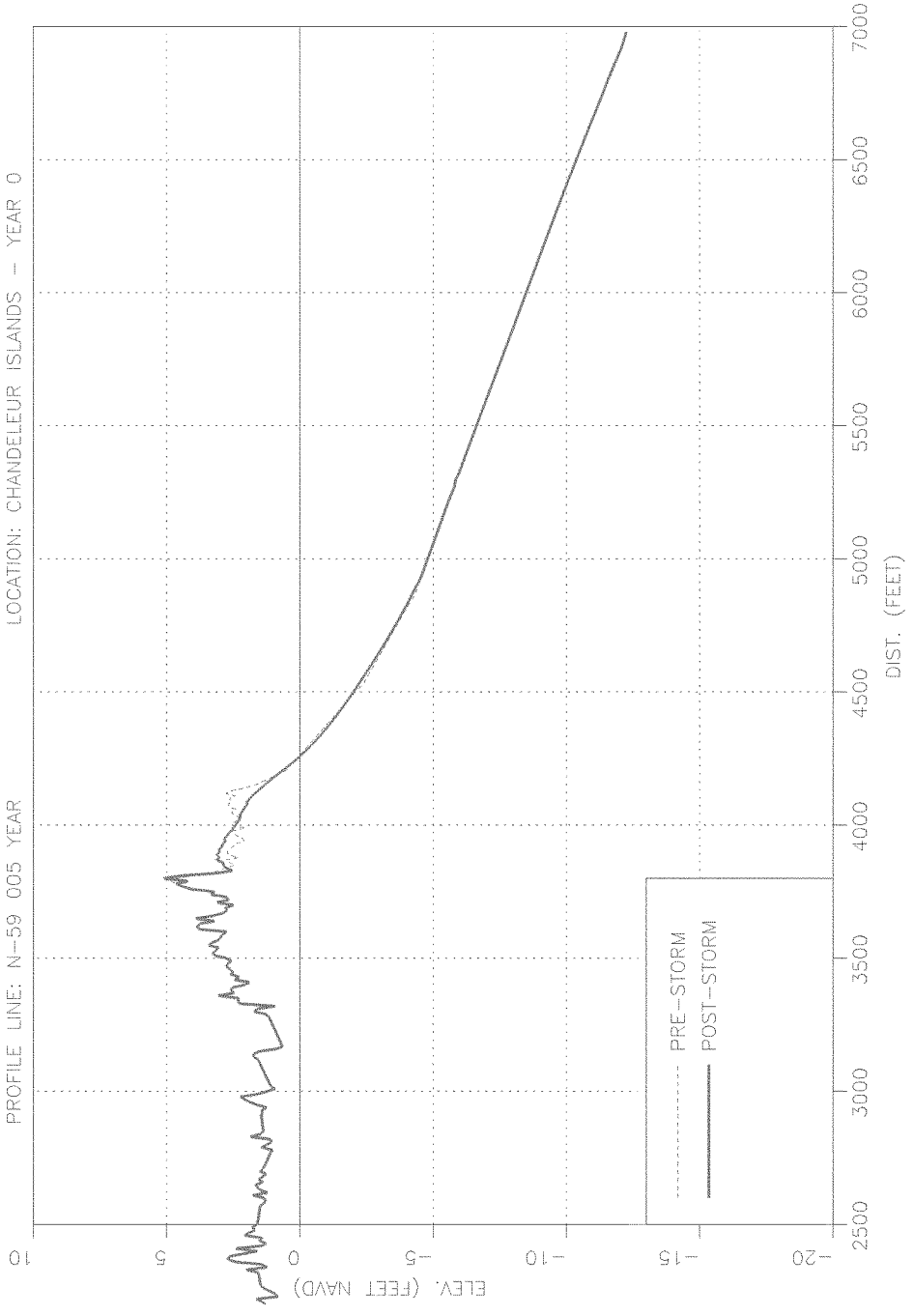

PROFILE LINE: N-56 100 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 0
PRE-STORM
POST-STORM
ELEV. (FEET NAVD)
DIST. (FEET)
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

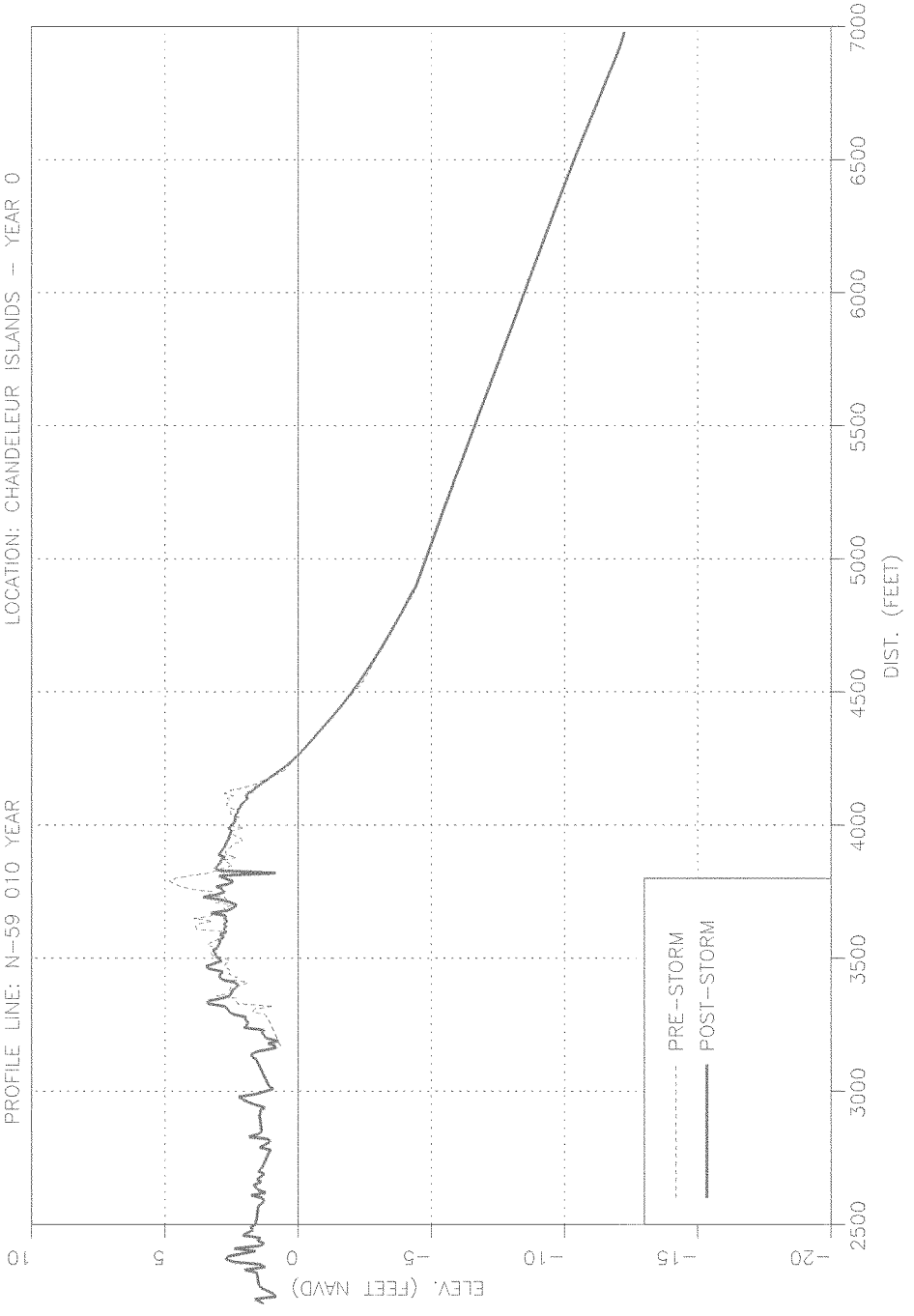

PROFILE LINE: N-59 001 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 0
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
2500
3000
3500
4000
4500
5000
5500
6000
6500
7000

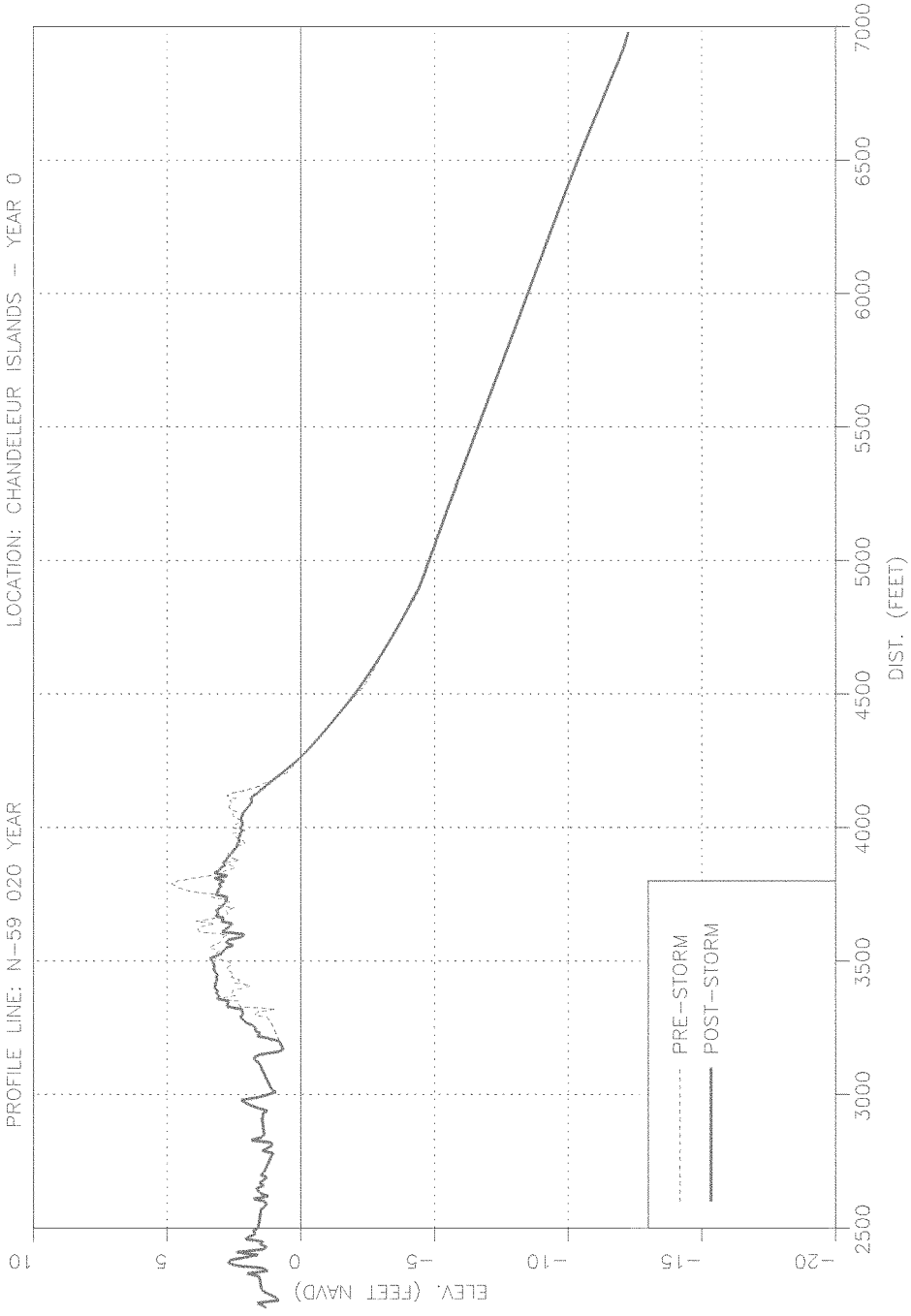

PROFILE LINE: N-59 002 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 0
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
2500
3000
3500
4000
4500
5000
5500
6000
6500
7000

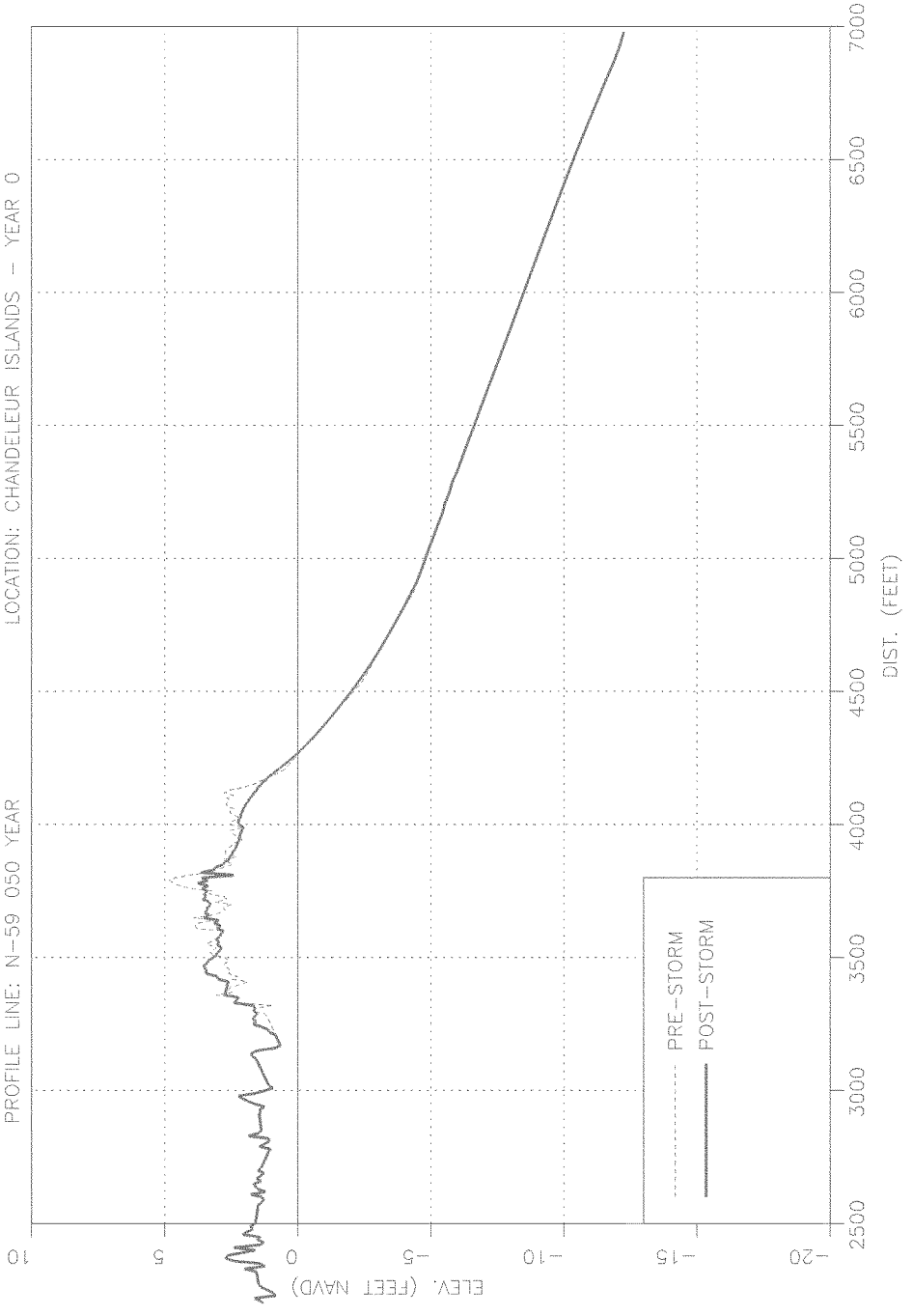

PROFILE LINE: N-59 003 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 0
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
2500
3000
3500
4000
4500
5000
5500
6000
6500
7000

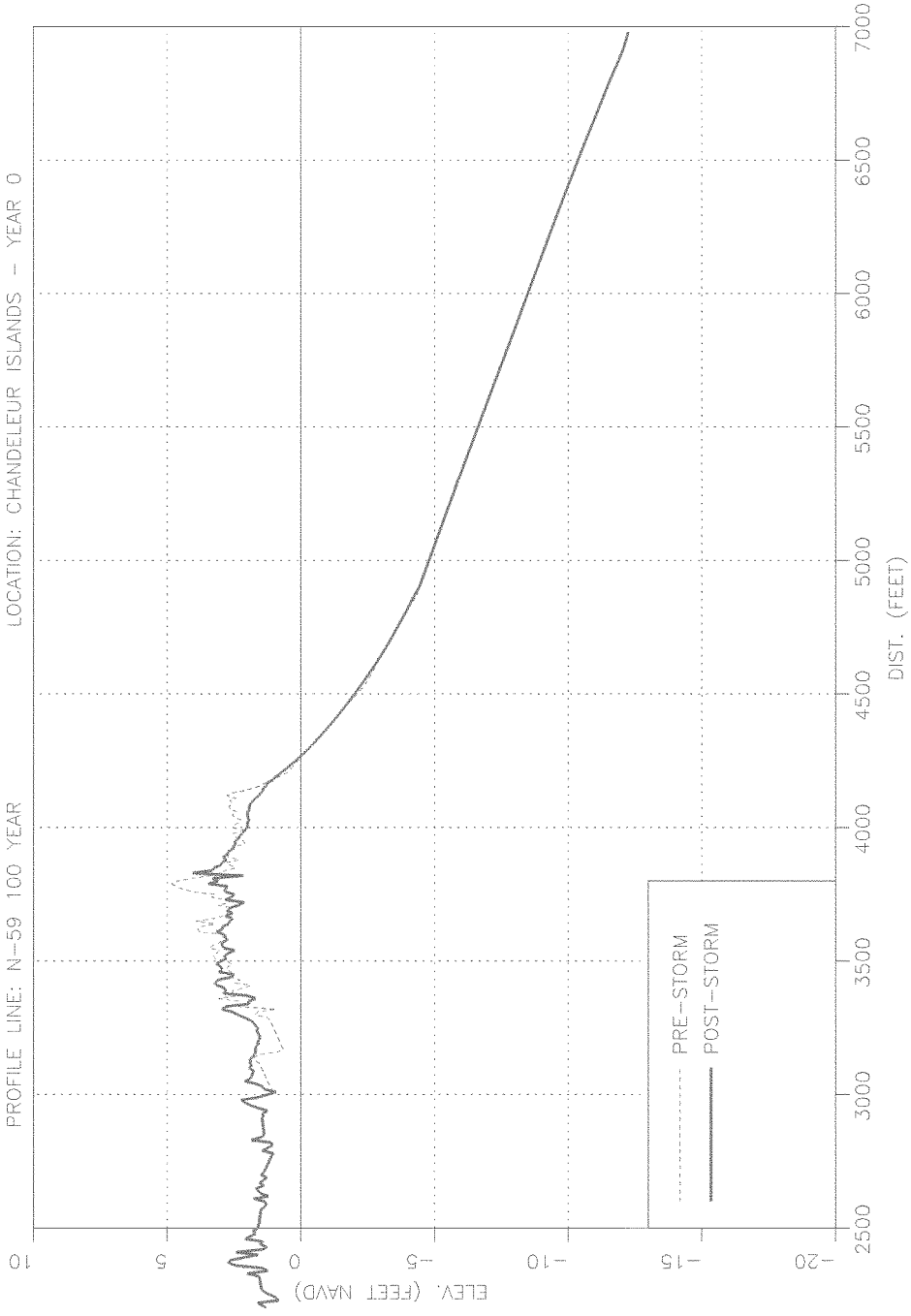

PROFILE LINE: N-59 004 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 0
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
2500
3000
3500
4000
4500
5000
5500
6000
6500
7000

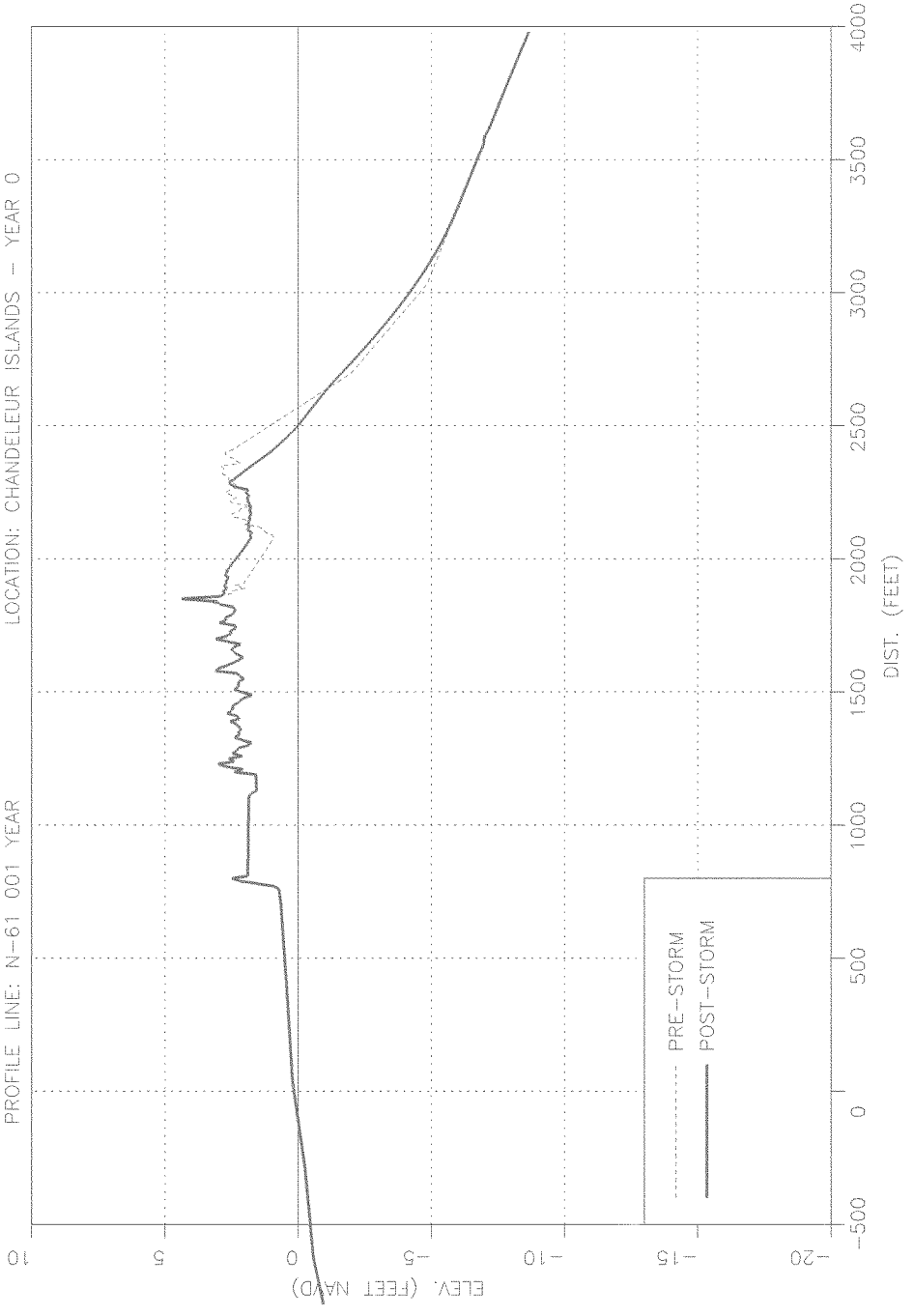

PROFILE LINE: N-59 005 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 0
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
2500
3000
3500
4000
4500
5000
5500
6000
6500
7000

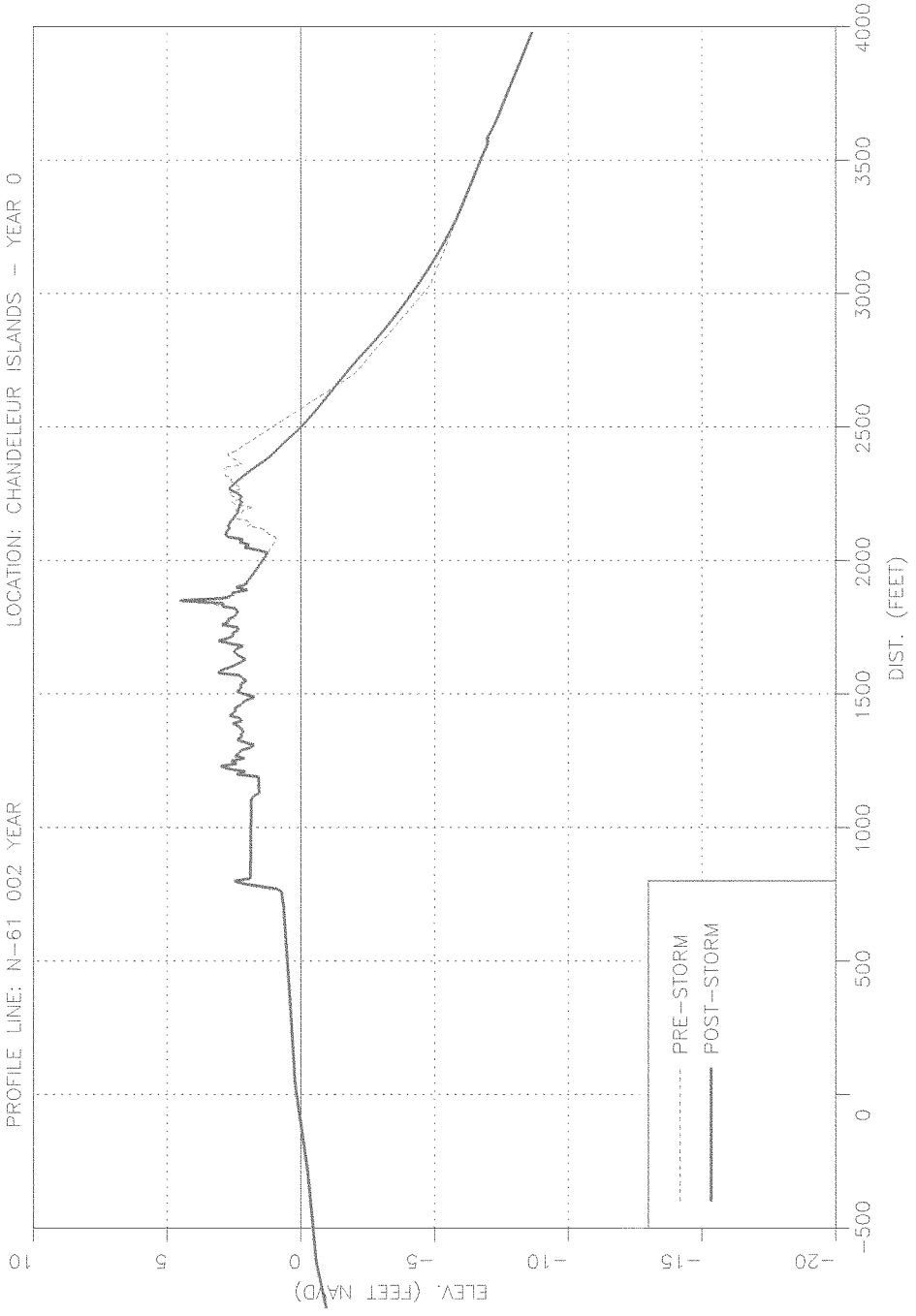

PROFILE LINE: N-59 010 YEAR
LOCATION: CHANDELEUR ISLANDS -- YEAR 0
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
2500
3000
3500
4000
4500
5000
5500
6000
6500
7000

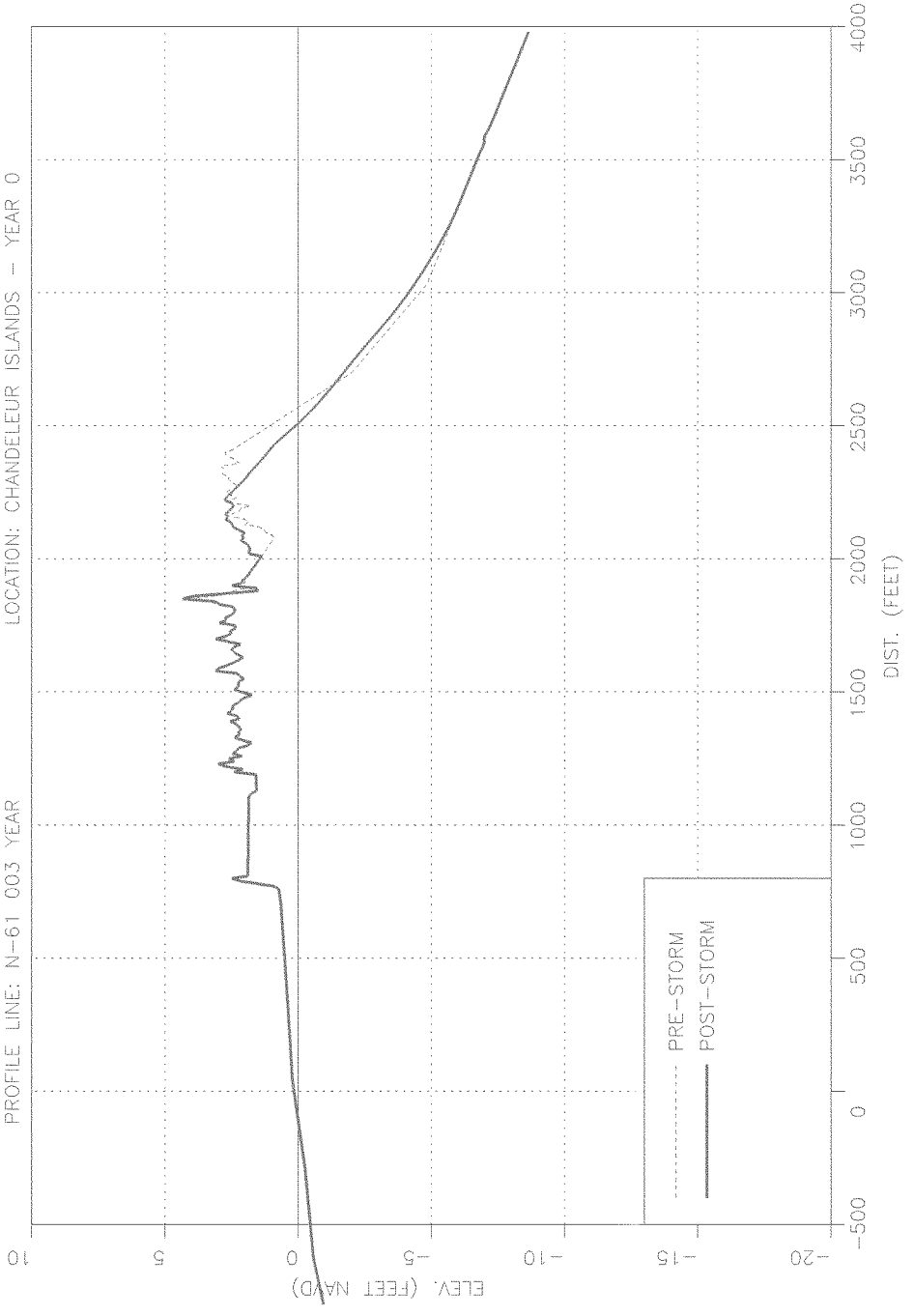

PROFILE LINE: N-59 020 YEAR
LOCATION: CHANDELEUR ISLANDS -- YEAR 0
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
2500
3000
3500
4000
4500
5000
5500
6000
6500
7000

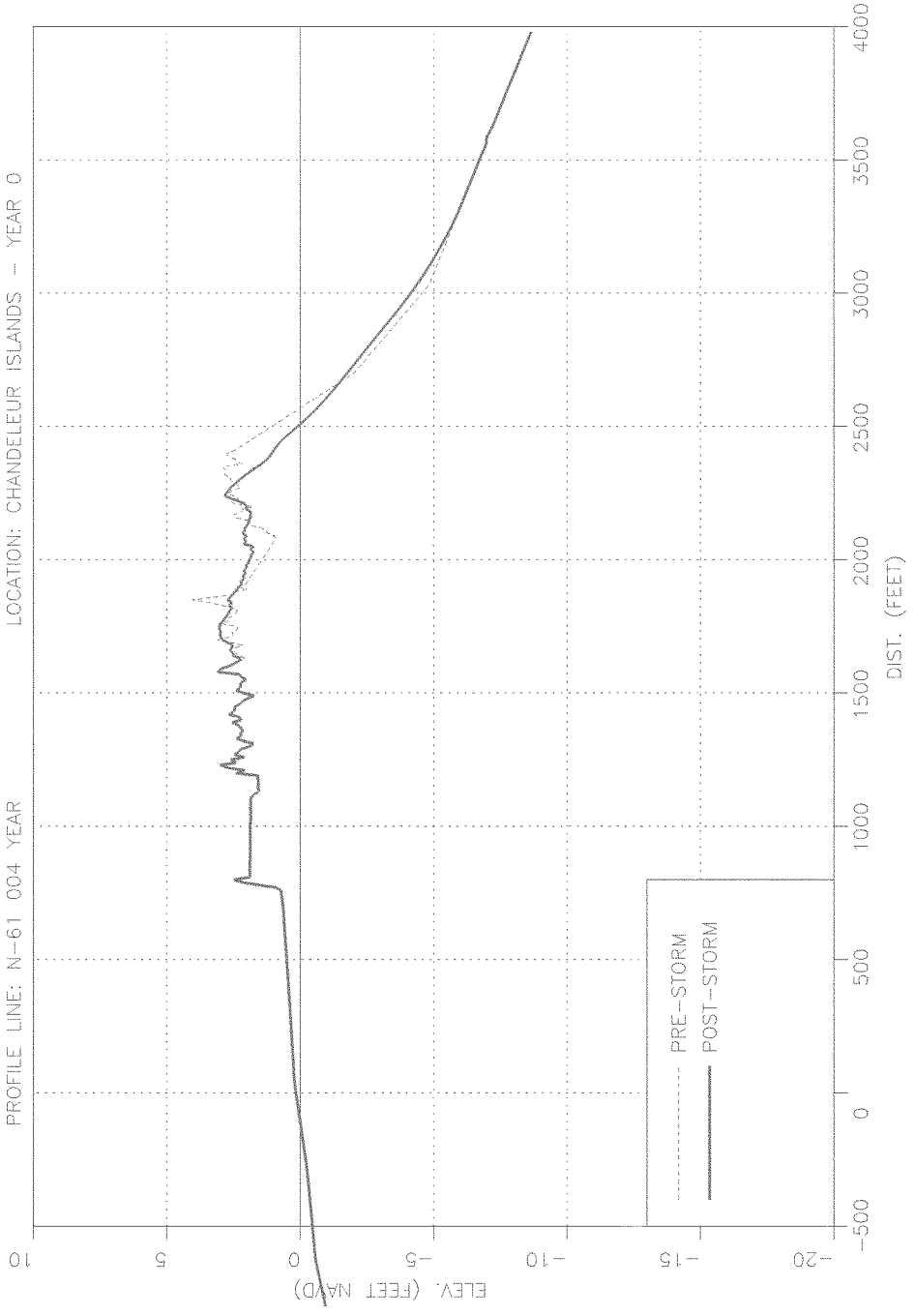

PROFILE LINE: N-59 050 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 0
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
2500
3000
3500
4000
4500
5000
5500
6000
6500
7000

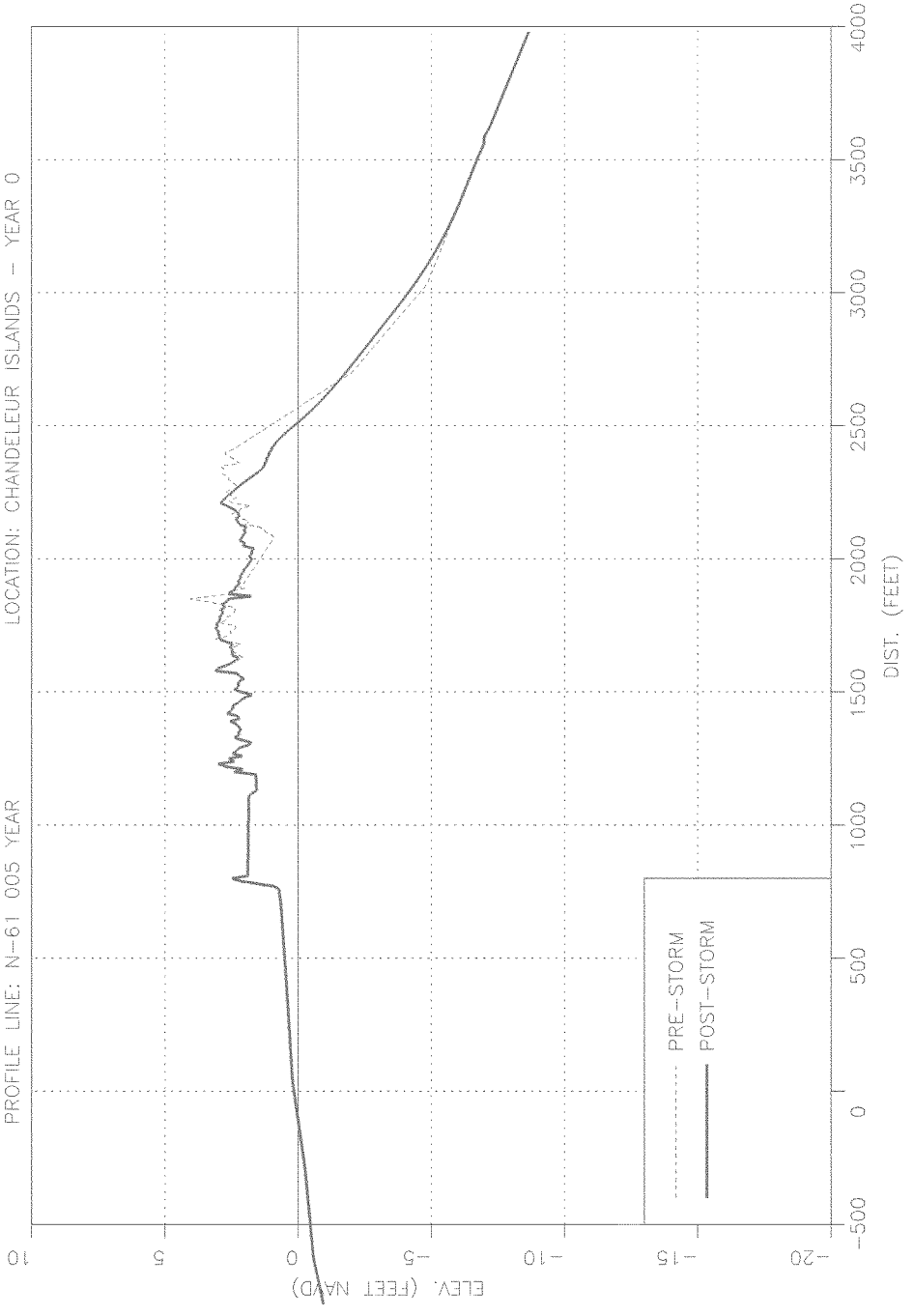

PROFILE LINE: N-59 100 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 0
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
2500
3000
3500
4000
4500
5000
5500
6000
6500
7000

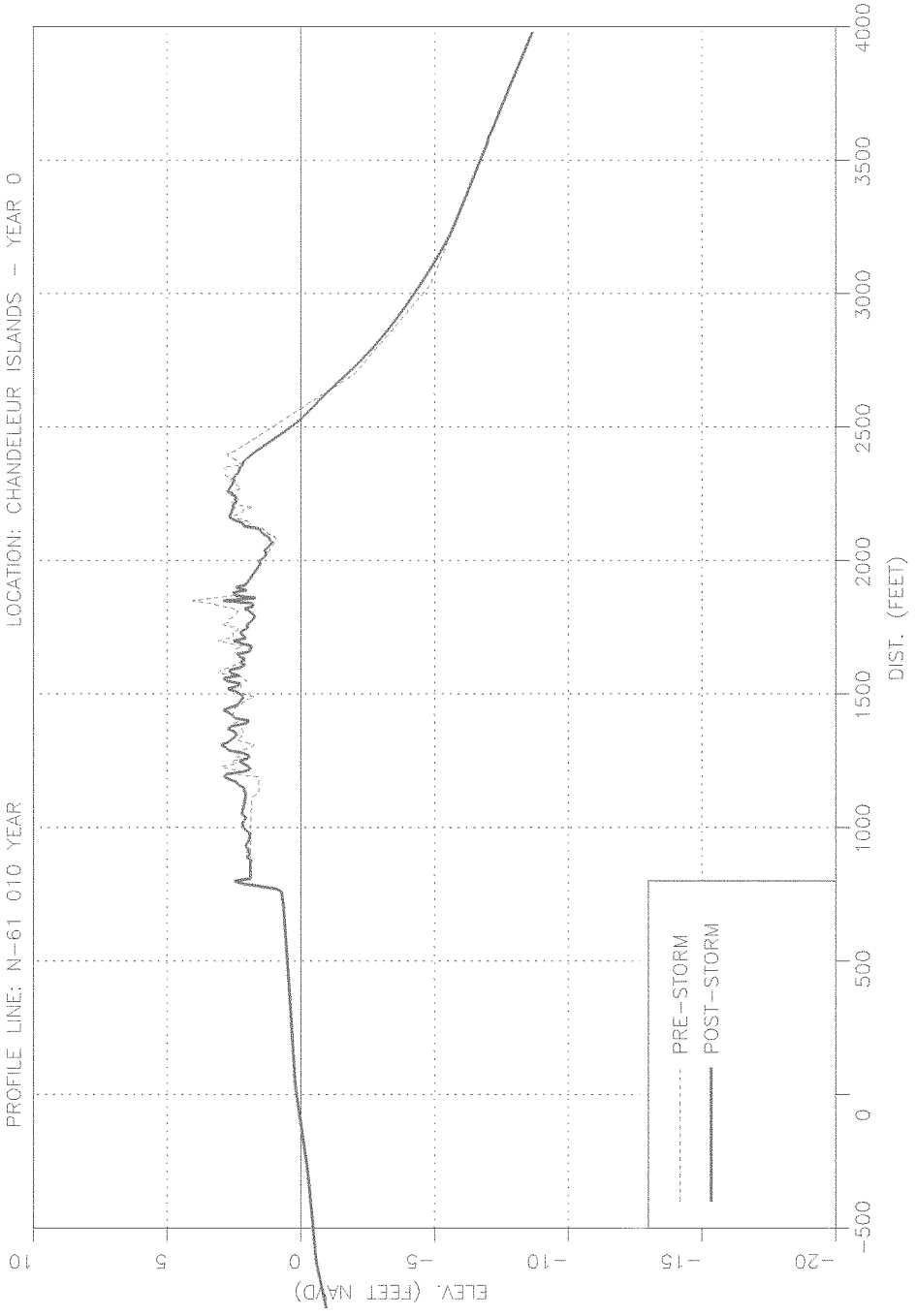

PROFILE LINE: N-61 001 YEAR
LOCATION: CHANDELEUR ISLANDS -- YEAR 0
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

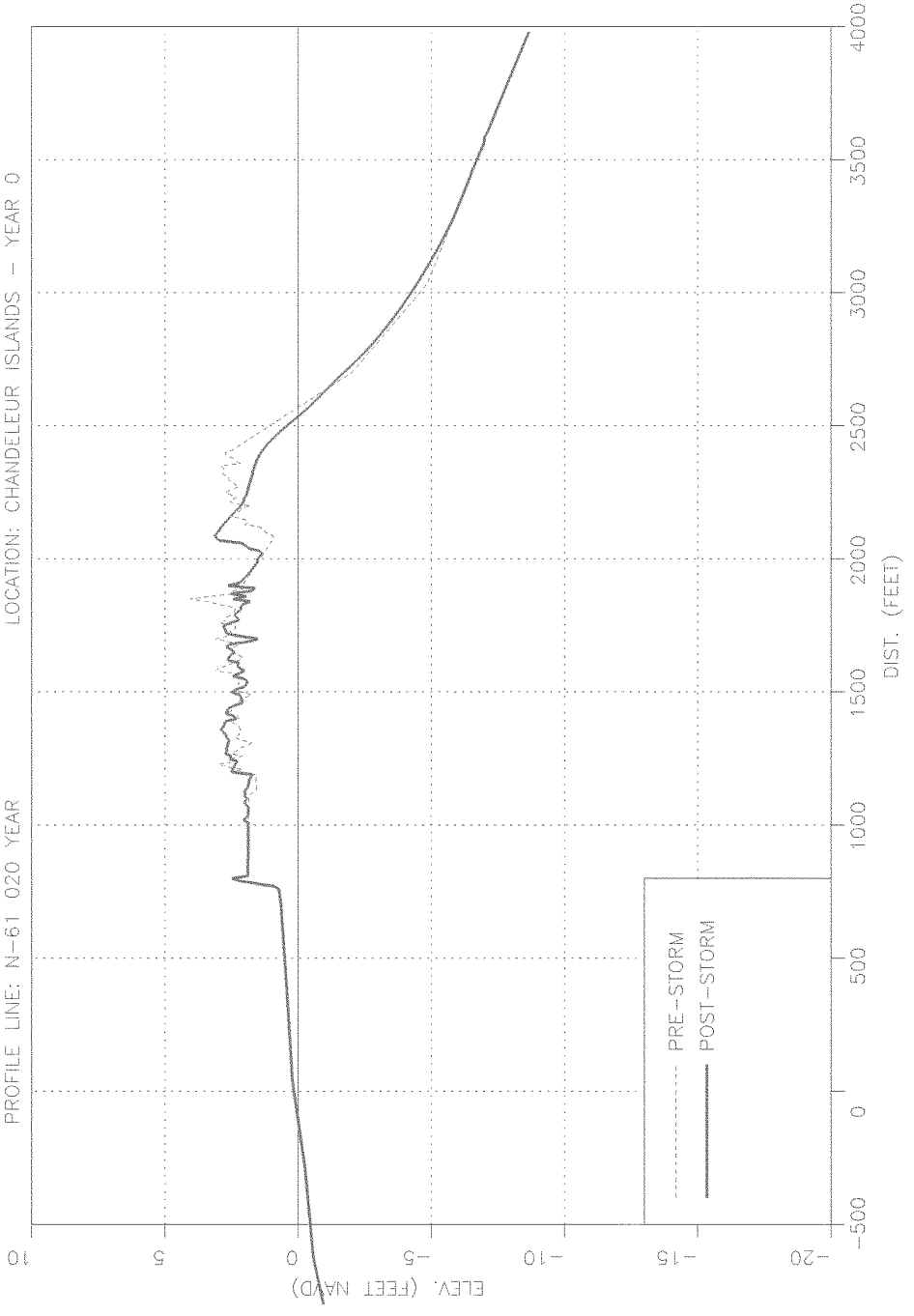

PROFILE LINE: N-61 002 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 0
PRE-STORM
POST-STORM
ELEV. (FEET NAVD)
DIST. (FEET)
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

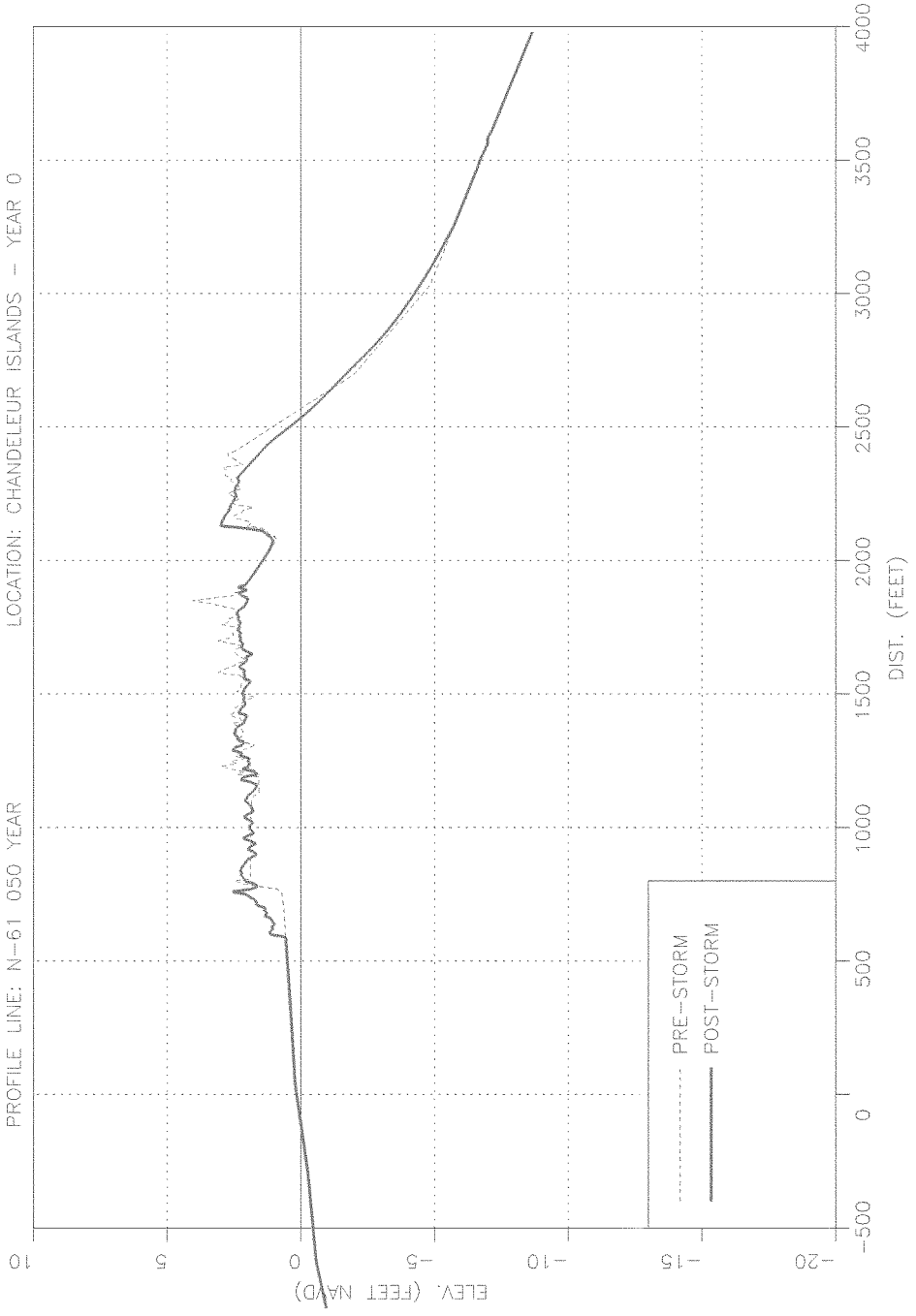

PROFILE LINE: N-61 003 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 0
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

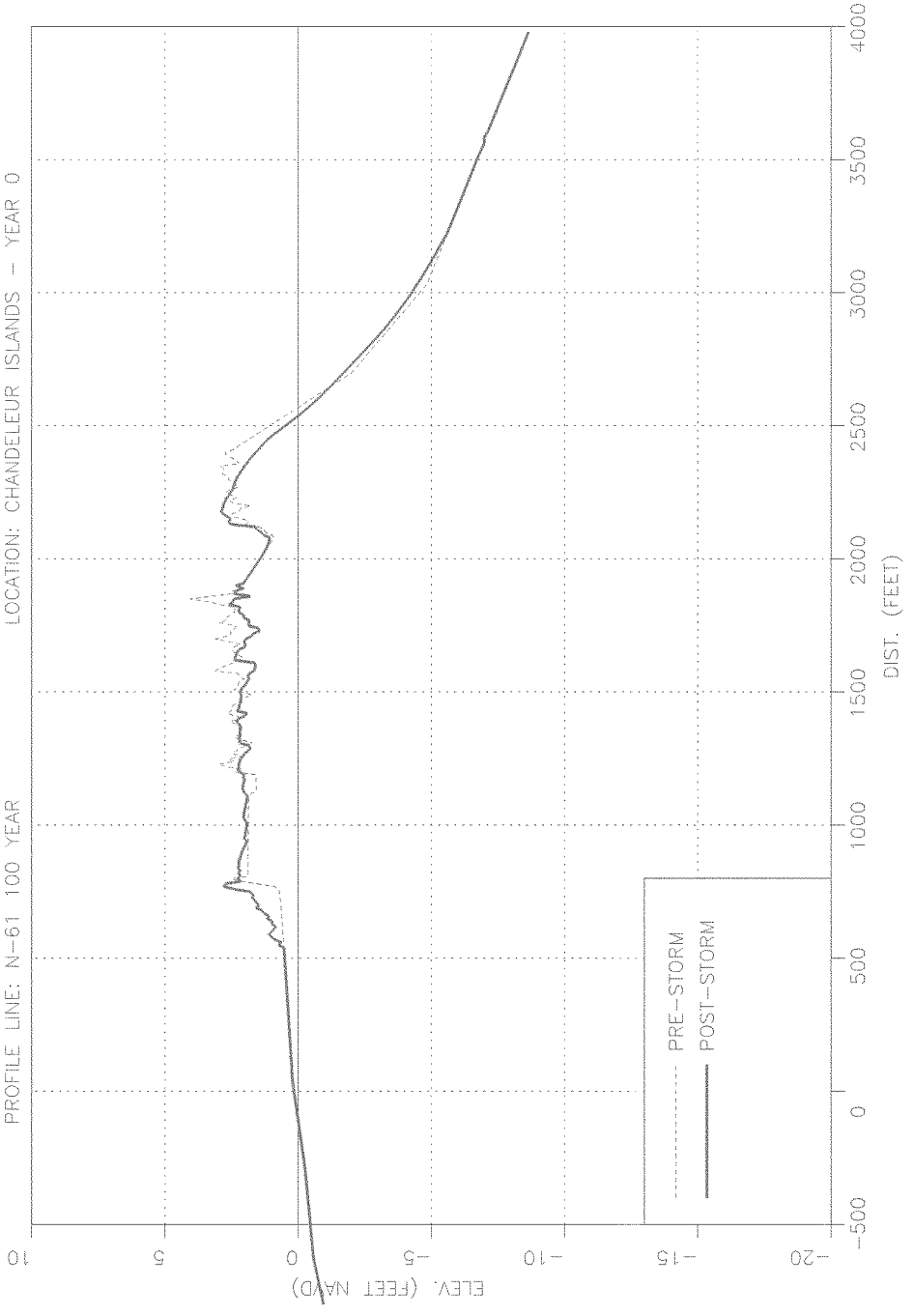

PROFILE LINE: N-61 004 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 0
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

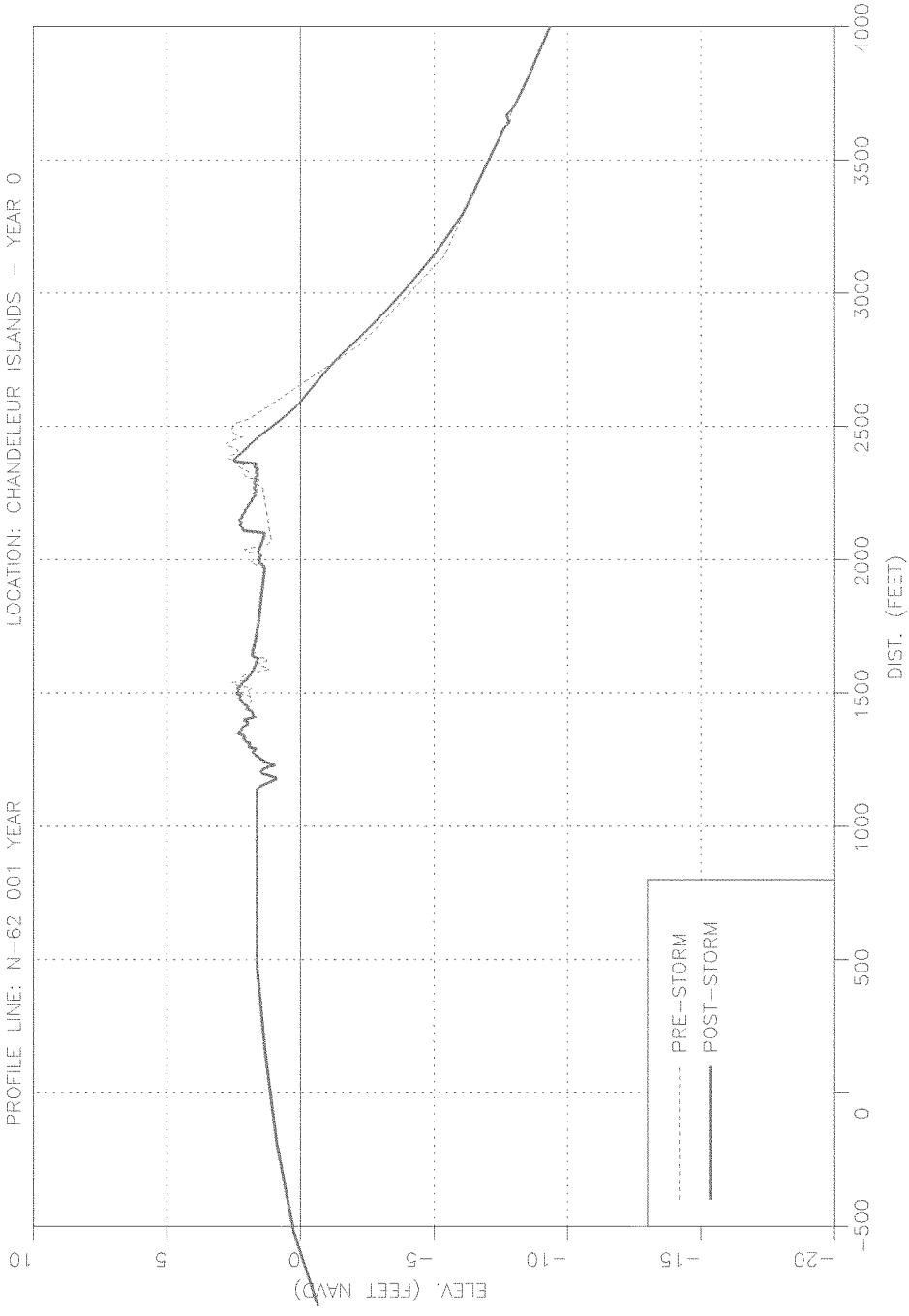

PROFILE LINE: N-61 005 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 0
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

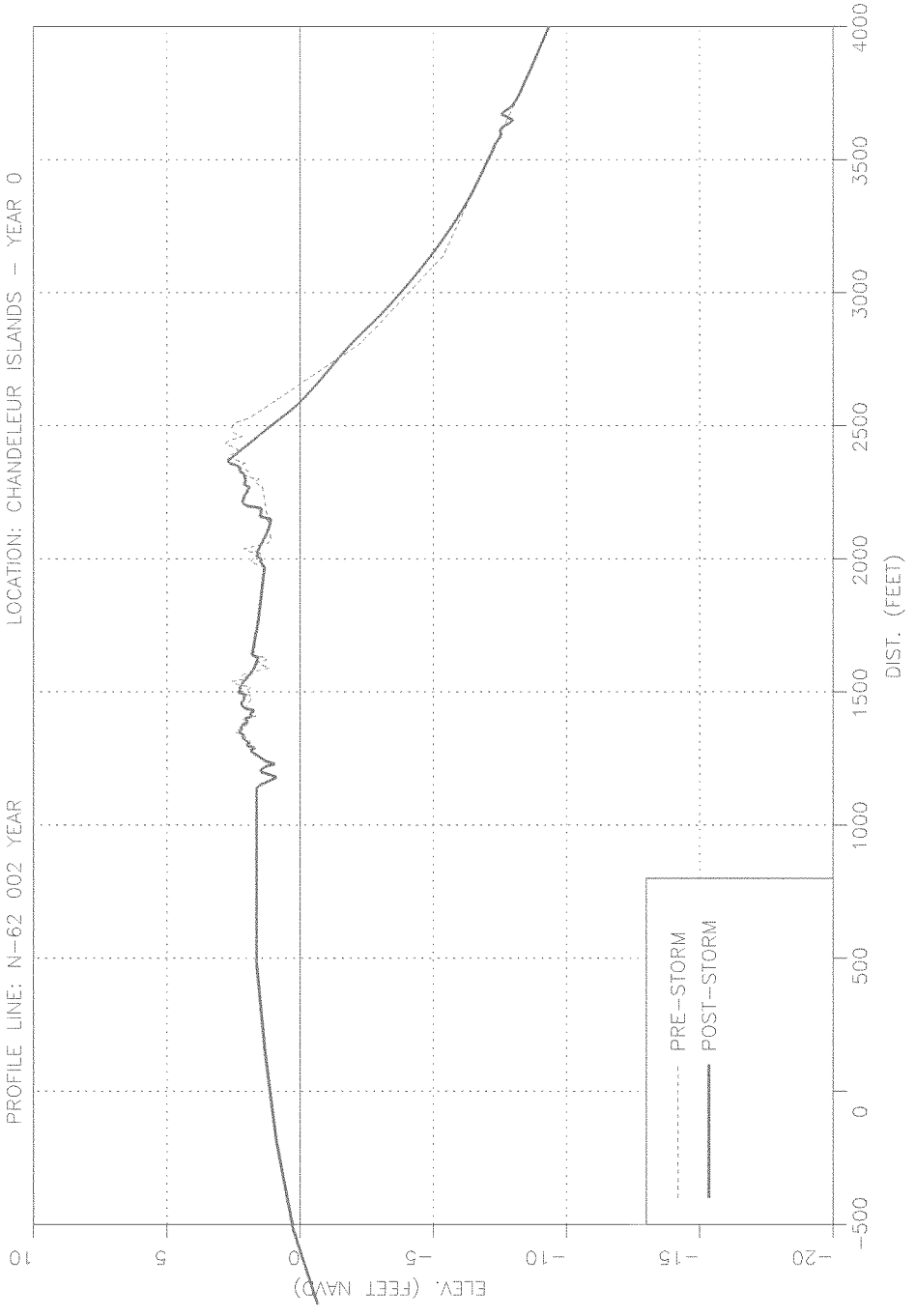

PROFILE LINE: N-61 010 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 0
PRE-STORM
POST-STORM
ELEV. (FEET NAVD)
DIST. (FEET)
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

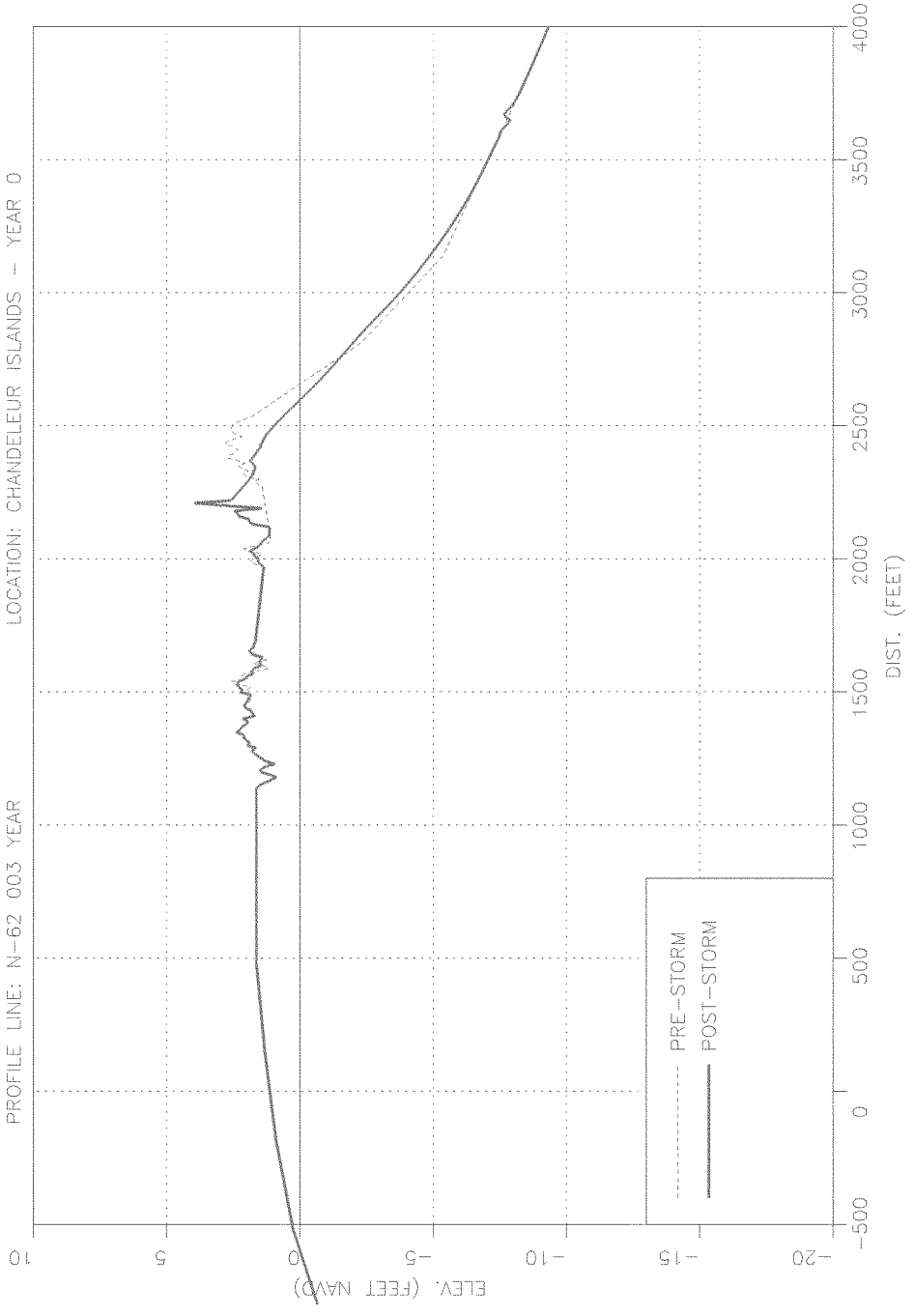

PROFILE LINE: N-61 020 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 0
PRE-STORM
POST-STORM
ELEV. (FEET NAVD)
DIST. (FEET)
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

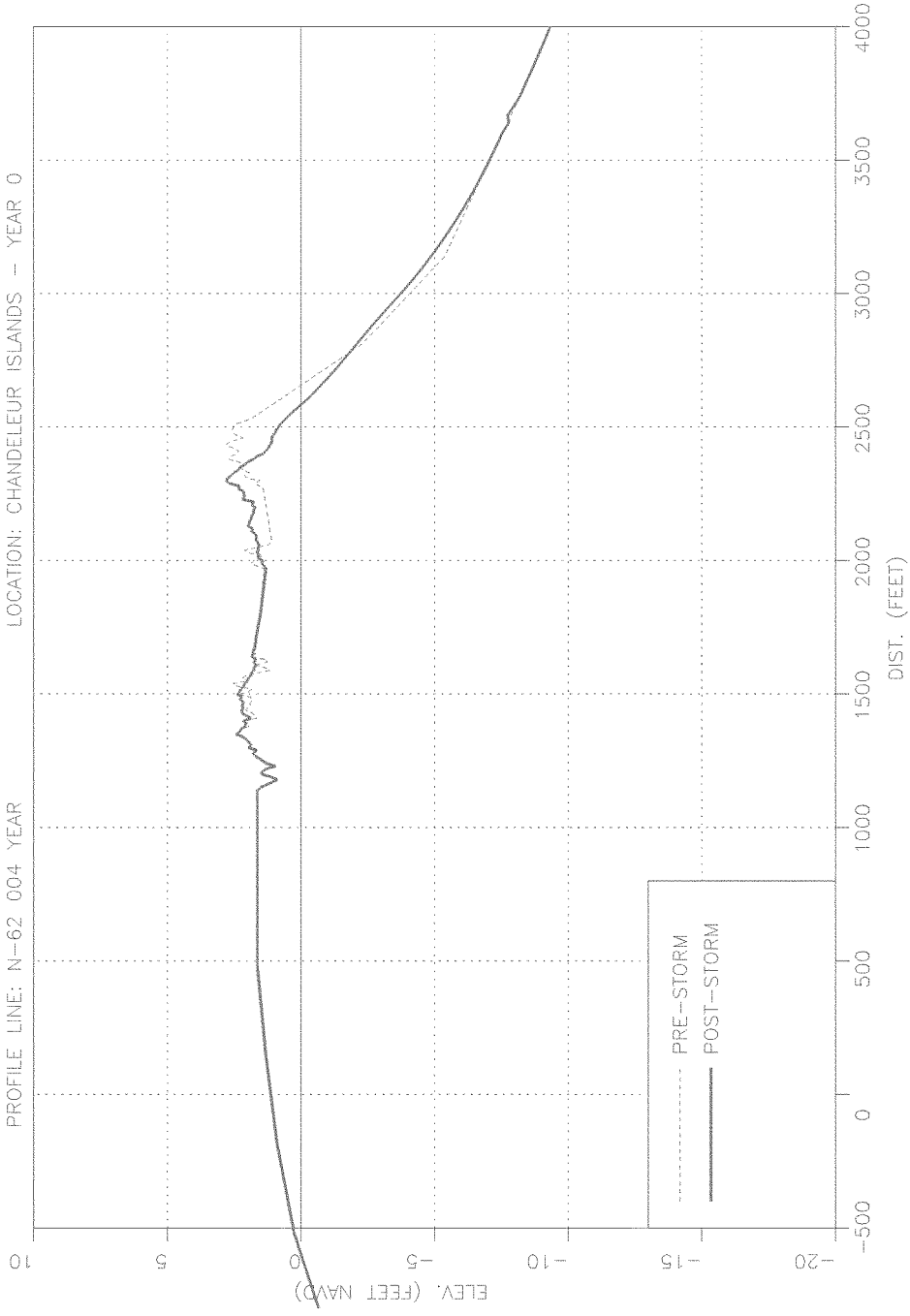

PROFILE LINE: N-61 050 YEAR
LOCATION: CHANDELEUR ISLANDS -- YEAR 0
PRE-STORM
POST-STORM
ELEV. (FEET NAVD)
DIST. (FEET)
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

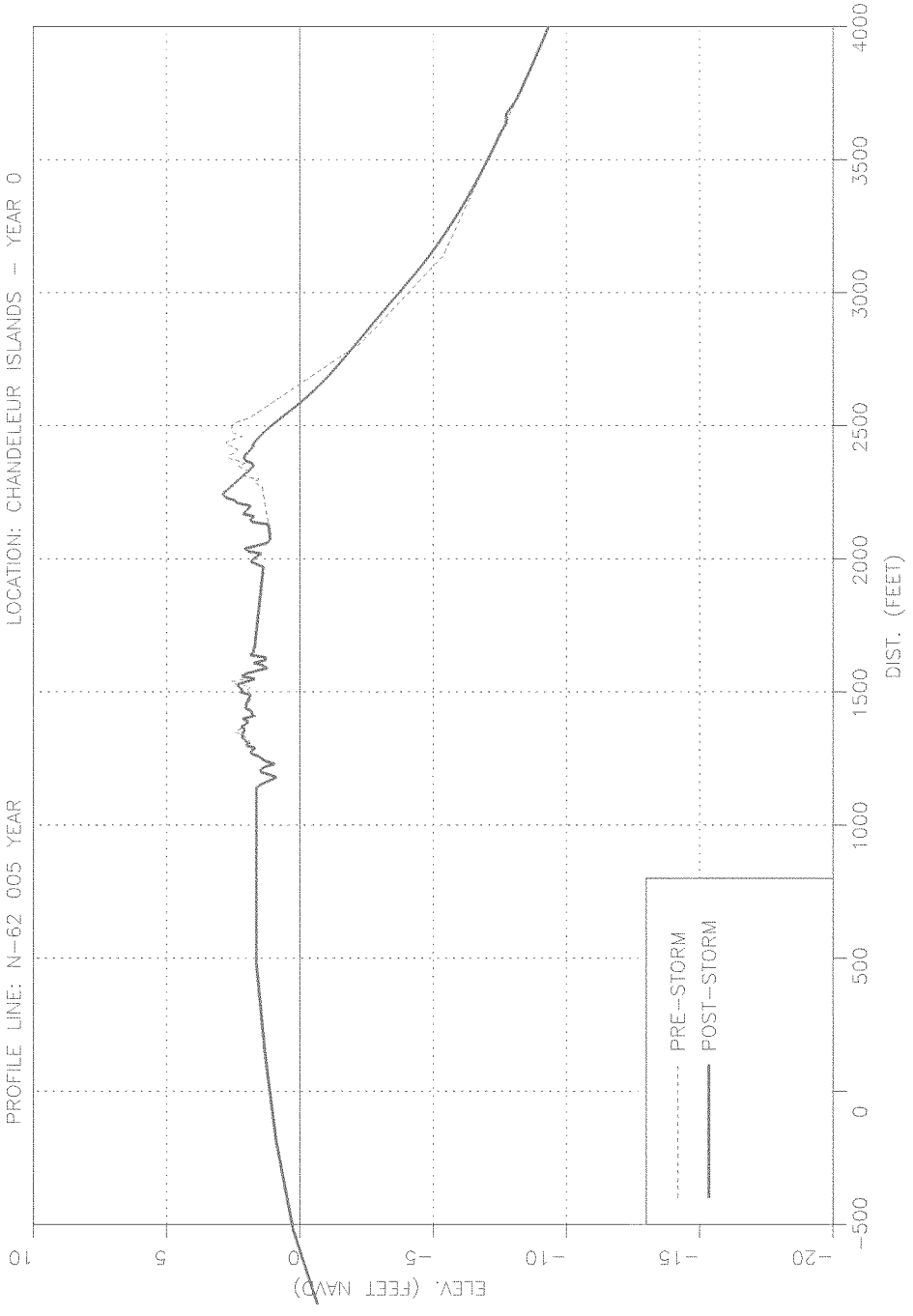

PROFILE LINE: N-61 100 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 0
PRE-STORM
POST-STORM
ELEV. (FEET NAVD)
DIST. (FEET)
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

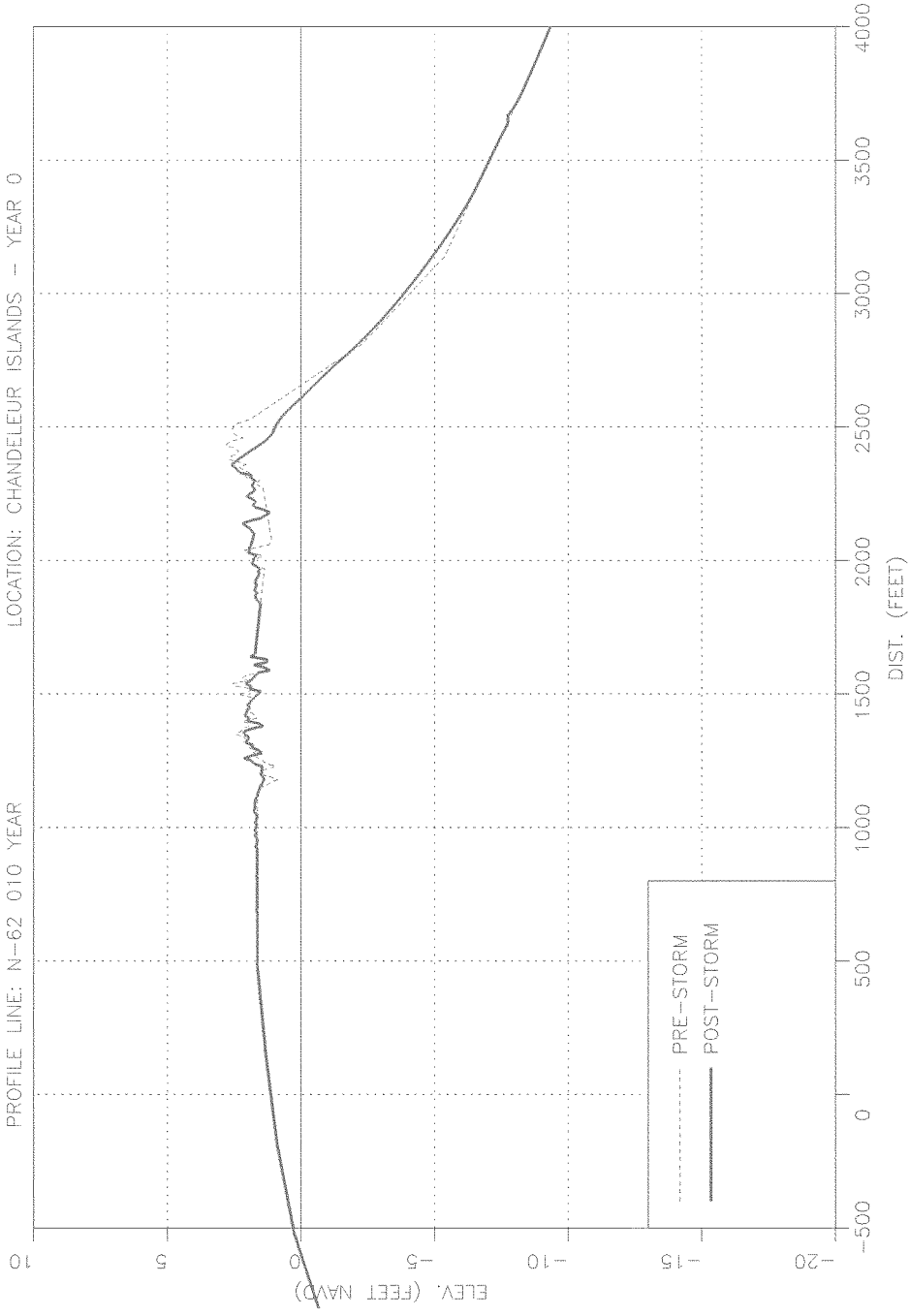

PROFILE LINE: N-62 001 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 0
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

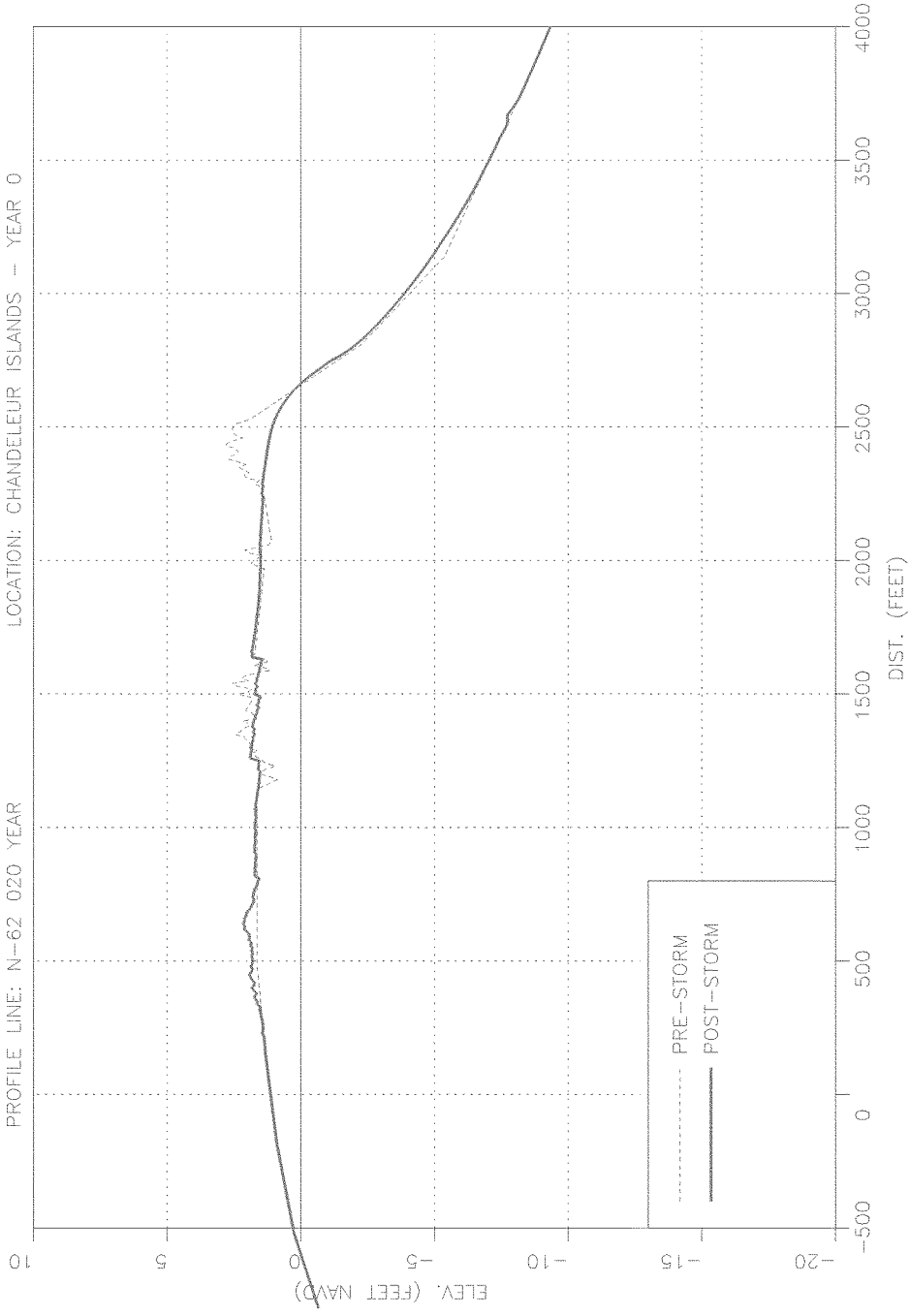

PROFILE LINE: N-62 002 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 0
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

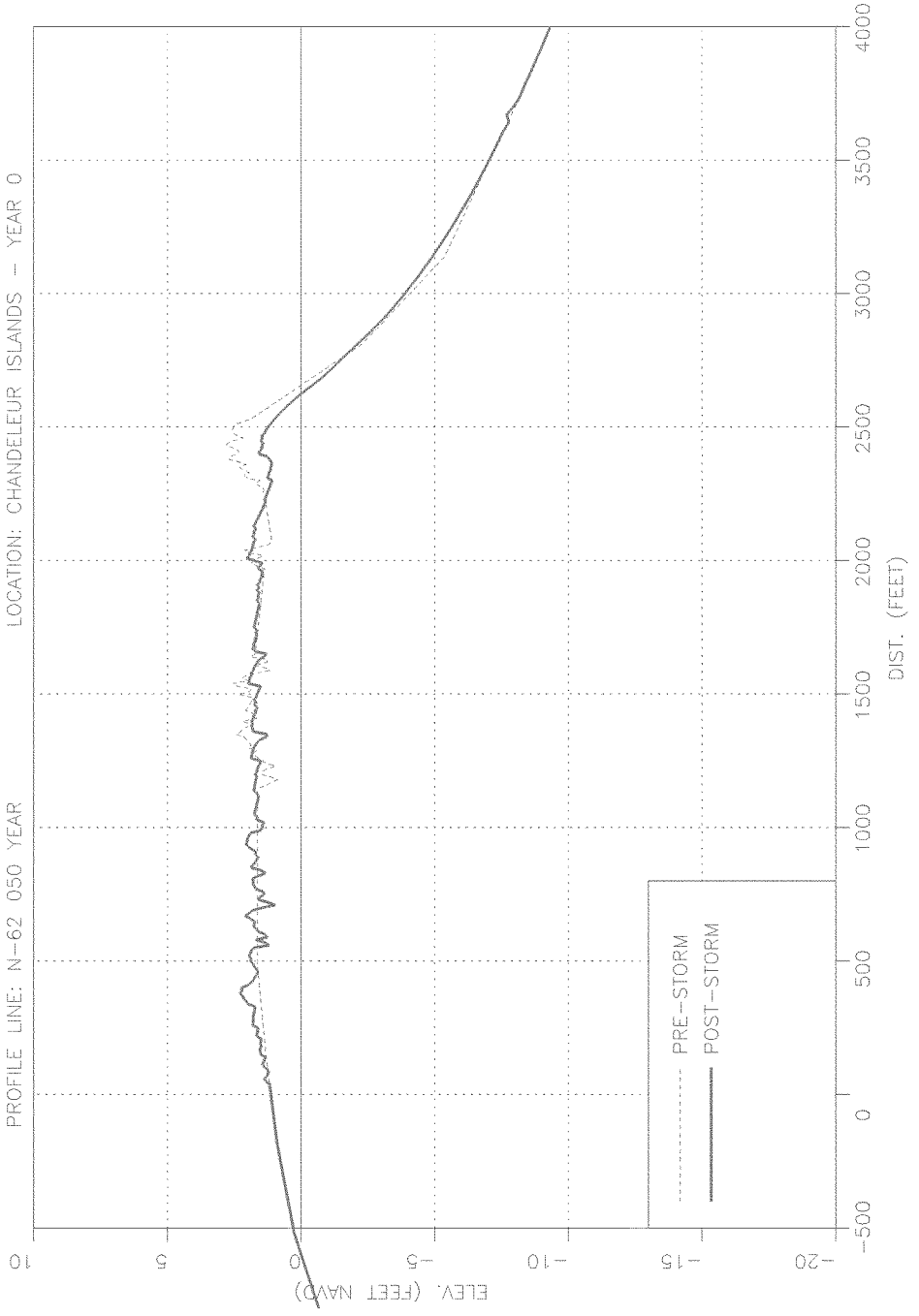

PROFILE LINE: N-62 003 YEAR
LOCATION: CHANDELEUR ISLANDS -- YEAR 0
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

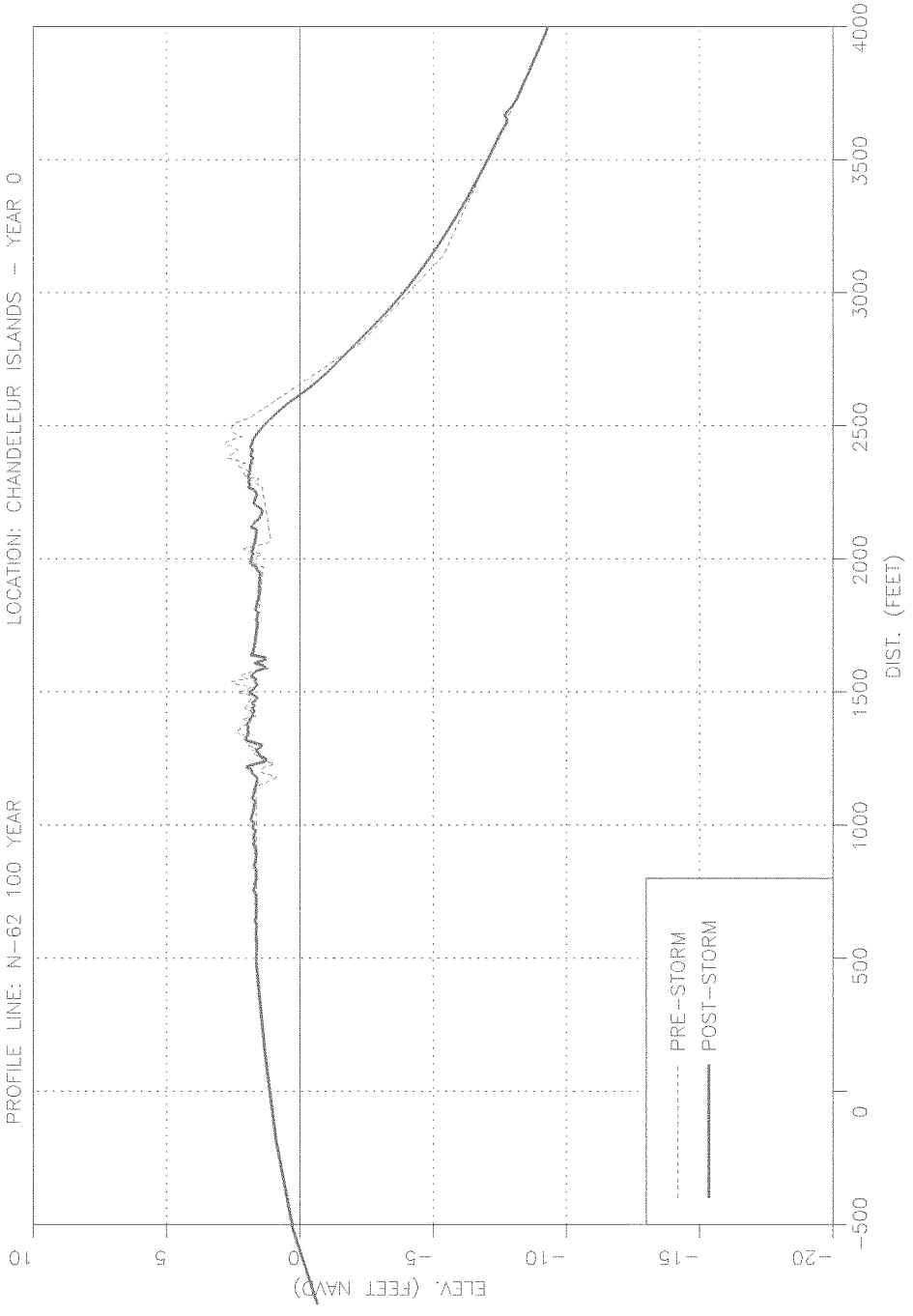

PROFILE LINE: N-62 004 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 0
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

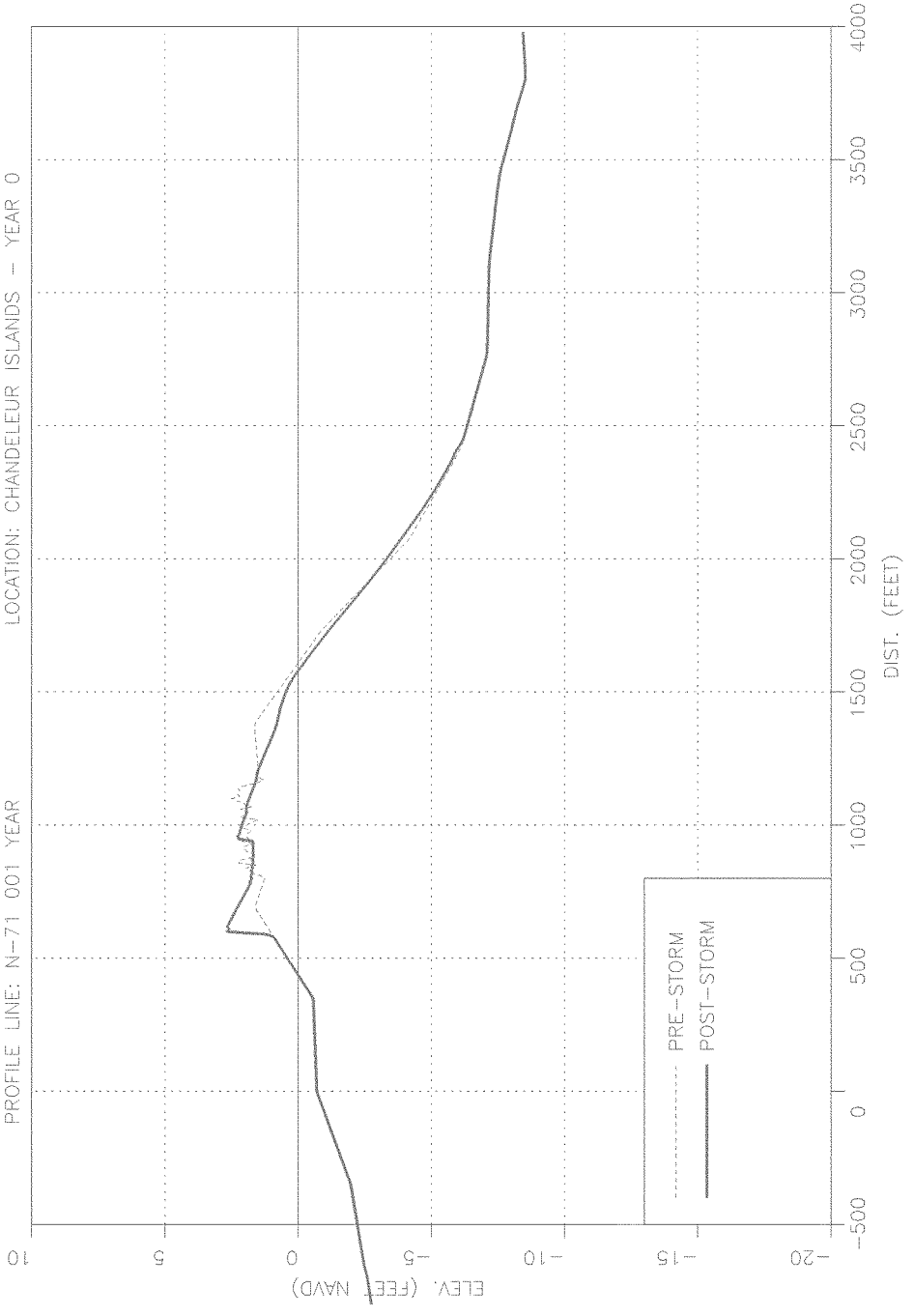

PROFILE LINE: N-62 005 YEAR
LOCATION: CHANDELEUR ISLANDS -- YEAR 0
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

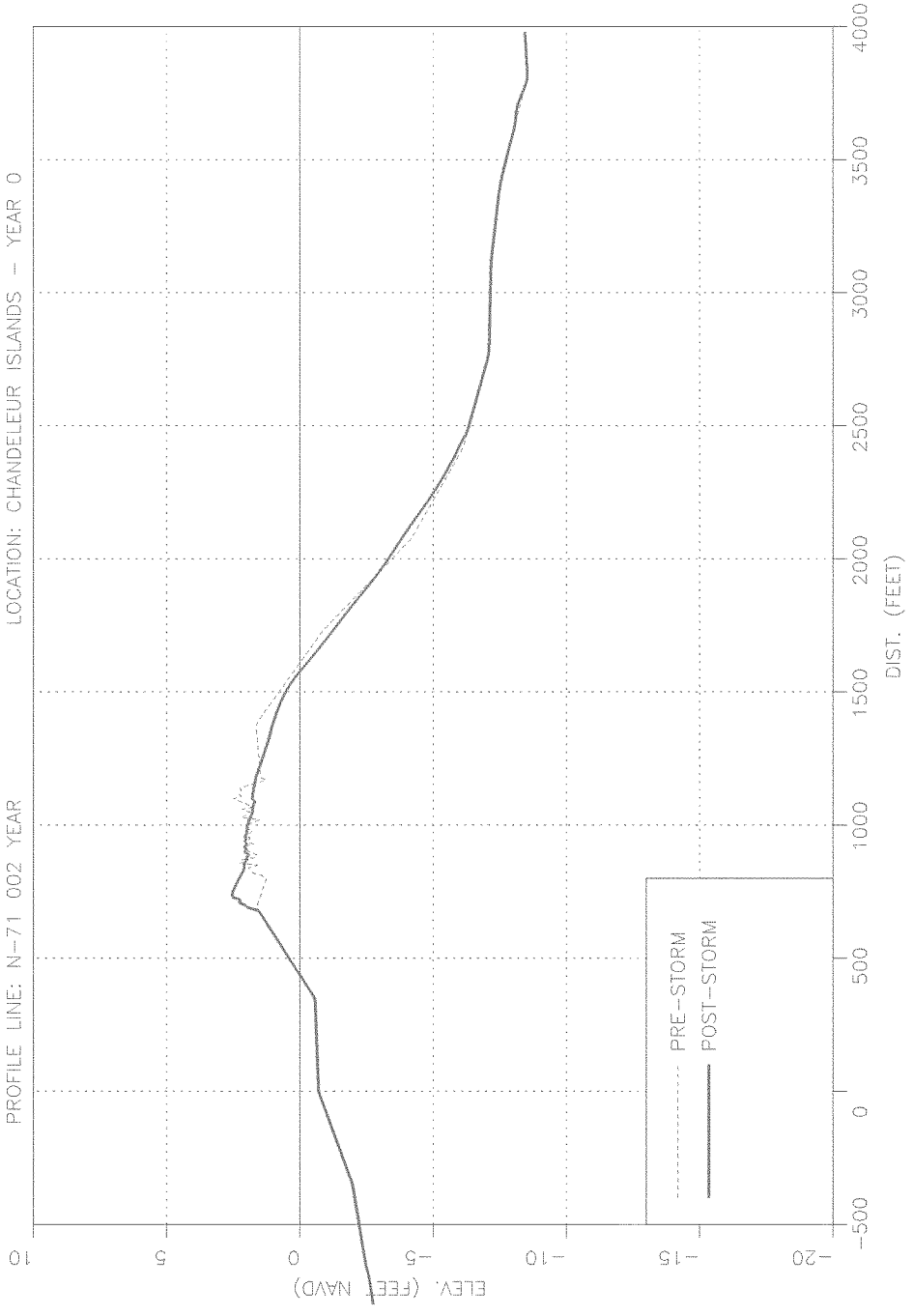

PROFILE LINE: N-62 010 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 0
ELEV. (FEET NAVD)
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000
DIST. (FEET)
PRE-STORM
POST-STORM

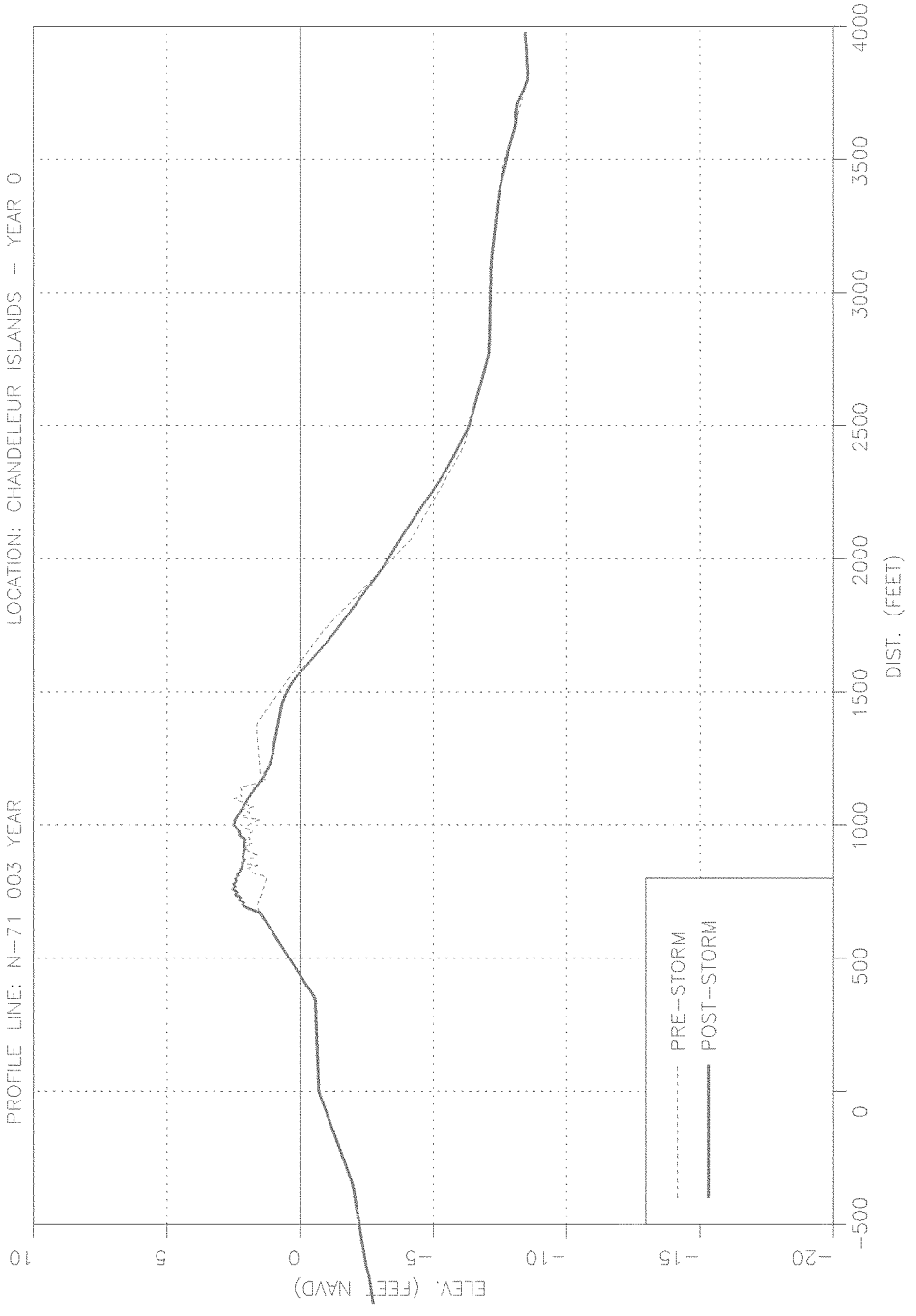

PROFILE LINE: N-62 020 YEAR
LOCATION: CHANDELEUR ISLANDS -- YEAR 0
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

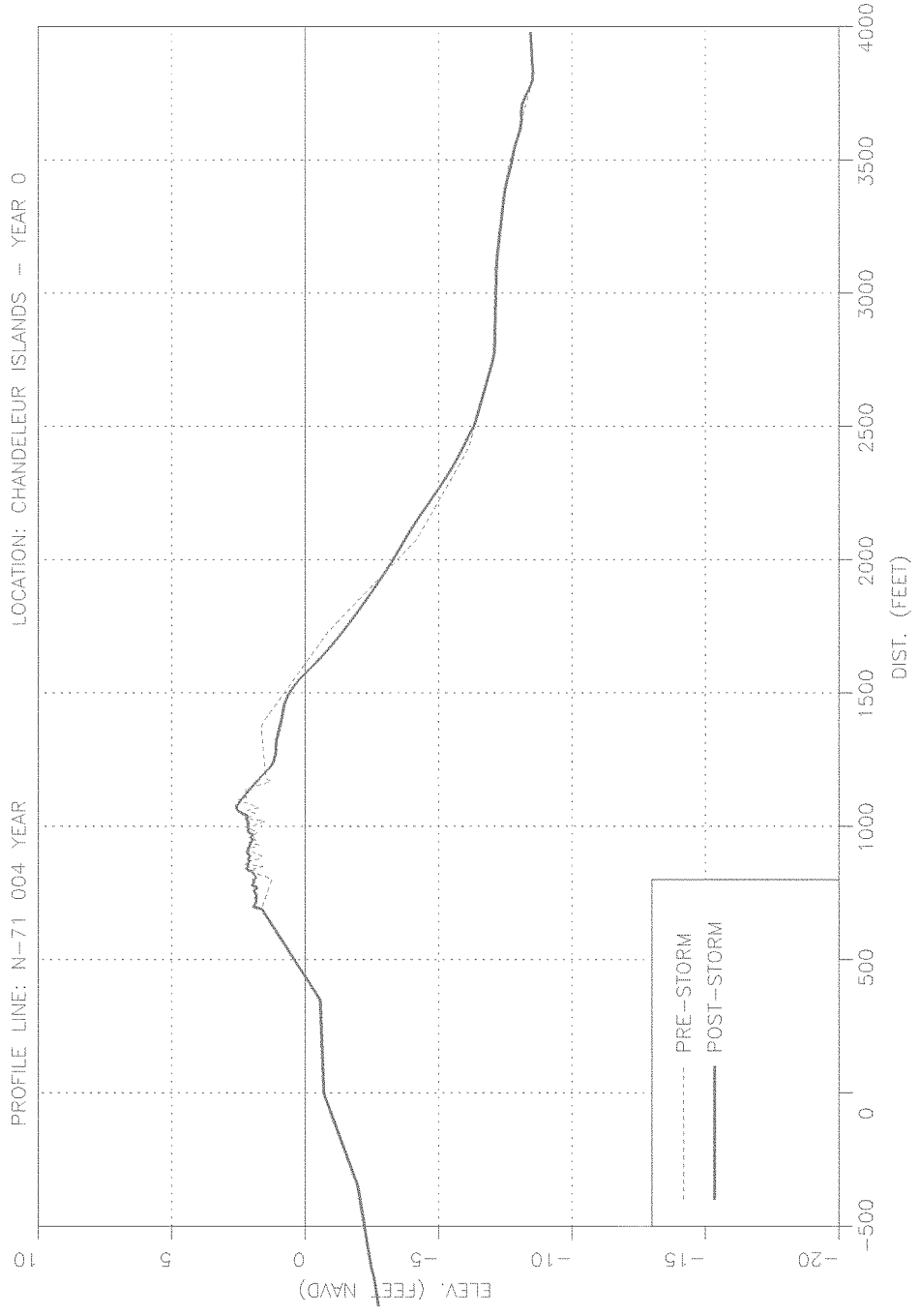

PROFILE LINE: N-62 050 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 0
PRE-STORM
POST-STORM
ELEV. (FEET NAVD)
DIST. (FEET)
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

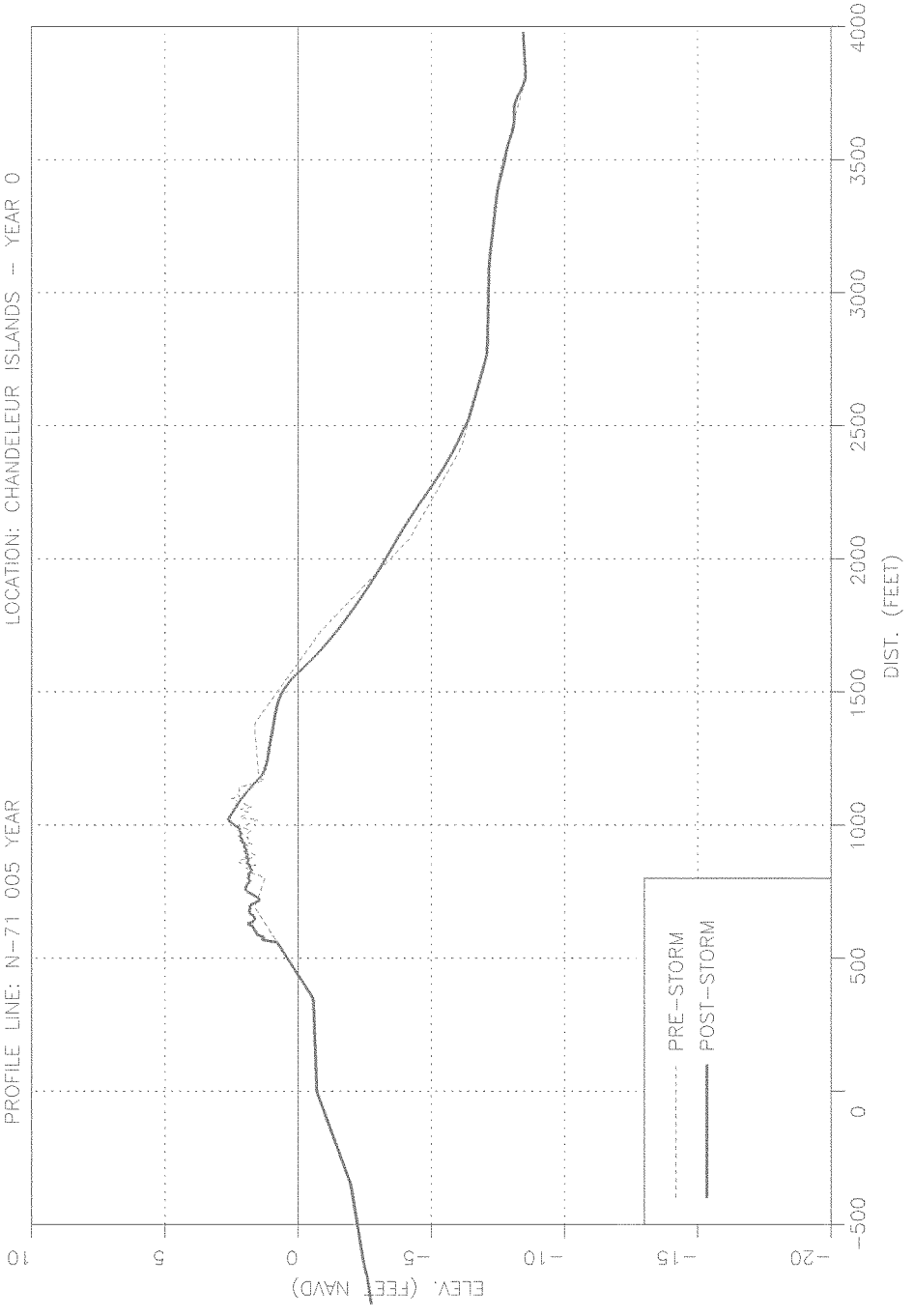

PROFILE LINE: N-62 100 YEAR
LOCATION: CHANDELEUR ISLANDS -- YEAR 0
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

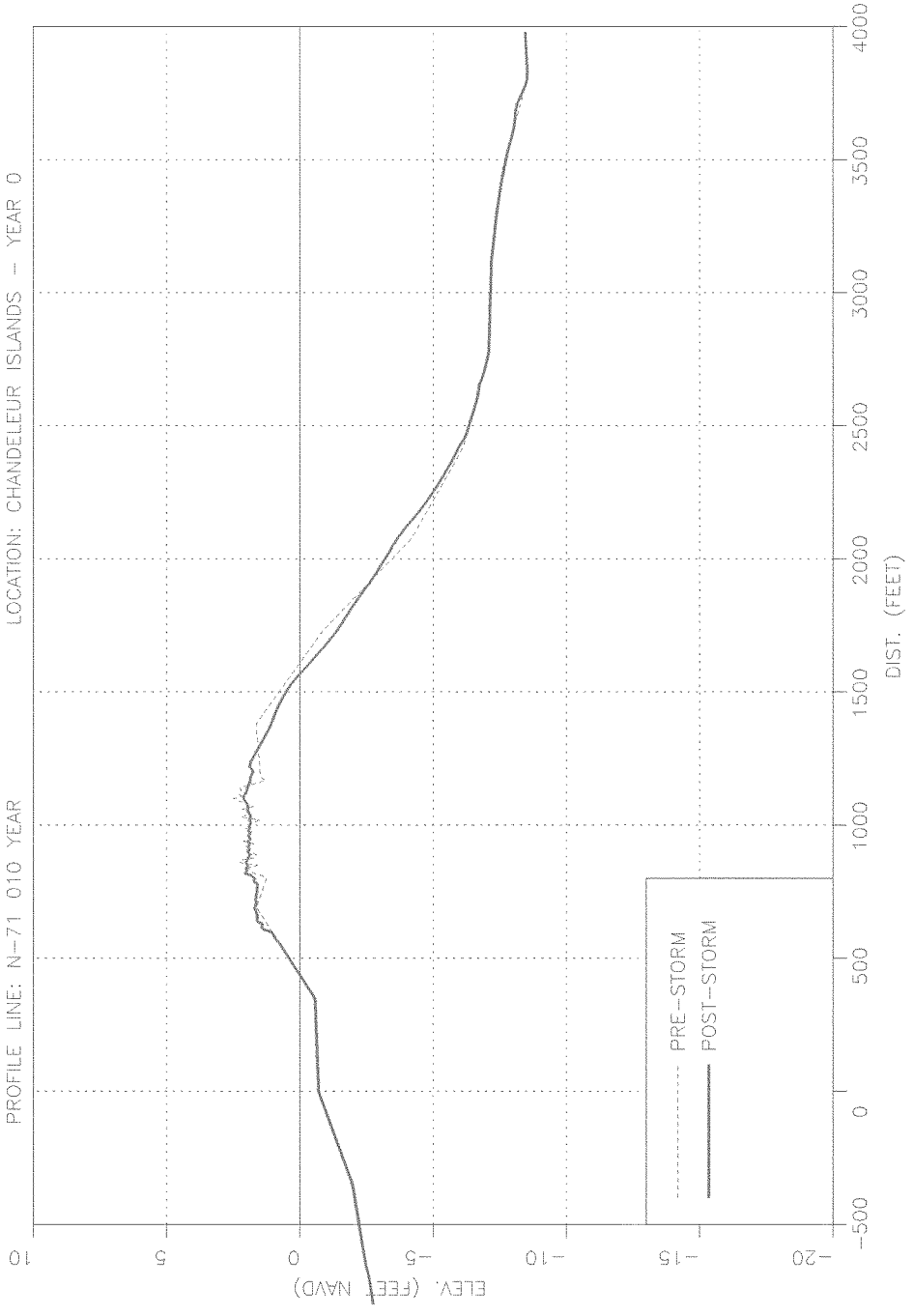

PROFILE LINE: N-71 001 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 0
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

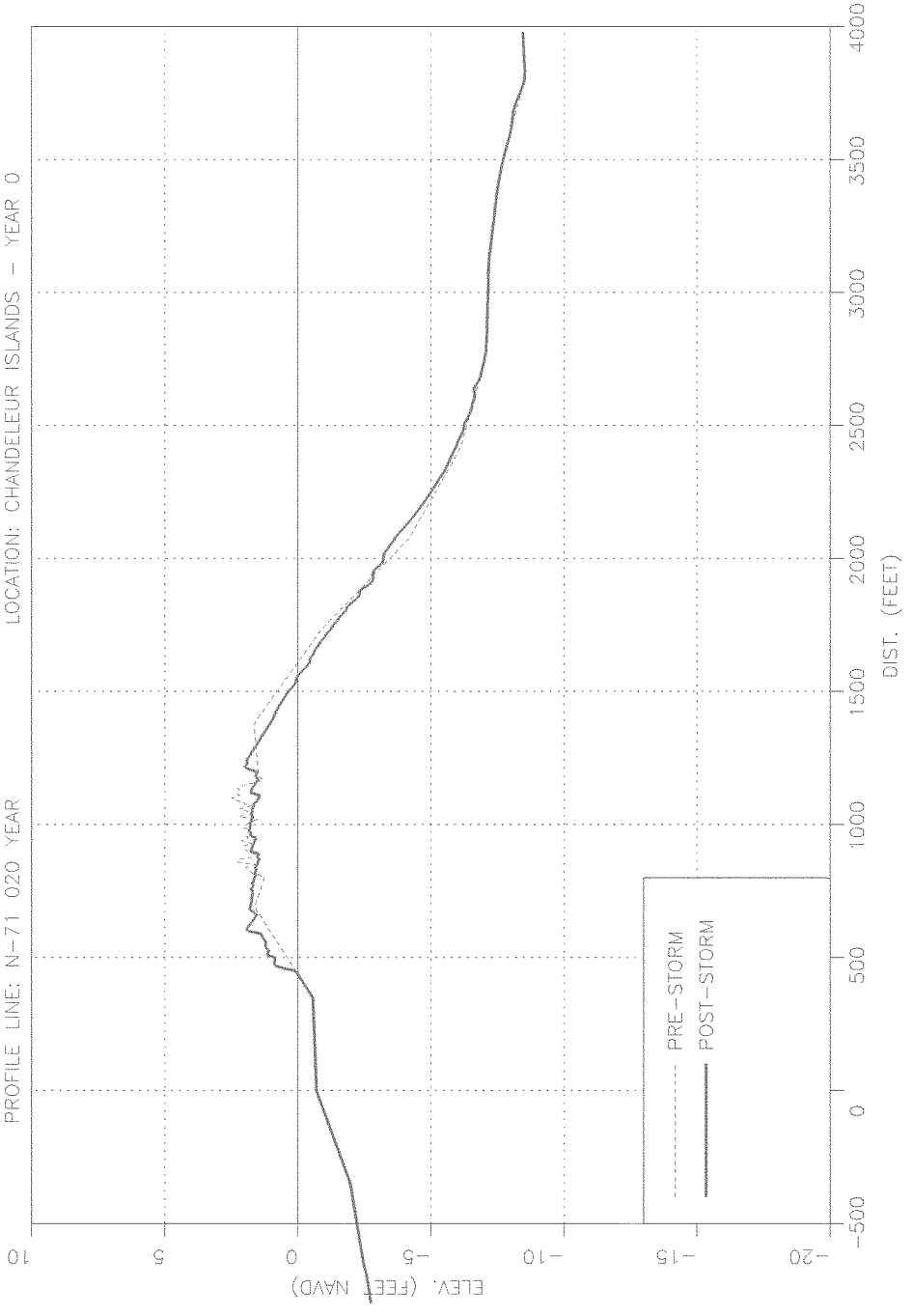

PROFILE LINE: N-71 002 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 0
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

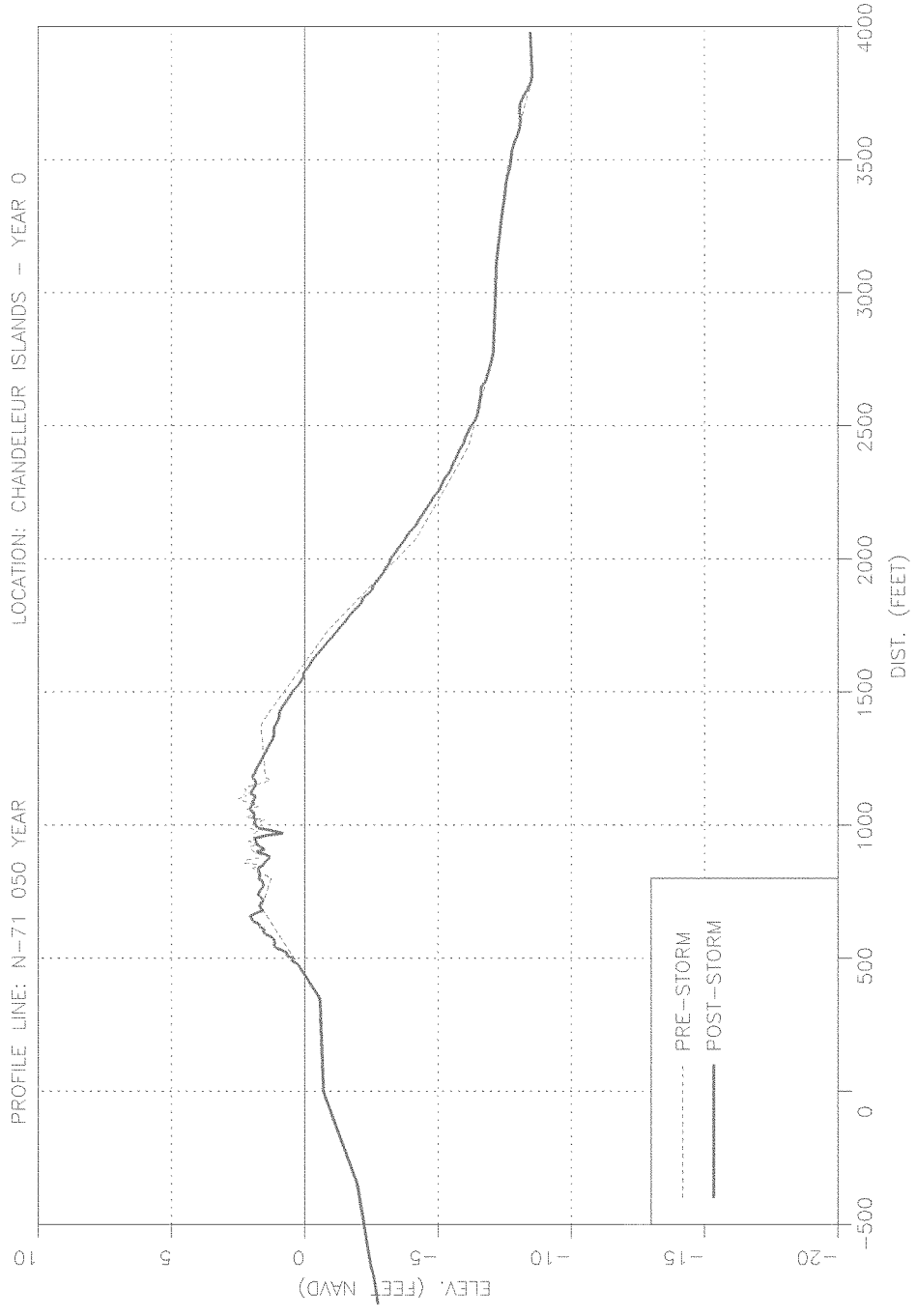

PROFILE LINE: N-71 003 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 0
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

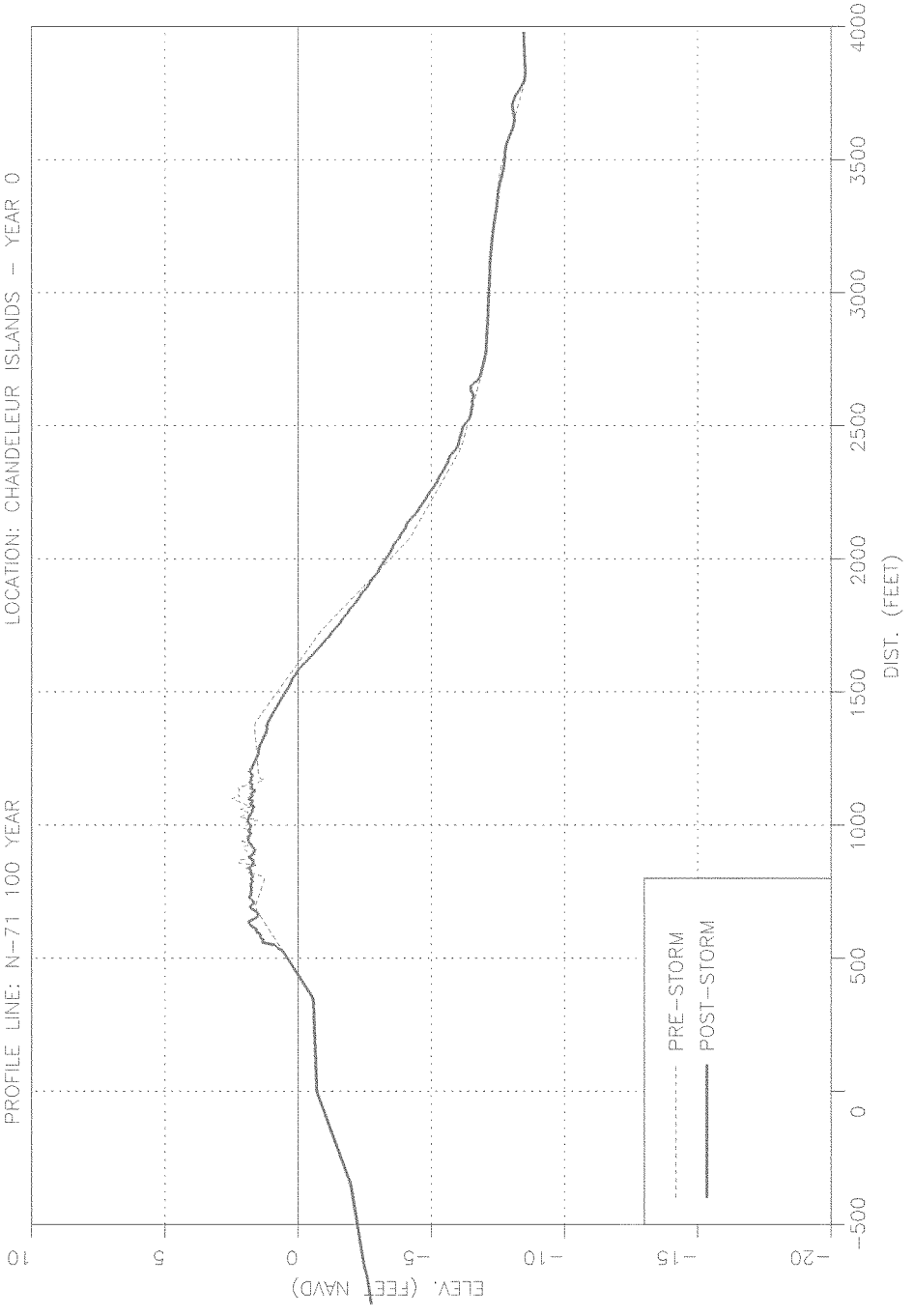

PROFILE LINE: N-71 004 YEAR
LOCATION: CHANDELEUR ISLANDS -- YEAR 0
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

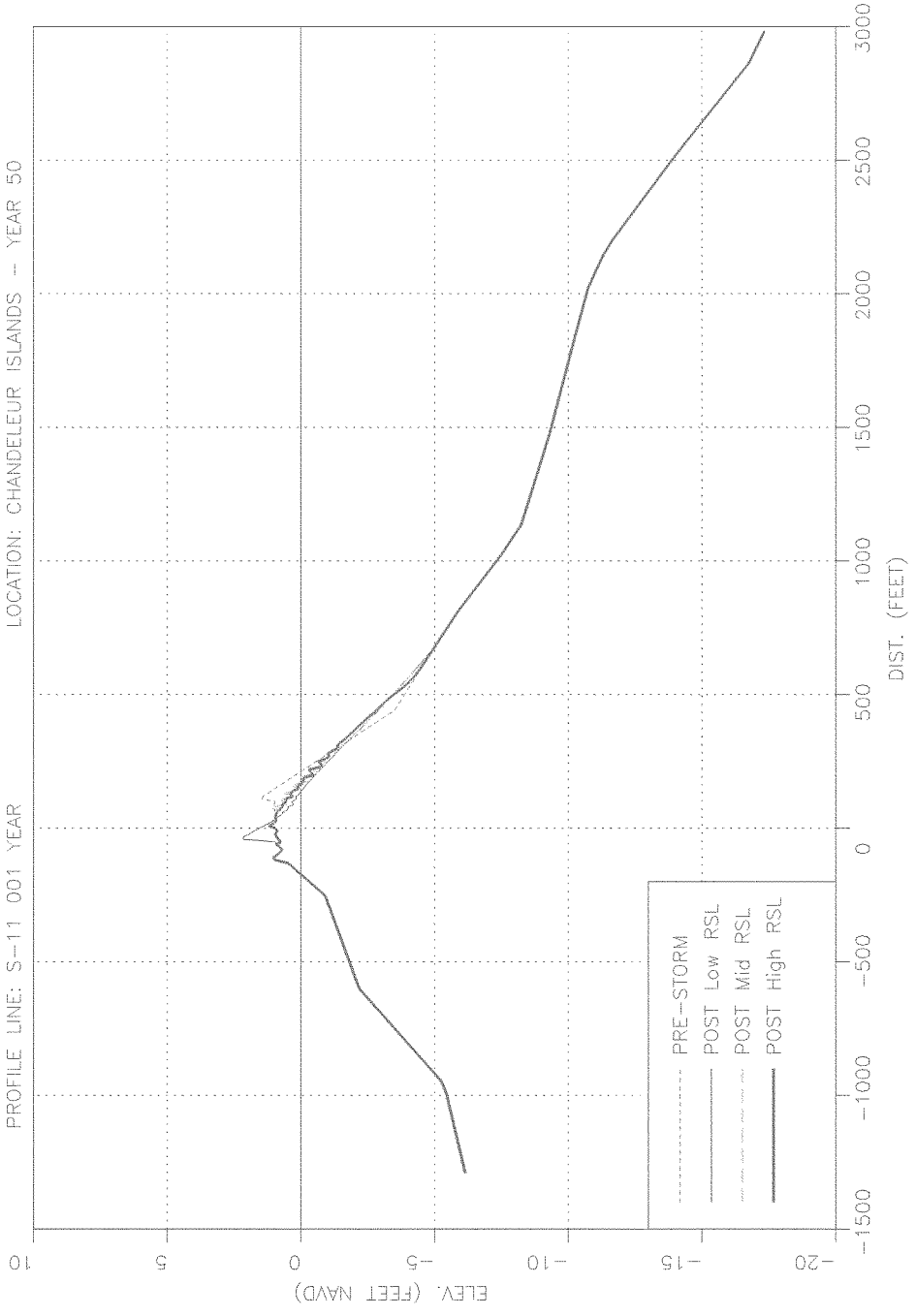

PROFILE LINE: N-71 005 YEAR
LOCATION: CHANDELEUR ISLANDS -- YEAR 0
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

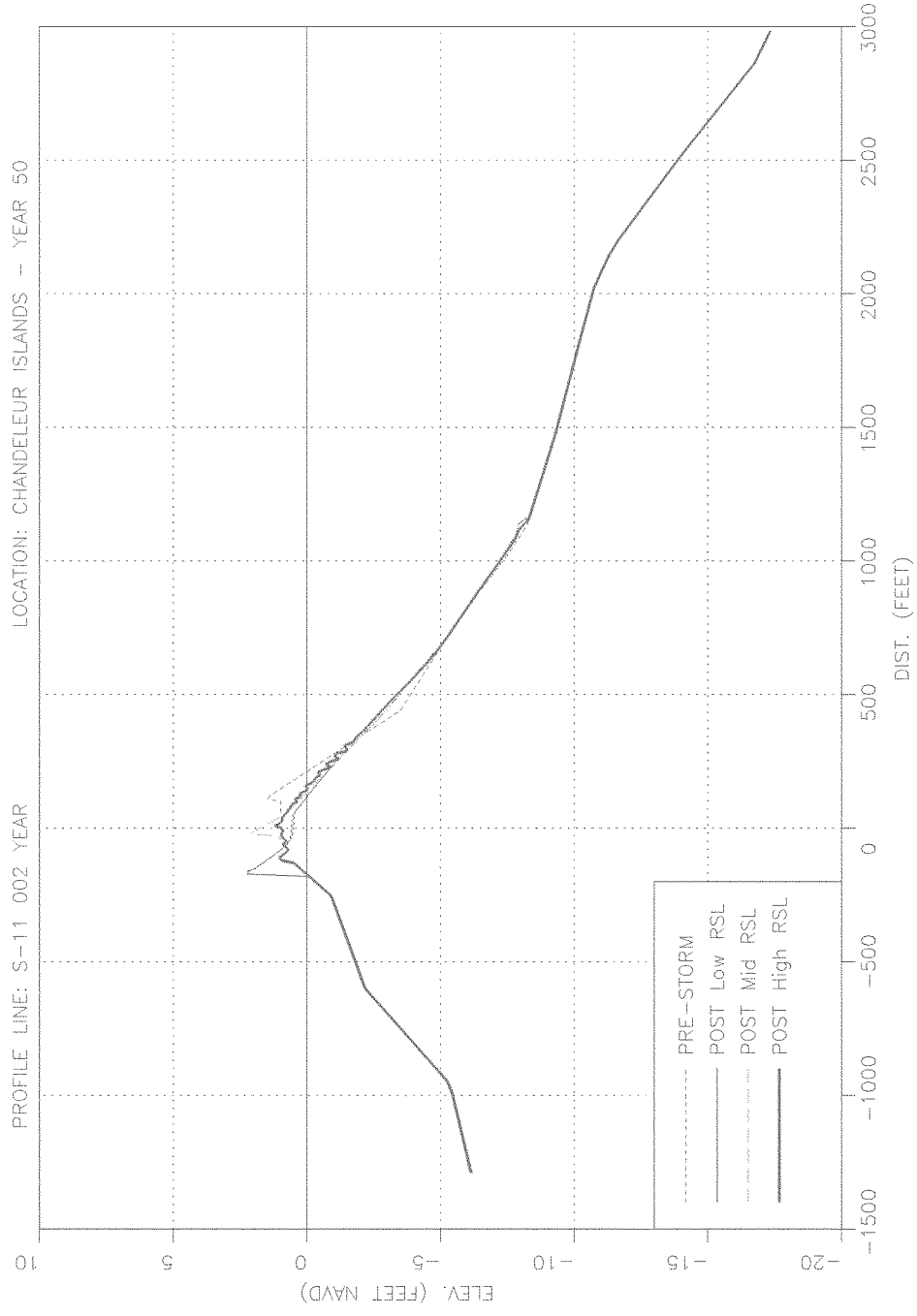

PROFILE LINE: N-71 010 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 0
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

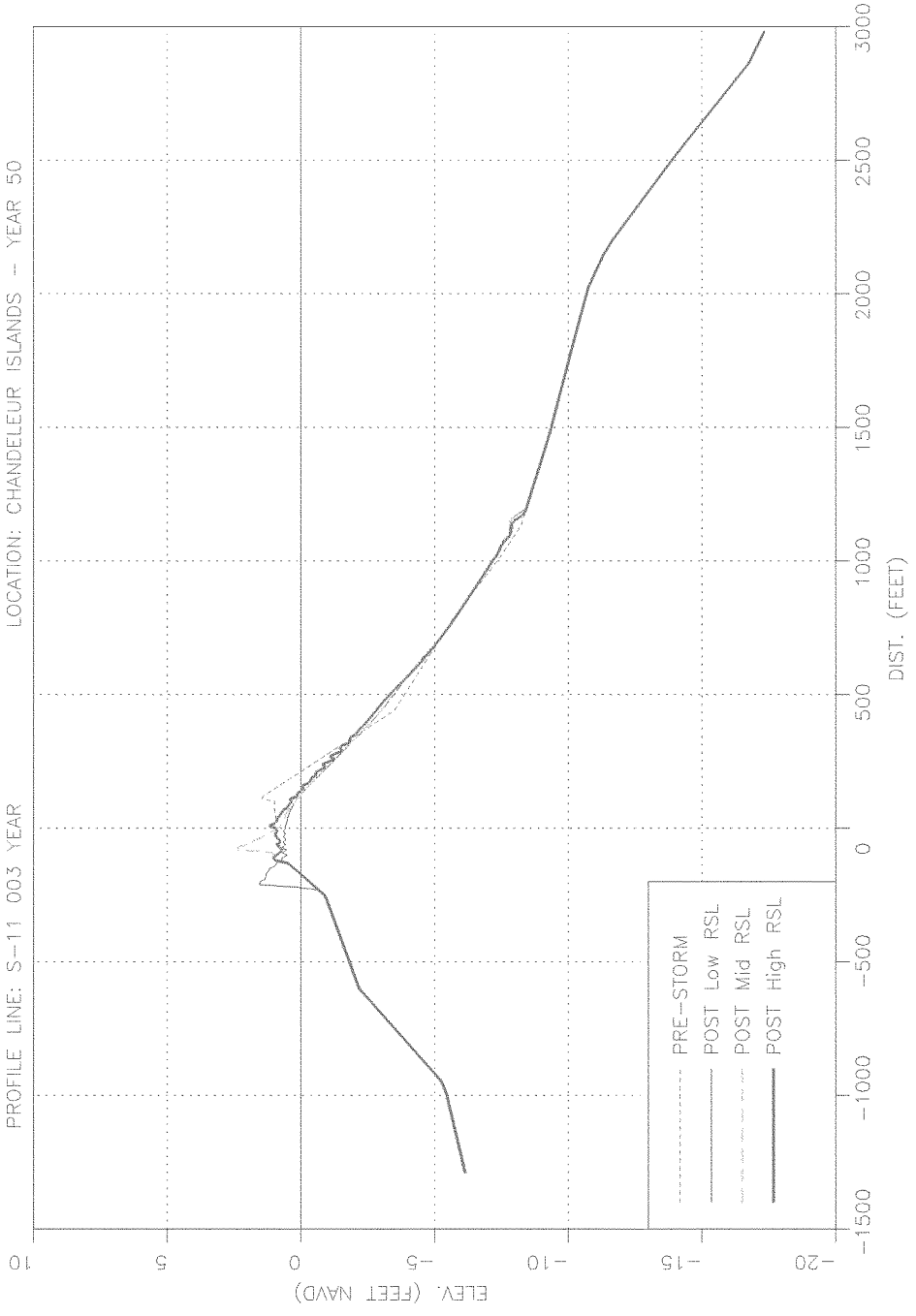

PROFILE LINE: N-71 020 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 0
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

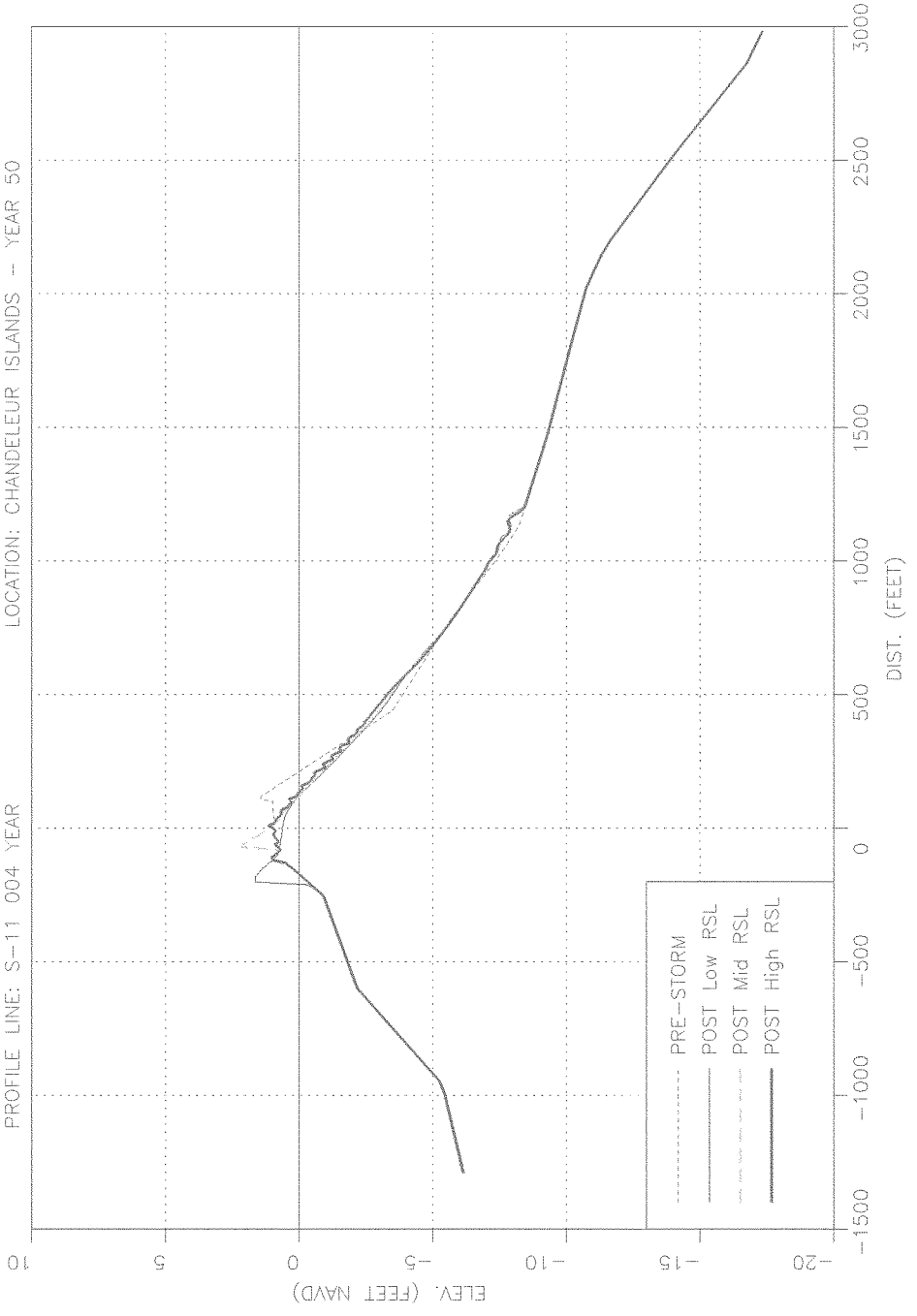

PROFILE LINE: N-71 050 YEAR
LOCATION: CHANDELEUR ISLANDS -- YEAR 0
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

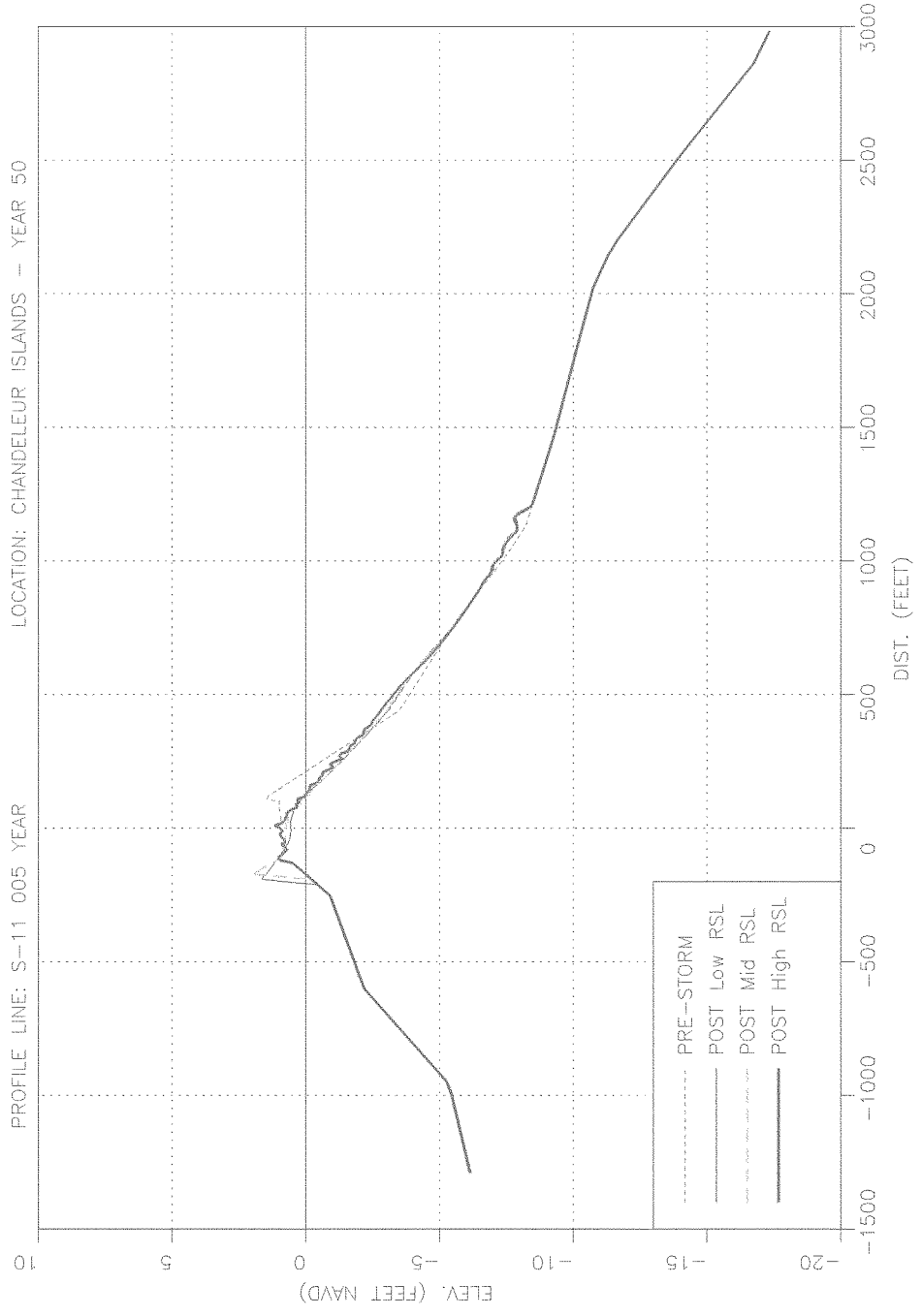

PROFILE LINE: N-71 100 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 0
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

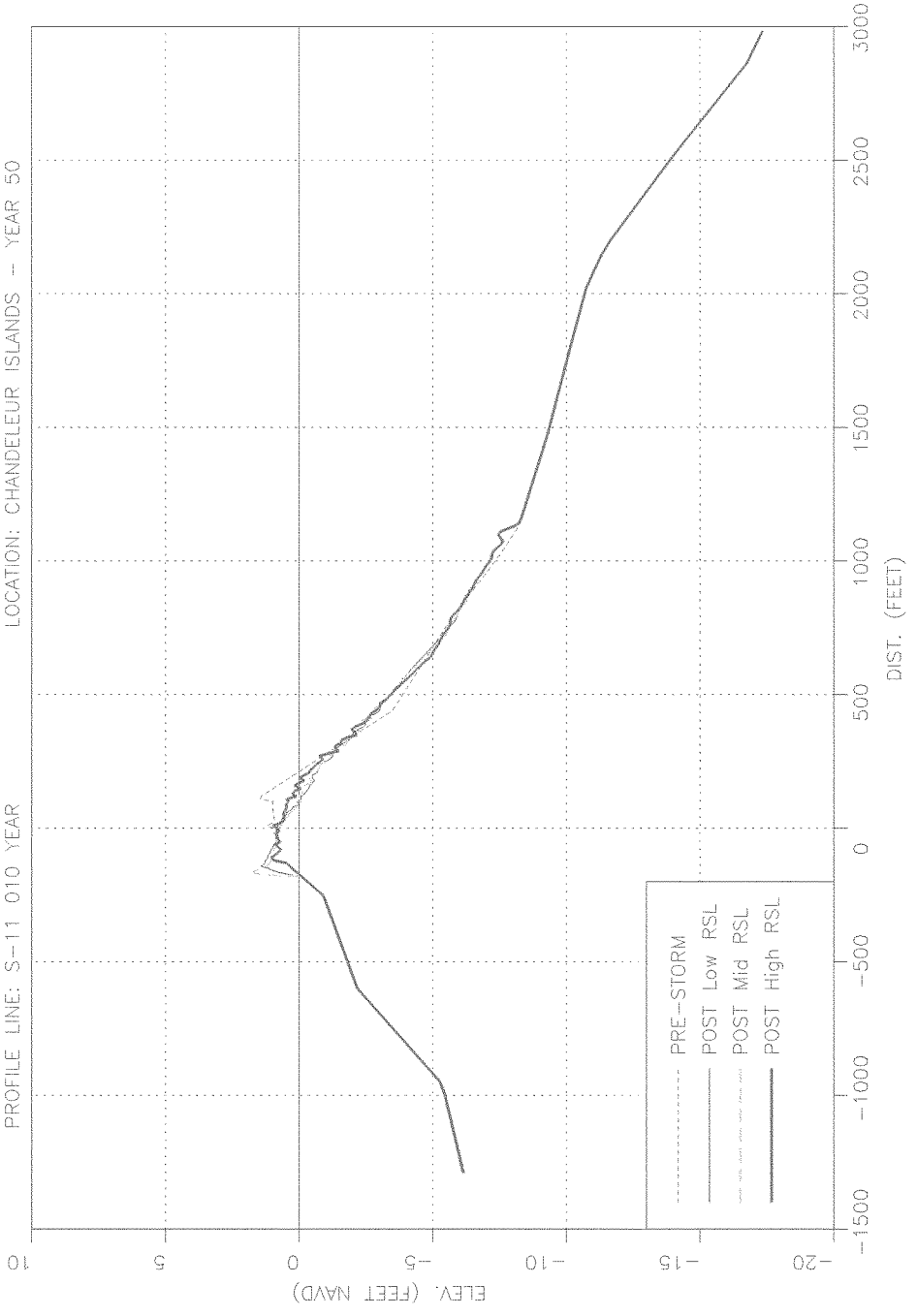

PROFILE LINE: S-11 001 YEAR
LOCATION: CHANDELEUR ISLANDS -- YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
POST Mid RSL
POST High RSL
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

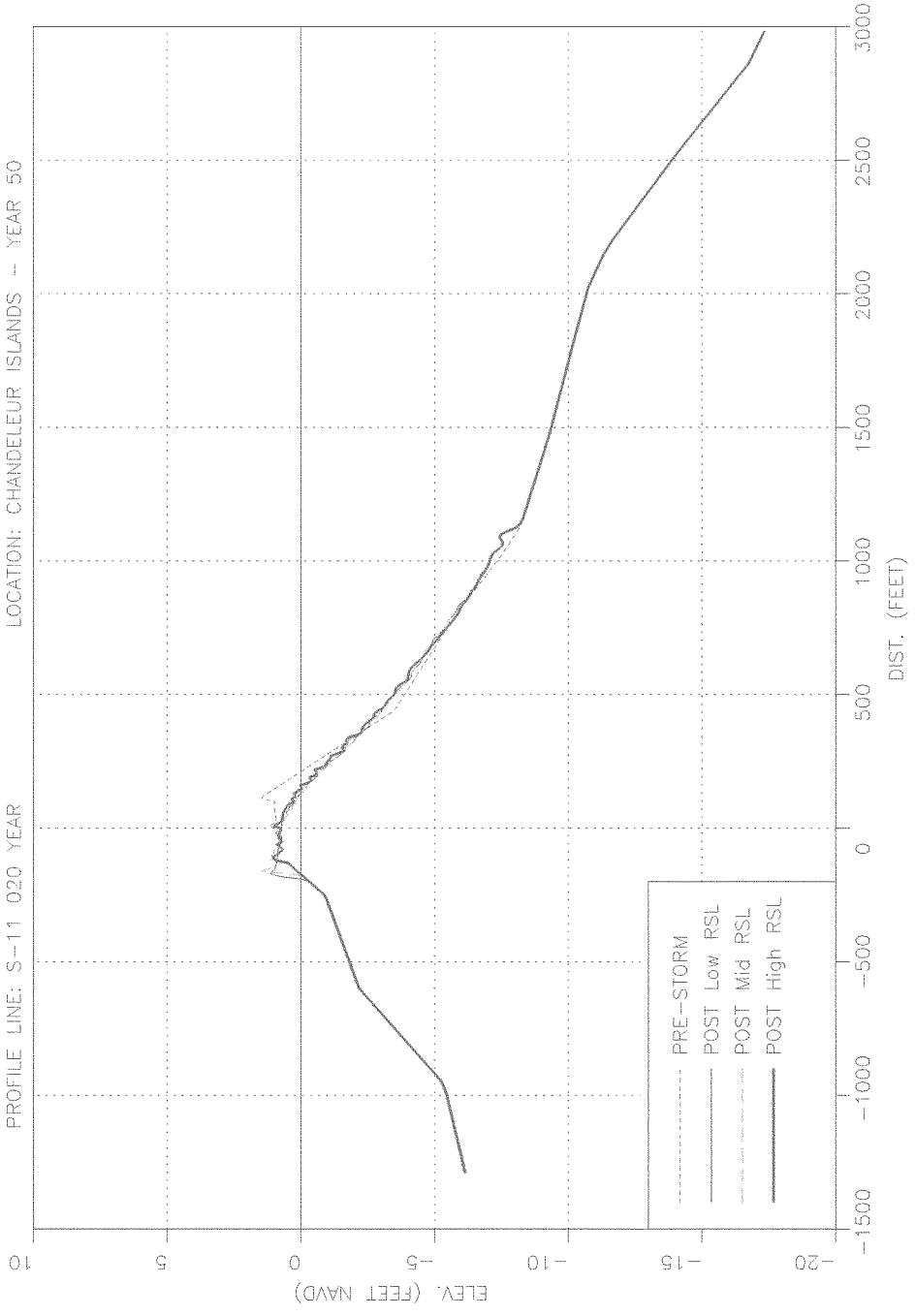

PROFILE LINE: S-11 002 YEAR
LOCATION: CHANDELEUR ISLANDS -- YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000
PRE-STORM
POST Low RSL
POST Mid RSL
POST High RSL

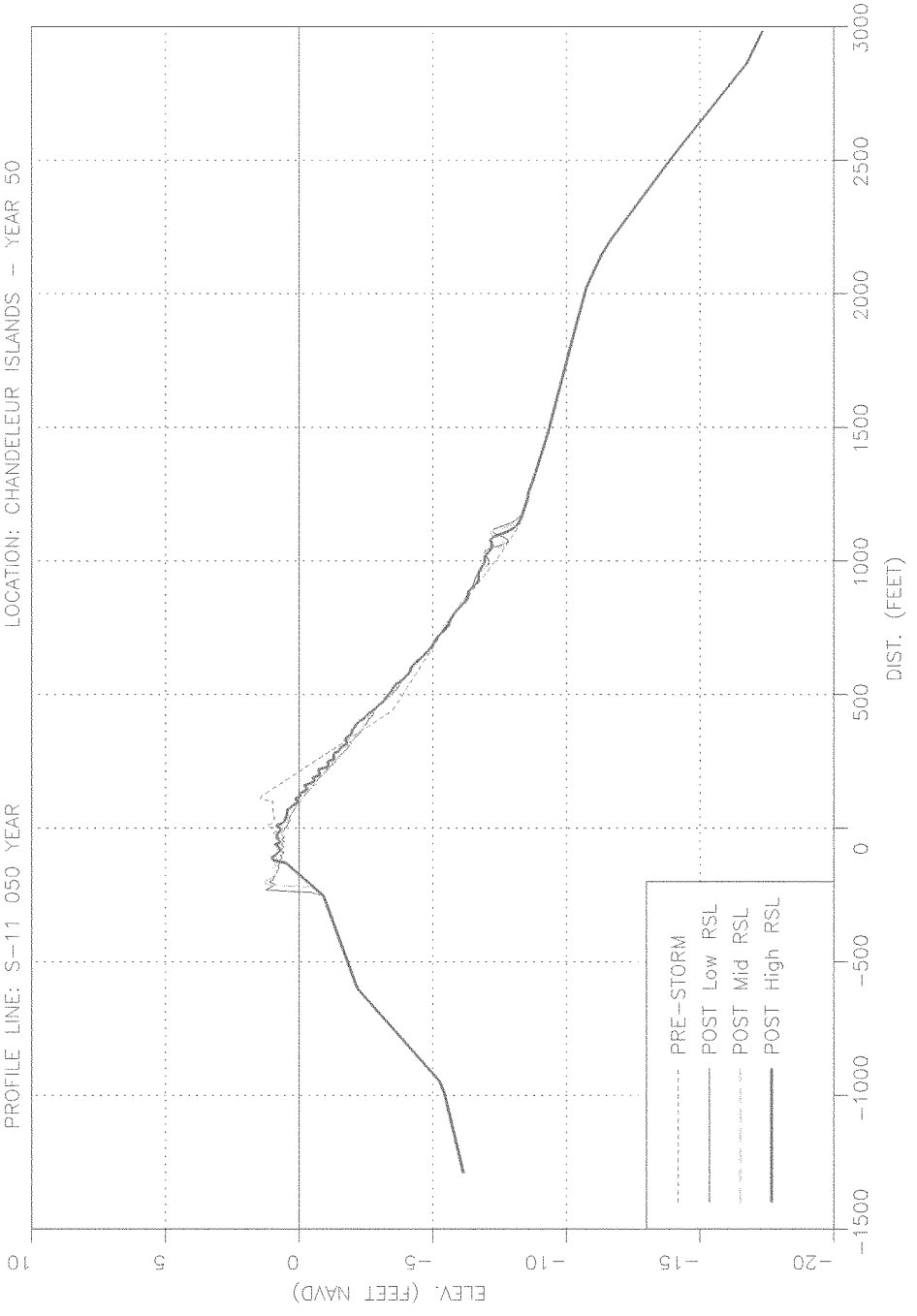

PROFILE LINE: S-11 003 YEAR
LOCATION: CHANDELEUR ISLANDS -- YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
POST Mid RSL
POST High RSL
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

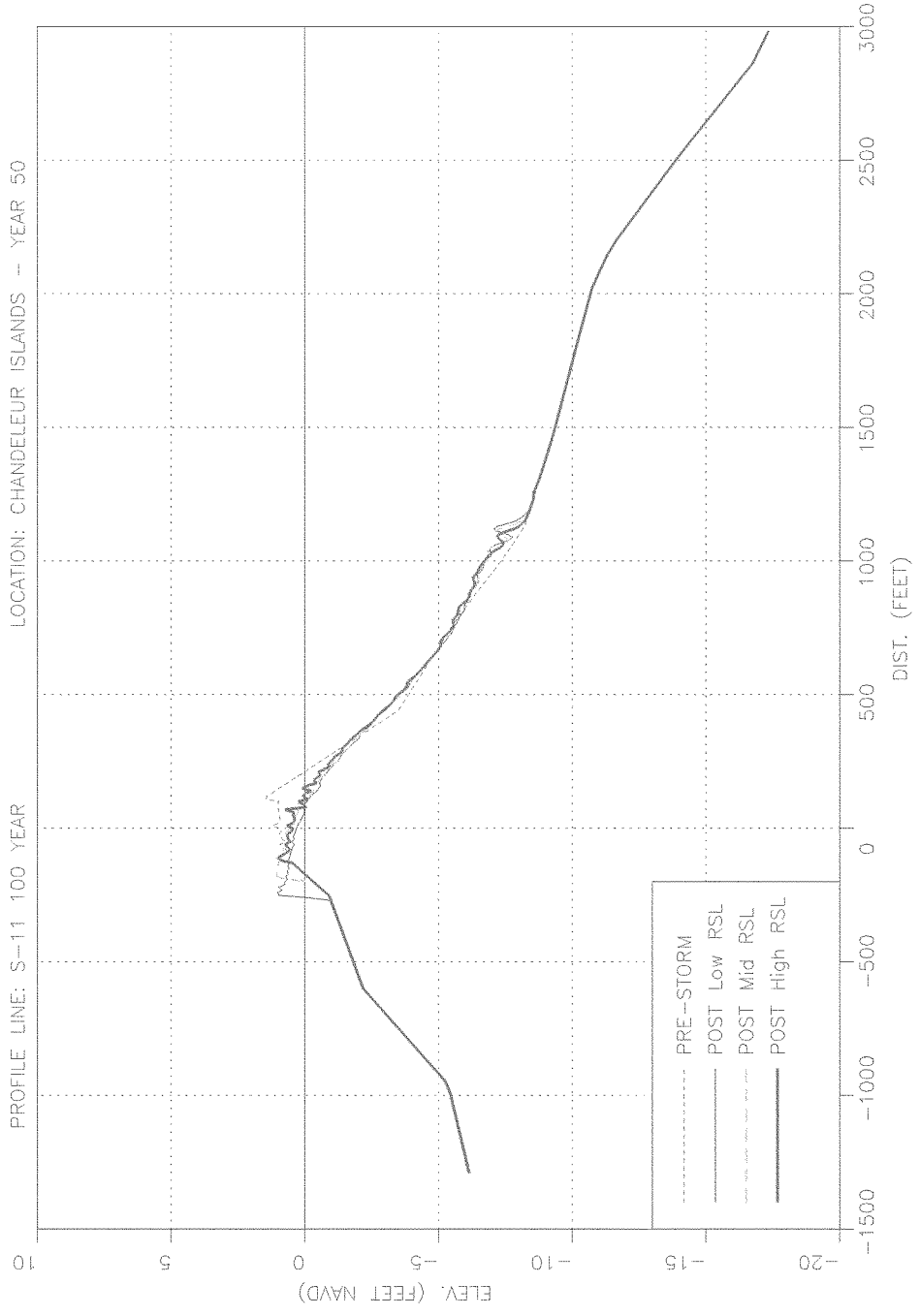

PROFILE LINE: S-11 004 YEAR
LOCATION: CHANDELEUR ISLANDS -- YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
POST Mid RSL
POST High RSL
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

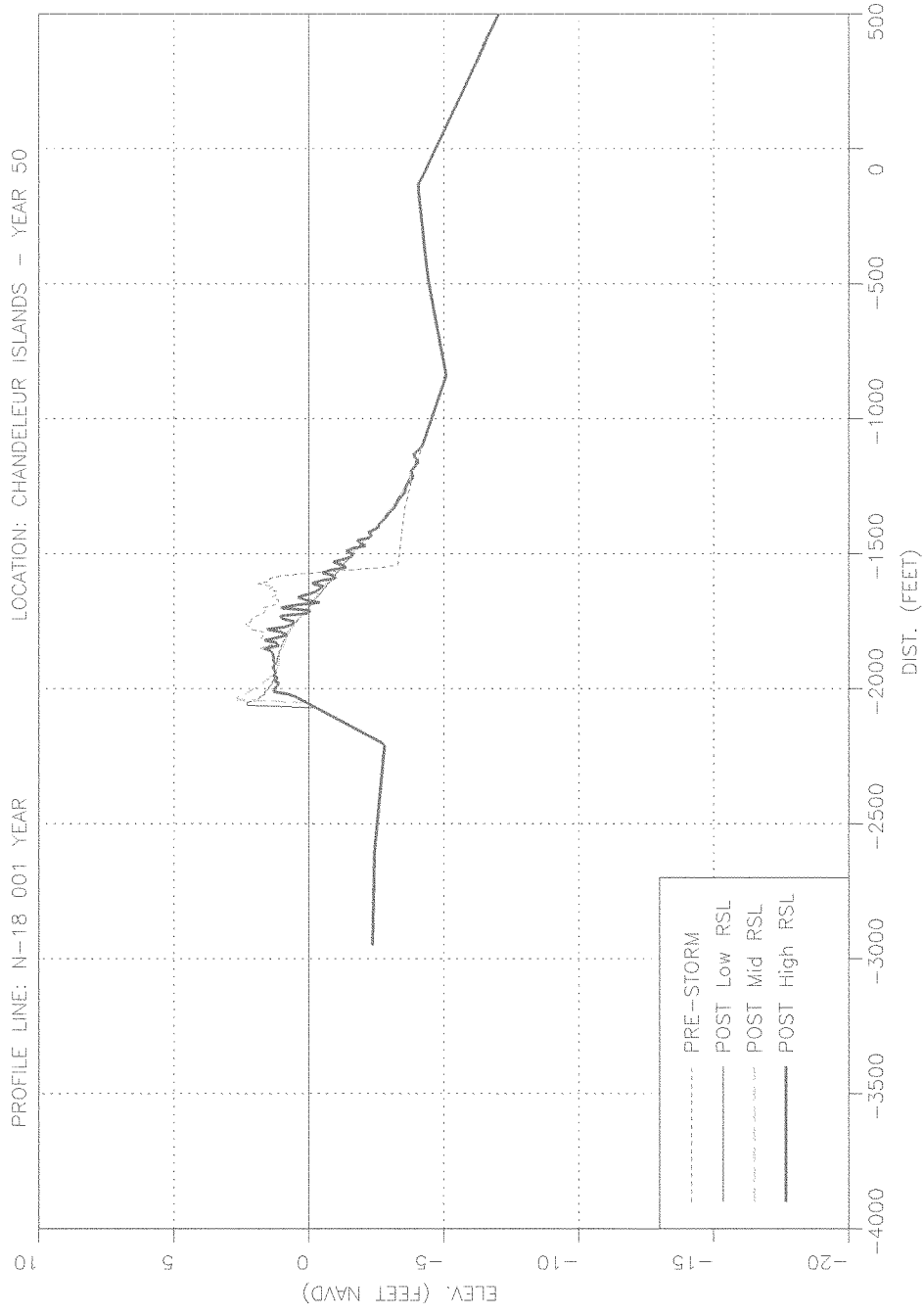

PROFILE LINE: S-11 005 YEAR
LOCATION: CHANDELEUR ISLANDS -- YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
POST Mid RSL
POST High RSL
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

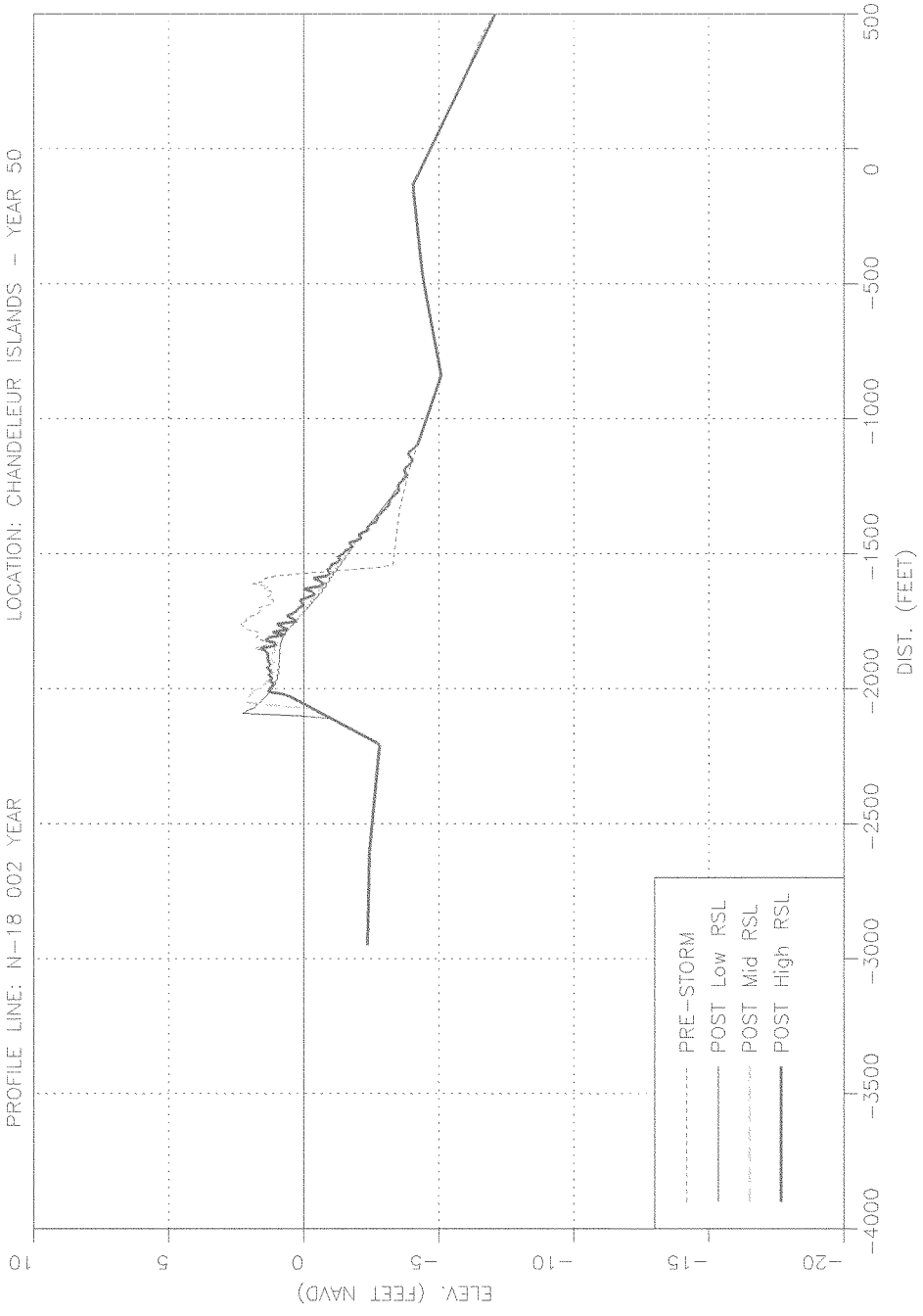

PROFILE LINE: S-11 010 YEAR
LOCATION: CHANDELEUR ISLANDS -- YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000
PRE-STORM
POST Low RSL
POST Mid RSL
POST High RSL

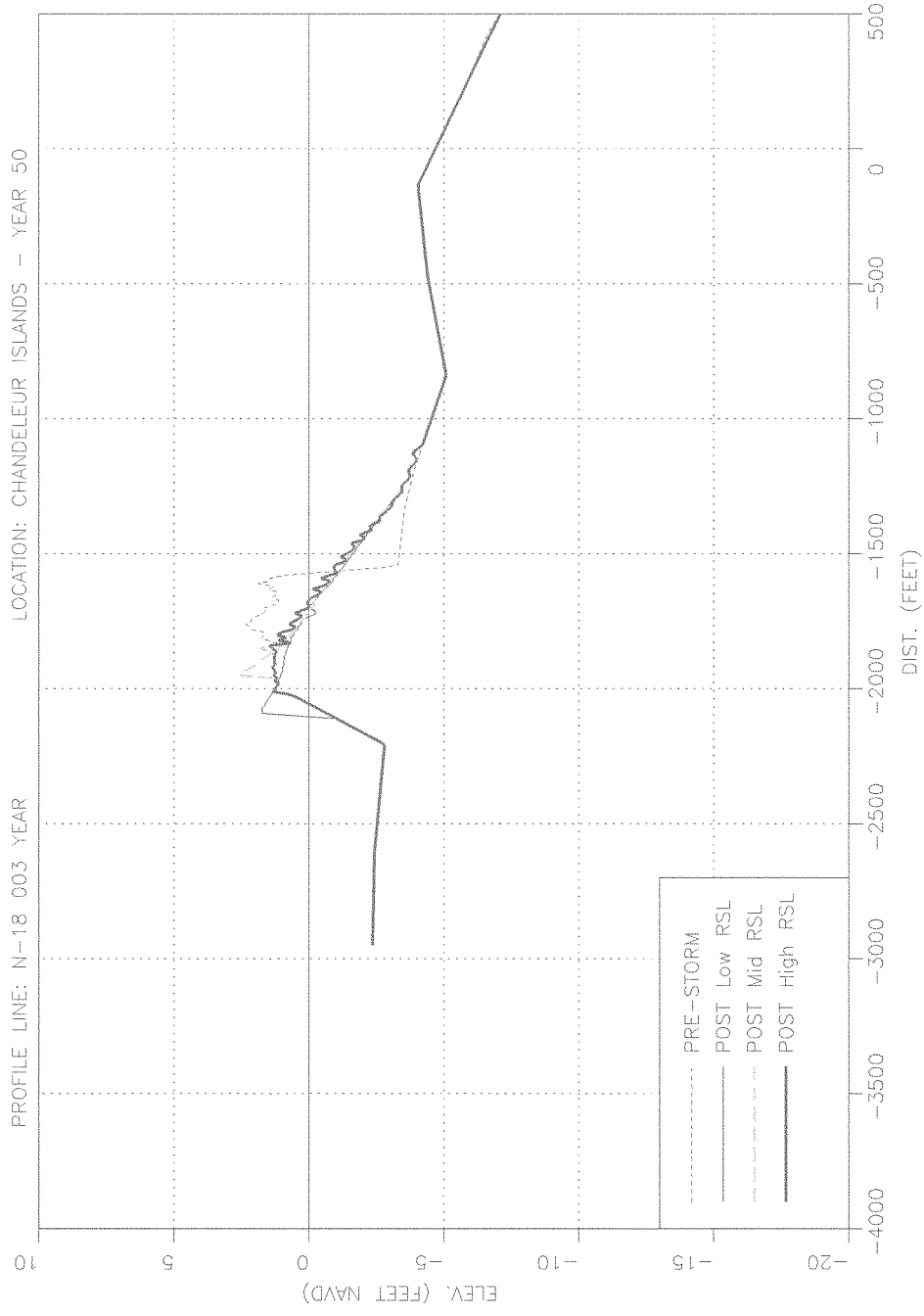

PROFILE LINE: S-11 020 YEAR
LOCATION: CHANDELEUR ISLANDS -- YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
POST Mid RSL
POST High RSL
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

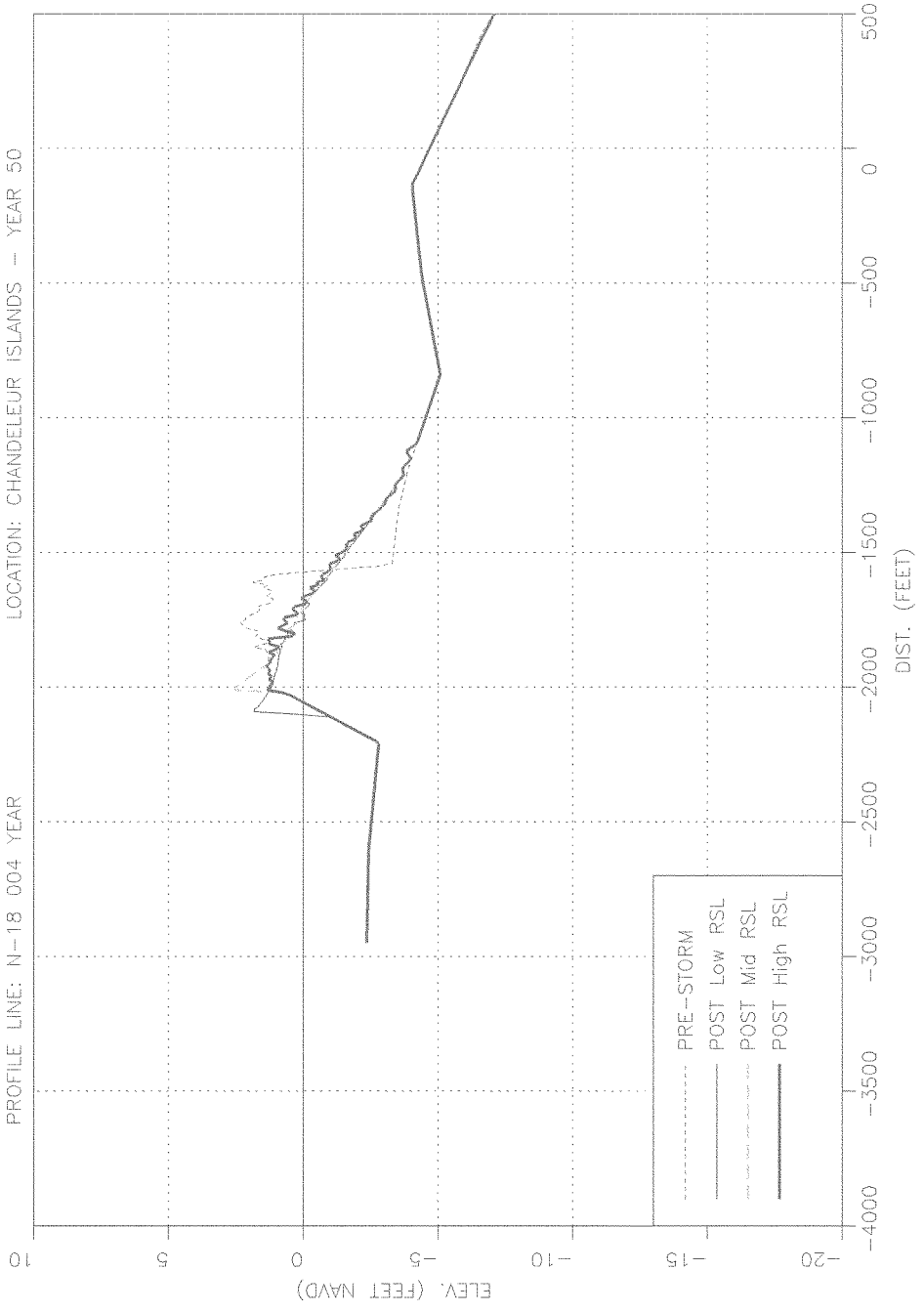

PROFILE LINE: S-11 050 YEAR
LOCATION: CHANDELEUR ISLANDS -- YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
POST Mid RSL
POST High RSL
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

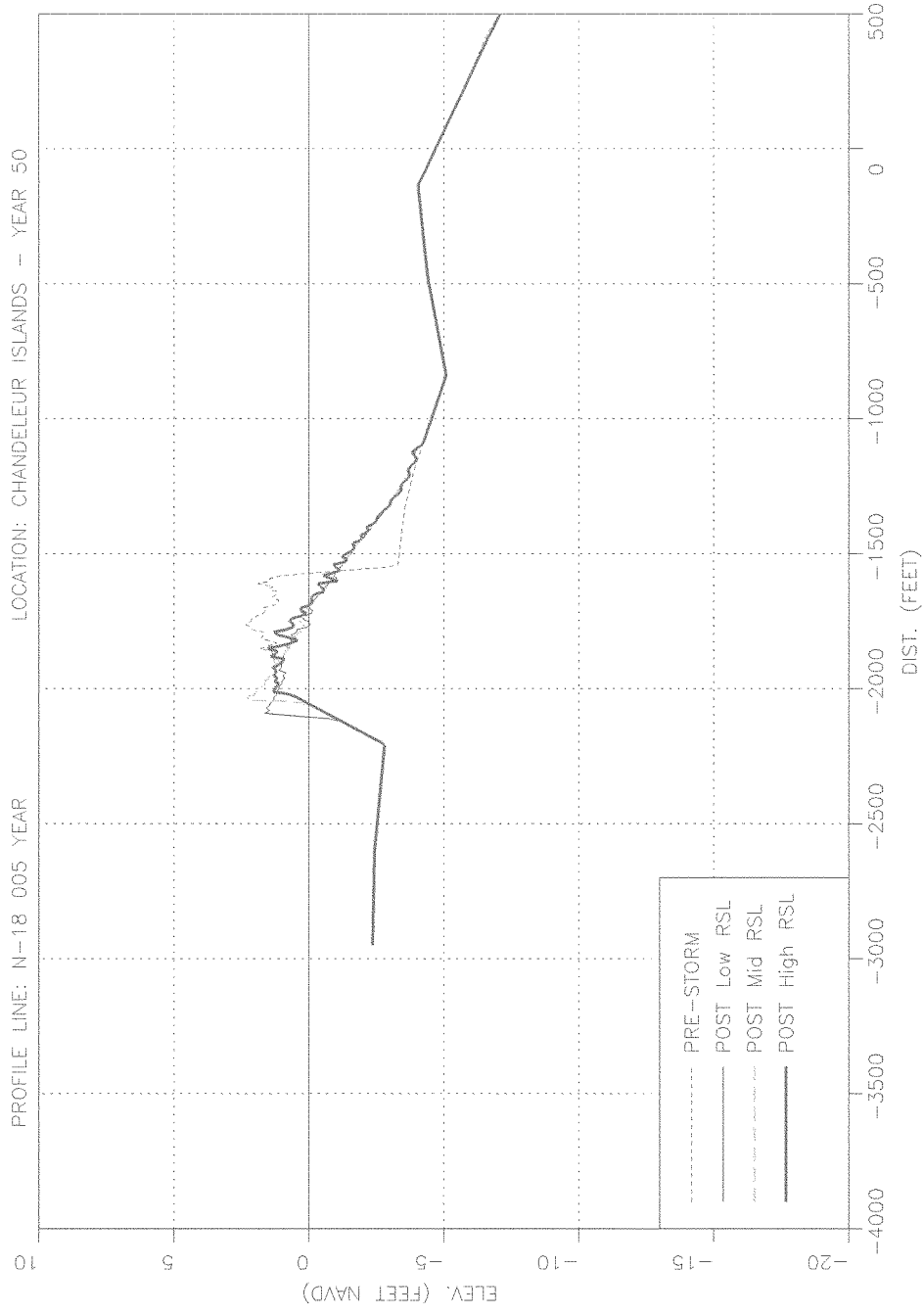

PROFILE LINE: S-11 100 YEAR
LOCATION: CHANDELEUR ISLANDS -- YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
POST Mid RSL
POST High RSL
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

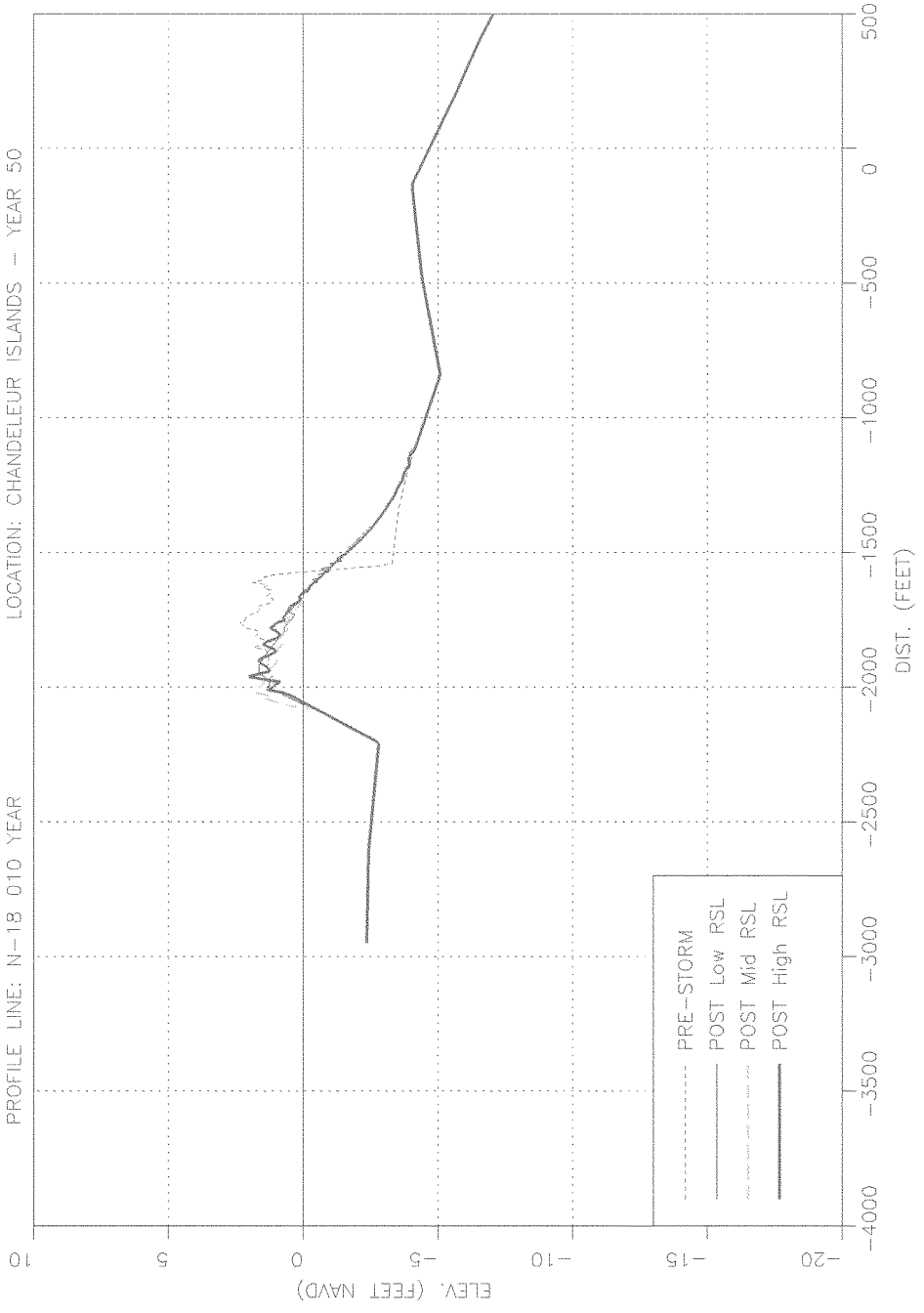

PROFILE LINE: N-18 001 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
10
5
0
-5
-10
-15
-20
-4000
-3500
-3000
-2500
-2000
-1500
-1000
-500
0
500
PRE-STORM
POST Low RSL
POST Mid RSL
POST High RSL

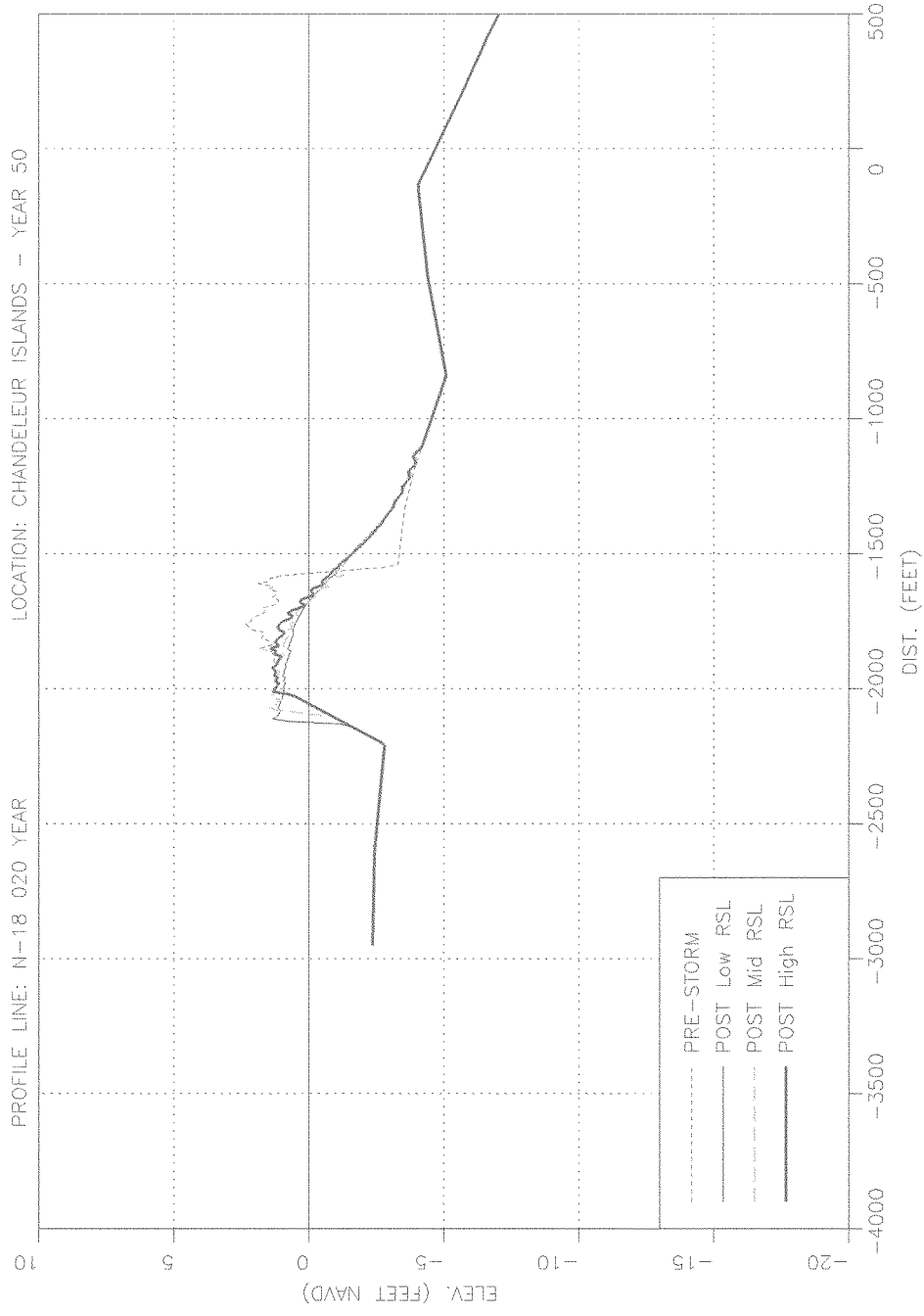

PROFILE LINE: N-18 002 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
POST Mid RSL
POST High RSL
10
5
0
-5
-10
-15
-20
-4000
-3500
-3000
-2500
-2000
-1500
-1000
-500
0
500

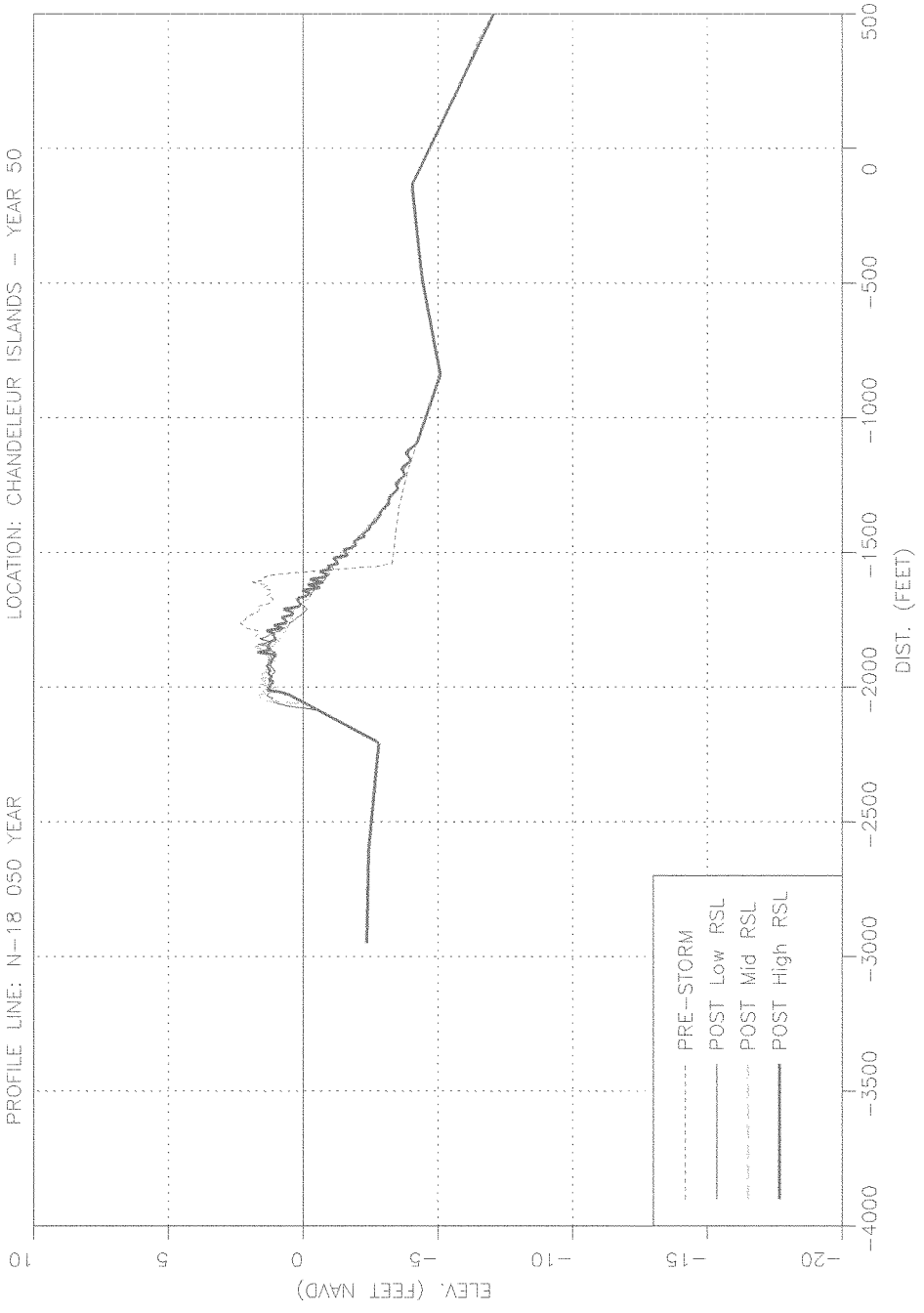

PROFILE LINE: N-18 003 YEAR
LOCATION: CHANDELEUR ISLANDS -- YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
POST Mid RSL
POST High RSL
10
5
0
-5
-10
-15
-20
-4000
-3500
-3000
-2500
-2000
-1500
-1000
-500
0
500

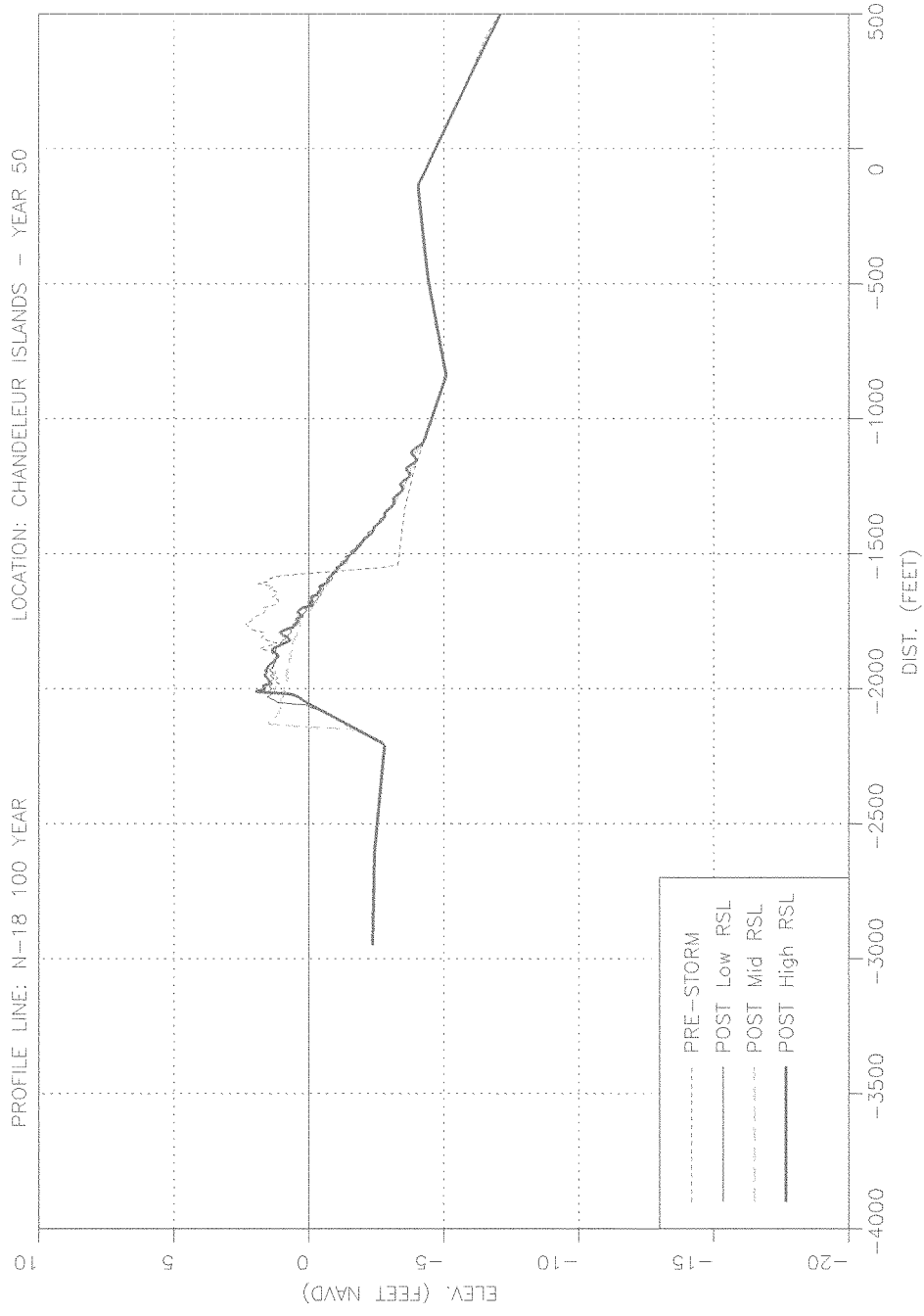

PROFILE LINE: N-18 004 YEAR
LOCATION: CHANDELEUR ISLANDS -- YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
POST Mid RSL
POST High RSL
10
5
0
-5
-10
-15
-20
-4000
-3500
-3000
-2500
-2000
-1500
-1000
-500
0
500

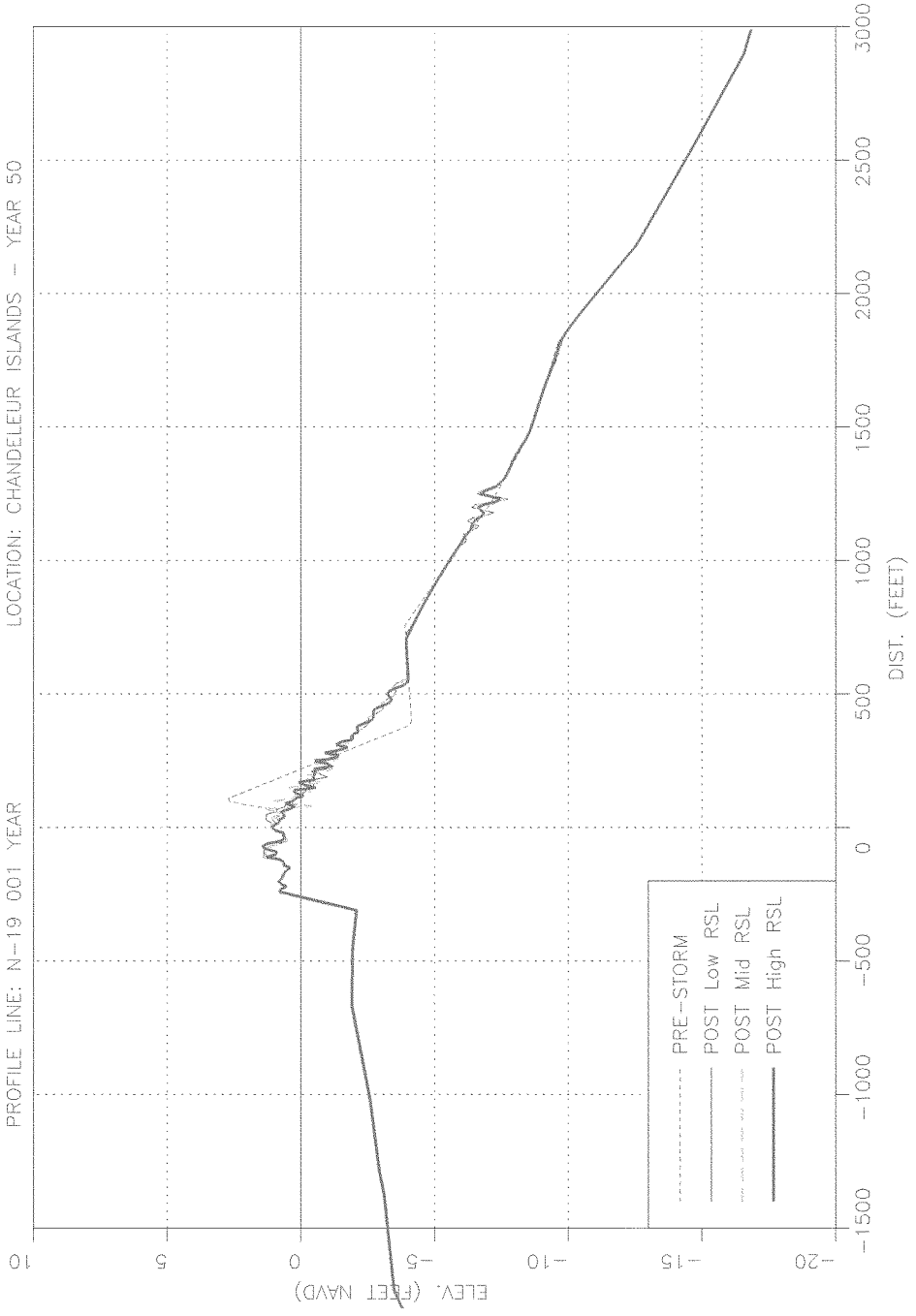

PROFILE LINE: N-18 005 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 50
PRE-STORM
POST Low RSL
POST Mid RSL
POST High RSL
ELEV. (FEET NAVD)
DIST. (FEET)
10
5
0
-5
-10
-15
-20
-4000
-3500
-3000
-2500
-2000
-1500
-1000
-500
0
500

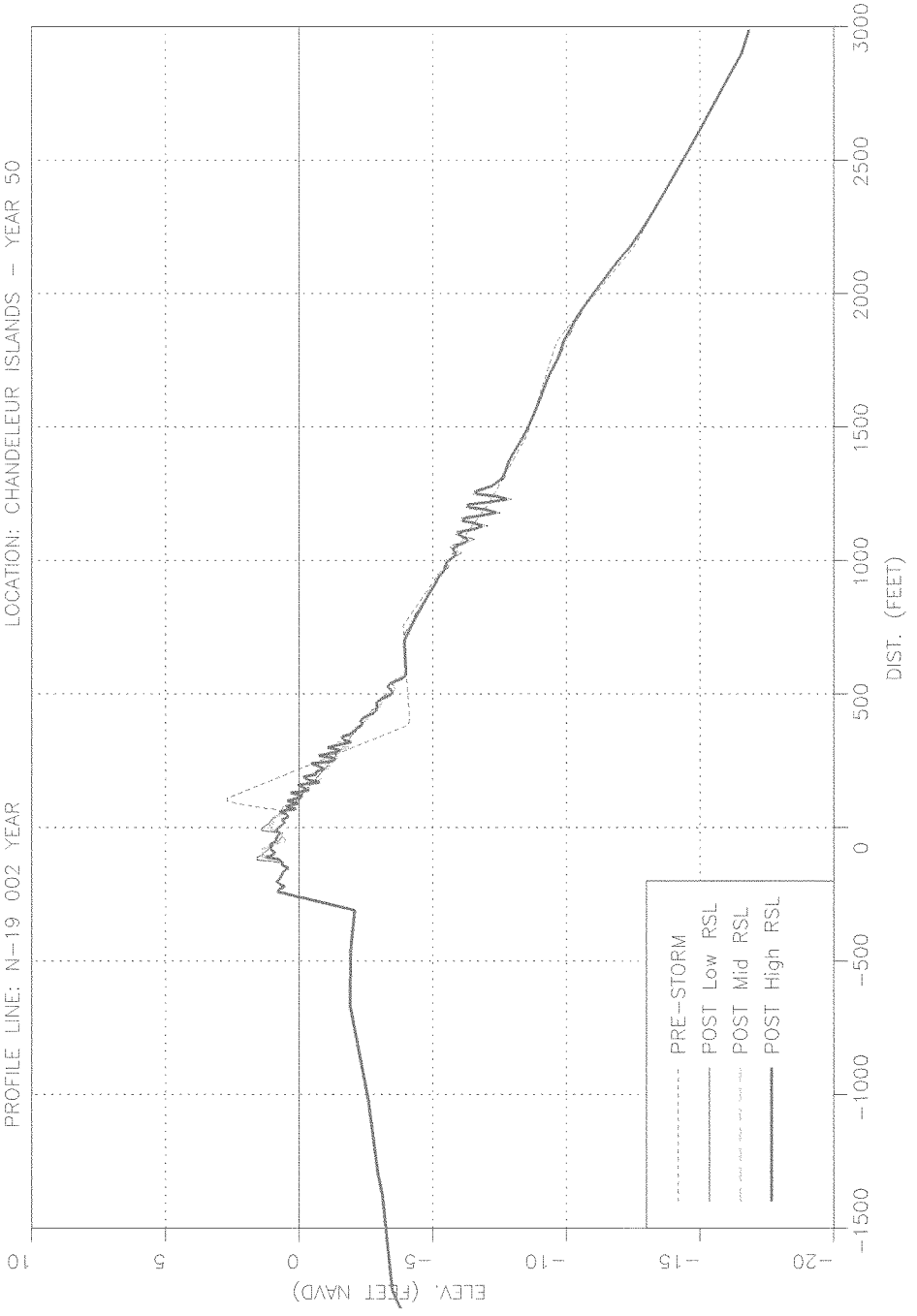

PROFILE LINE: N-18 010 YEAR
LOCATION: CHANDELEUR ISLANDS -- YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
POST Mid RSL
POST High RSL
10
5
0
-5
-10
-15
-20
-4000
-3500
-3000
-2500
-2000
-1500
-1000
-500
0
500

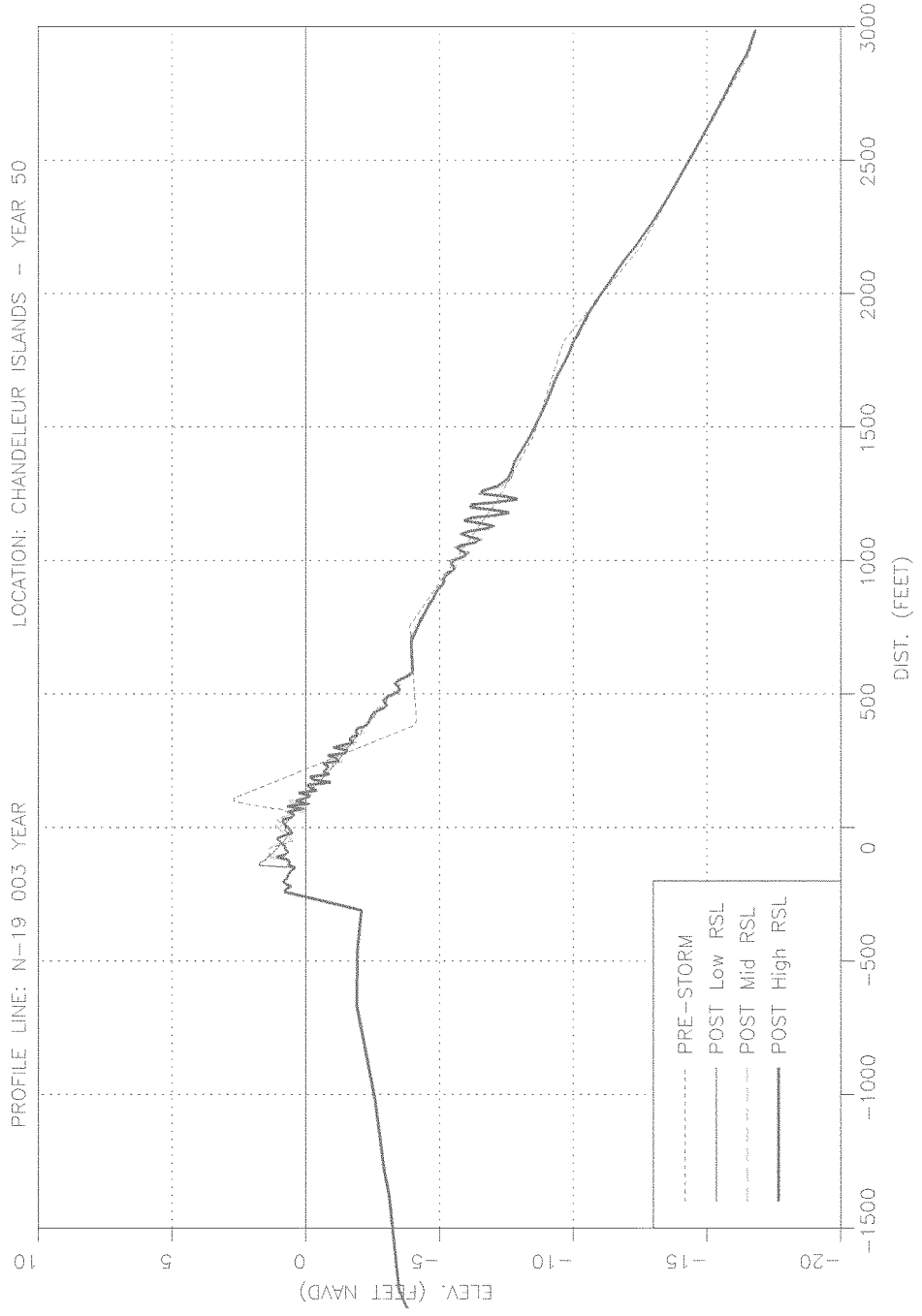

PROFILE LINE: N-18 020 YEAR
LOCATION: CHANDELEUR ISLANDS -- YEAR 50
PRE-STORM
POST Low RSL
POST Mid RSL
POST High RSL
ELEV. (FEET NAVD)
DIST. (FEET)
10
5
0
-5
-10
-15
-20
-4000
-3500
-3000
-2500
-2000
-1500
-1000
-500
0
500

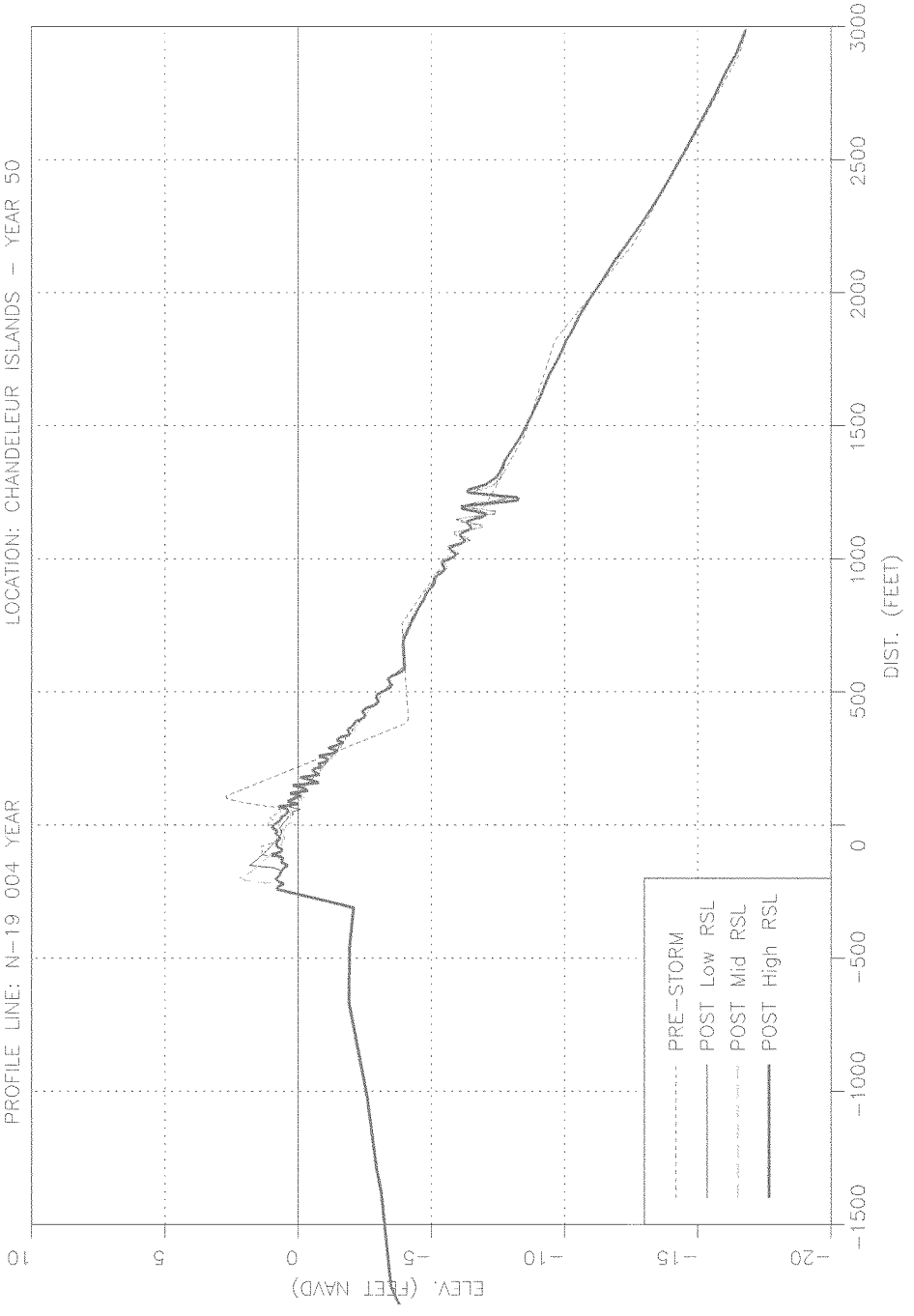

PROFILE LINE: N-18 050 YEAR
LOCATION: CHANDELEUR ISLANDS -- YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
POST Mid RSL
POST High RSL
10
5
0
-5
-10
-15
-20
-4000
-3500
-3000
-2500
-2000
-1500
-1000
-500
0
500

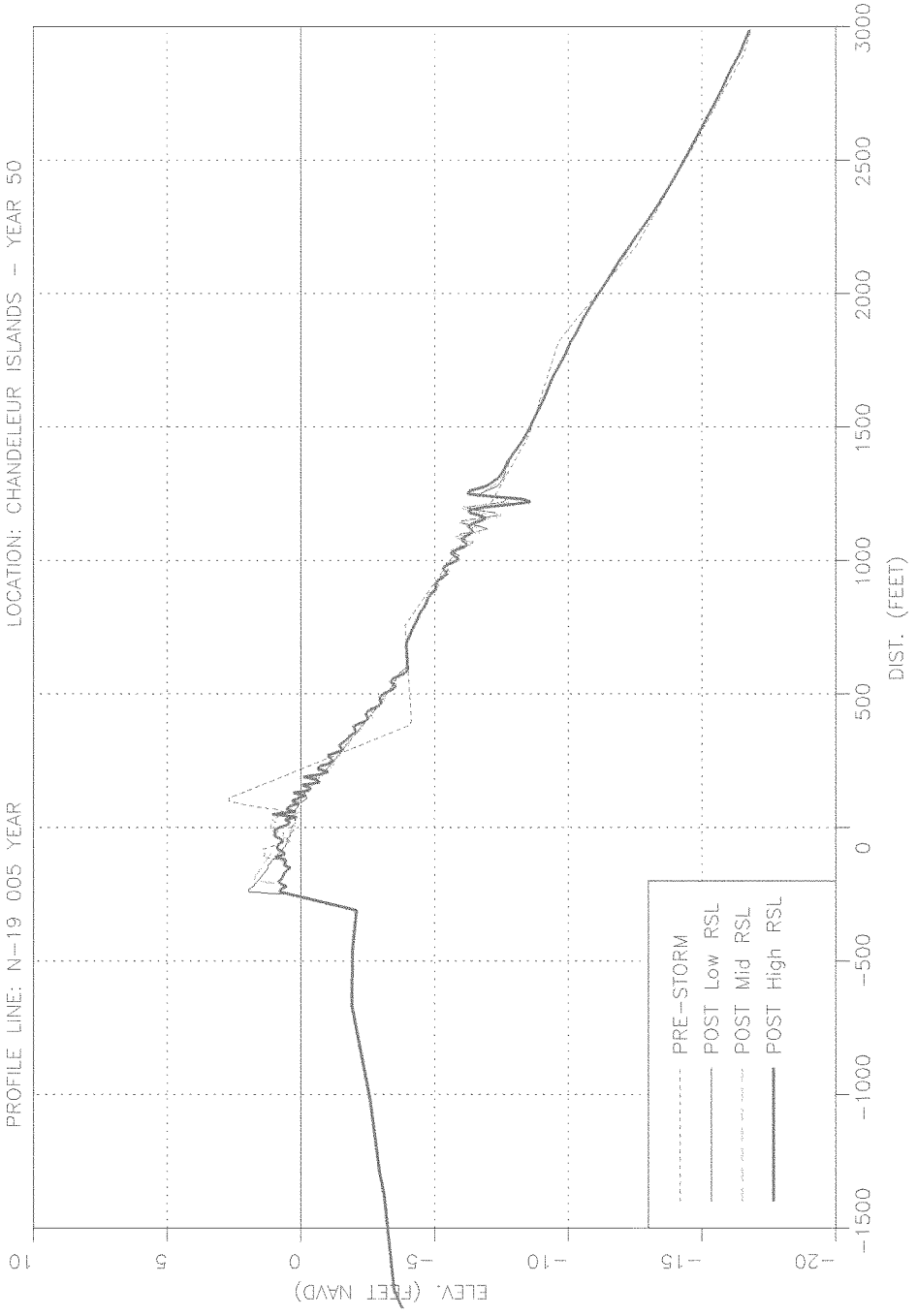

PROFILE LINE: N-18 100 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 50
PRE-STORM
POST Low RSL
POST Mid RSL
POST High RSL
ELEV. (FEET NAVD)
DIST. (FEET)
10
5
0
-5
-10
-15
-20
-4000
-3500
-3000
-2500
-2000
-1500
-1000
-500
0
500

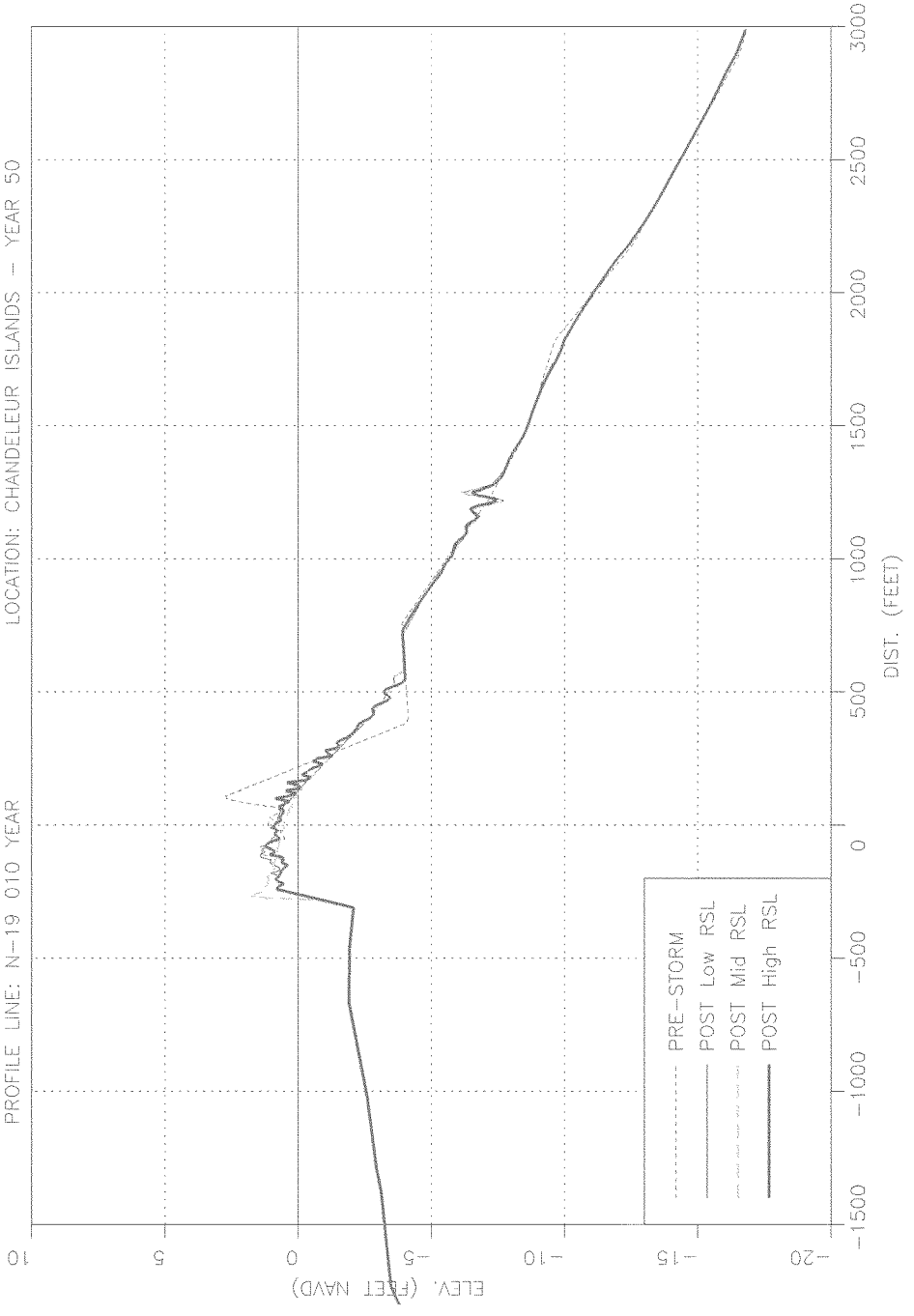

PROFILE LINE: N-19 001 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
POST Mid RSL
POST High RSL
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

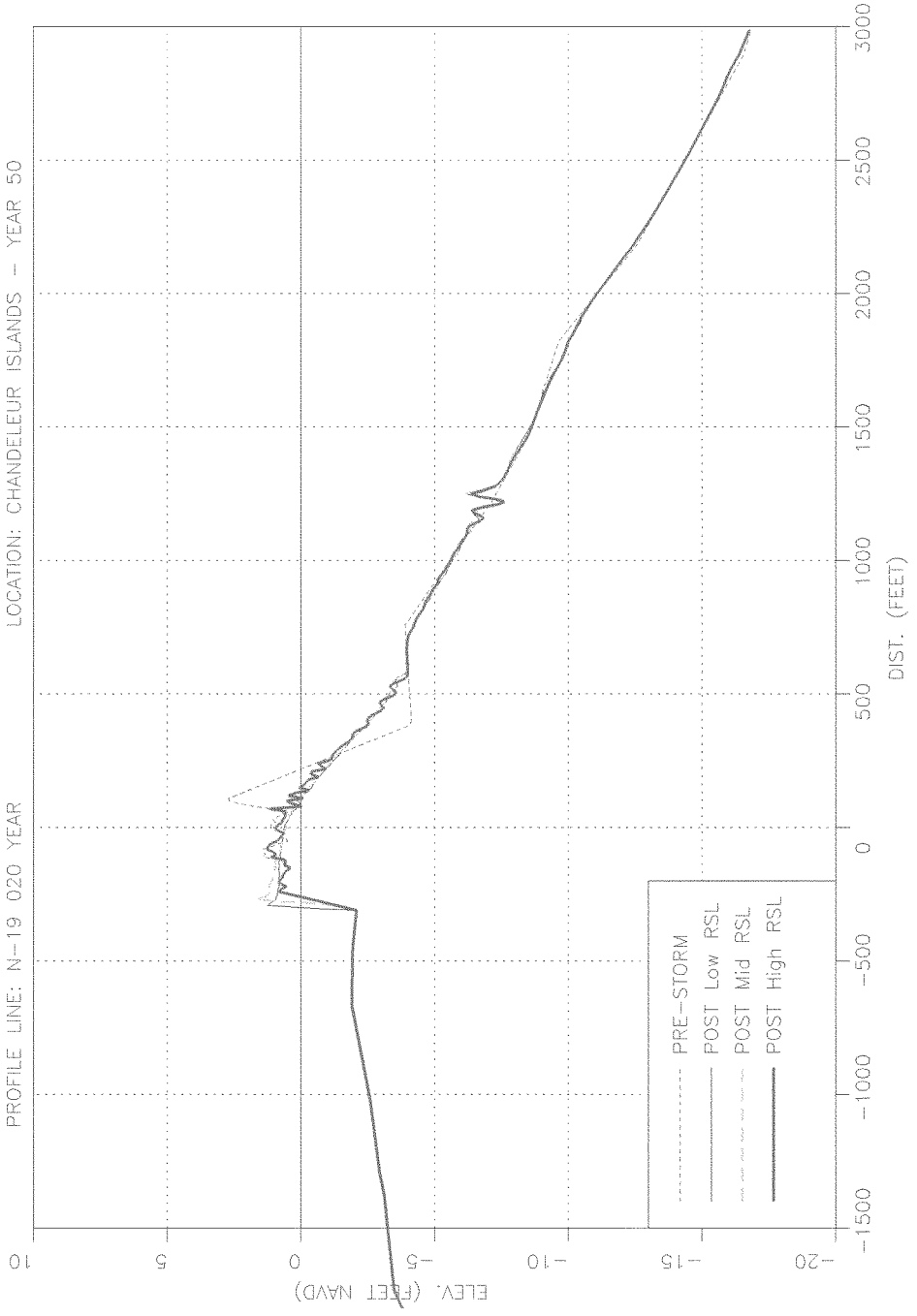

PROFILE LINE: N-19 002 YEAR
LOCATION: CHANDELEUR ISLANDS -- YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
POST Mid RSL
POST High RSL
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

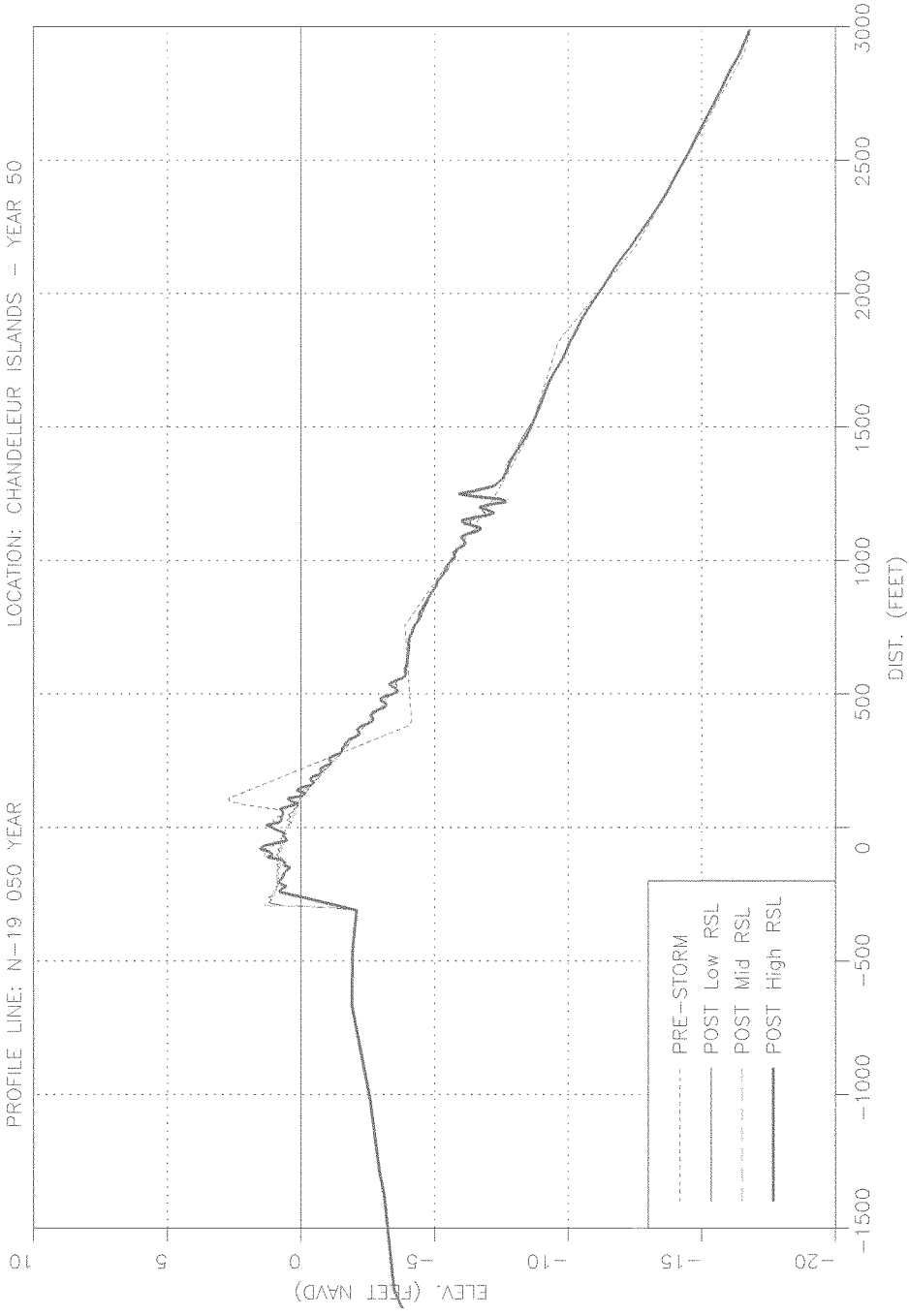

PROFILE LINE: N-19 003 YEAR
LOCATION: CHANDELEUR ISLANDS -- YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
POST Mid RSL
POST High RSL
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

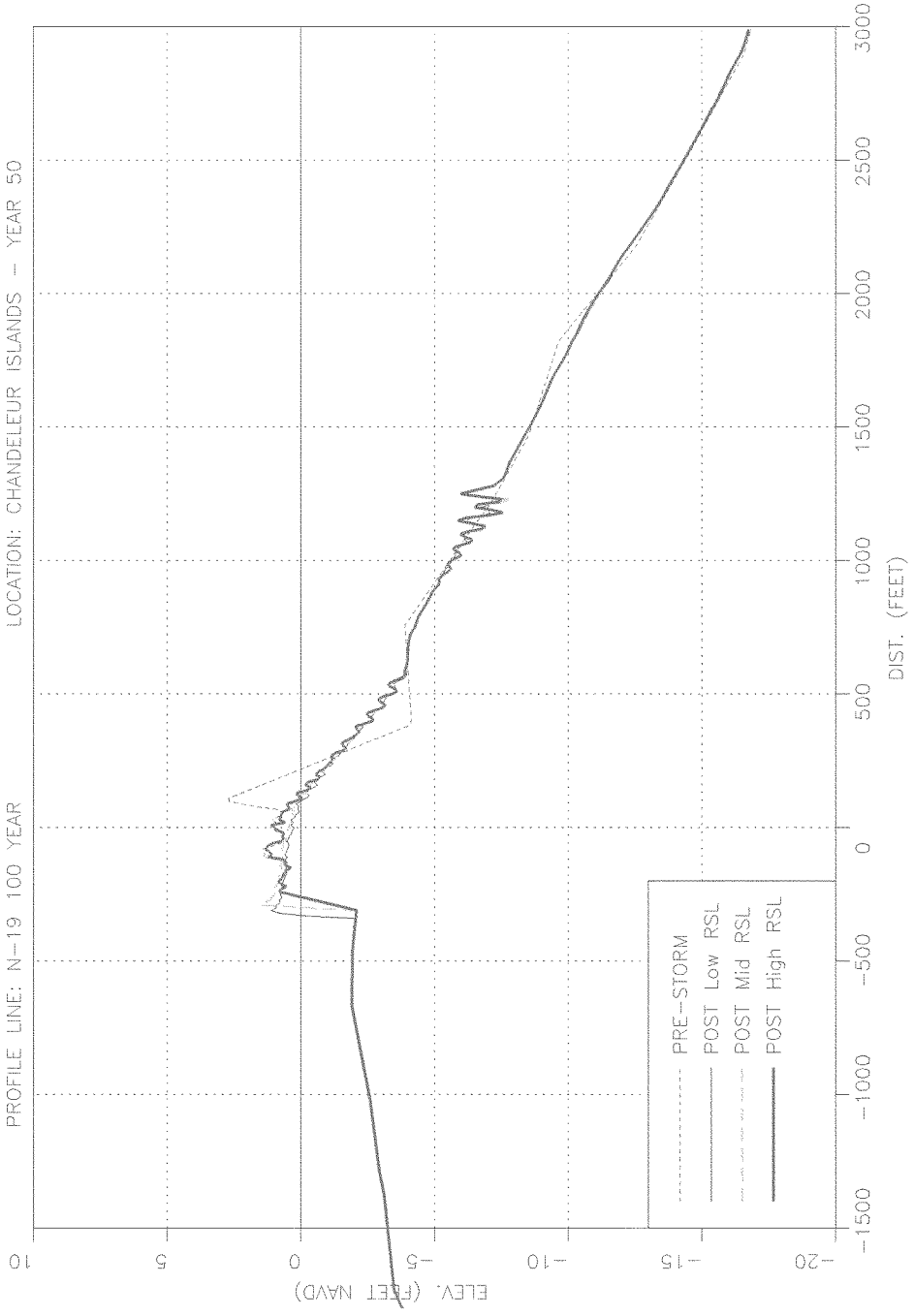

PROFILE LINE: N-19 004 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
POST Mid RSL
POST High RSL
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

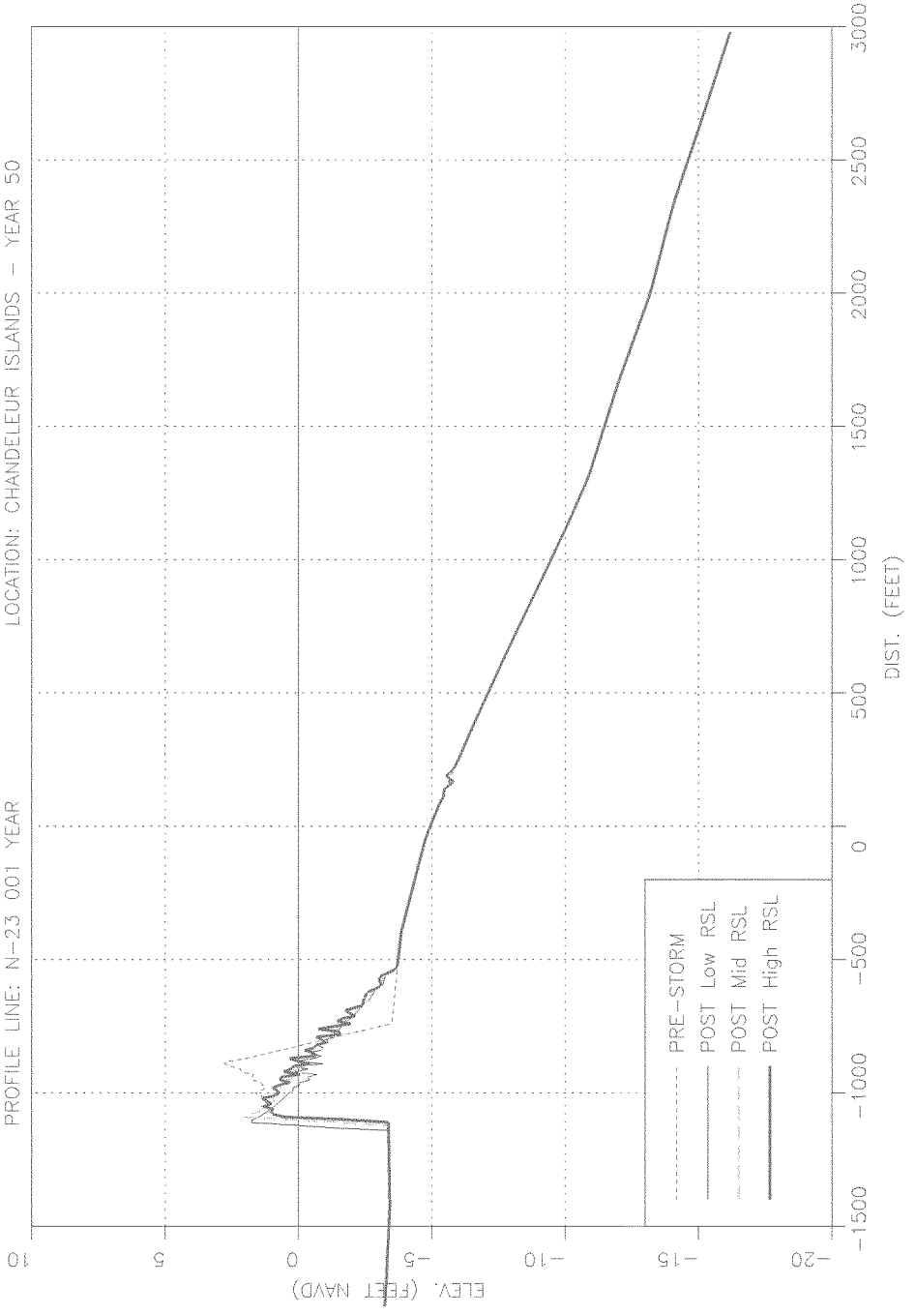

PROFILE LINE: N-19 005 YEAR
LOCATION: CHANDELEUR ISLANDS -- YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
POST Mid RSL
POST High RSL
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

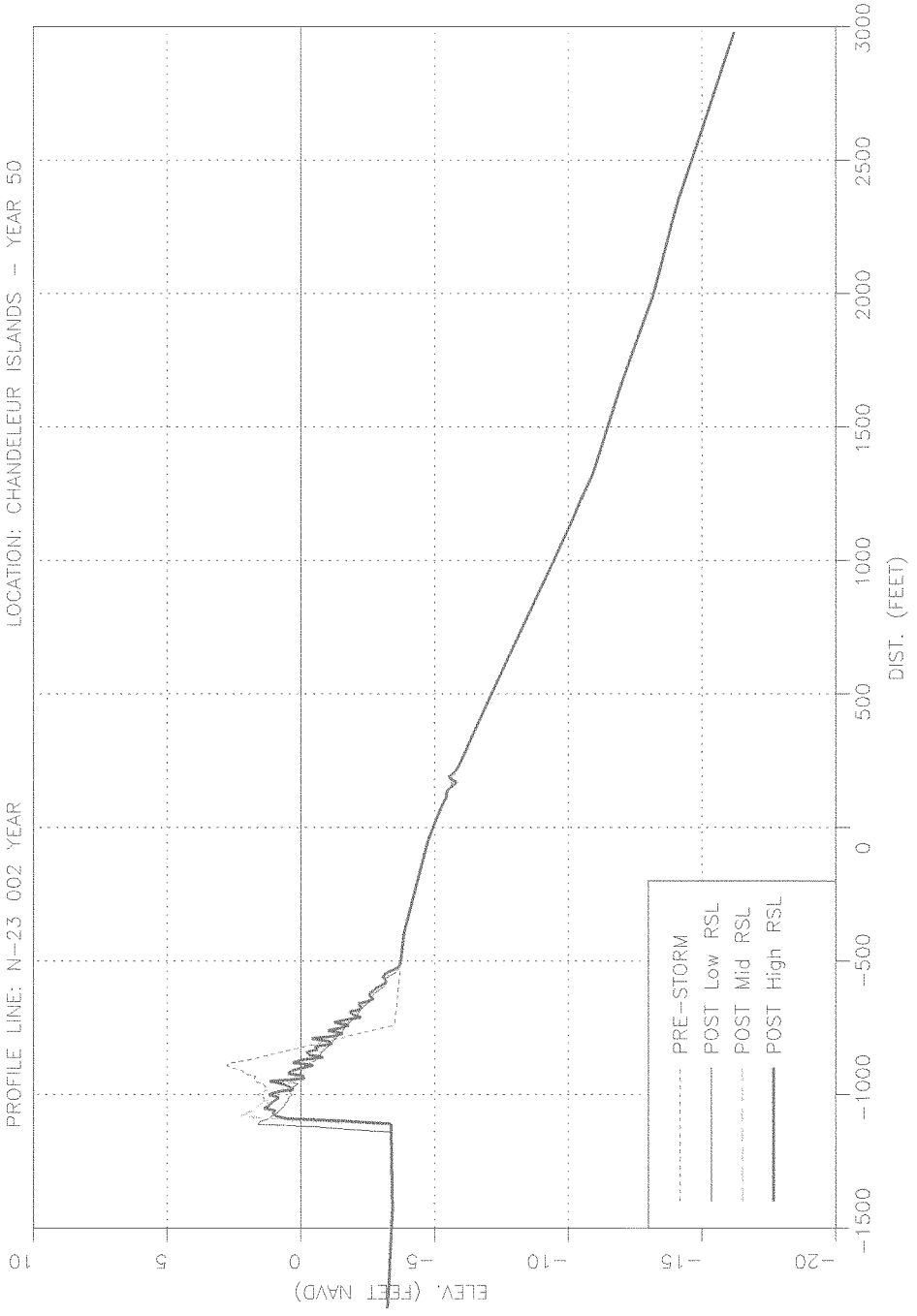

PROFILE LINE: N-19 010 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000
PRE-STORM
POST Low RSL
POST Mid RSL
POST High RSL

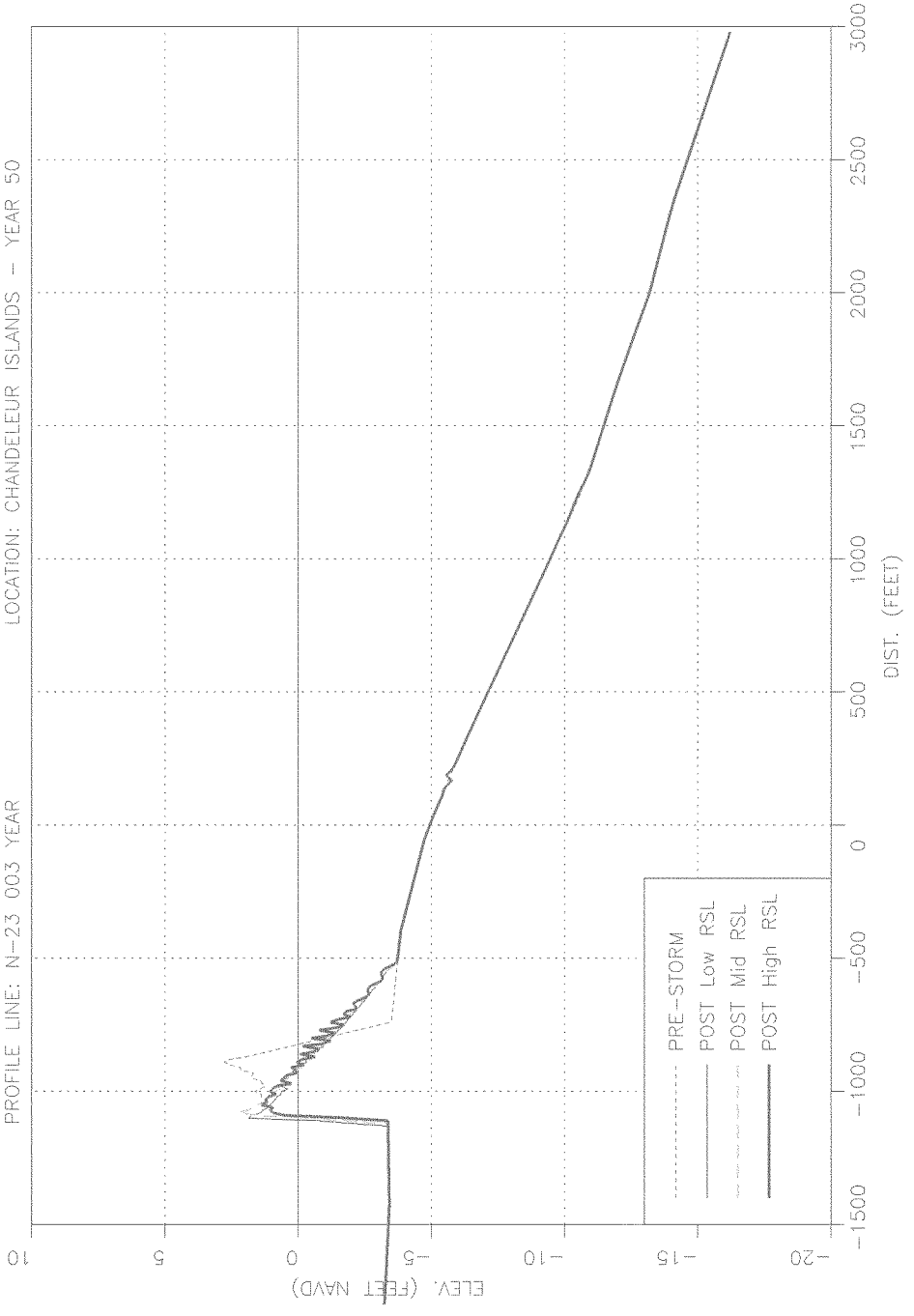

PROFILE LINE: N-19 020 YEAR
LOCATION: CHANDELEUR ISLANDS -- YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
POST Mid RSL
POST High RSL
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

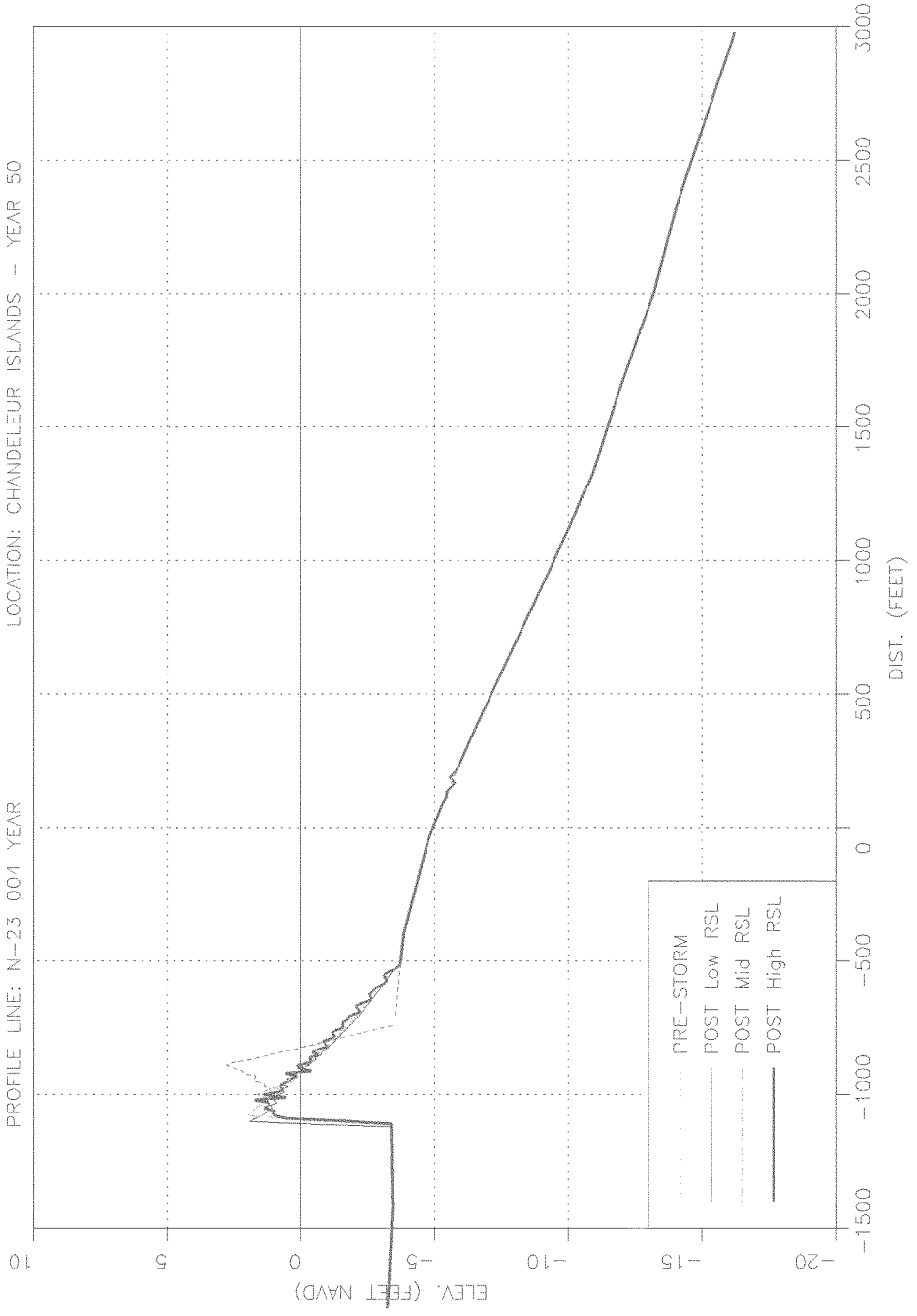

PROFILE LINE: N-19 050 YEAR
LOCATION: CHANDELEUR ISLANDS -- YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
POST Mid RSL
POST High RSL
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

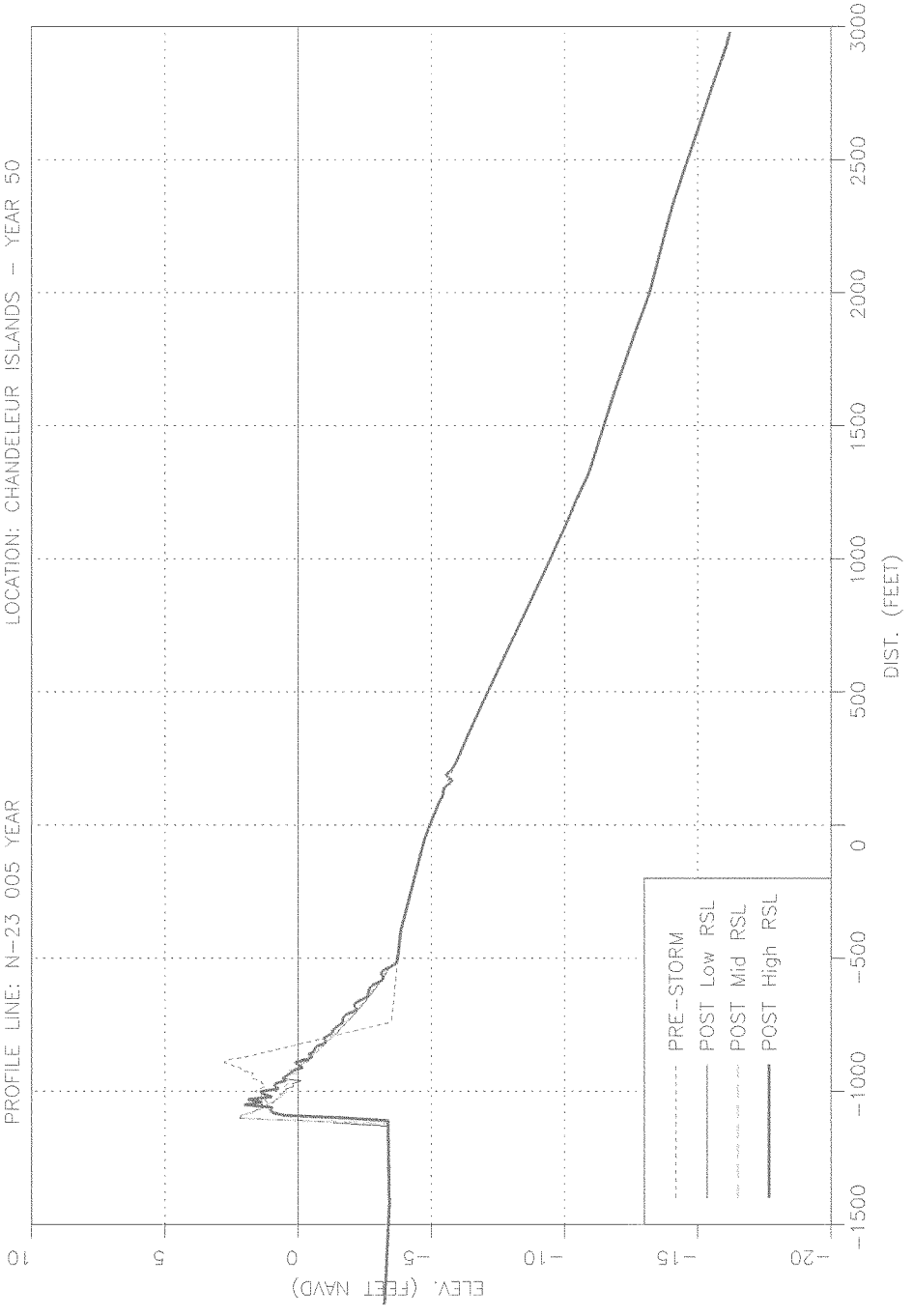

PROFILE LINE: N-19 100 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
POST Mid RSL
POST High RSL
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

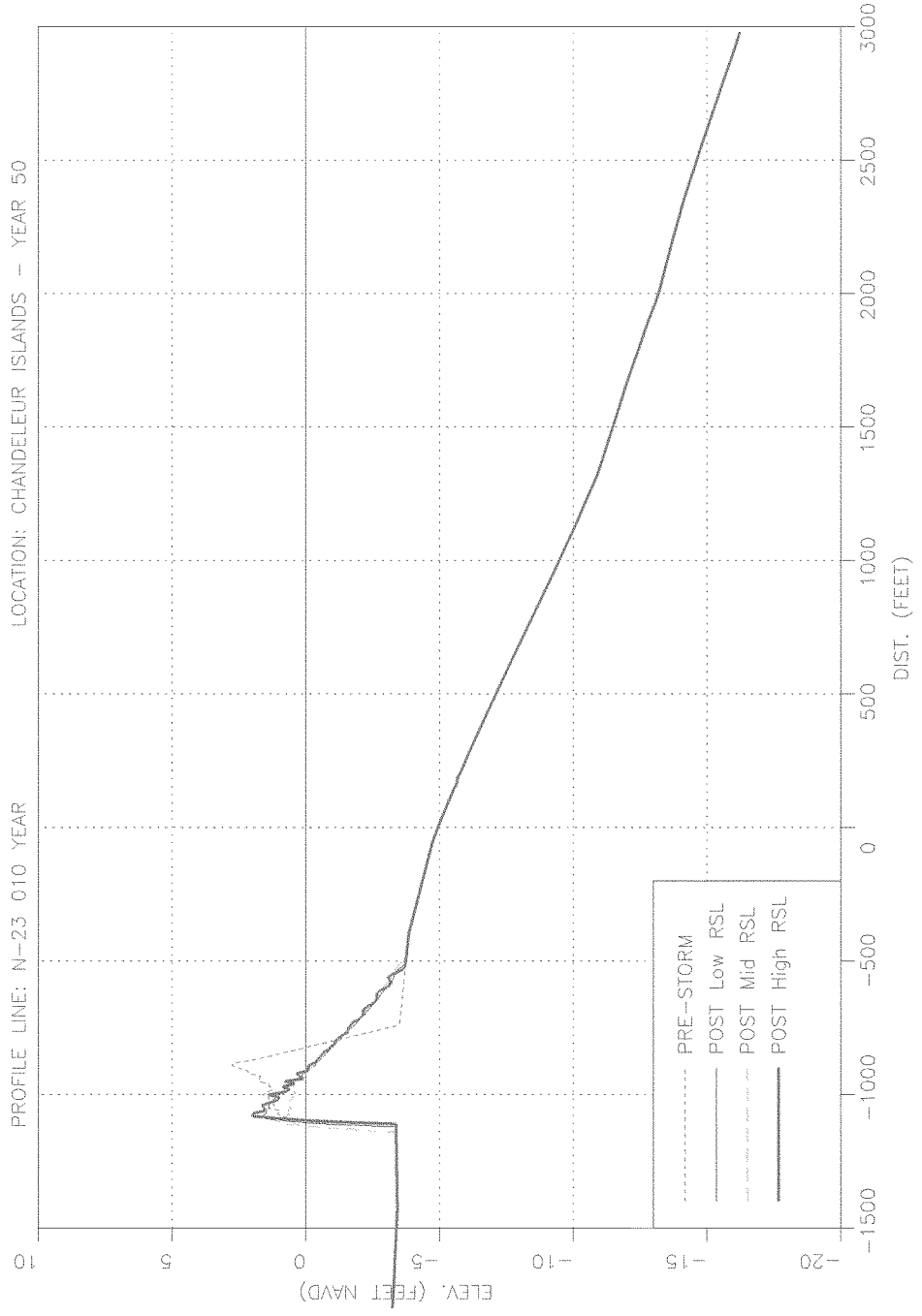

PROFILE LINE: N-23 001 YEAR
LOCATION: CHANDELEUR ISLANDS -- YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
POST Mid RSL
POST High RSL
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

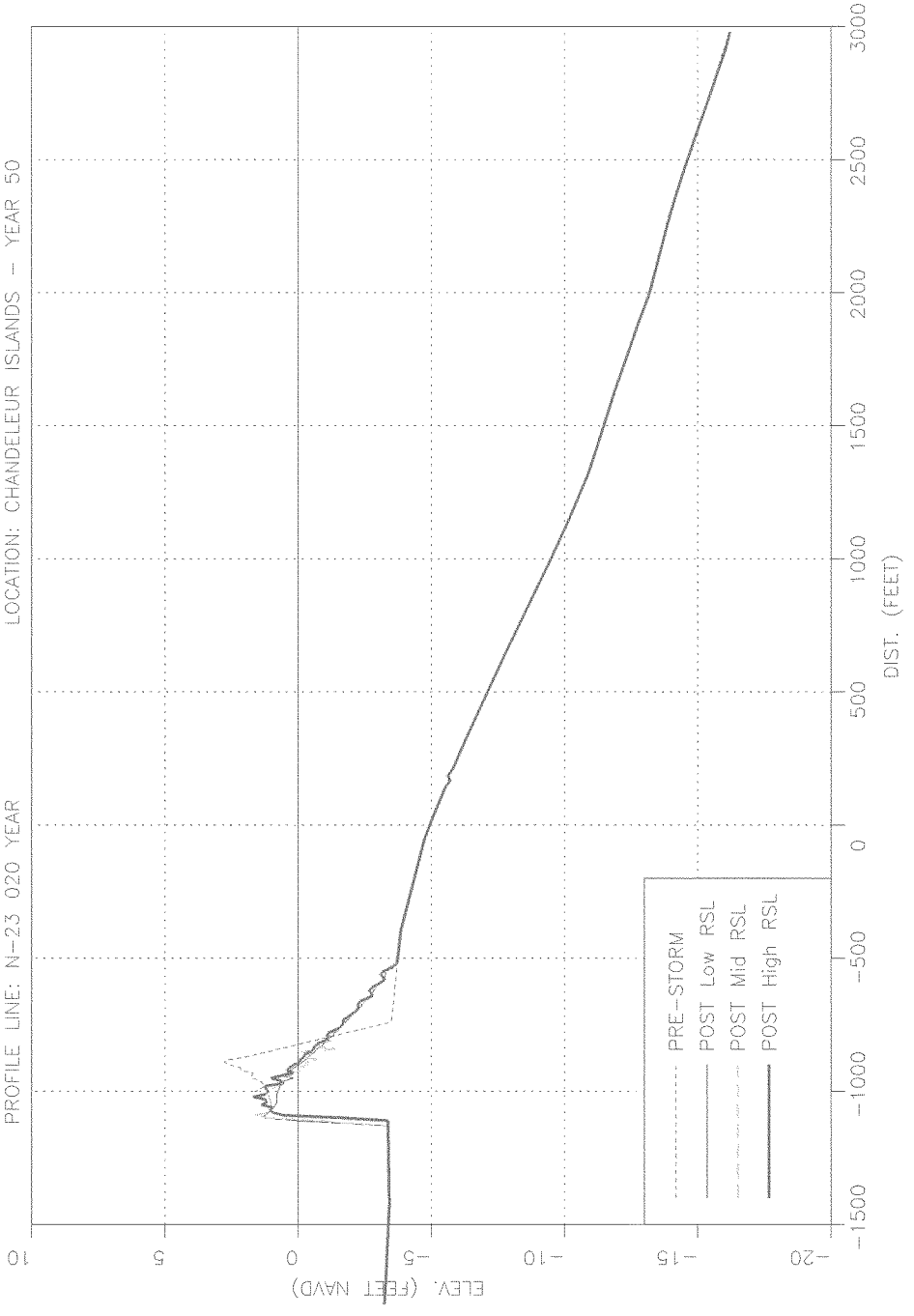

PROFILE LINE: N-23 002 YEAR
LOCATION: CHANDELEUR ISLANDS -- YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
POST Mid RSL
POST High RSL
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

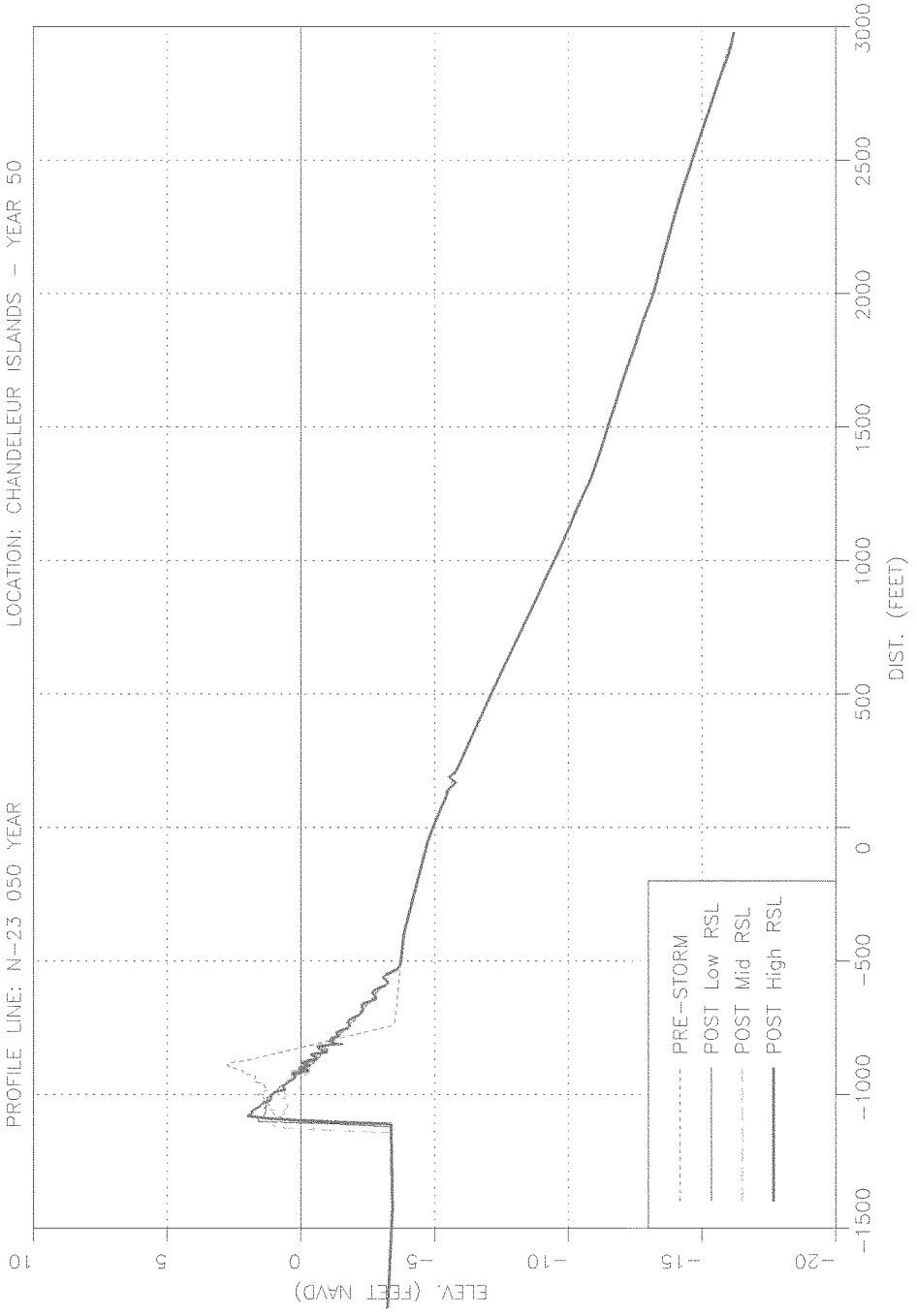

PROFILE LINE: N-23 003 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
POST Mid RSL
POST High RSL
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

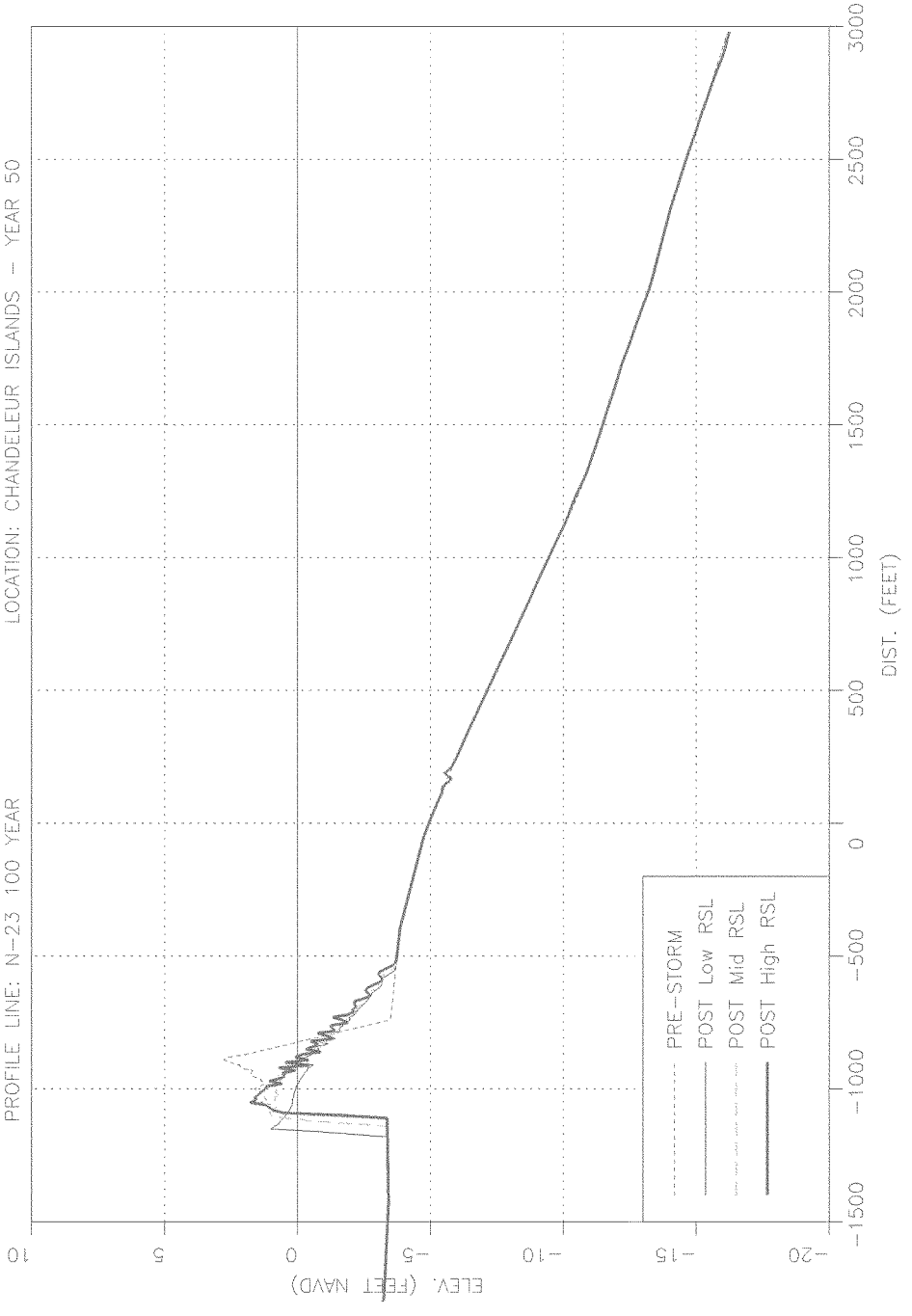

PROFILE LINE: N-23 004 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
POST Mid RSL
POST High RSL
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

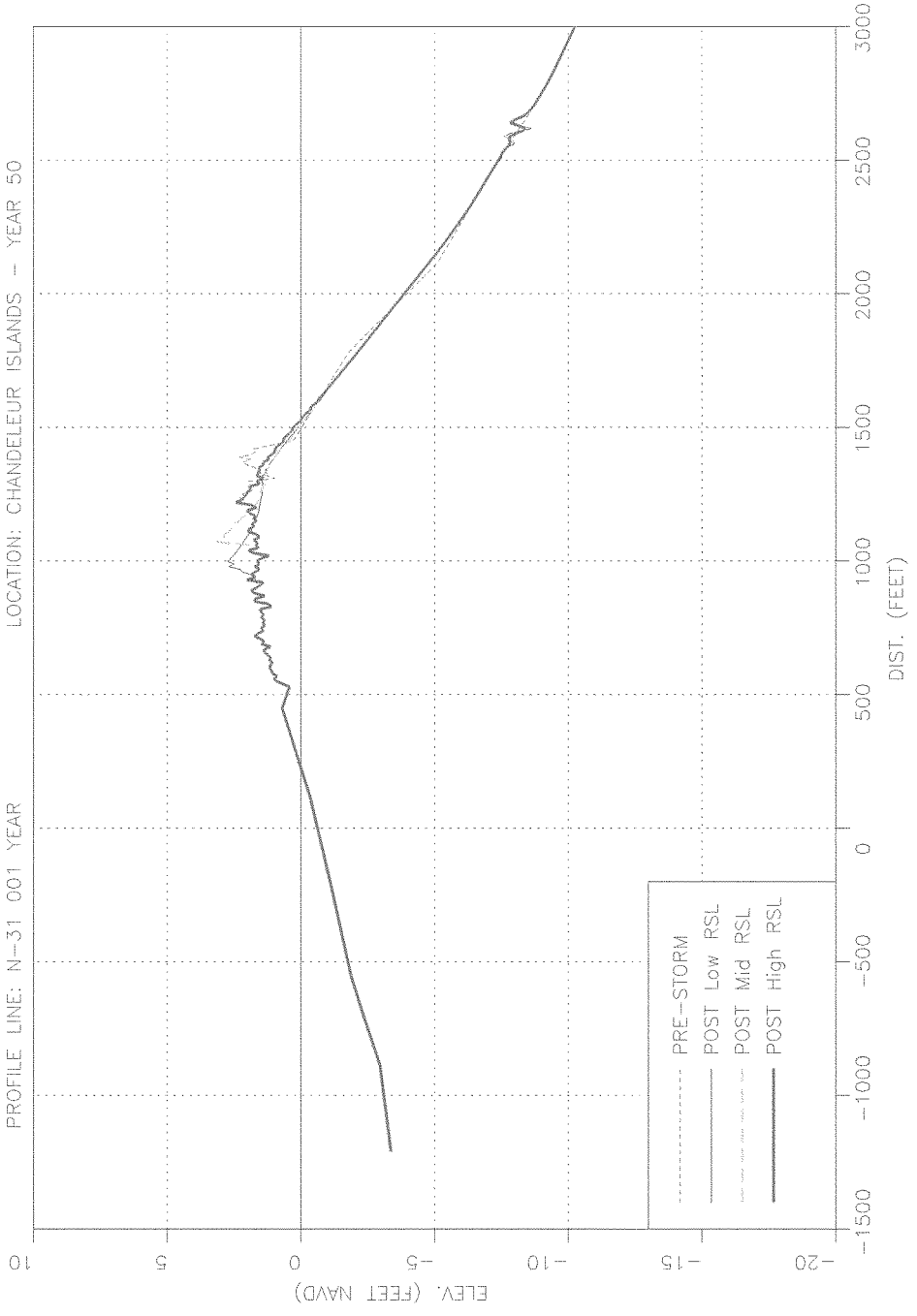

PROFILE LINE: N-23 005 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
POST Mid RSL
POST High RSL
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

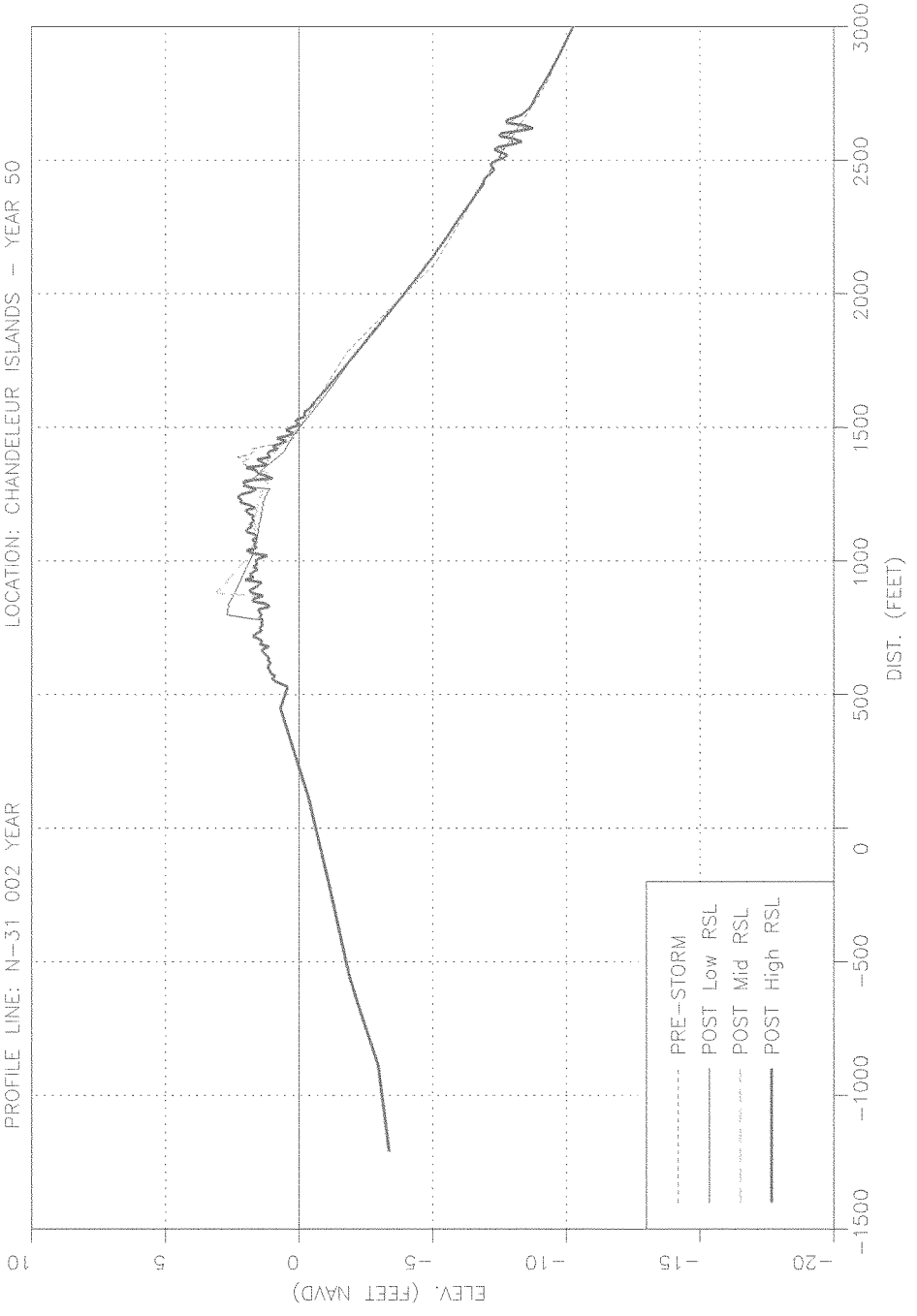

PROFILE LINE: N-23 010 YEAR
LOCATION: CHANDELEUR ISLANDS -- YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000
PRE-STORM
POST Low RSL
POST Mid RSL
POST High RSL

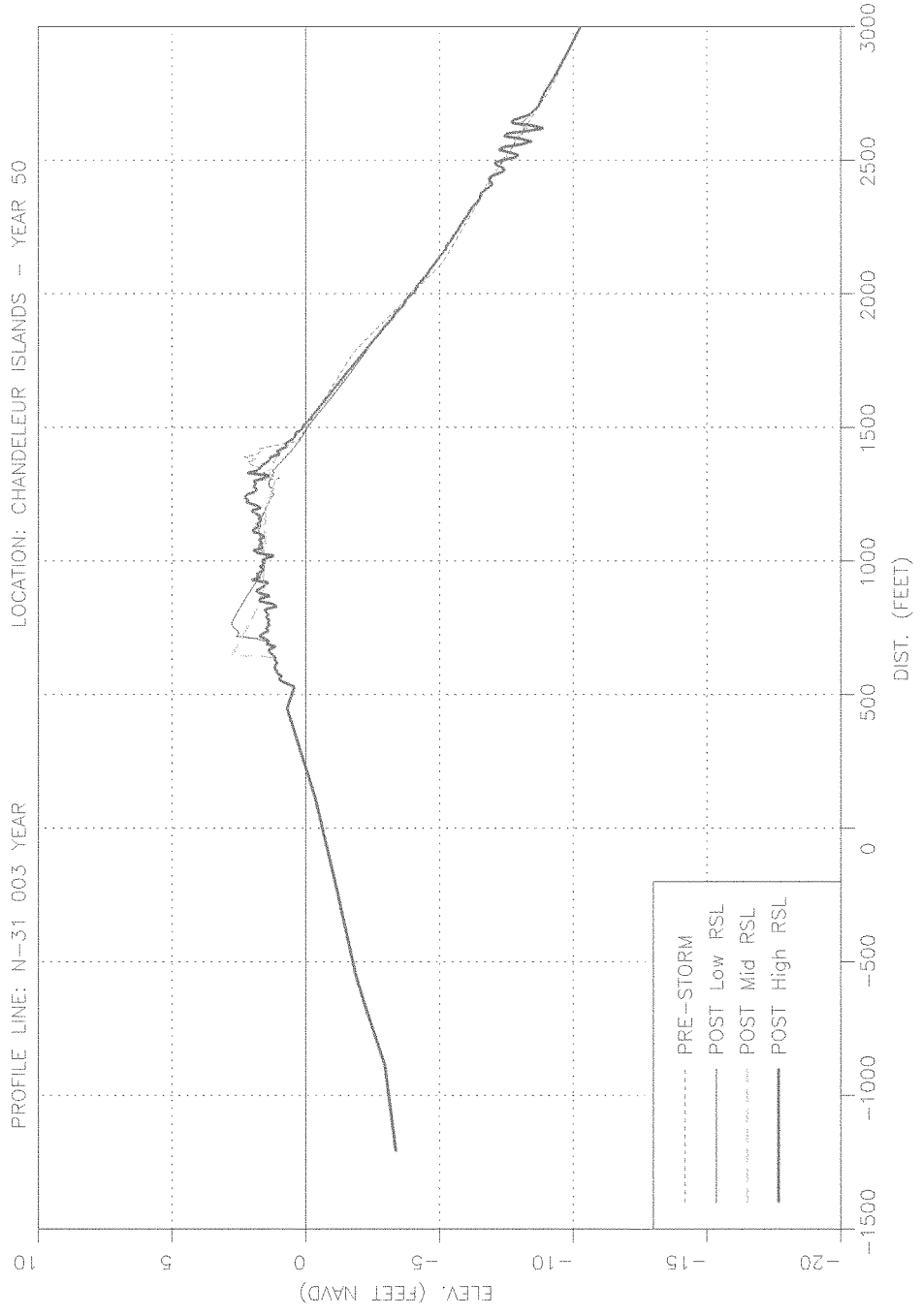

PROFILE LINE: N-23 020 YEAR
LOCATION: CHANDELEUR ISLANDS -- YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
POST Mid RSL
POST High RSL
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

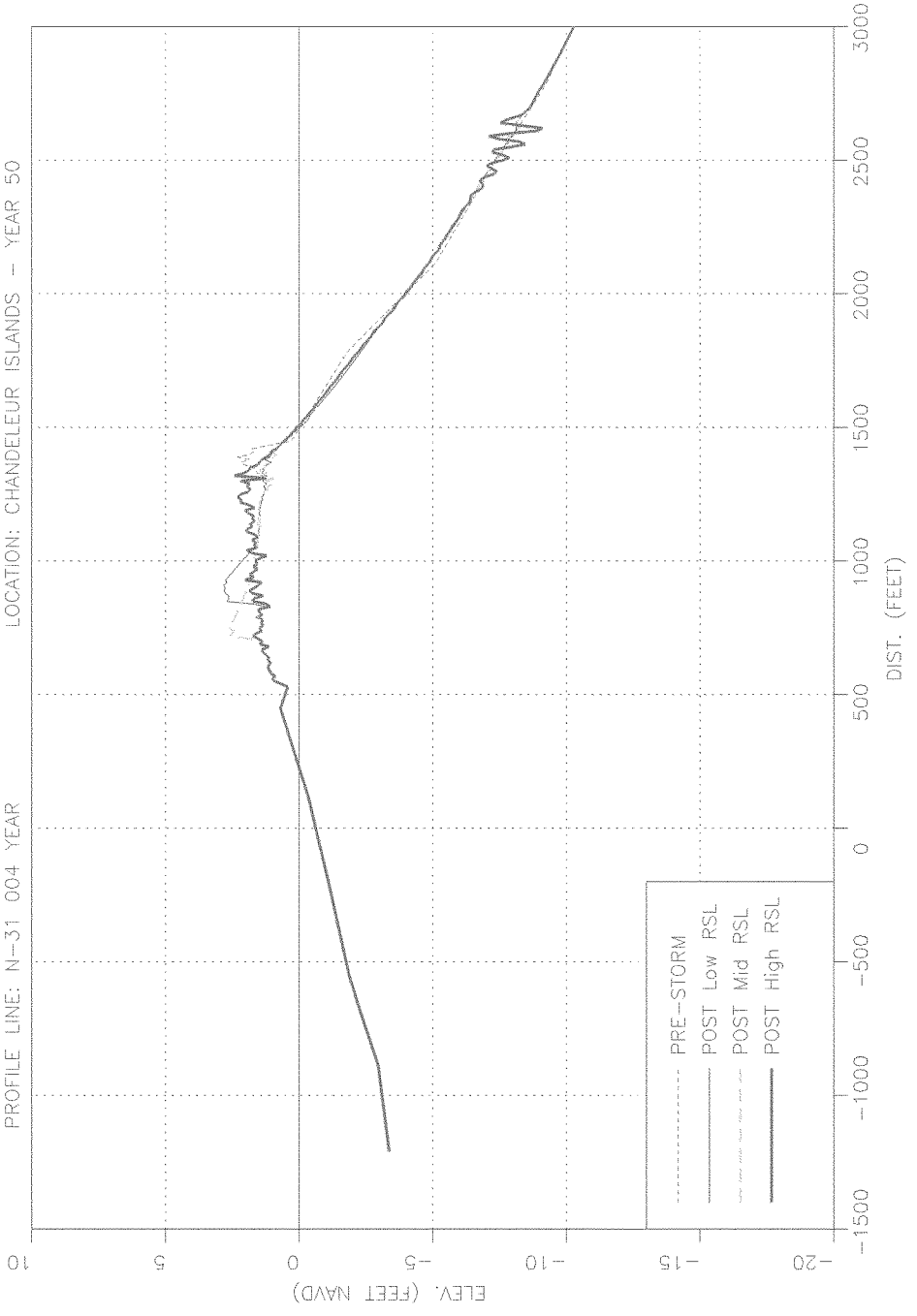

PROFILE LINE: N-23 050 YEAR
LOCATION: CHANDELEUR ISLANDS -- YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
POST Mid RSL
POST High RSL
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

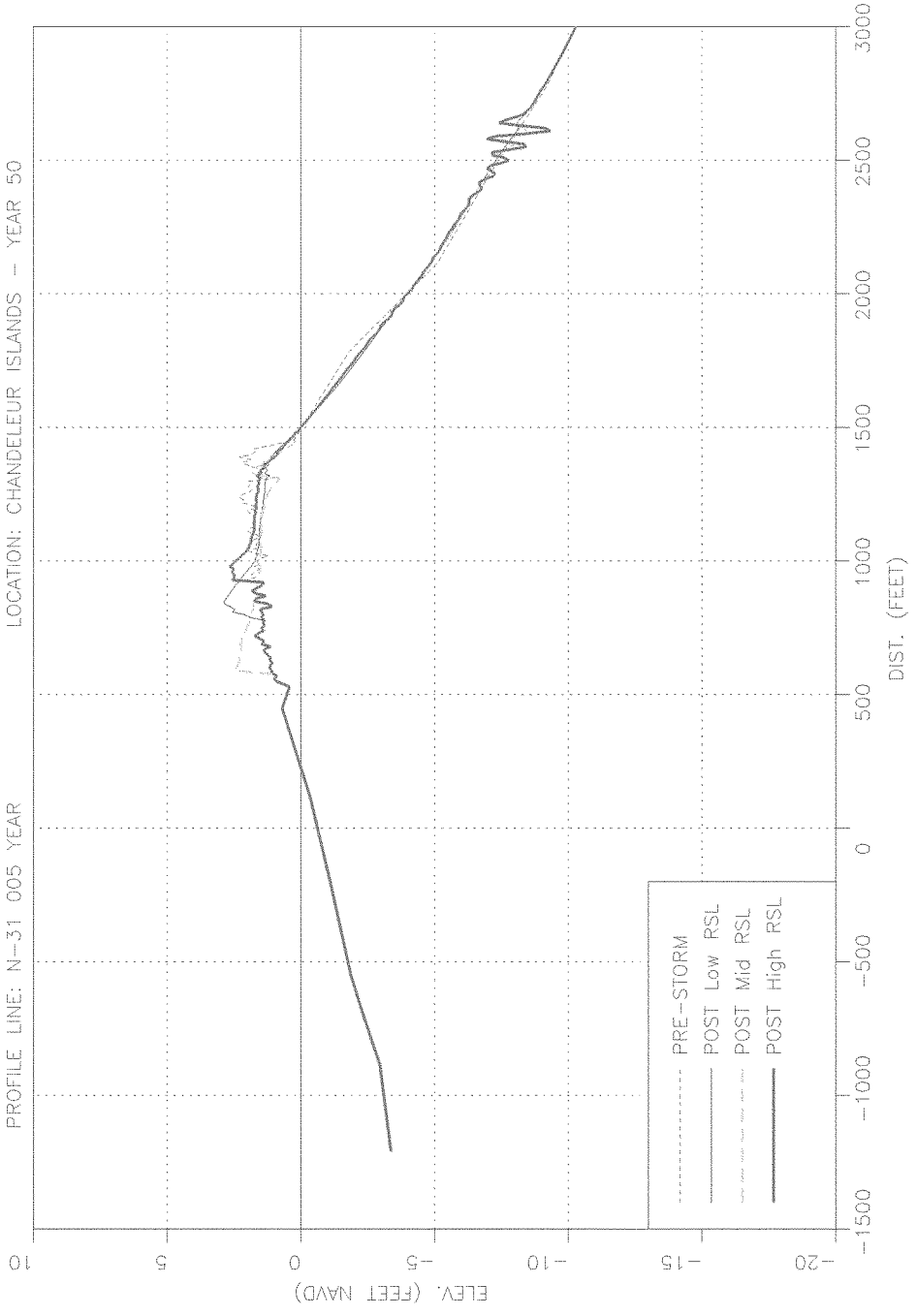

PROFILE LINE: N-23 100 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
POST Mid RSL
POST High RSL
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

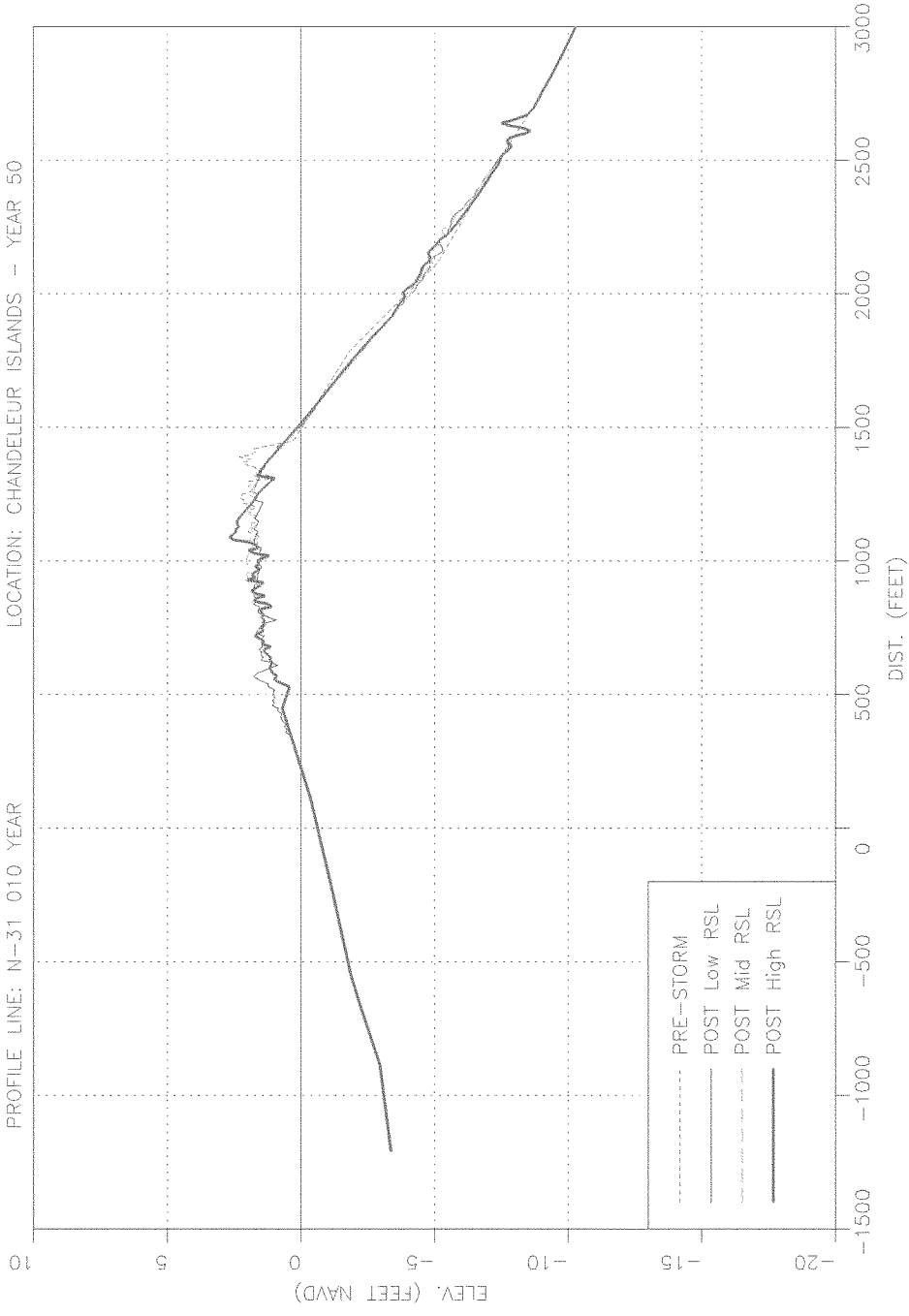

PROFILE LINE: N-31 001 YEAR
LOCATION: CHANDELEUR ISLANDS -- YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
POST Mid RSL
POST High RSL
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

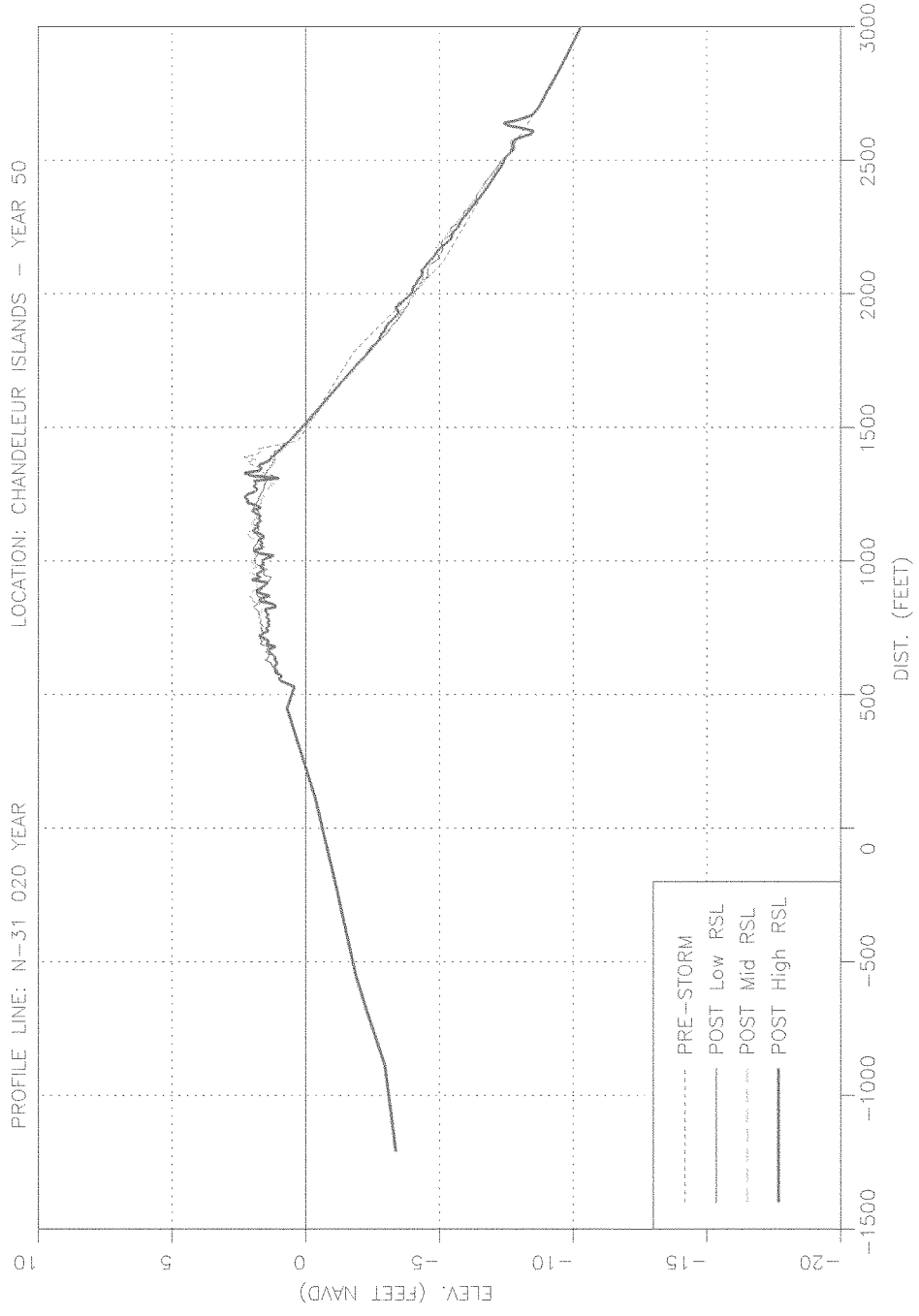

PROFILE LINE: N-31 002 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
POST Mid RSL
POST High RSL
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

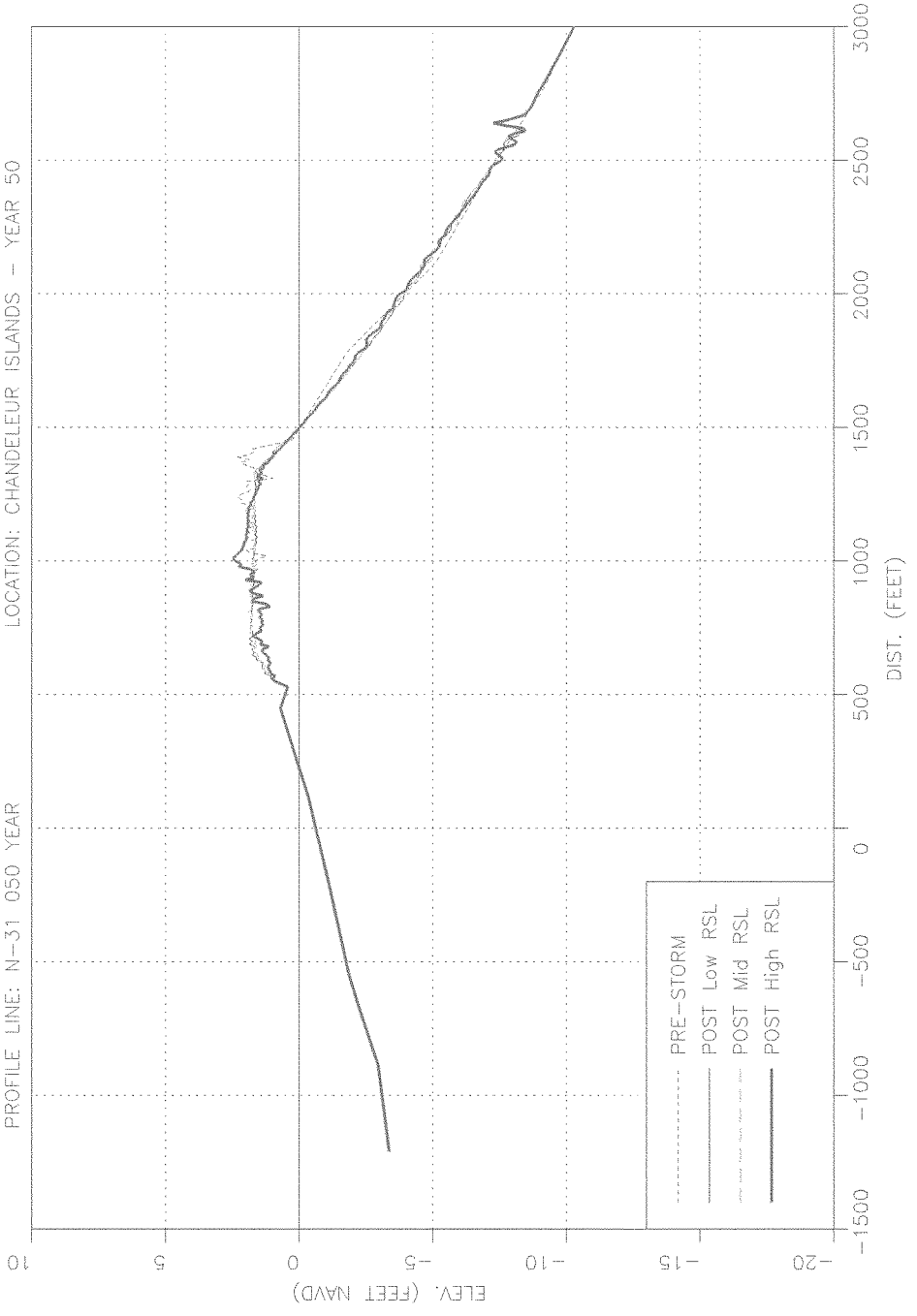

PROFILE LINE: N-31 003 YEAR
LOCATION: CHANDELEUR ISLANDS -- YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
POST Mid RSL
POST High RSL
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

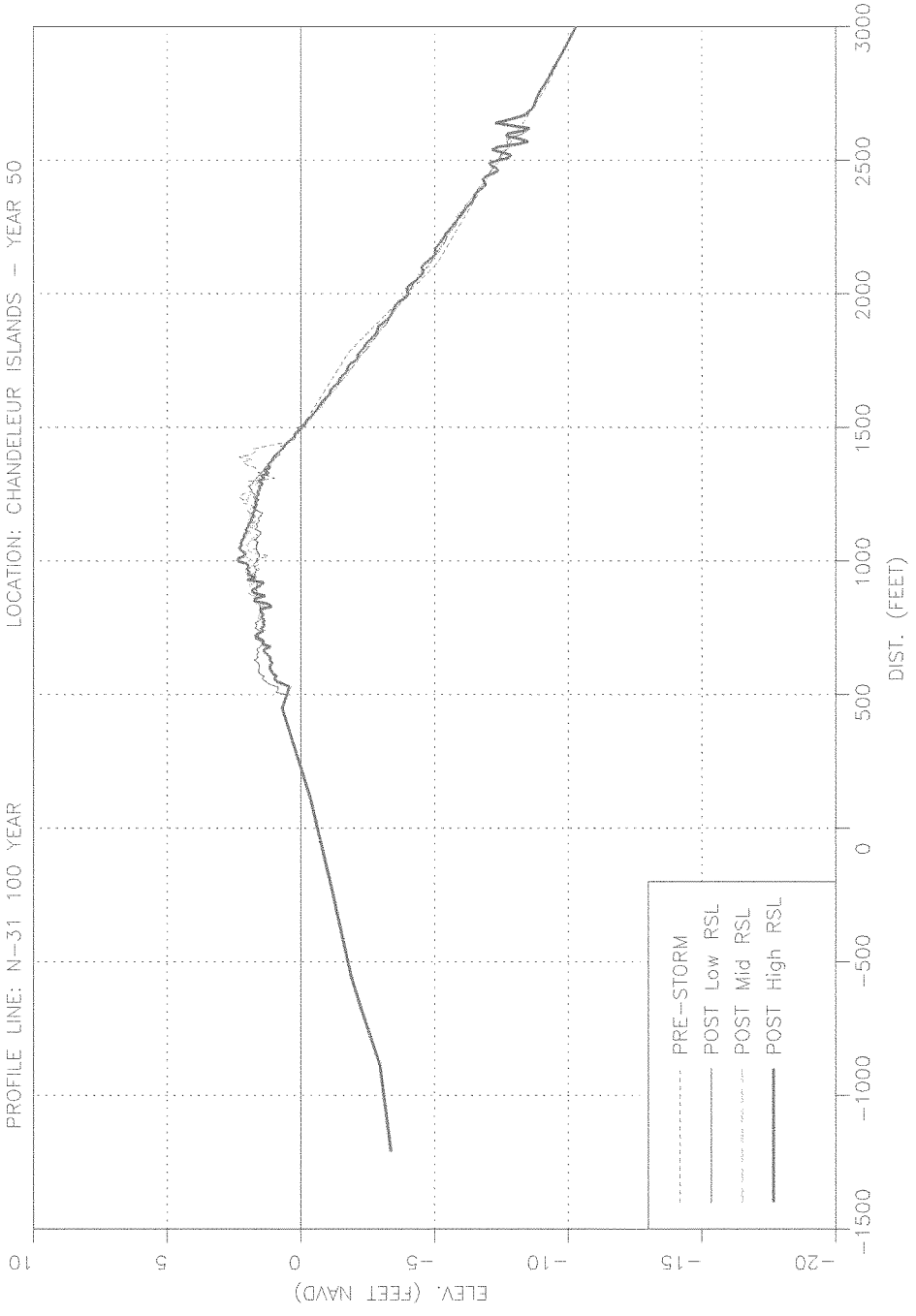

PROFILE LINE: N-31 004 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000
PRE-STORM
POST Low RSL
POST Mid RSL
POST High RSL

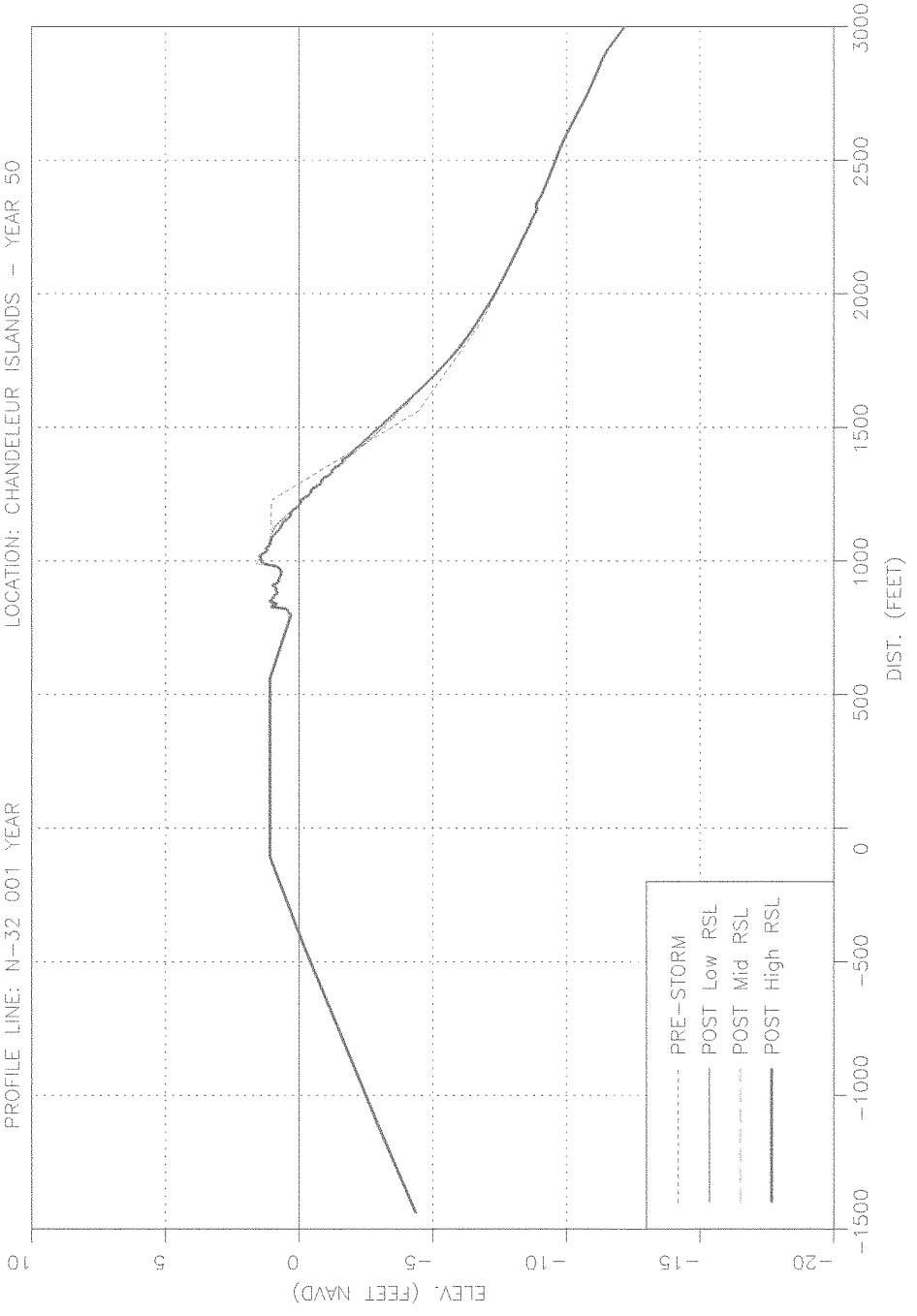

PROFILE LINE: N-31 005 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
POST Mid RSL
POST High RSL
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

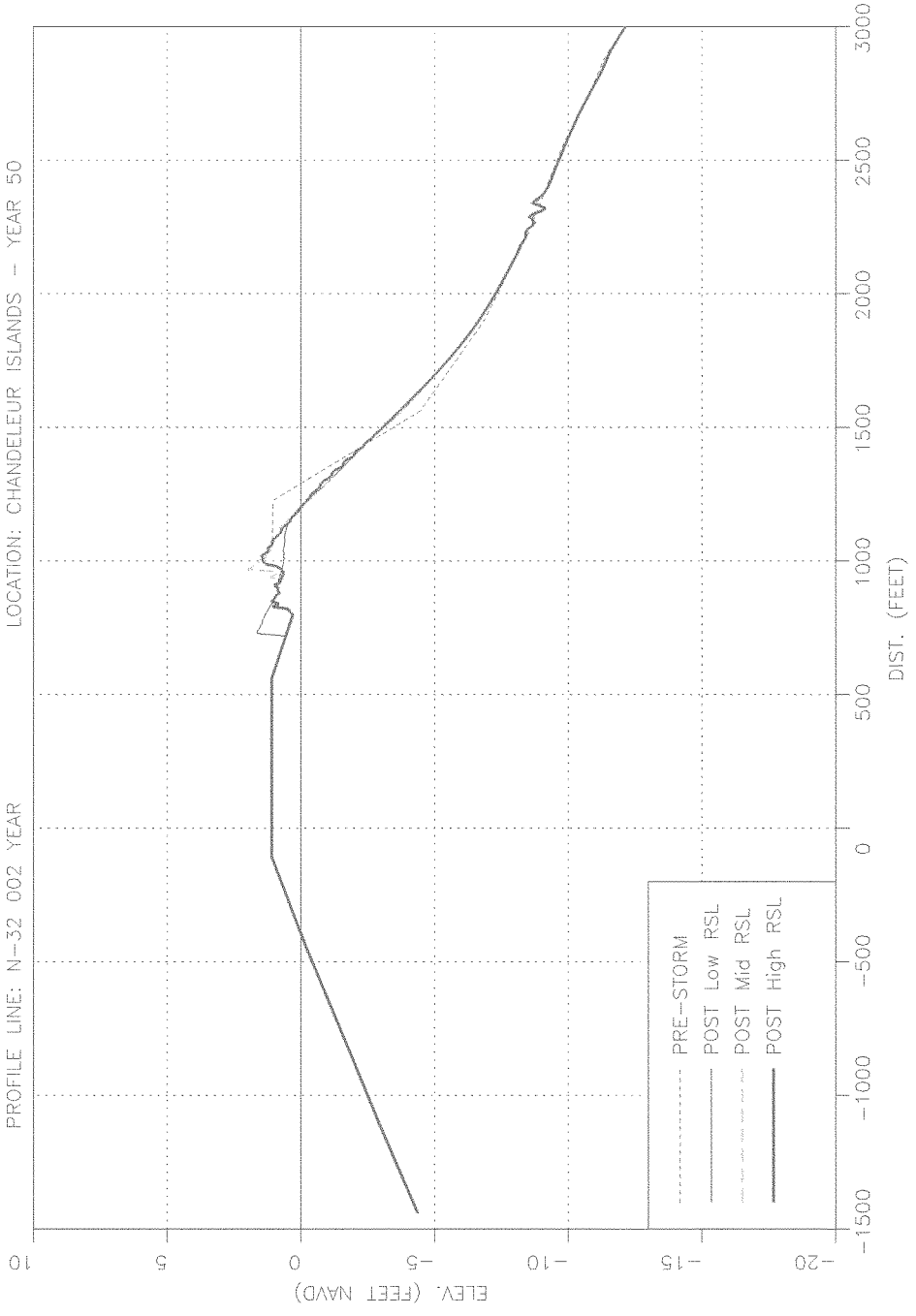

PROFILE LINE: N-31 010 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000
PRE-STORM
POST Low RSL
POST Mid RSL
POST High RSL

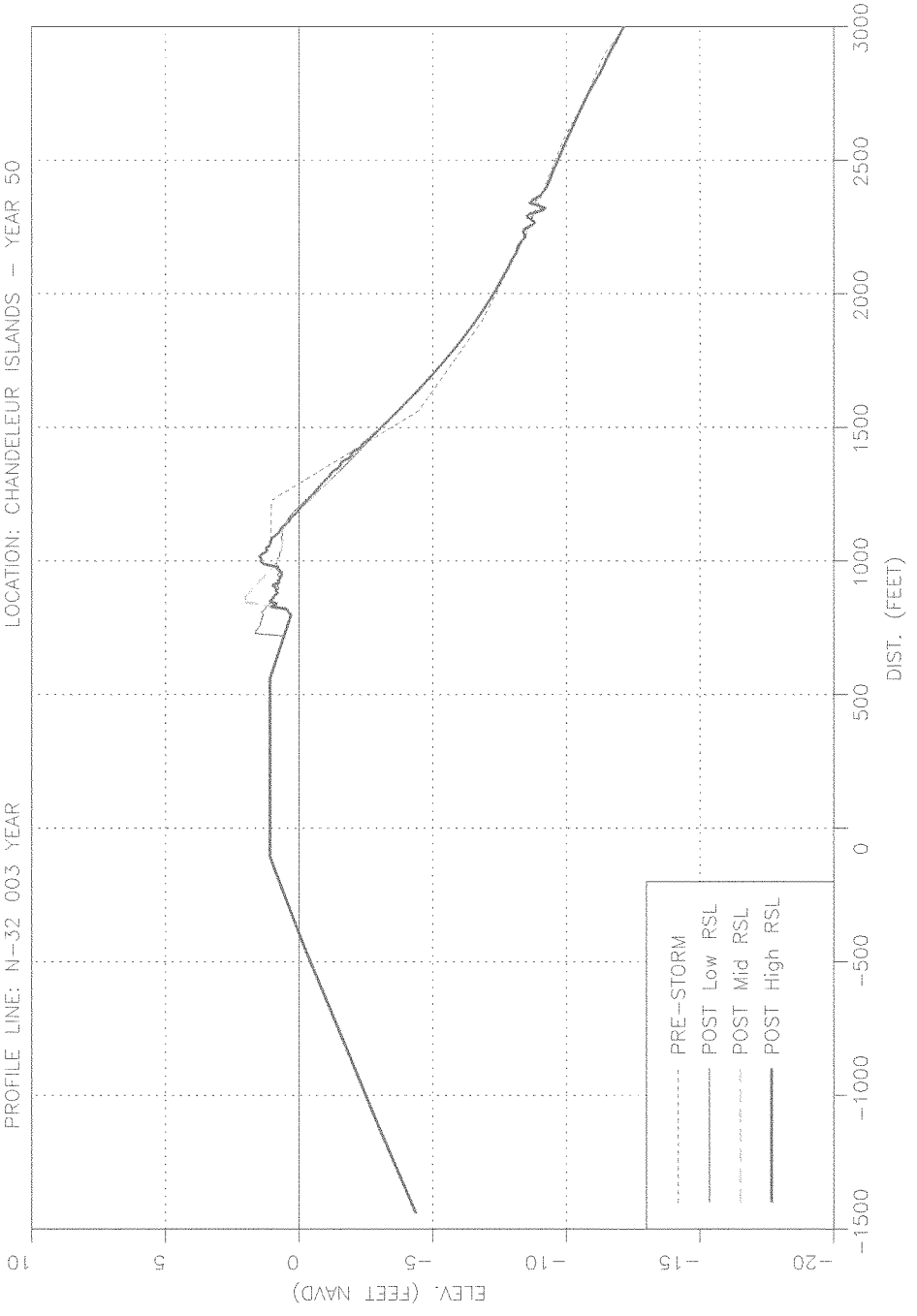

PROFILE LINE: N-31 020 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
POST Mid RSL
POST High RSL
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

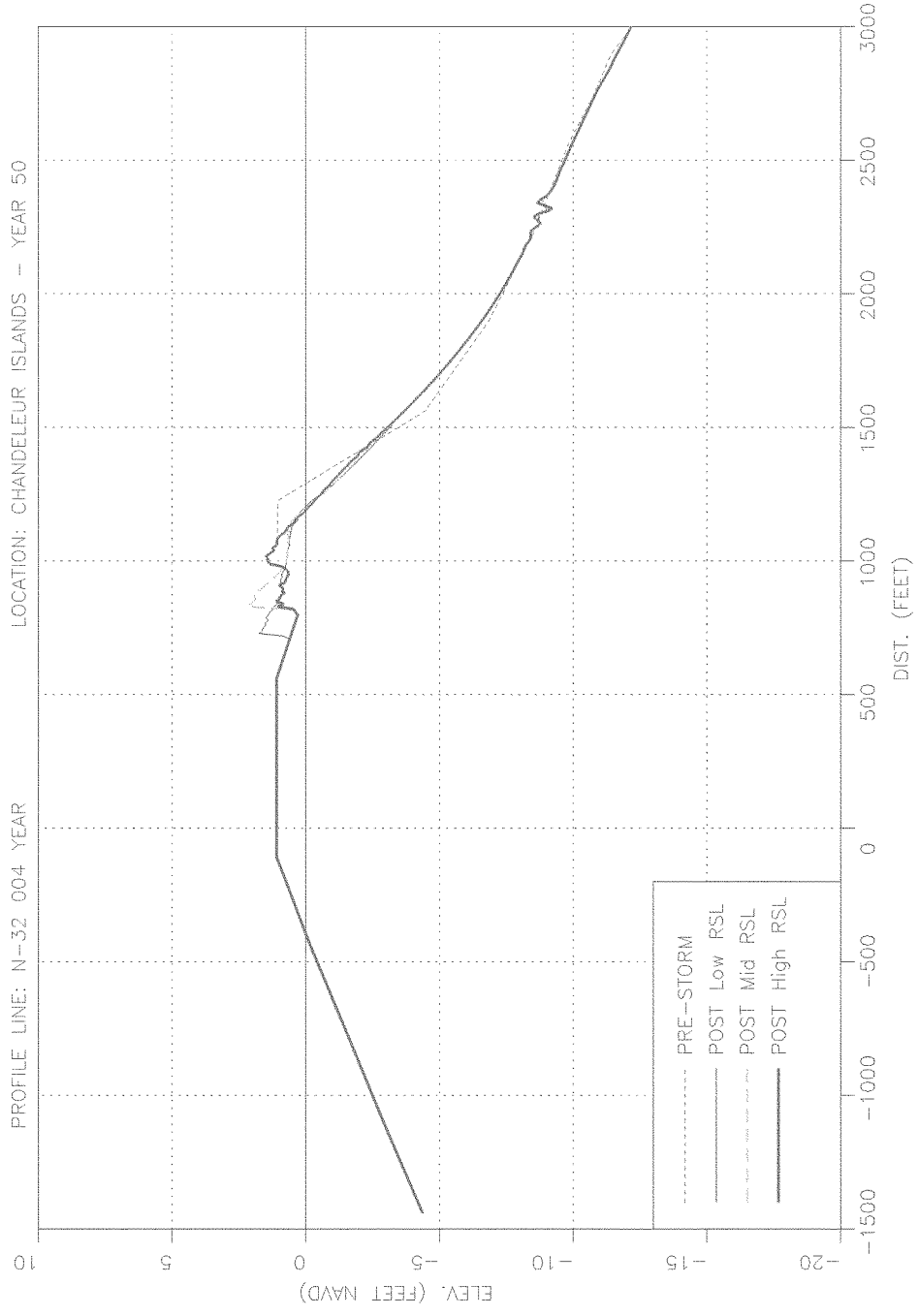

PROFILE LINE: N-31 050 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000
PRE-STORM
POST Low RSL
POST Mid RSL
POST High RSL

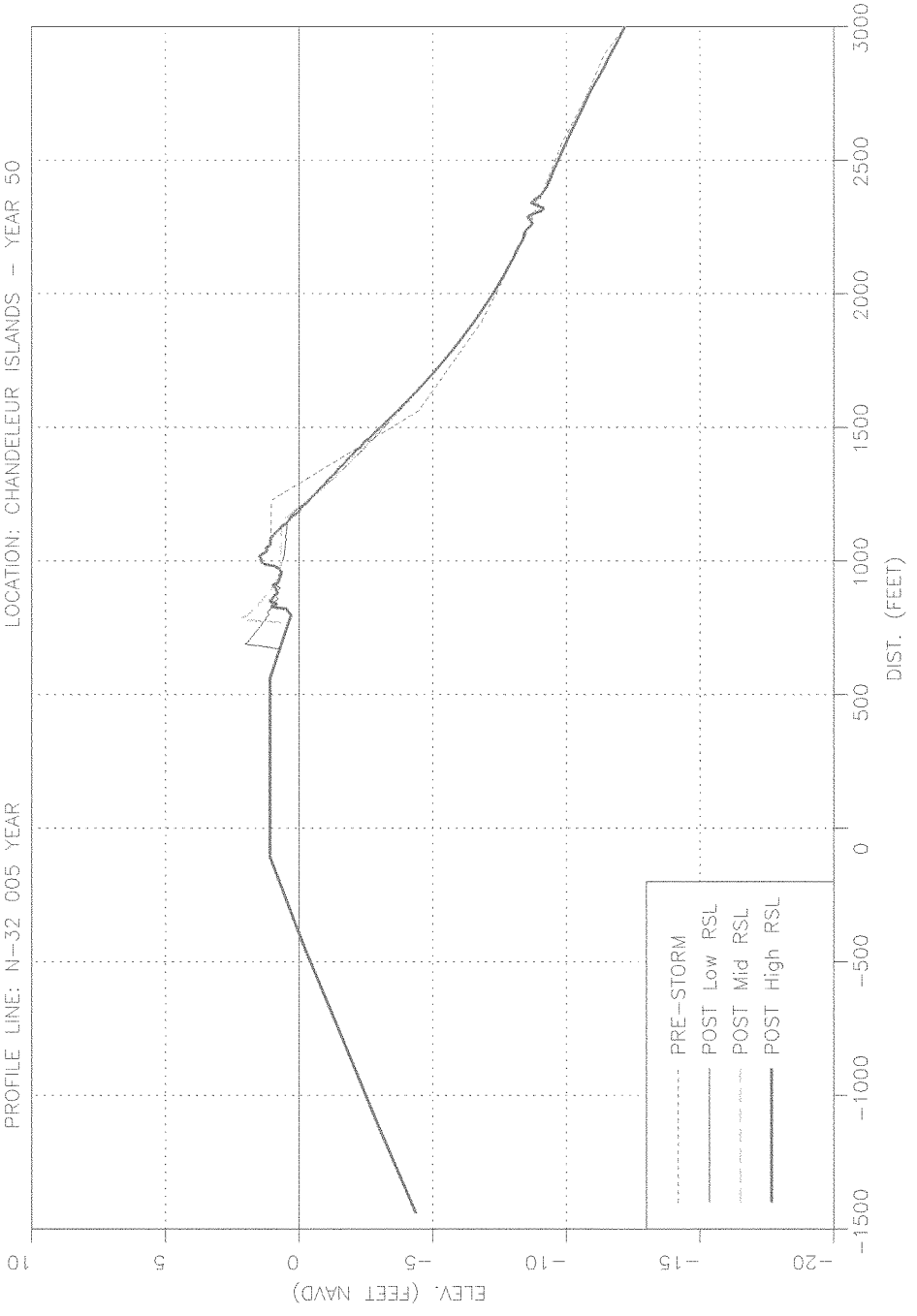

PROFILE LINE: N-31 100 YEAR
LOCATION: CHANDELEUR ISLANDS -- YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
POST Mid RSL
POST High RSL
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

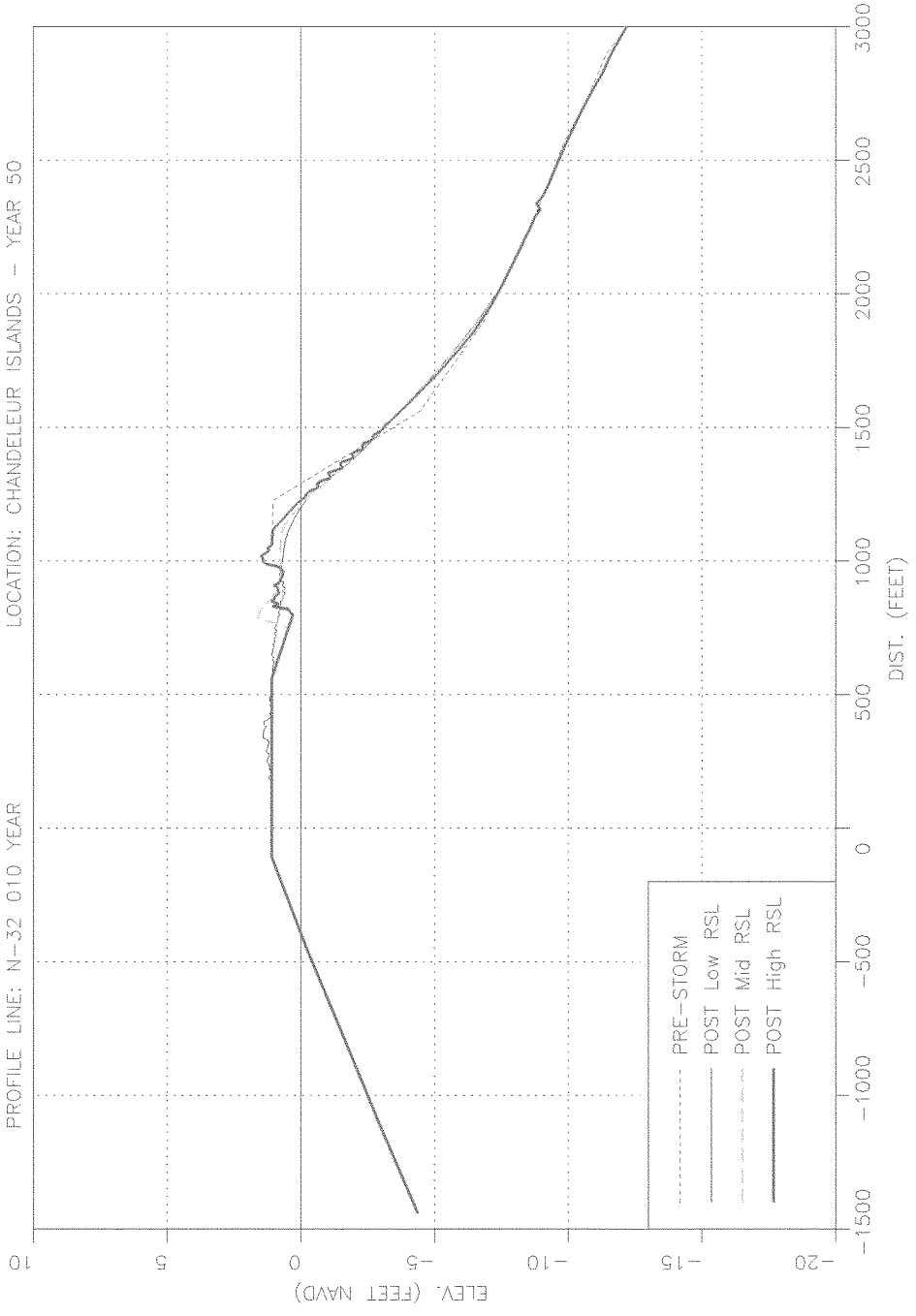

PROFILE LINE: N-32 001 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000
PRE-STORM
POST Low RSL
POST Mid RSL
POST High RSL

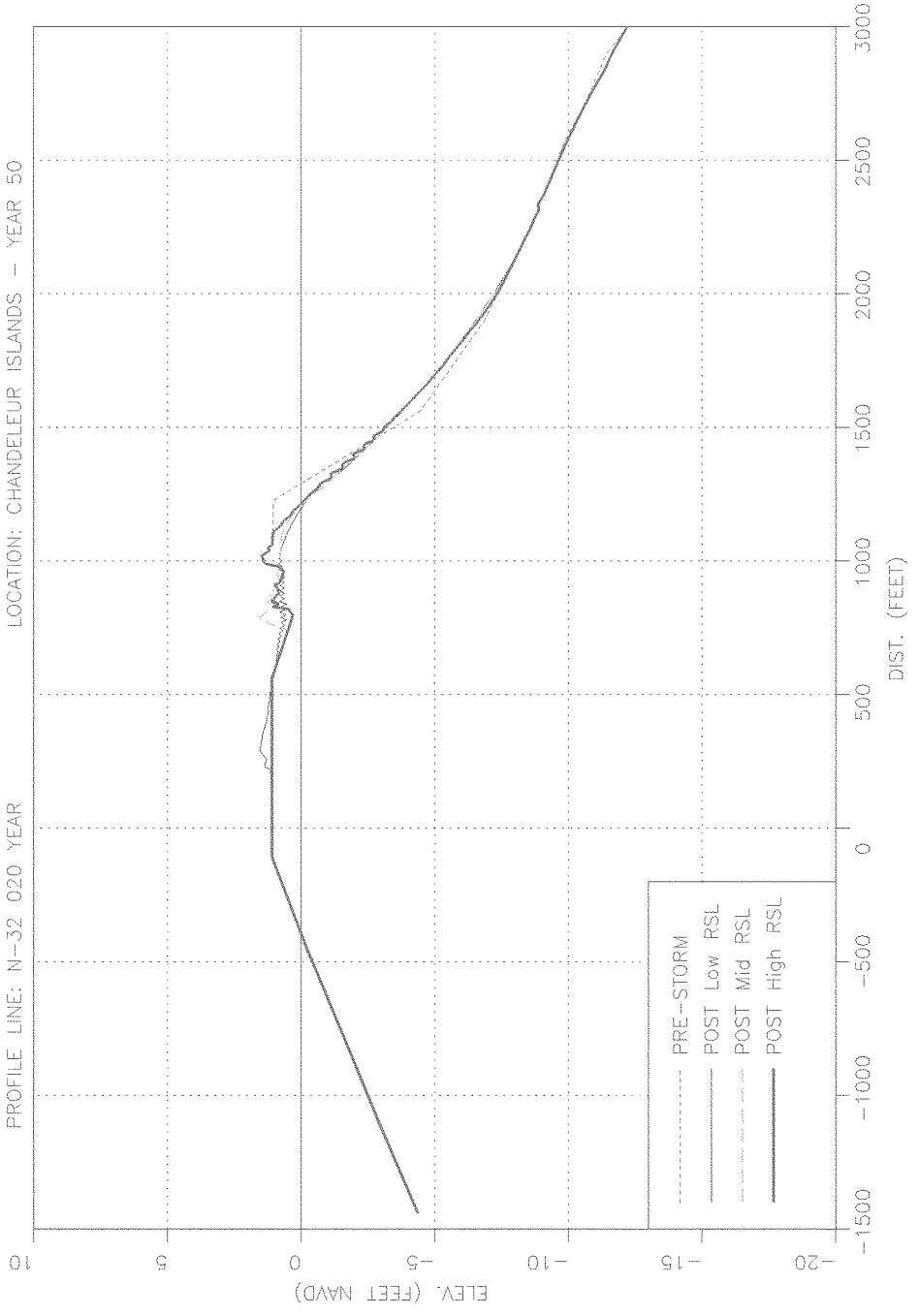

PROFILE LINE: N-32 002 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
POST Mid RSL
POST High RSL
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

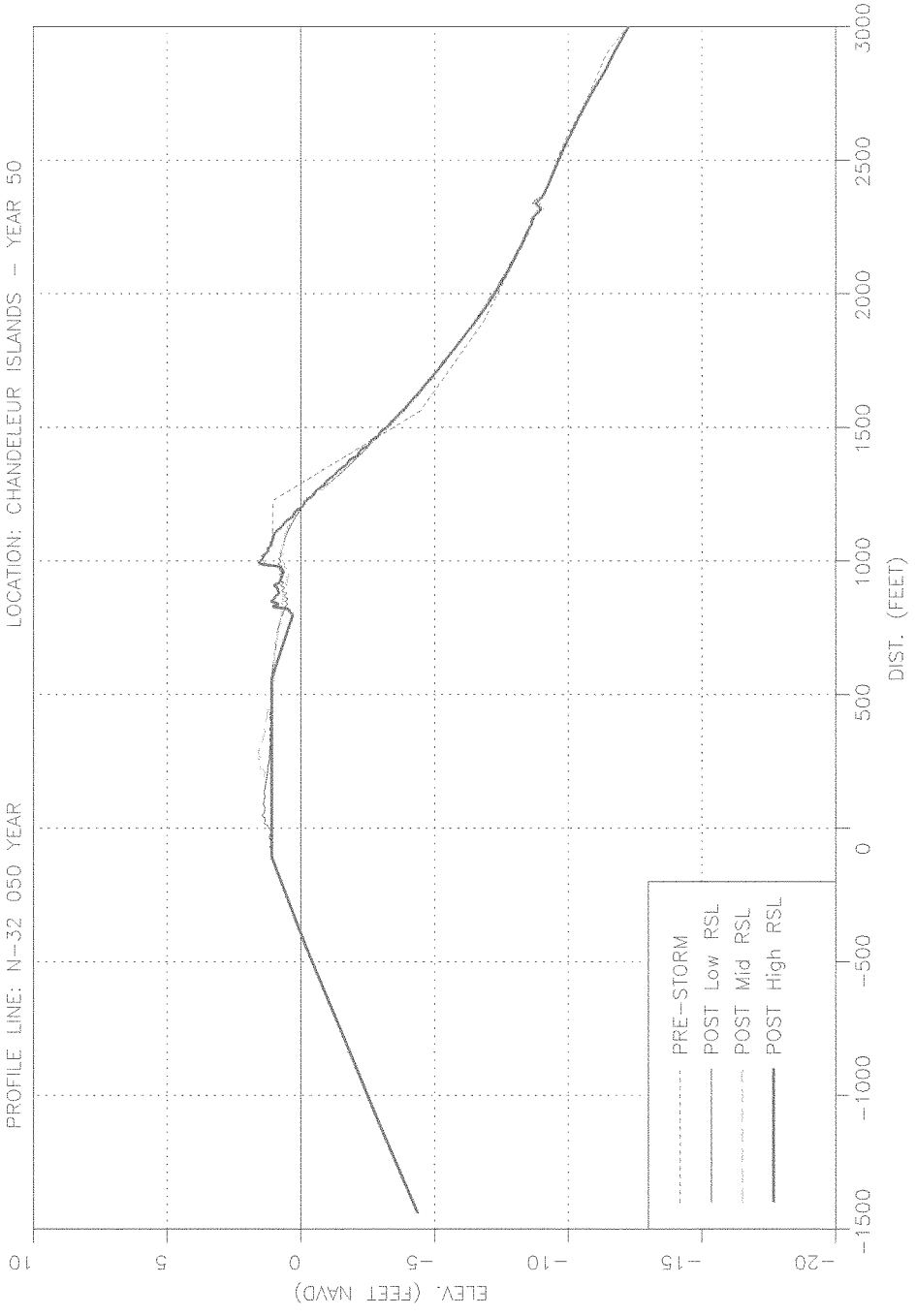

PROFILE LINE: N-32 003 YEAR
LOCATION: CHANDELEUR ISLANDS -- YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
POST Mid RSL
POST High RSL
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

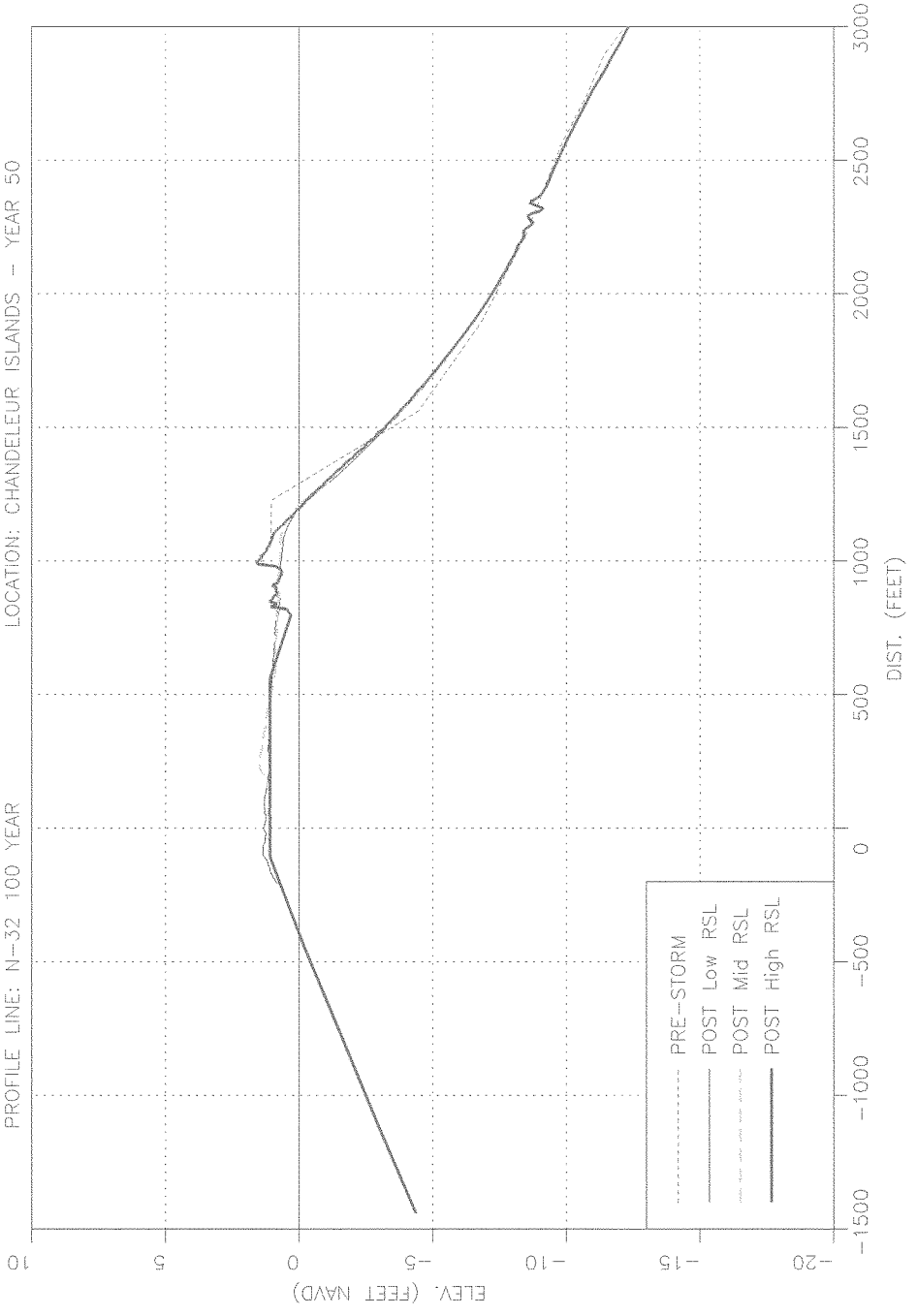

PROFILE LINE: N-32 004 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
POST Mid RSL
POST High RSL
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

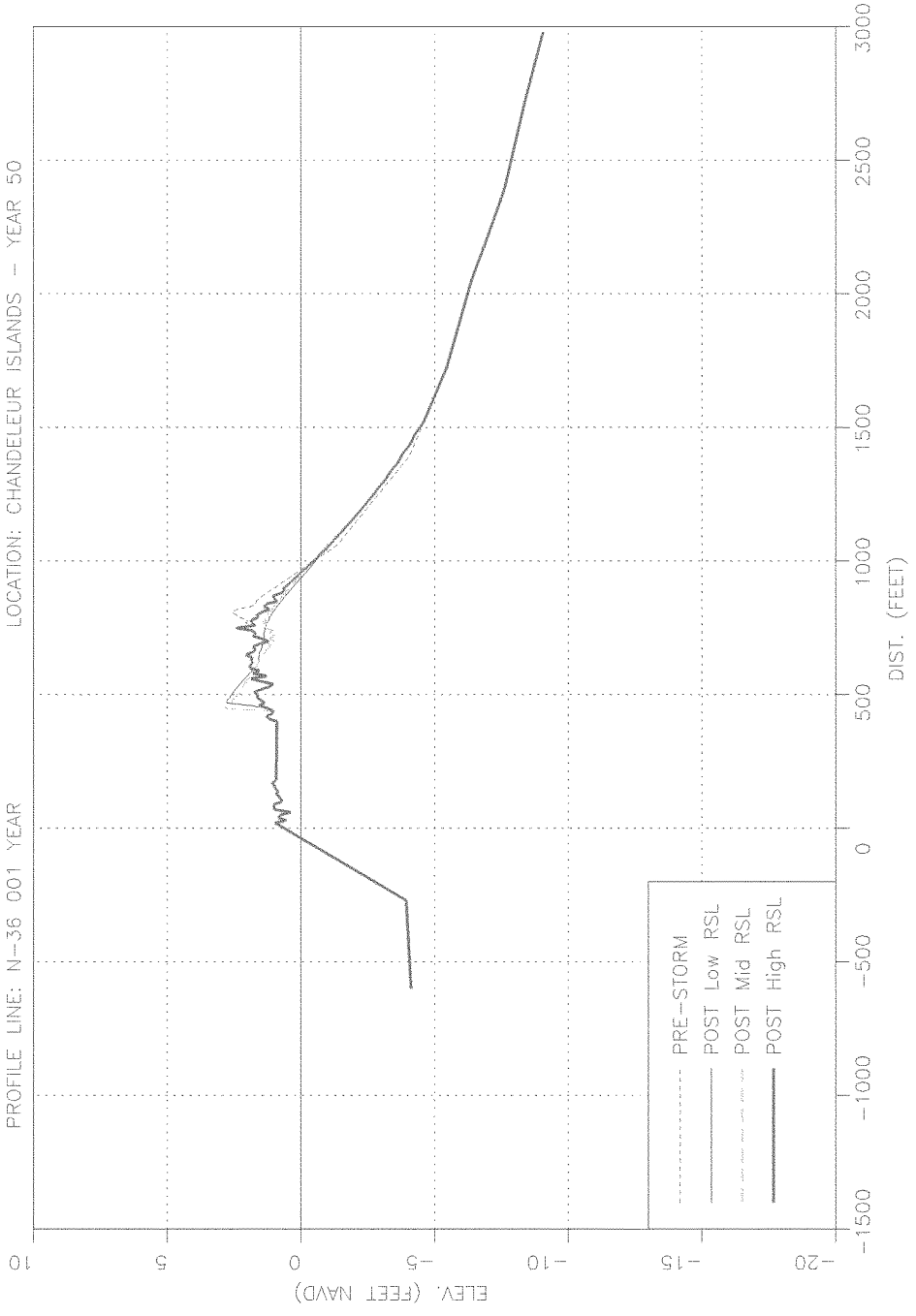

PROFILE LINE: N-32 005 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000
PRE-STORM
POST Low RSL
POST Mid RSL
POST High RSL

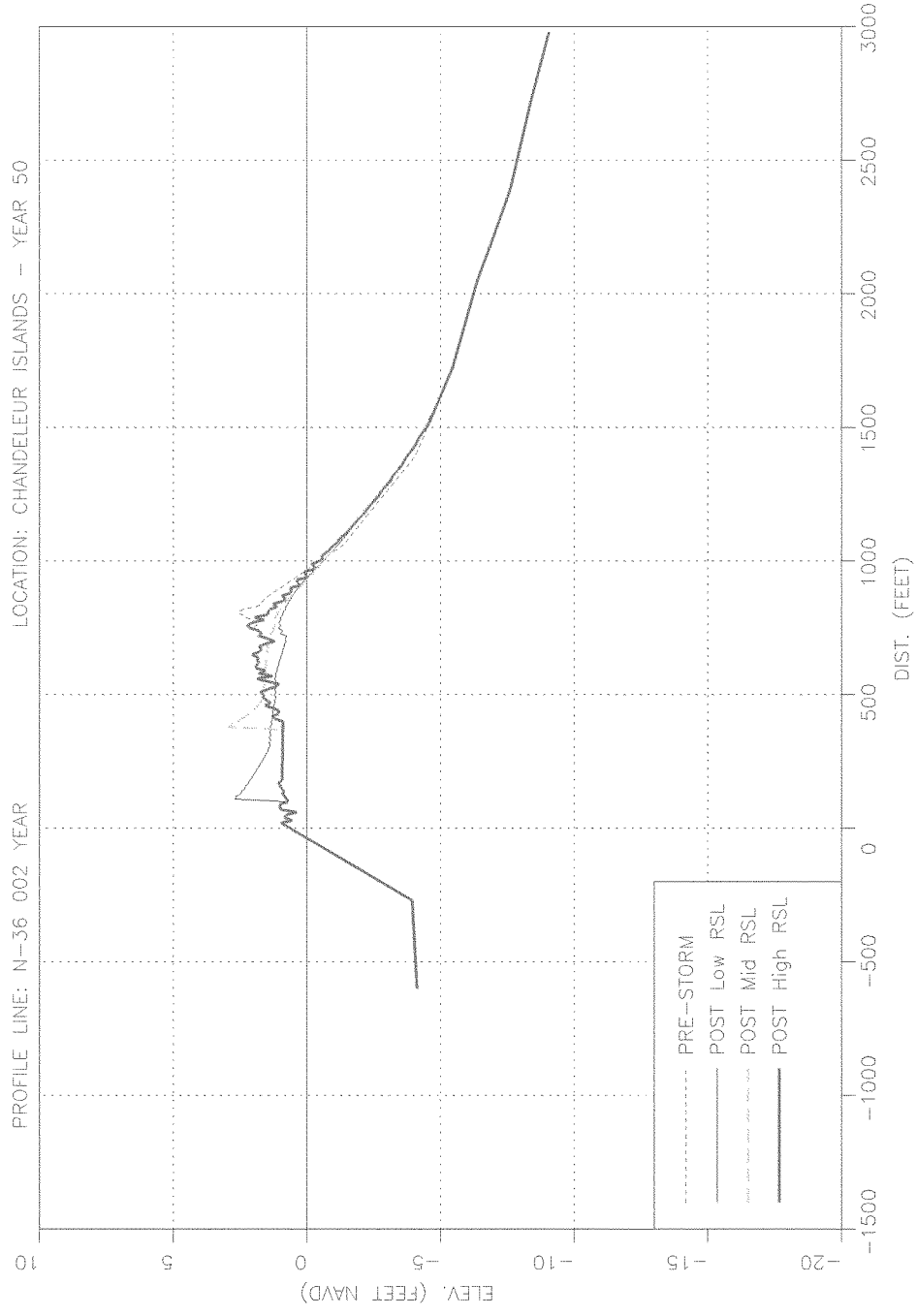

PROFILE LINE: N-32 010 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
POST Mid RSL
POST High RSL
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

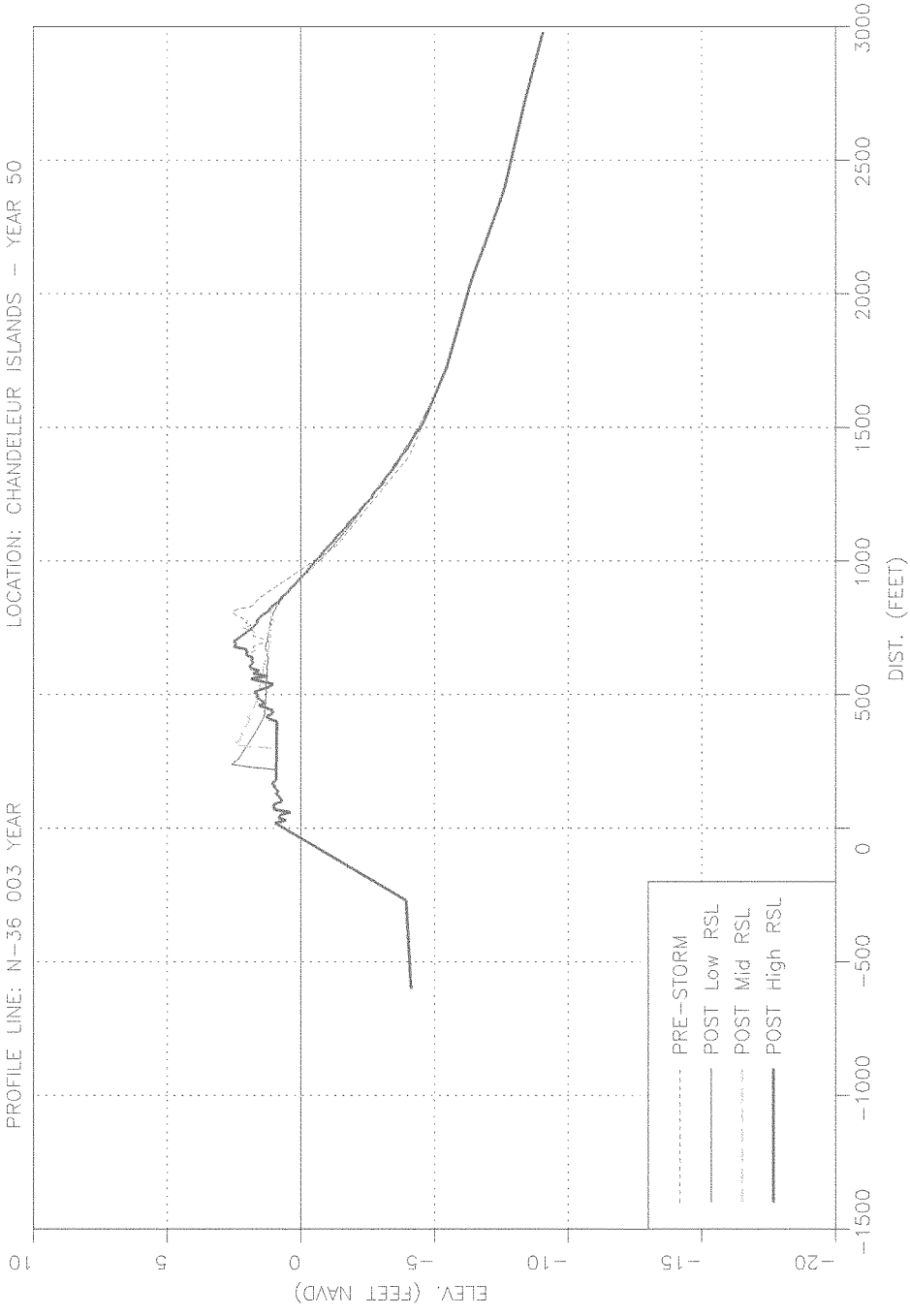

PROFILE LINE: N-32 020 YEAR
LOCATION: CHANDELEUR ISLANDS -- YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
POST Mid RSL
POST High RSL
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

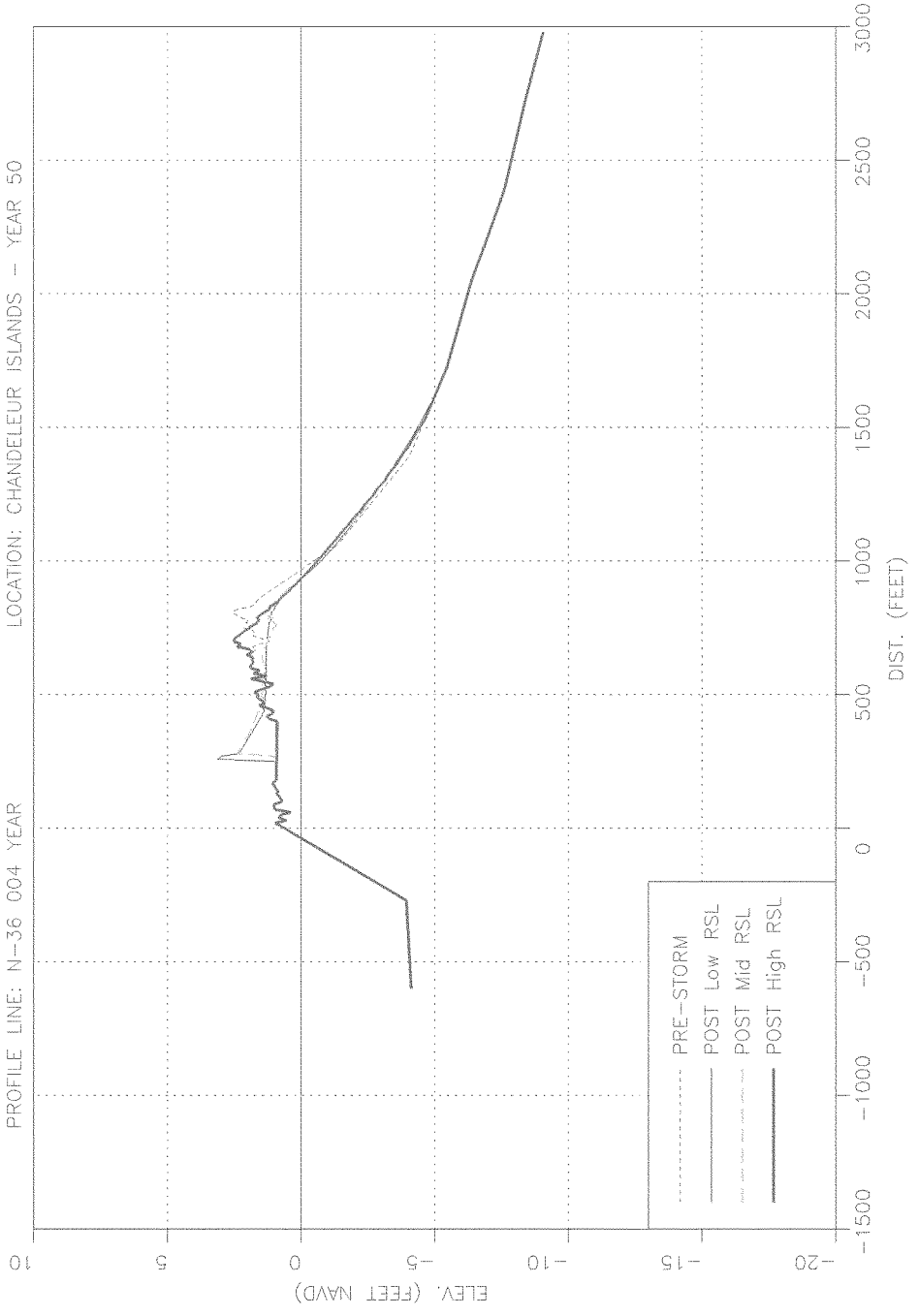

PROFILE LINE: N-32 050 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
POST Mid RSL
POST High RSL
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

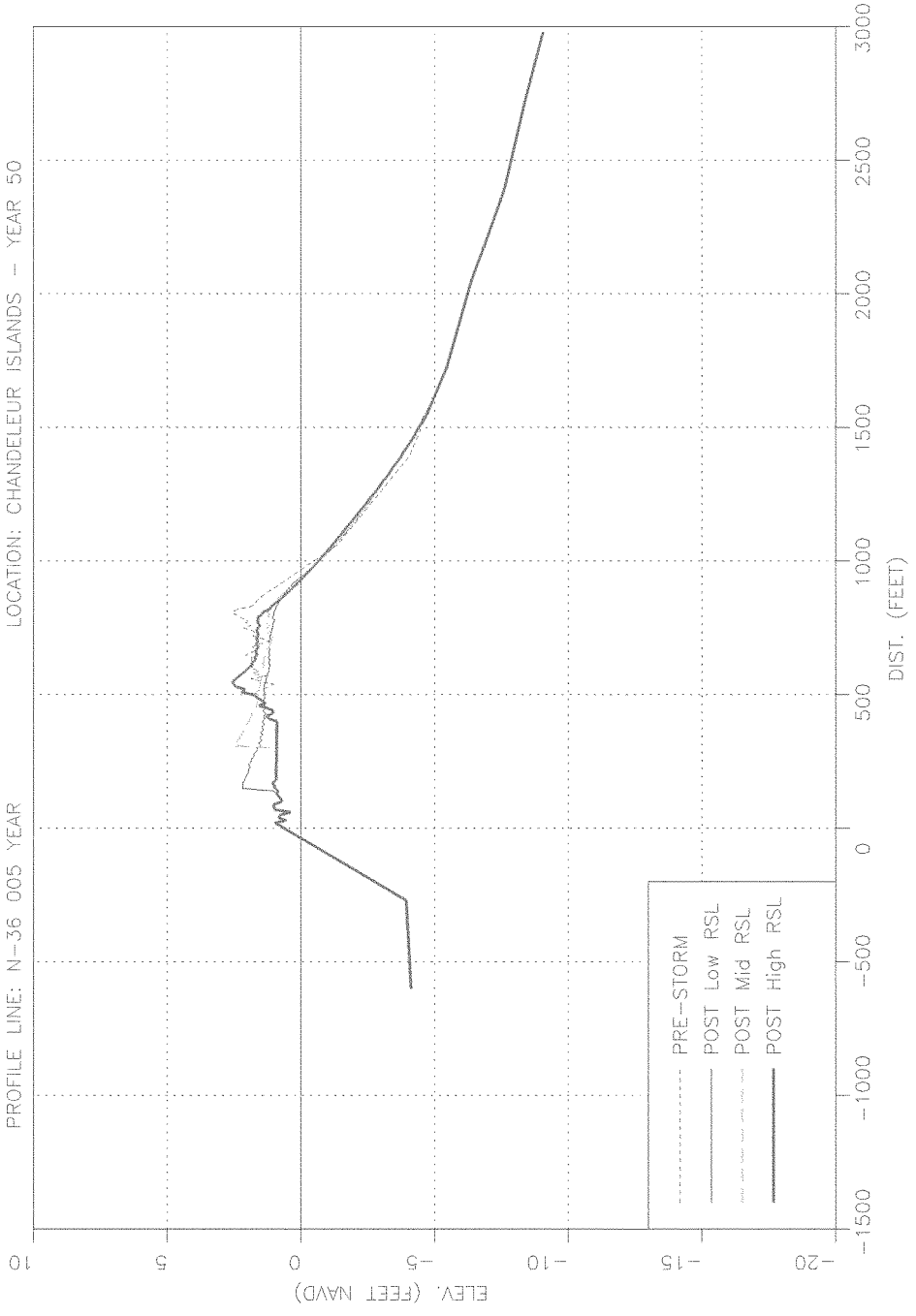

PROFILE LINE: N-32 100 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
POST Mid RSL
POST High RSL
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

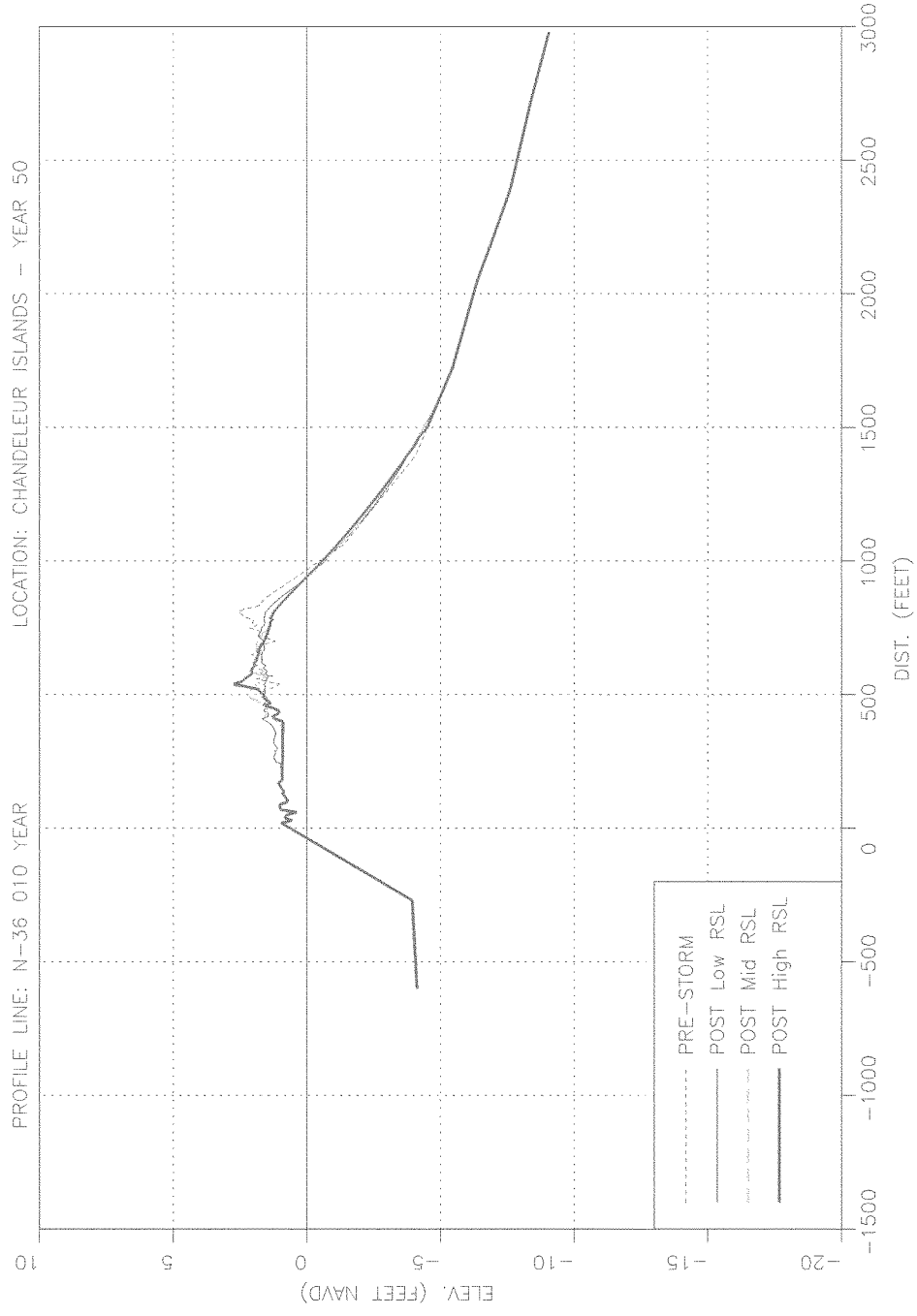

PROFILE LINE: N-36 001 YEAR
LOCATION: CHANDELEUR ISLANDS -- YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
POST Mid RSL
POST High RSL
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

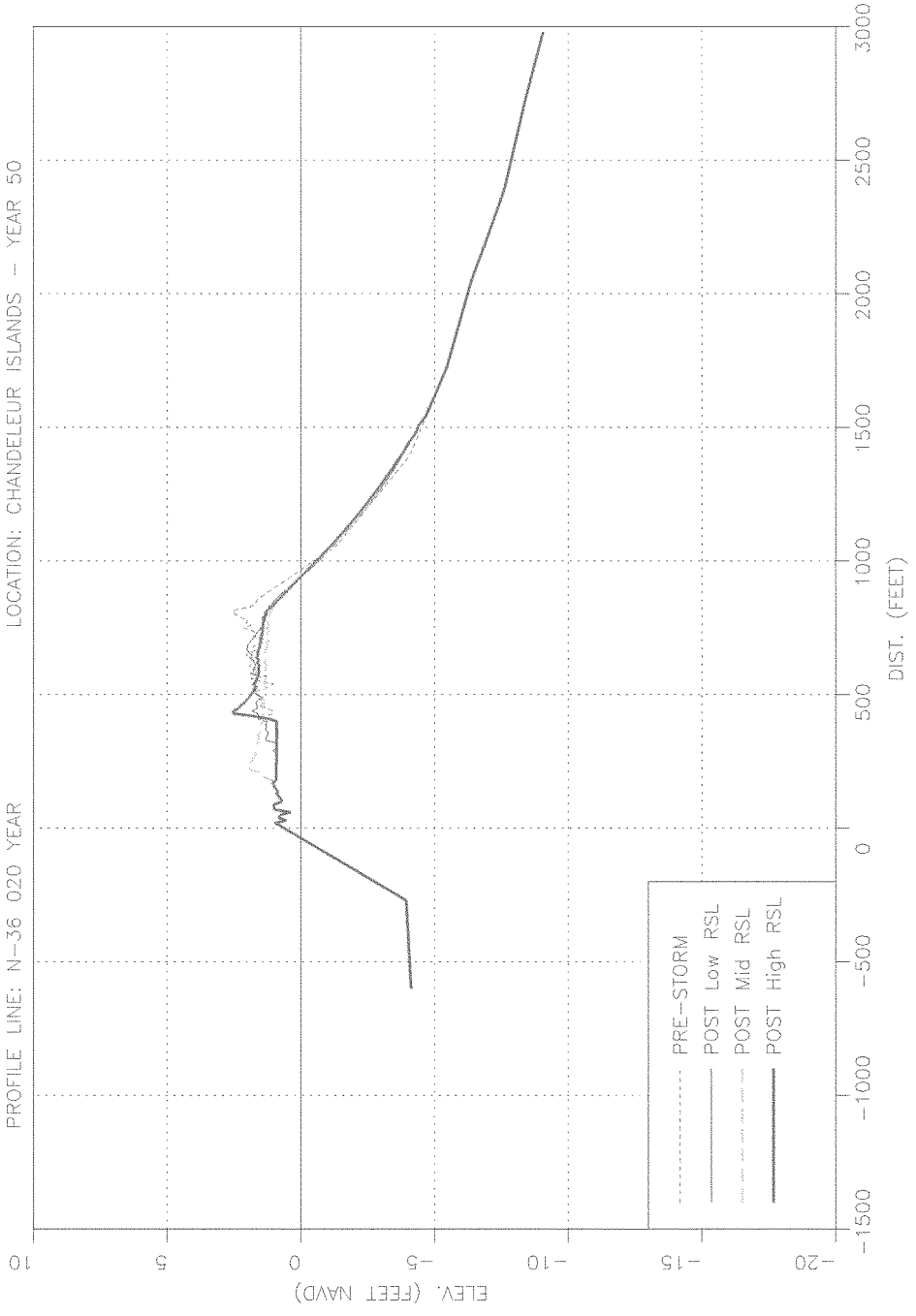

PROFILE LINE: N-36 002 YEAR
LOCATION: CHANDELEUR ISLANDS -- YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000
PRE-STORM
POST Low RSL
POST Mid RSL
POST High RSL

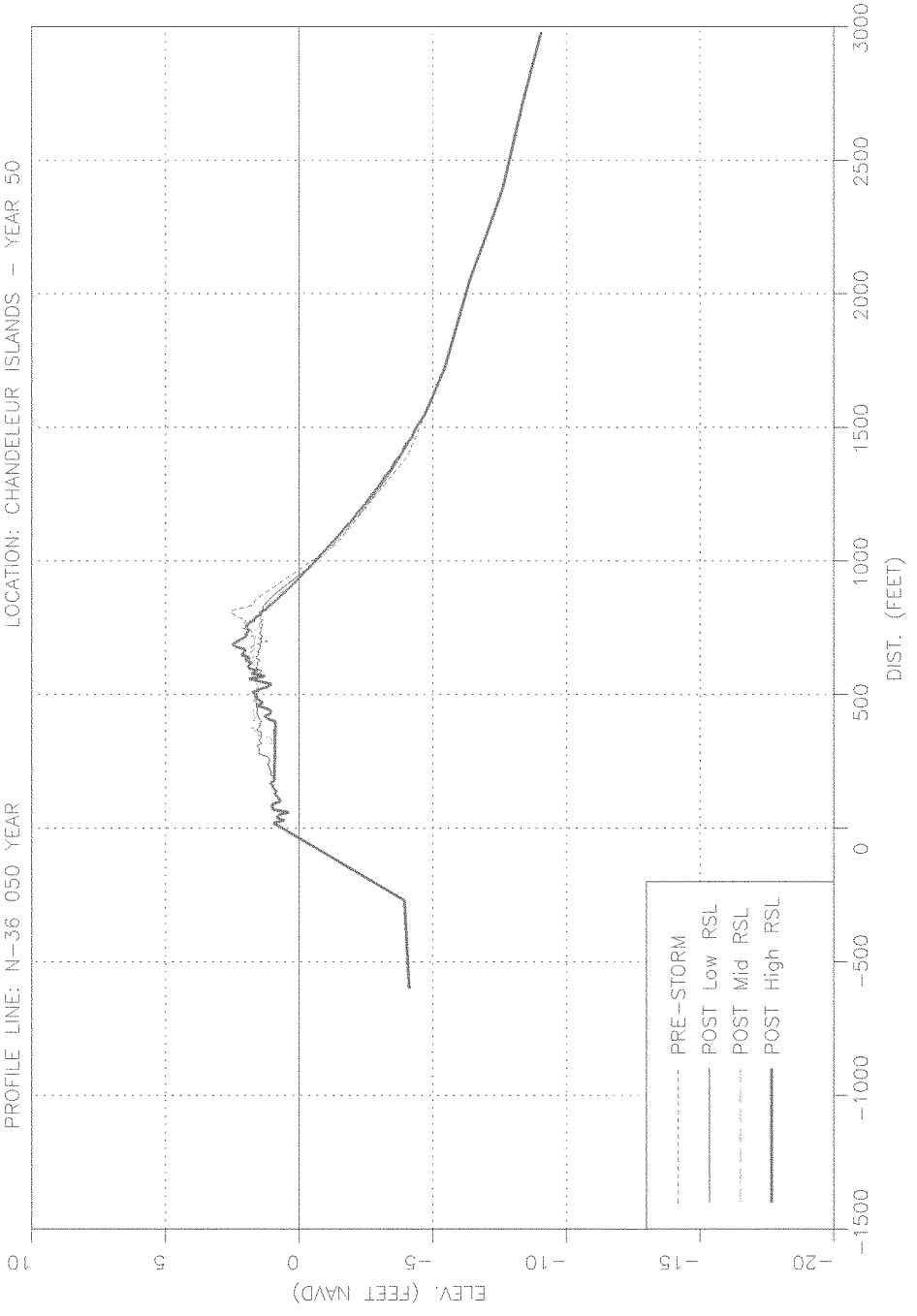

PROFILE LINE: N-36 003 YEAR
LOCATION: CHANDELEUR ISLANDS -- YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
POST Mid RSL
POST High RSL
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000


PROFILE LINE: N-36 004 YEAR
LOCATION: CHANDELEUR ISLANDS -- YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
POST Mid RSL
POST High RSL
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

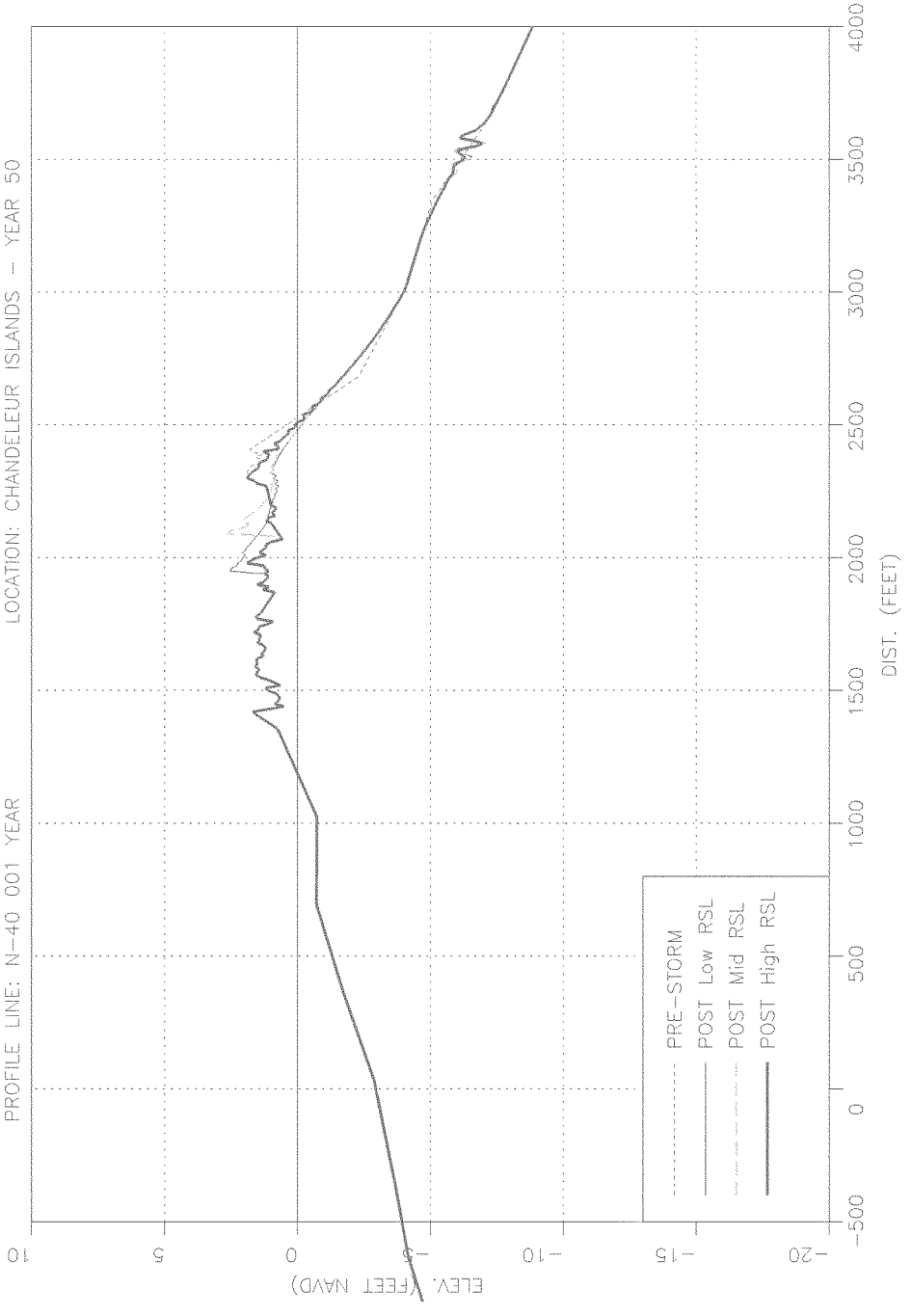

PROFILE LINE: N-36 005 YEAR
LOCATION: CHANDELEUR ISLANDS -- YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
POST Mid RSL
POST High RSL
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

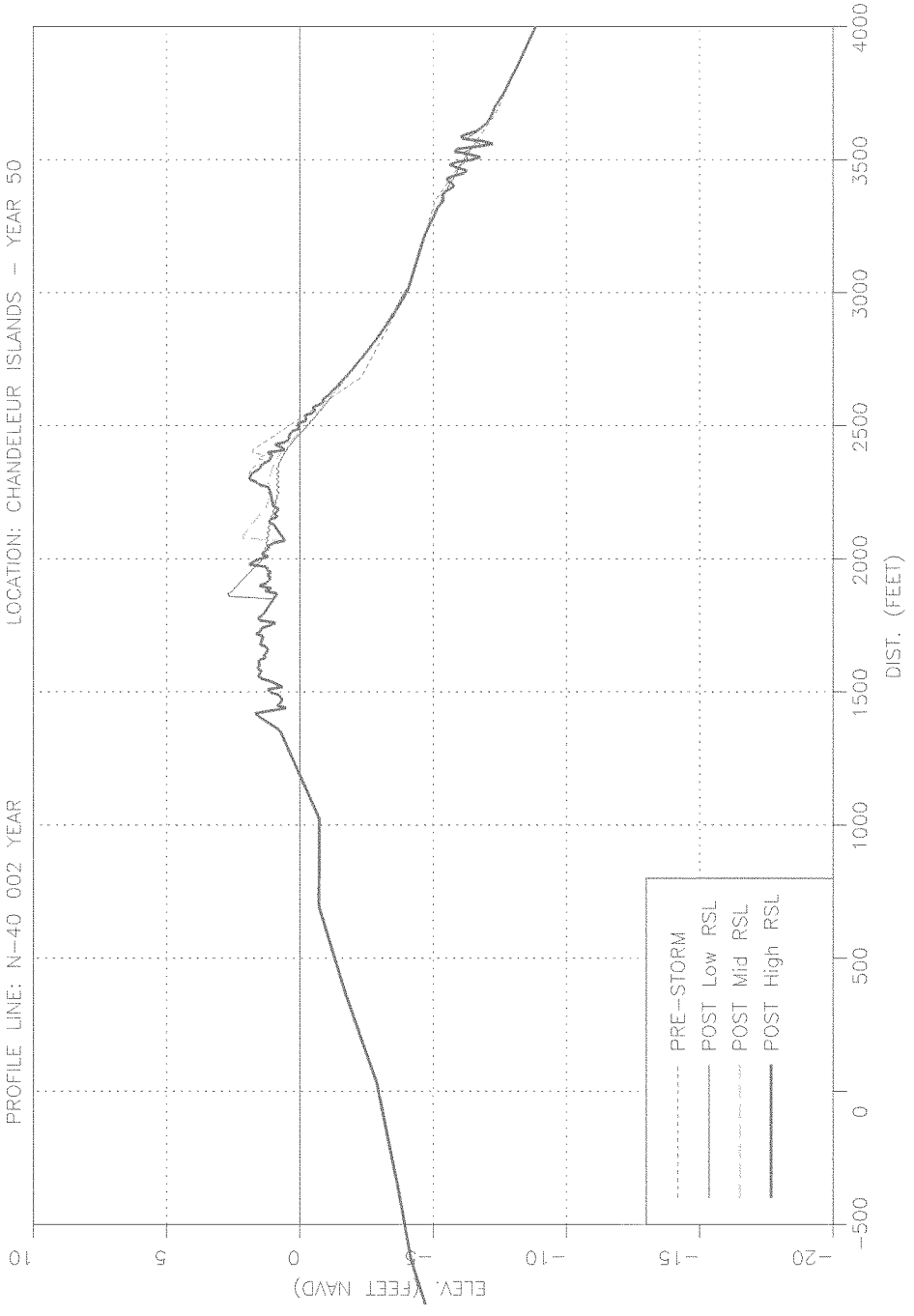

PROFILE LINE: N-36 010 YEAR
LOCATION: CHANDELEUR ISLANDS -- YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000
PRE-STORM
POST Low RSL
POST Mid RSL
POST High RSL

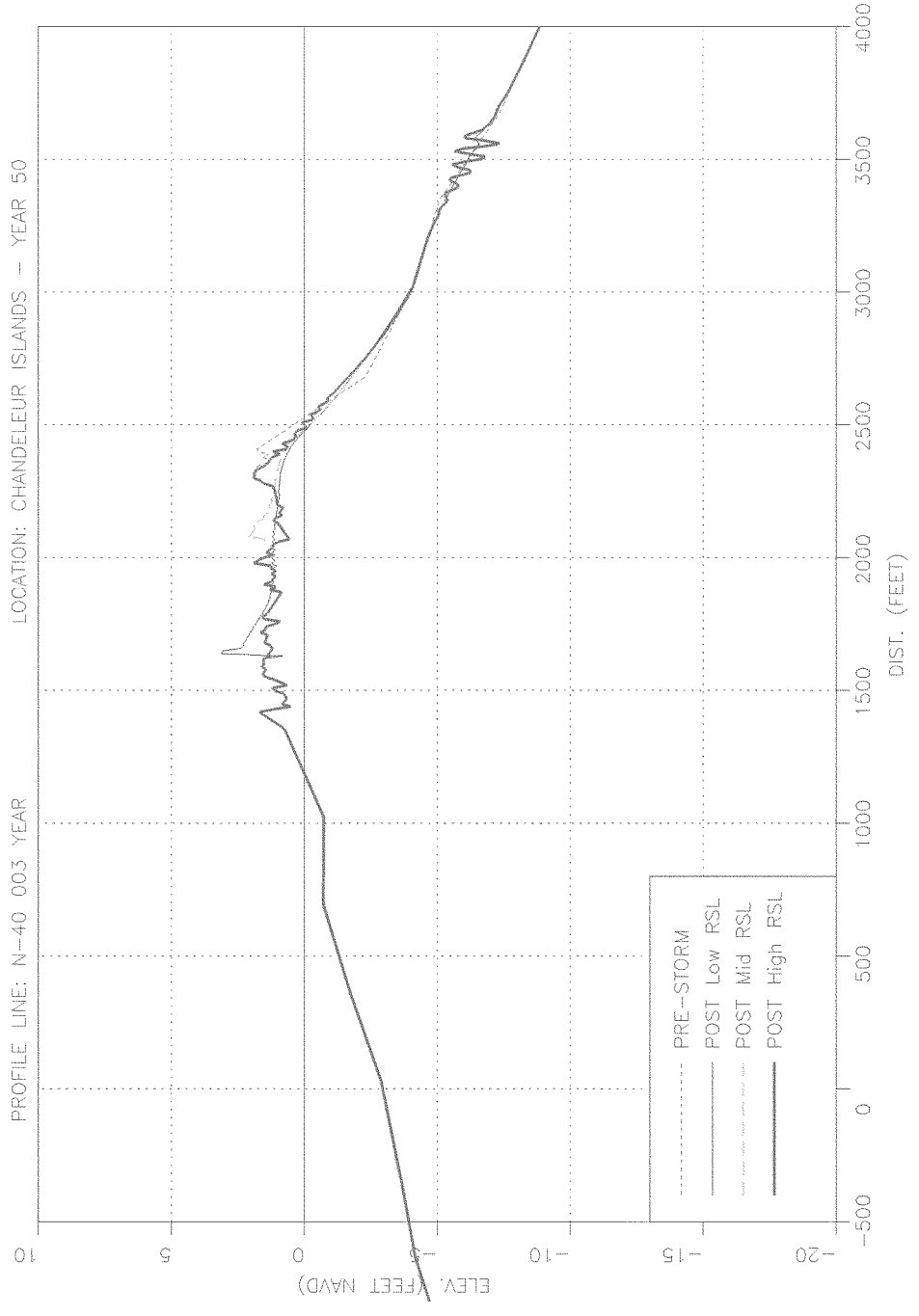

PROFILE LINE: N-36 020 YEAR
LOCATION: CHANDELEUR ISLANDS -- YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
POST Mid RSL
POST High RSL
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

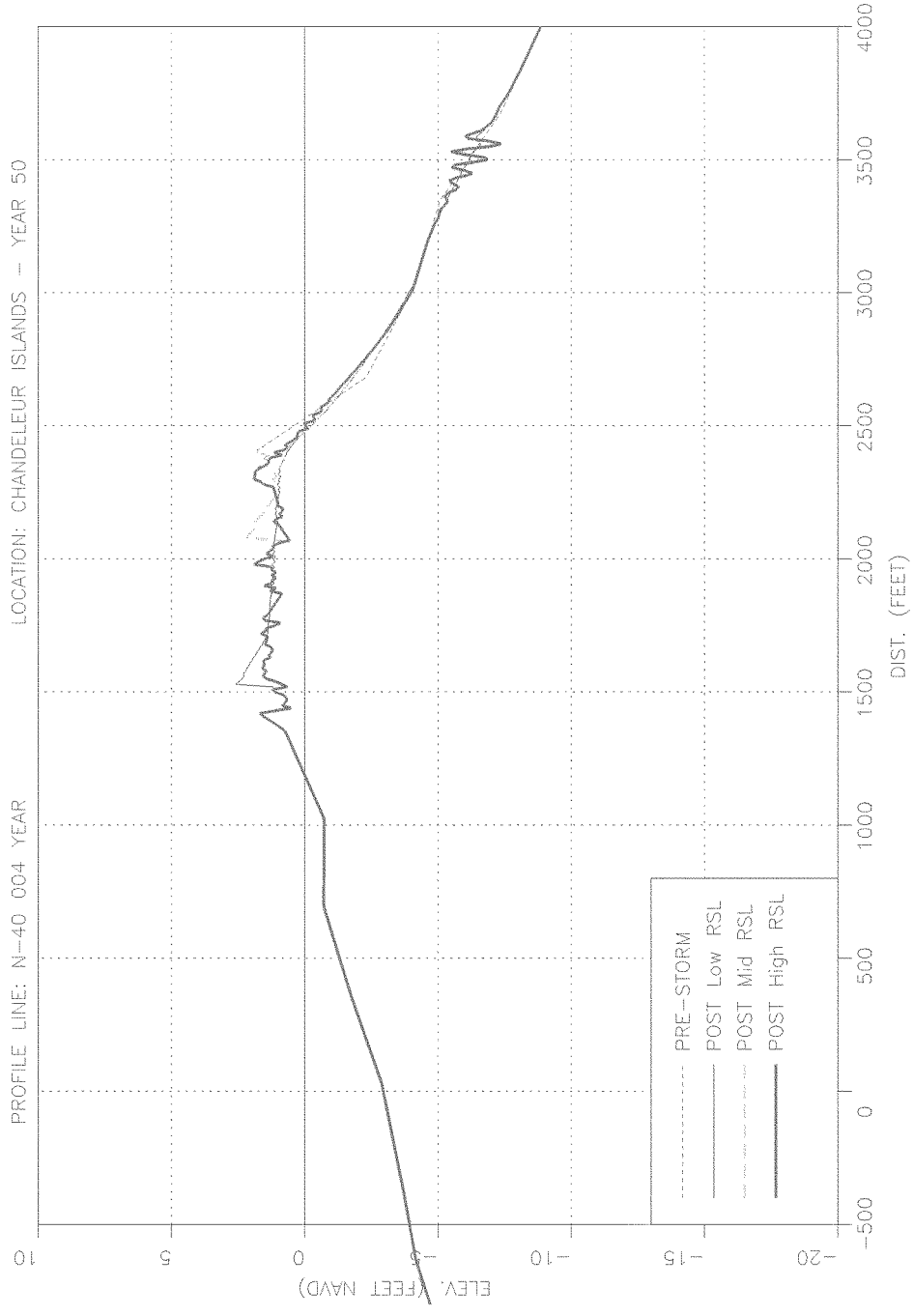

PROFILE LINE: N-36 050 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000
PRE-STORM
POST Low RSL
POST Mid RSL
POST High RSL

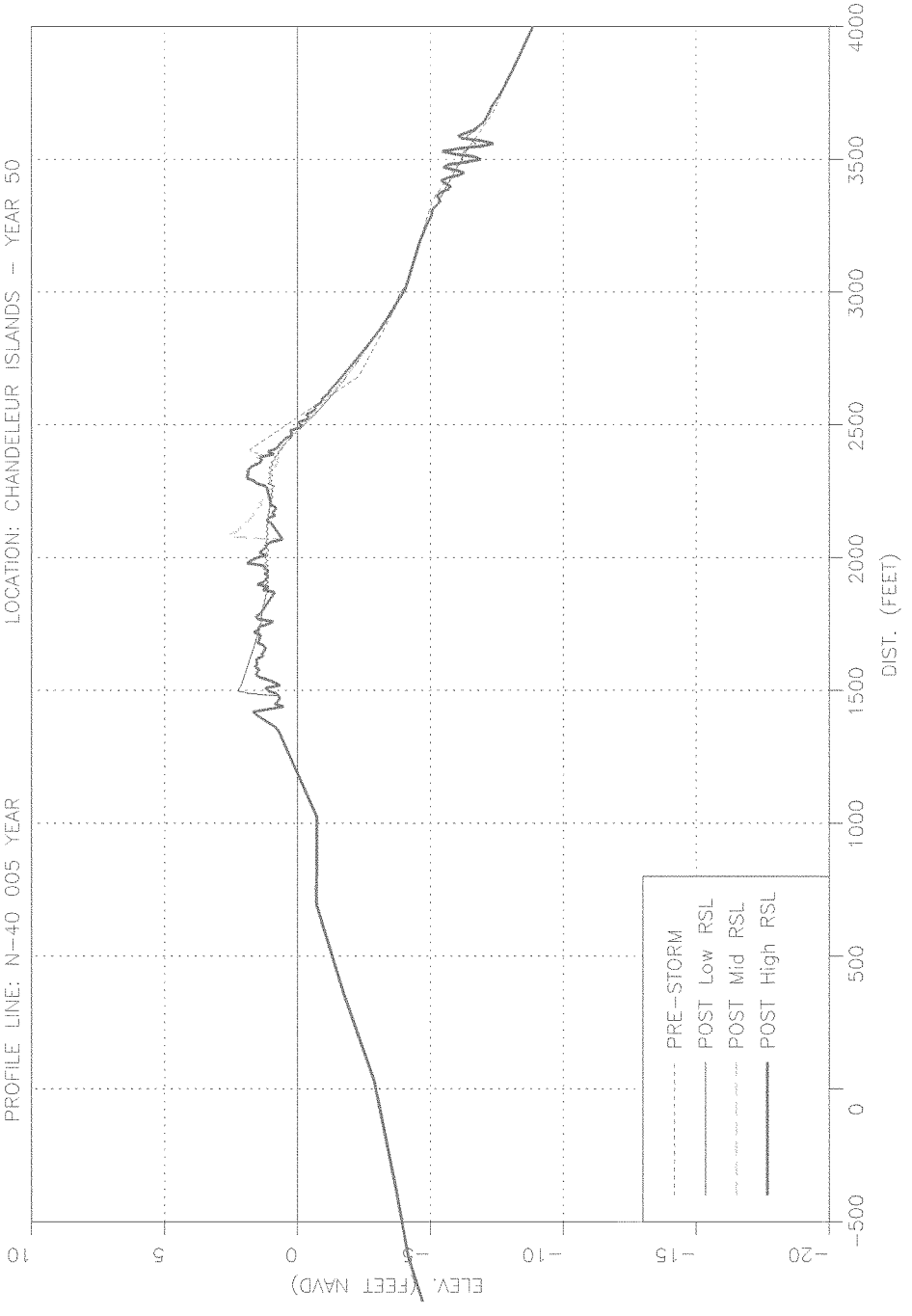

PROFILE LINE: N-36 100 YEAR
LOCATION: CHANDELEUR ISLANDS -- YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
POST Mid RSL
POST High RSL
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

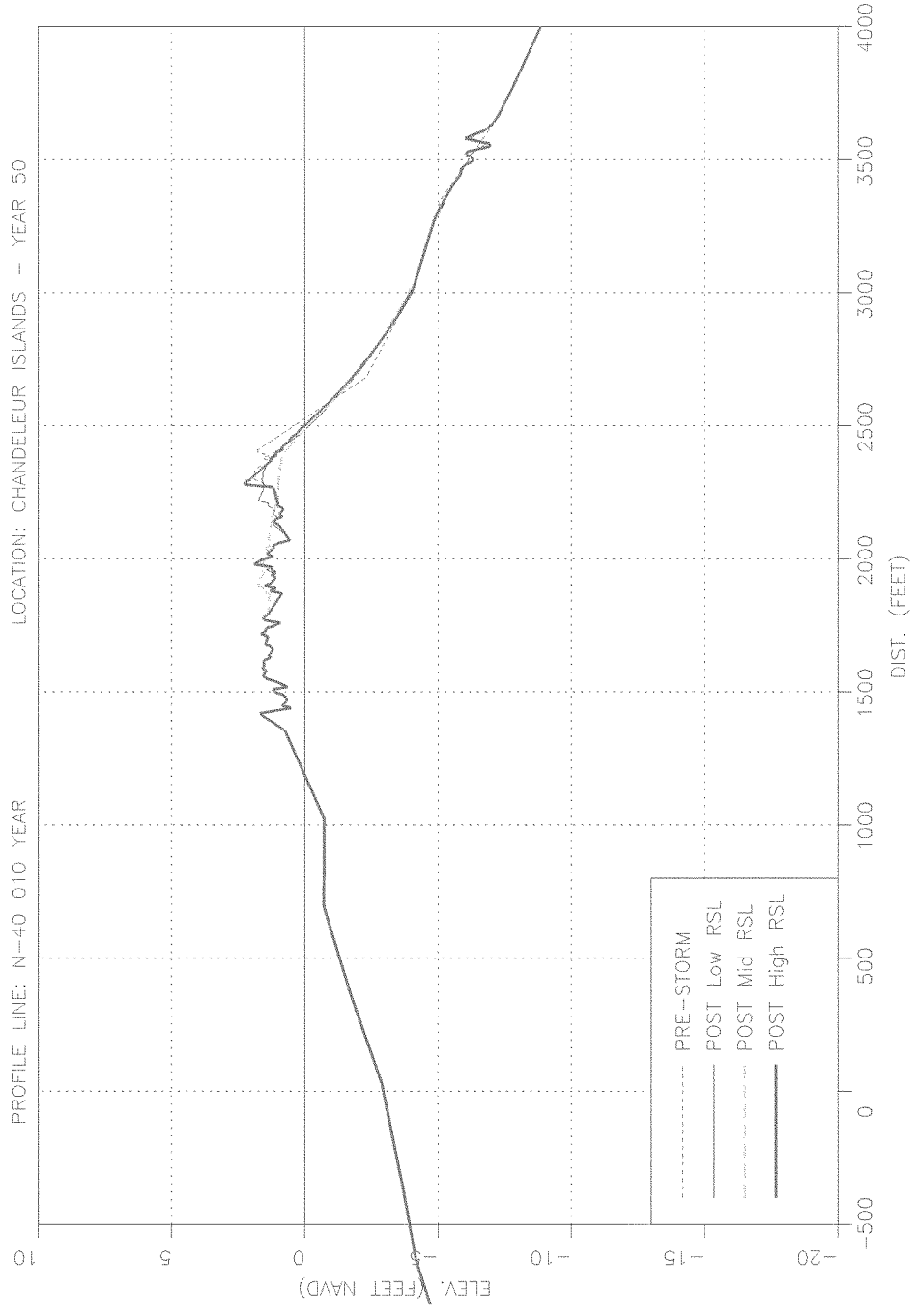

PROFILE LINE: N-40 001 YEAR
LOCATION: CHANDELEUR ISLANDS -- YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000
PRE-STORM
POST Low RSL
POST Mid RSL
POST High RSL

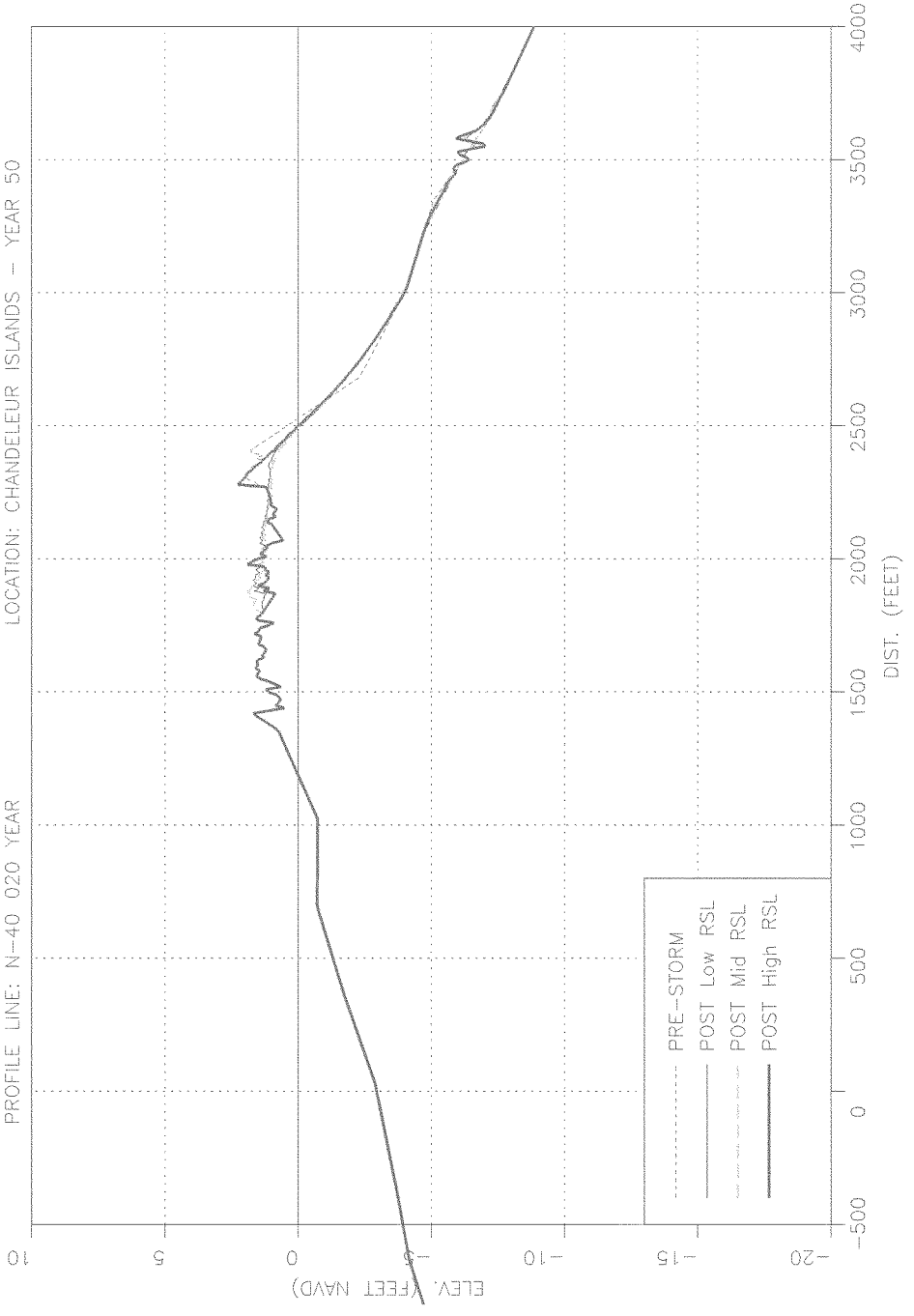

PROFILE LINE: N-40 002 YEAR
LOCATION: CHANDELEUR ISLANDS -- YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
POST Mid RSL
POST High RSL
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

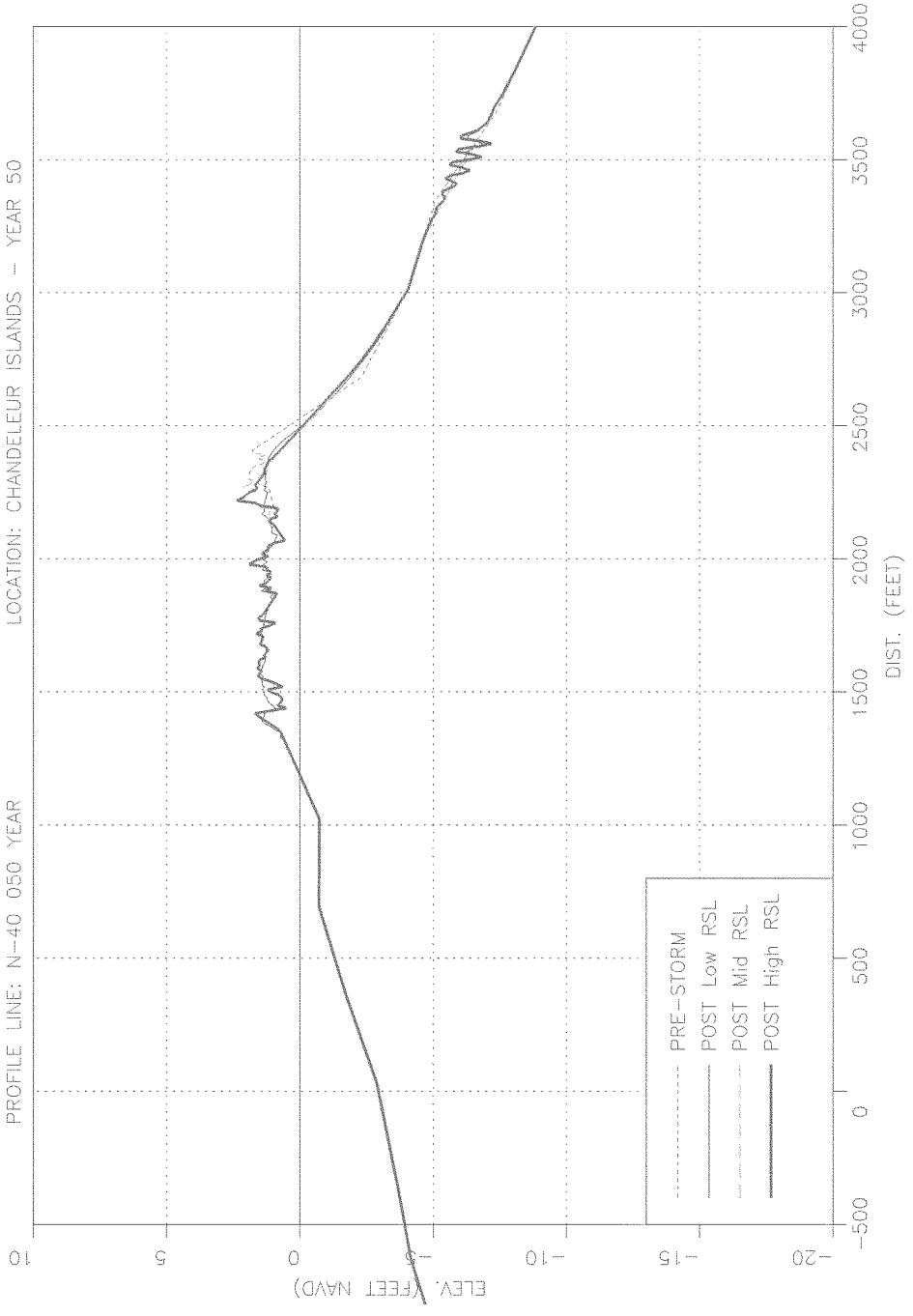

PROFILE LINE: N-40 003 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000
PRE-STORM
POST Low RSL
POST Mid RSL
POST High RSL

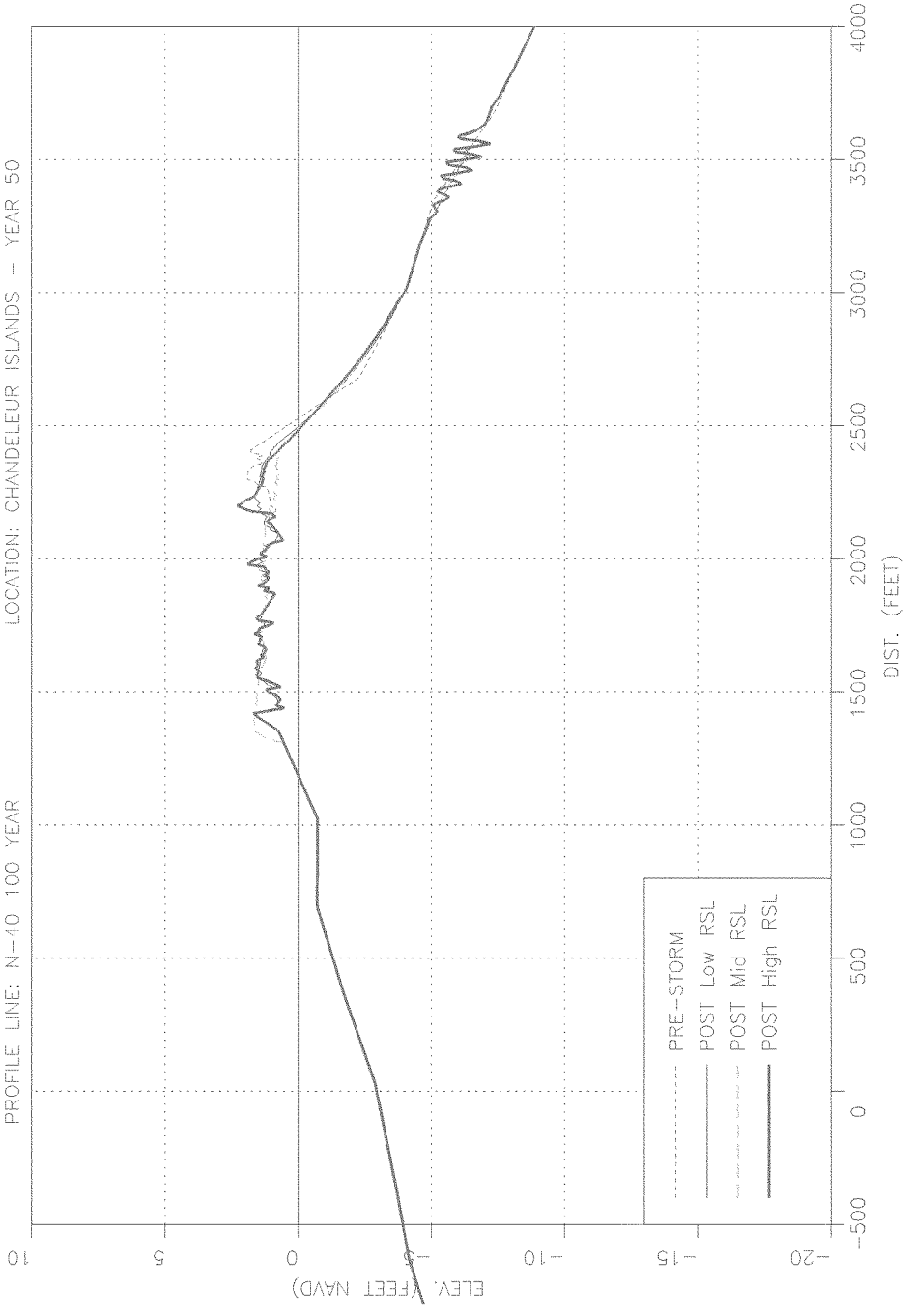

PROFILE LINE: N-40 004 YEAR
LOCATION: CHANDELEUR ISLANDS -- YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
POST Mid RSL
POST High RSL
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

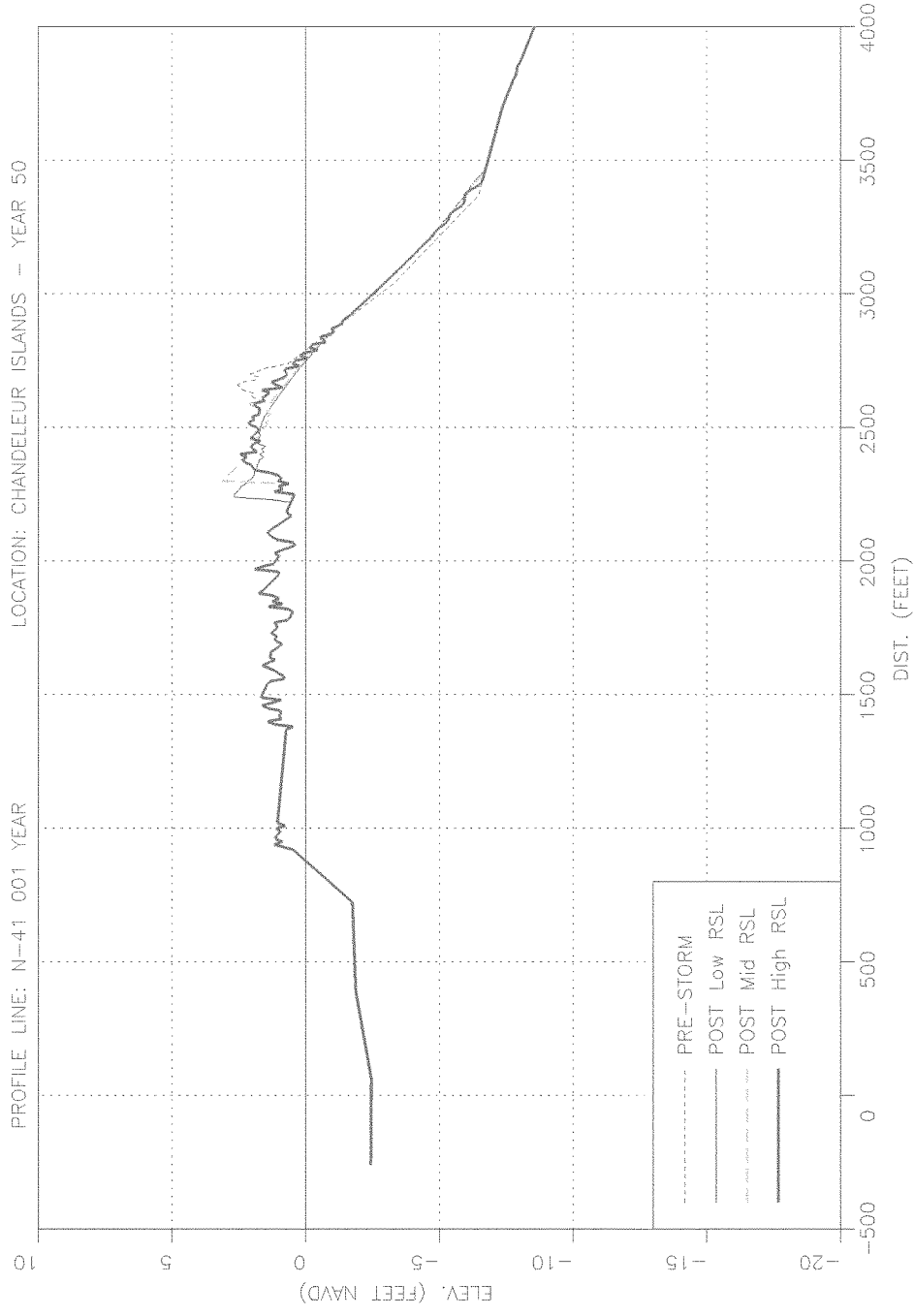

PROFILE LINE: N-40 005 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
POST Mid RSL
POST High RSL
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

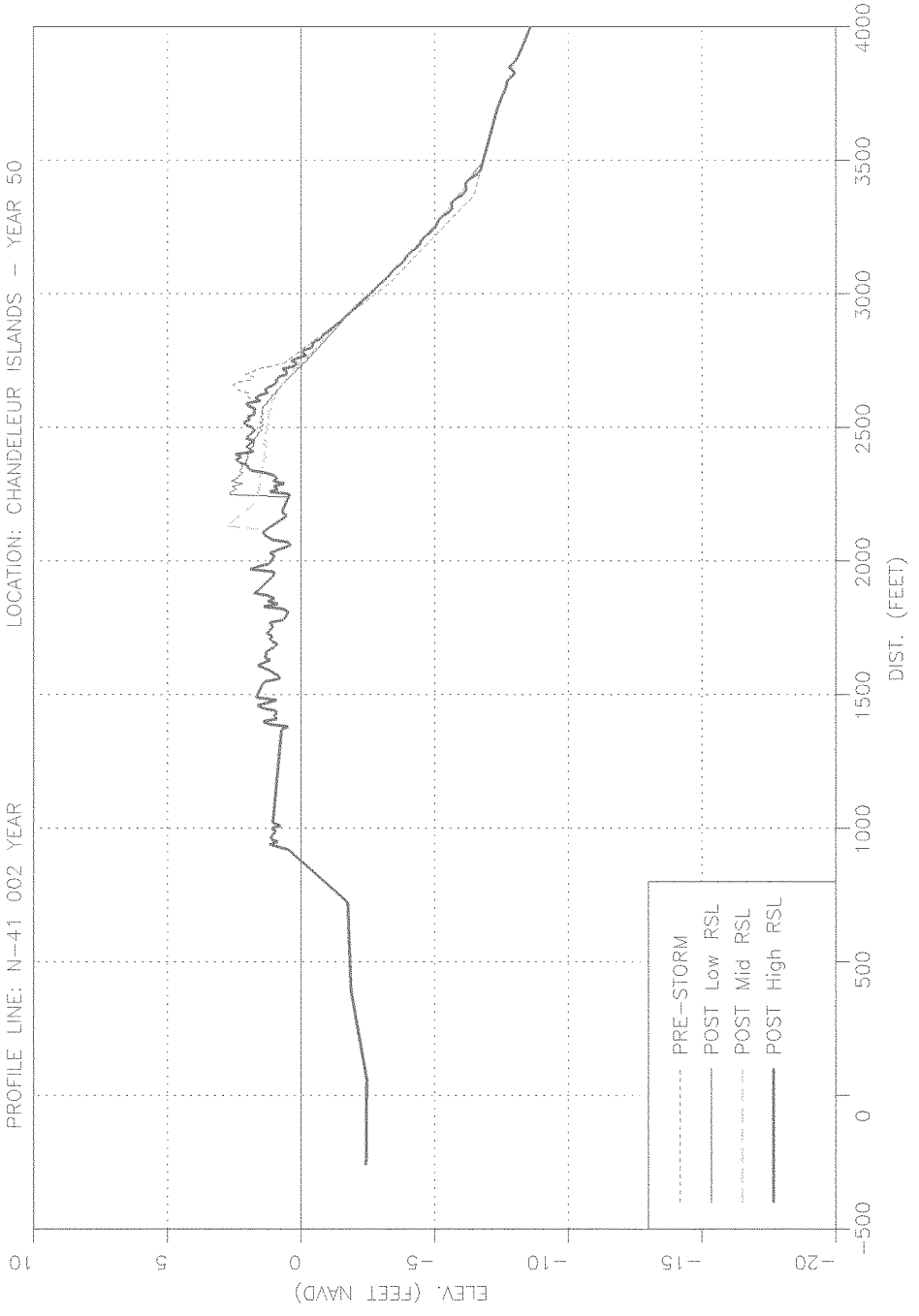

PROFILE LINE: N-40 010 YEAR
LOCATION: CHANDELEUR ISLANDS -- YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
POST Mid RSL
POST High RSL
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

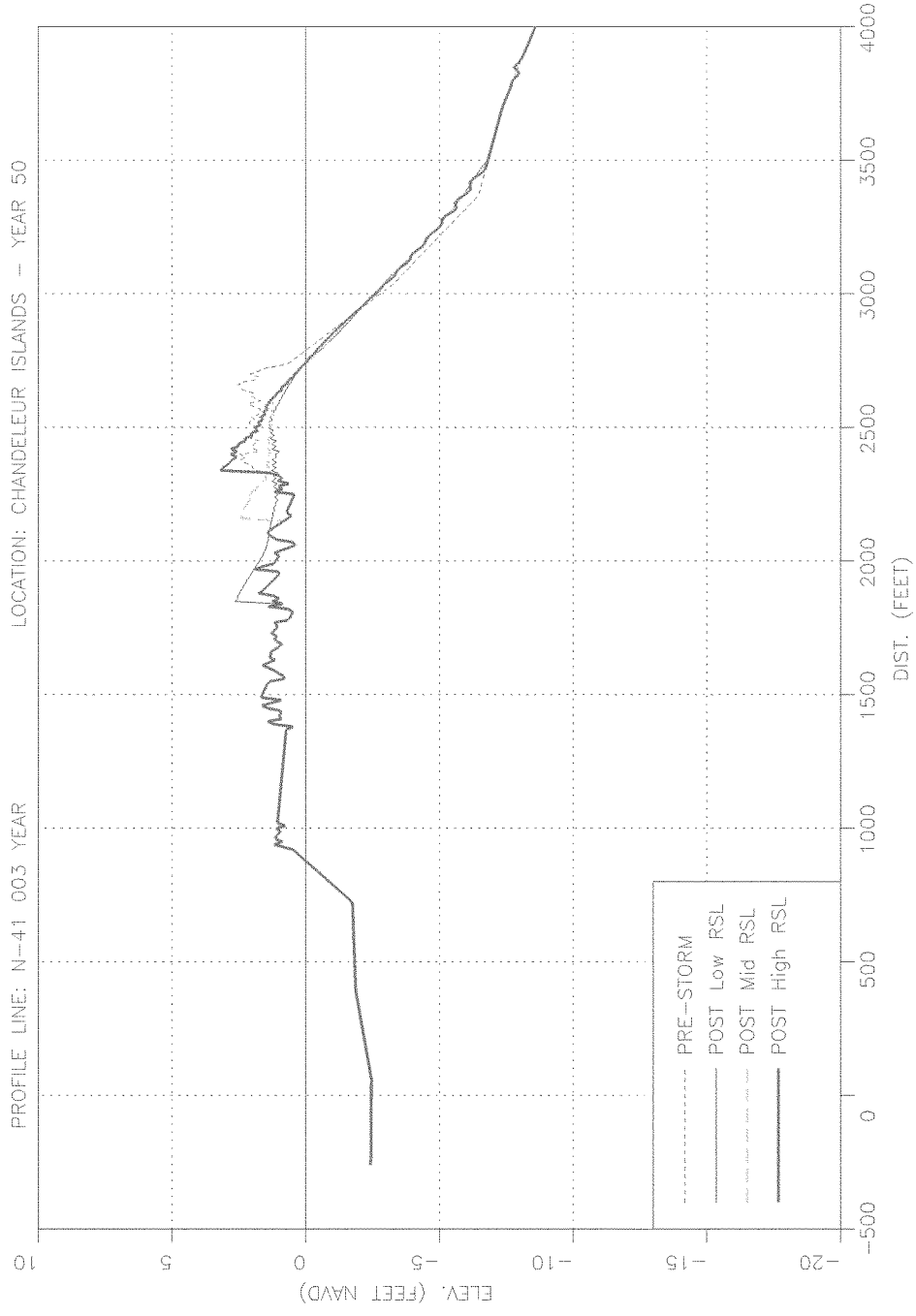

PROFILE LINE: N-40 020 YEAR
LOCATION: CHANDELEUR ISLANDS -- YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
POST Mid RSL
POST High RSL
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

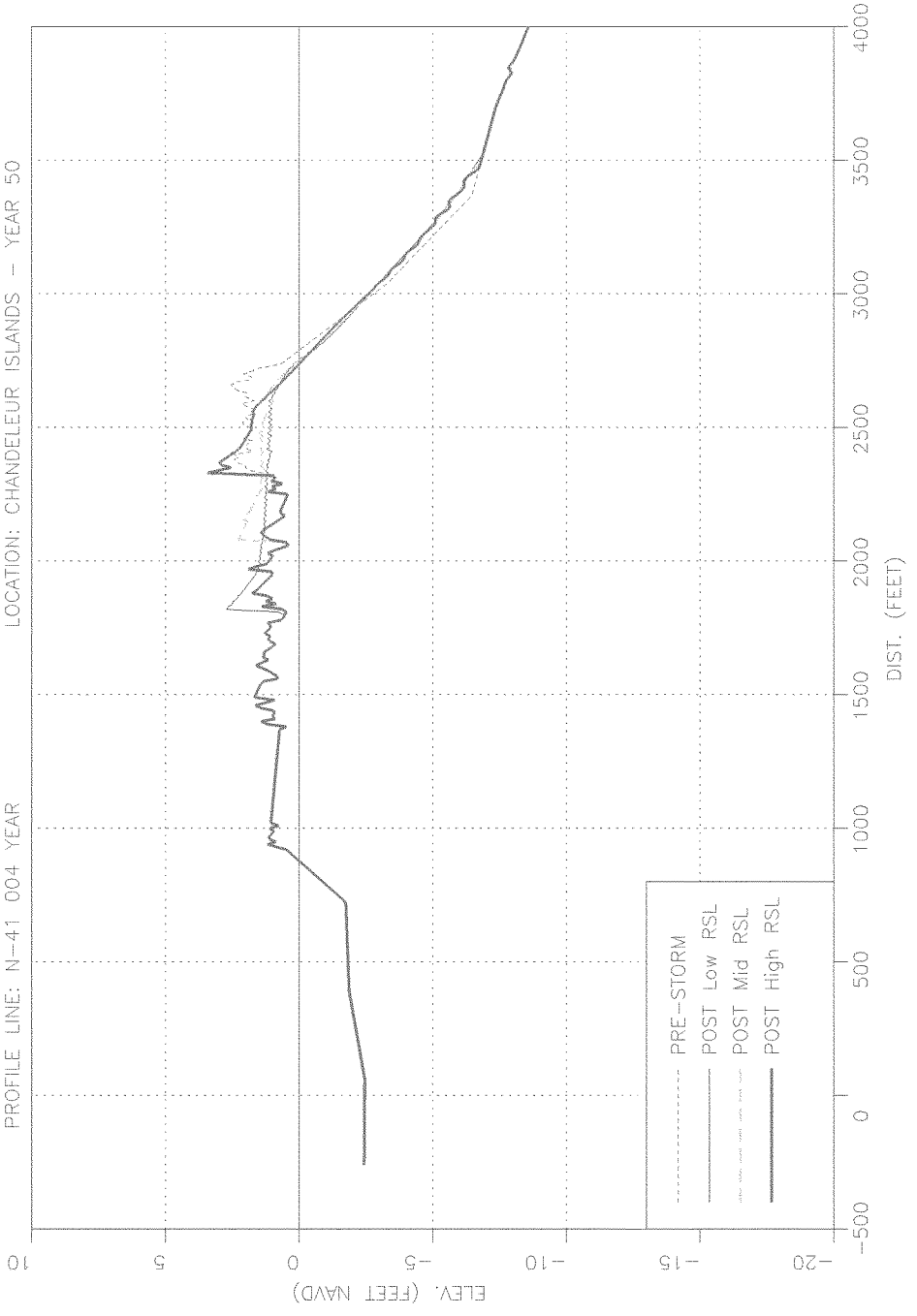

PROFILE LINE: N-40 050 YEAR
LOCATION: CHANDELEUR ISLANDS -- YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
POST Mid RSL
POST High RSL
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

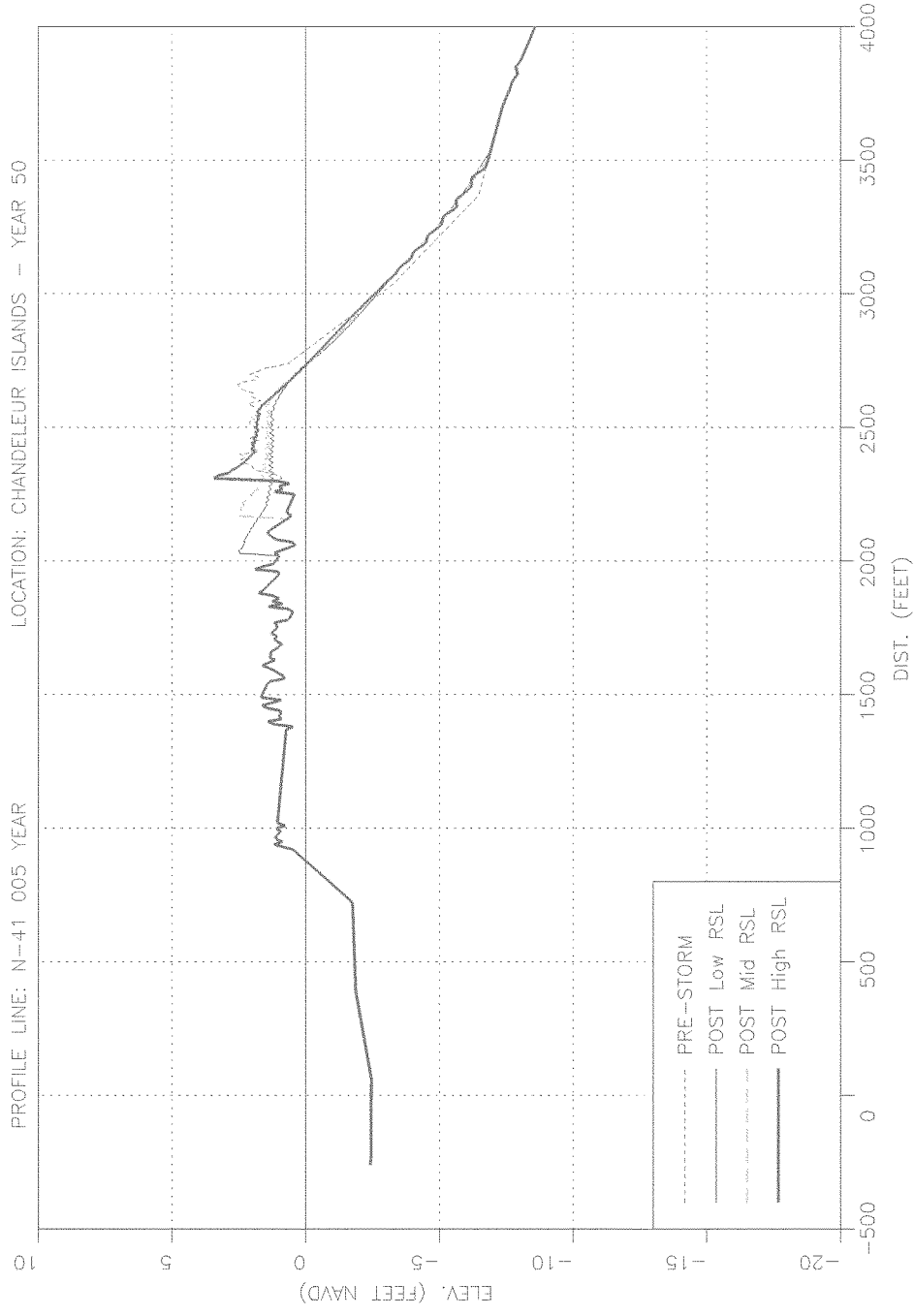

PROFILE LINE: N-40 100 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
POST Mid RSL
POST High RSL
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

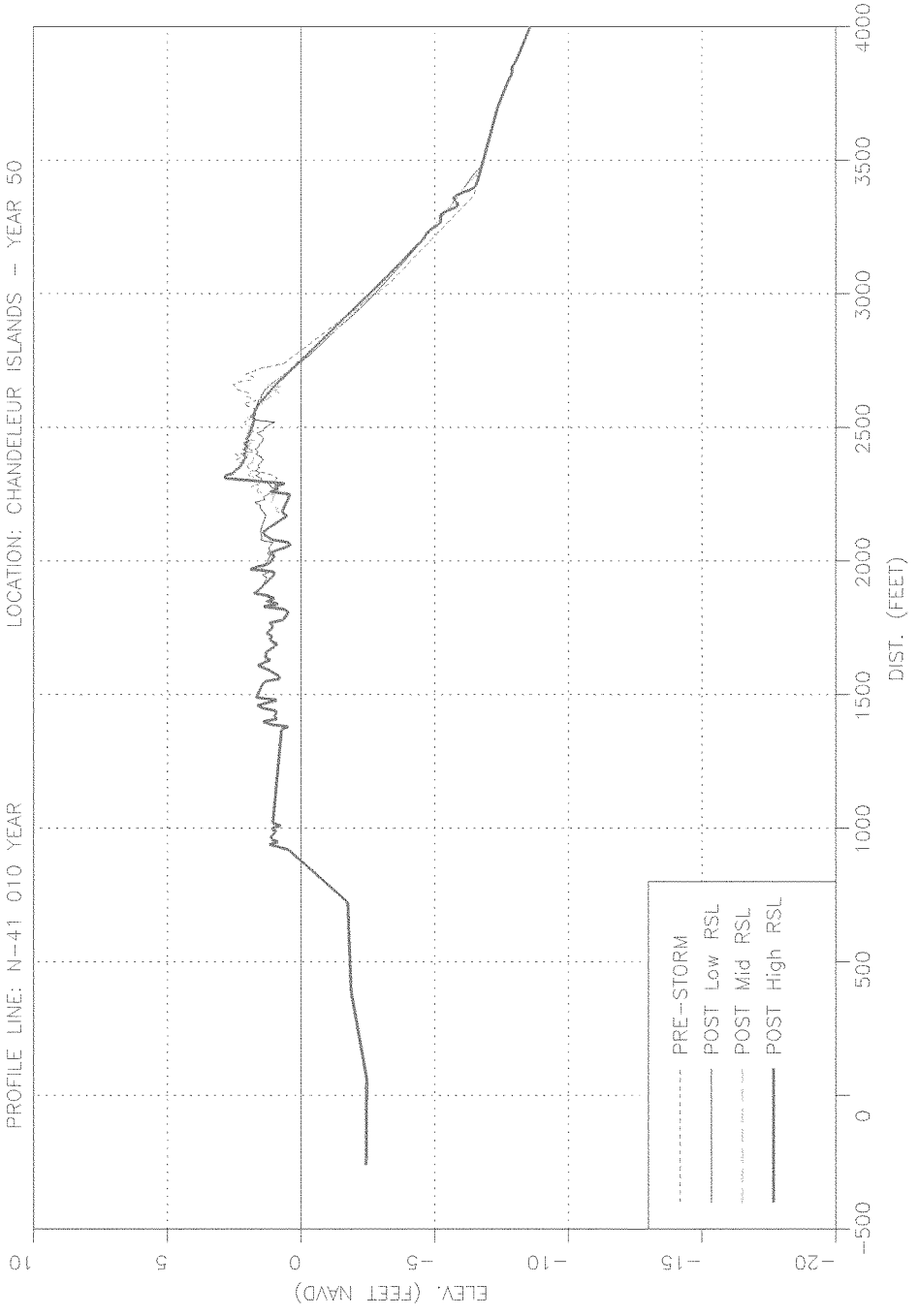

PROFILE LINE: N-41 001 YEAR
LOCATION: CHANDELEUR ISLANDS -- YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
POST Mid RSL
POST High RSL
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

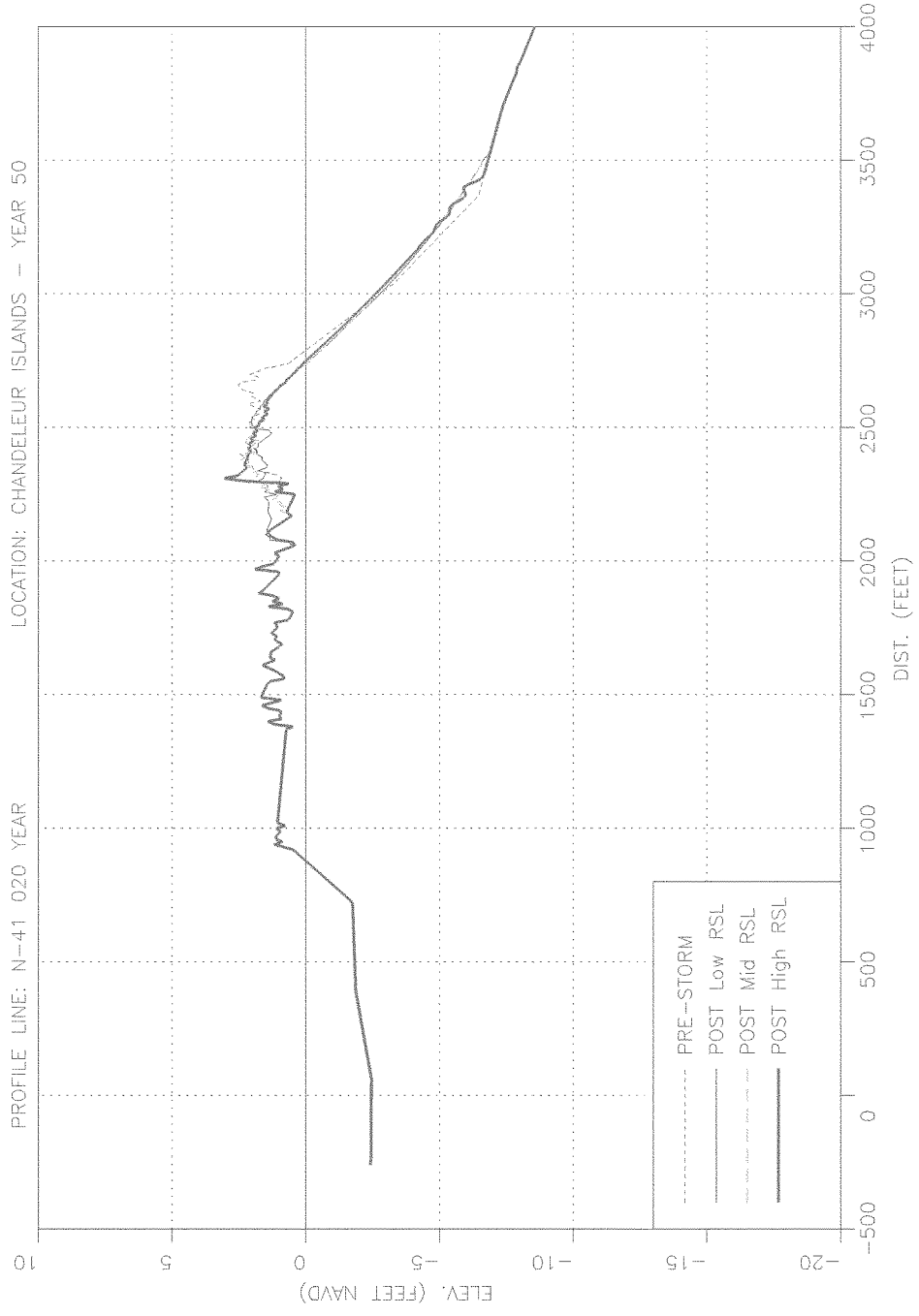

PROFILE LINE: N-41 002 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
POST Mid RSL
POST High RSL
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

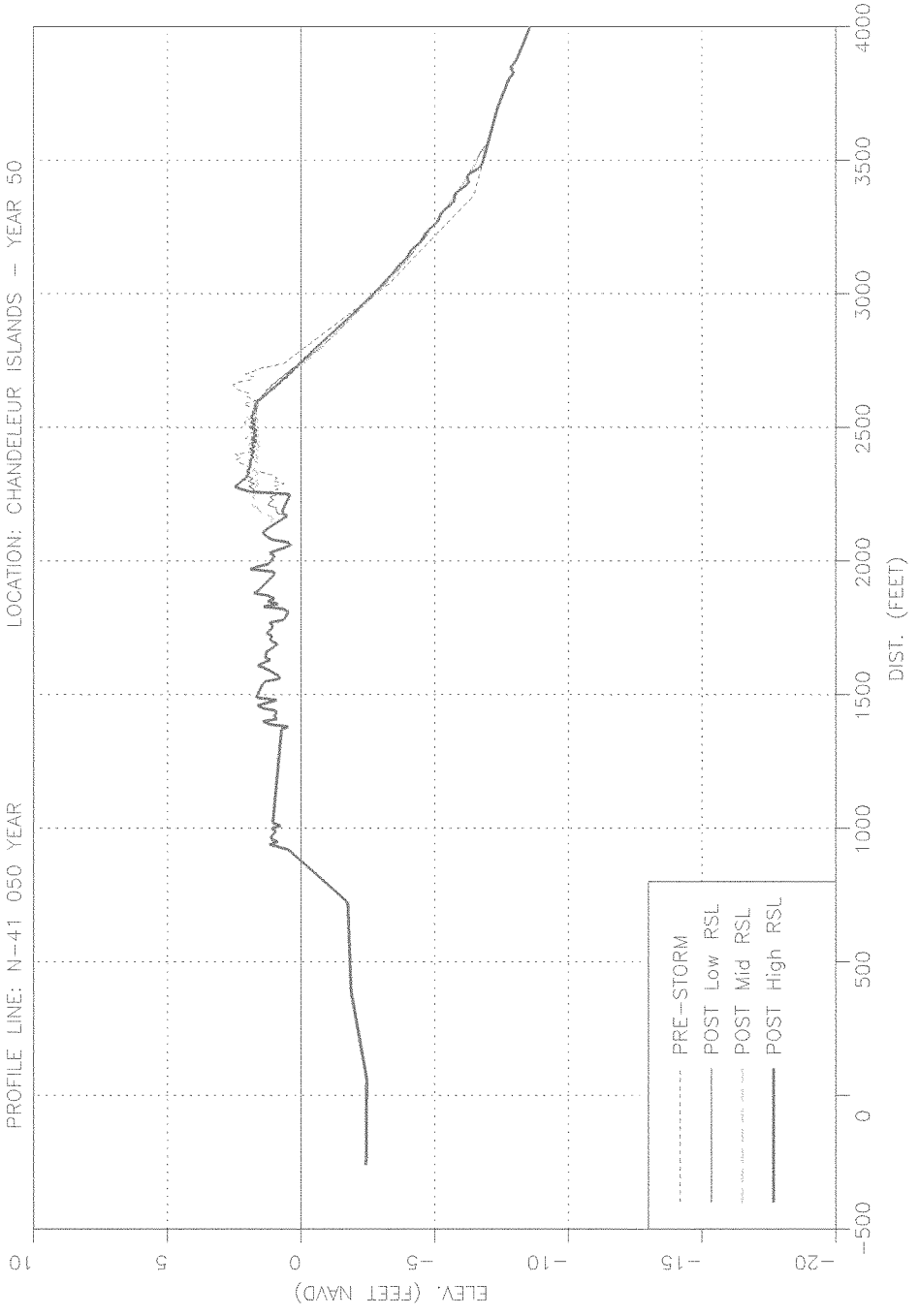

PROFILE LINE: N-41 003 YEAR
LOCATION: CHANDELEUR ISLANDS -- YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
POST Mid RSL
POST High RSL
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

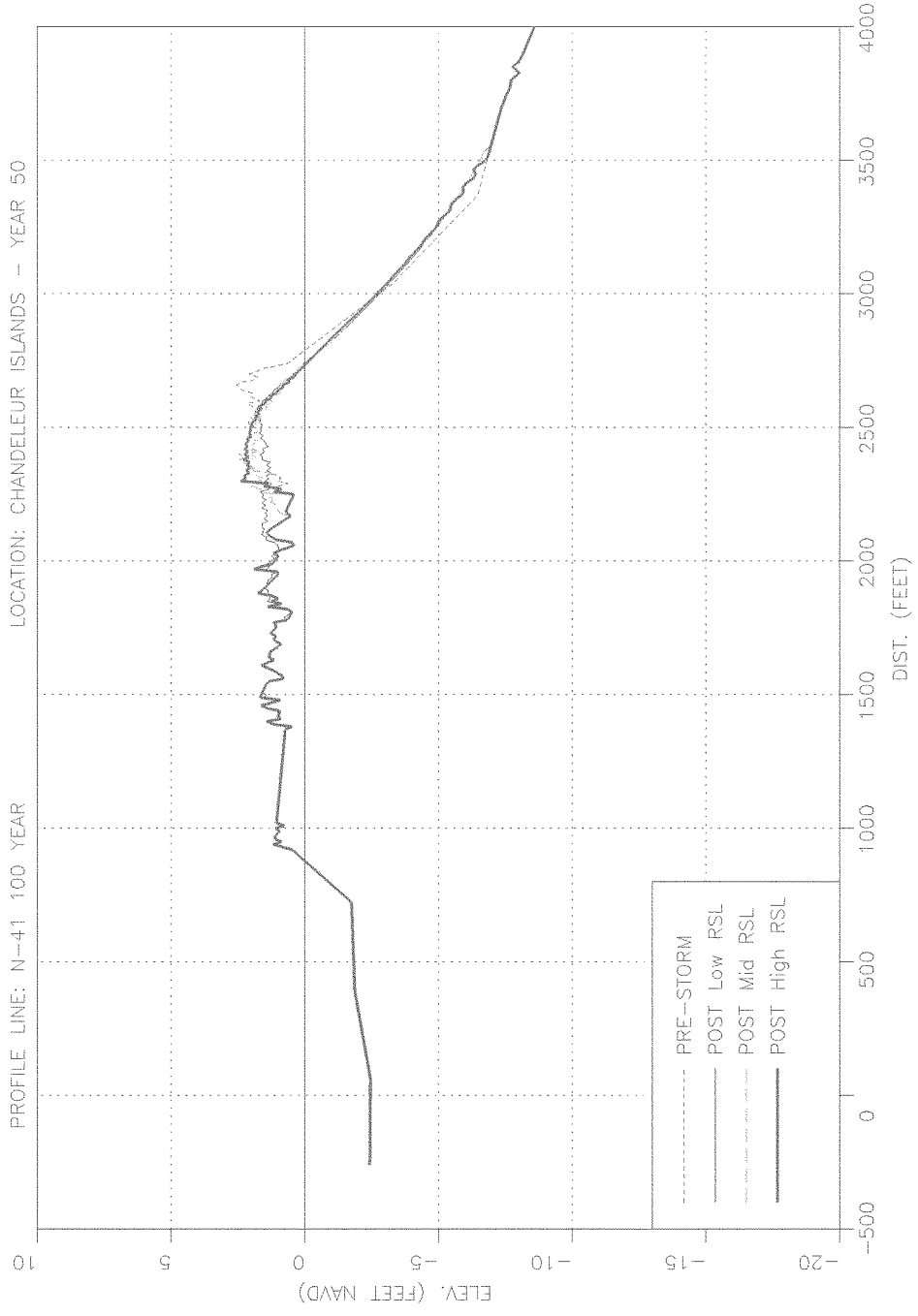

PROFILE LINE: N-41 004 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
POST Mid RSL
POST High RSL
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

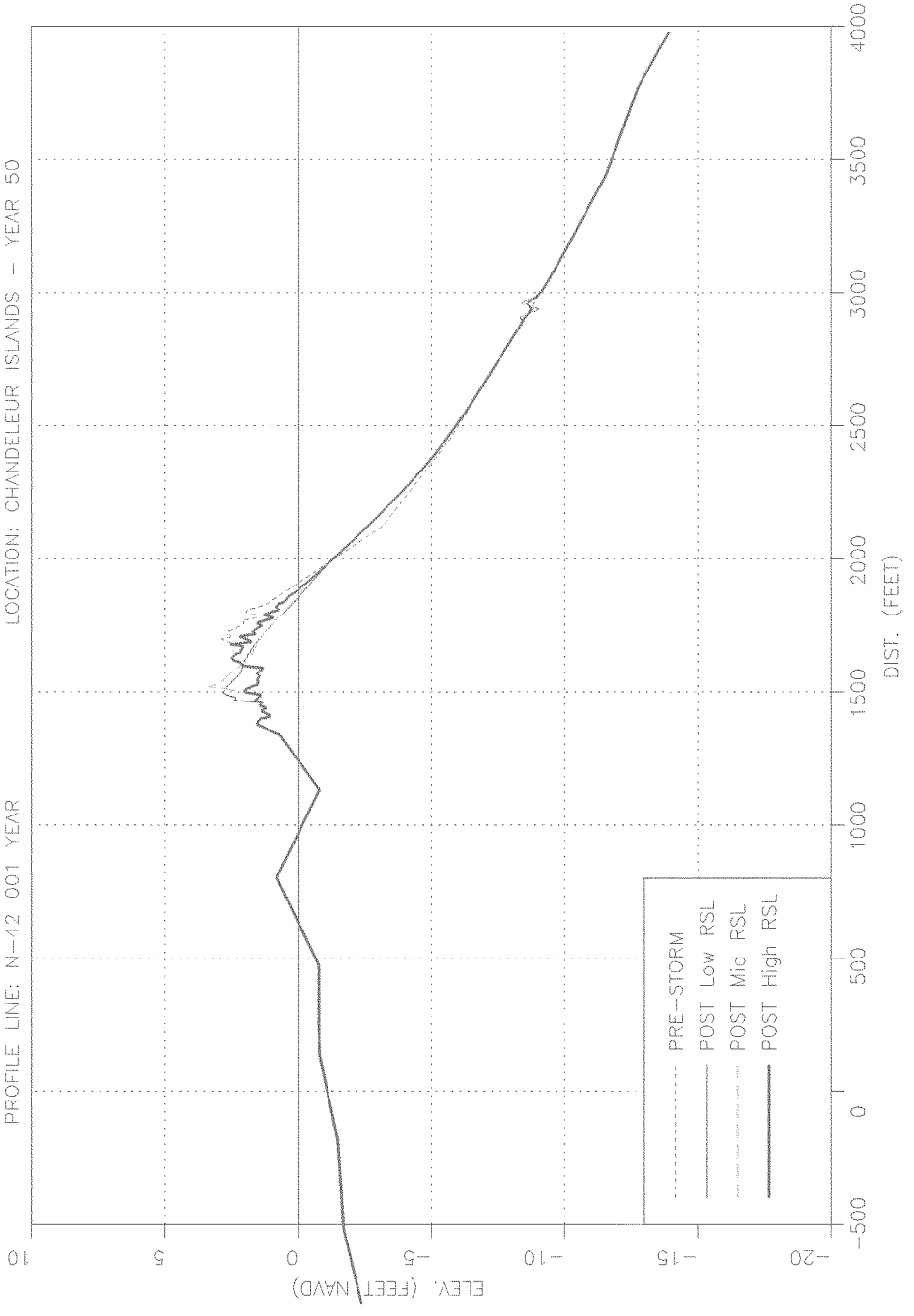

PROFILE LINE: N-41 005 YEAR
LOCATION: CHANDELEUR ISLANDS -- YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
POST Mid RSL
POST High RSL
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

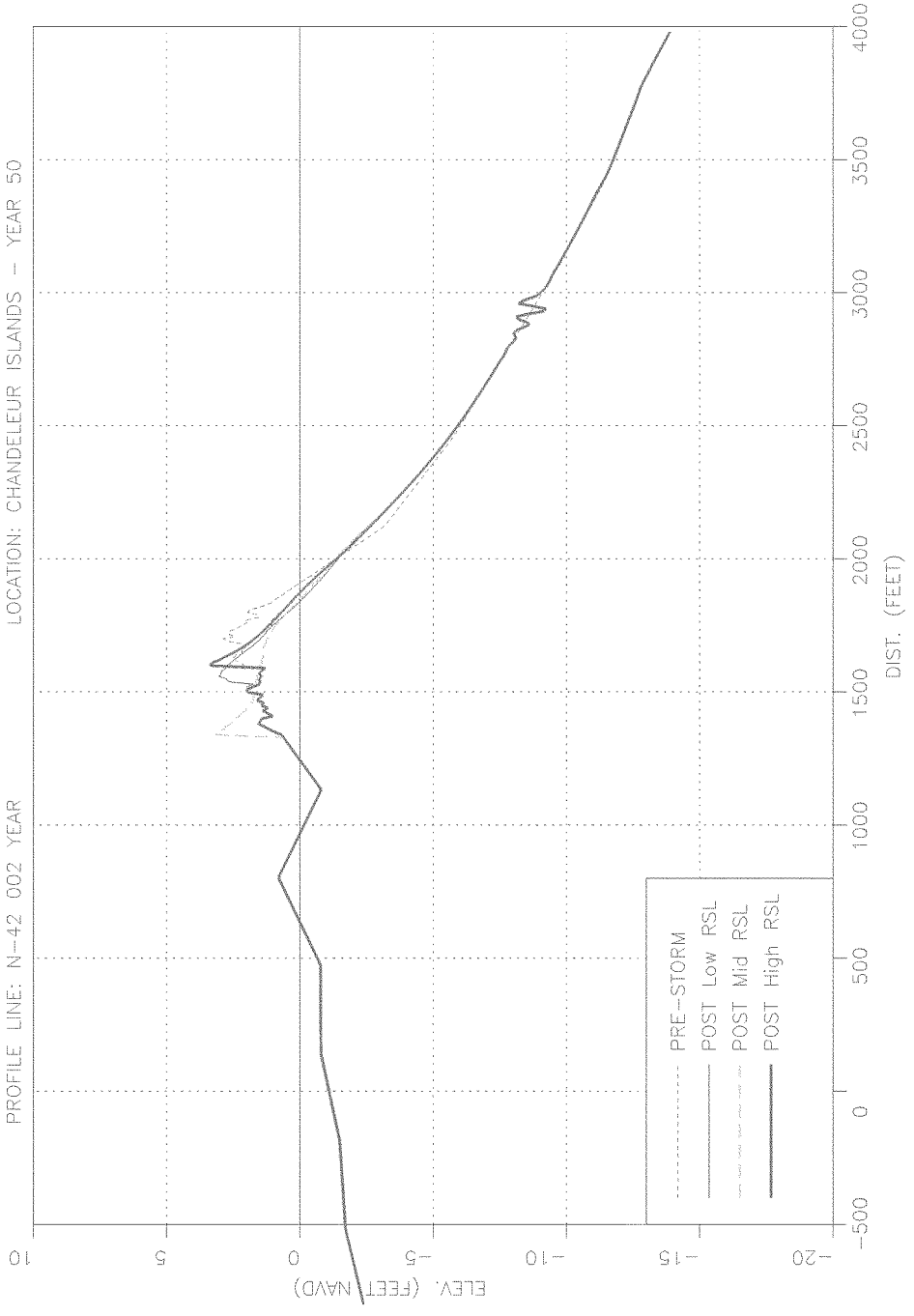

PROFILE LINE: N-41 010 YEAR
LOCATION: CHANDELEUR ISLANDS -- YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
POST Mid RSL
POST High RSL
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

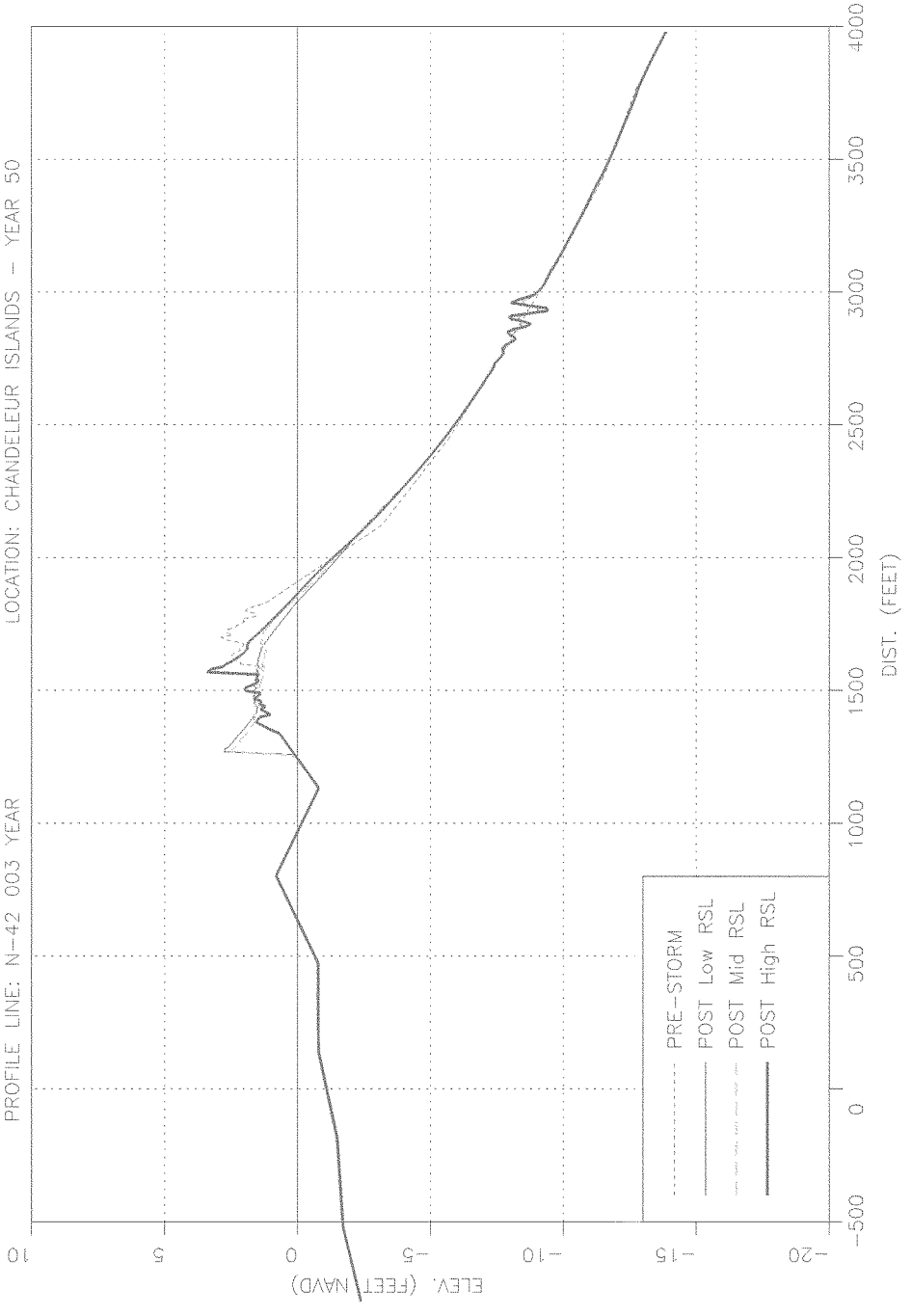

PROFILE LINE: N-41 020 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
POST Mid RSL
POST High RSL
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

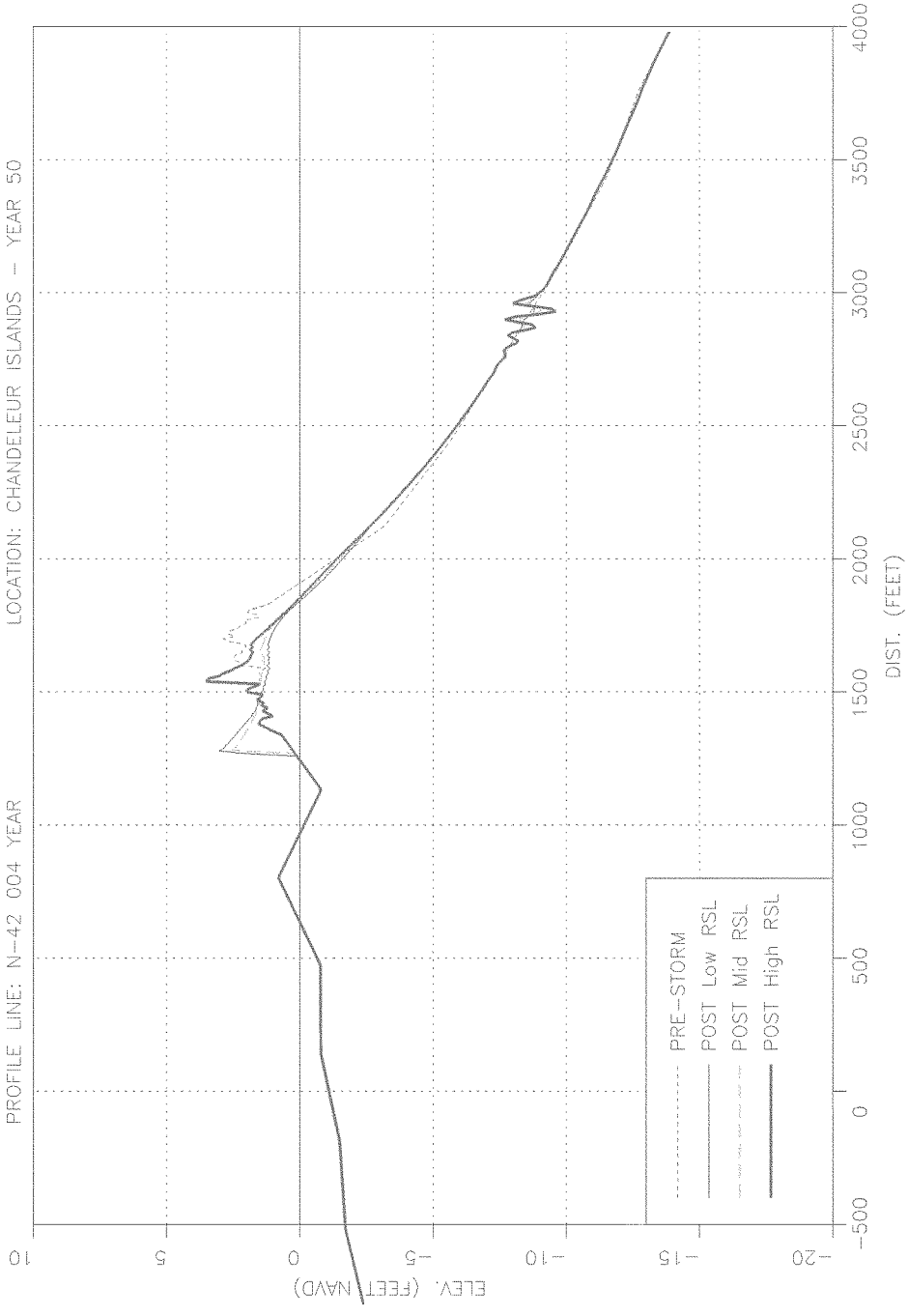

PROFILE LINE: N-41 050 YEAR
LOCATION: CHANDELEUR ISLANDS -- YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000
PRE-STORM
POST Low RSL
POST Mid RSL
POST High RSL

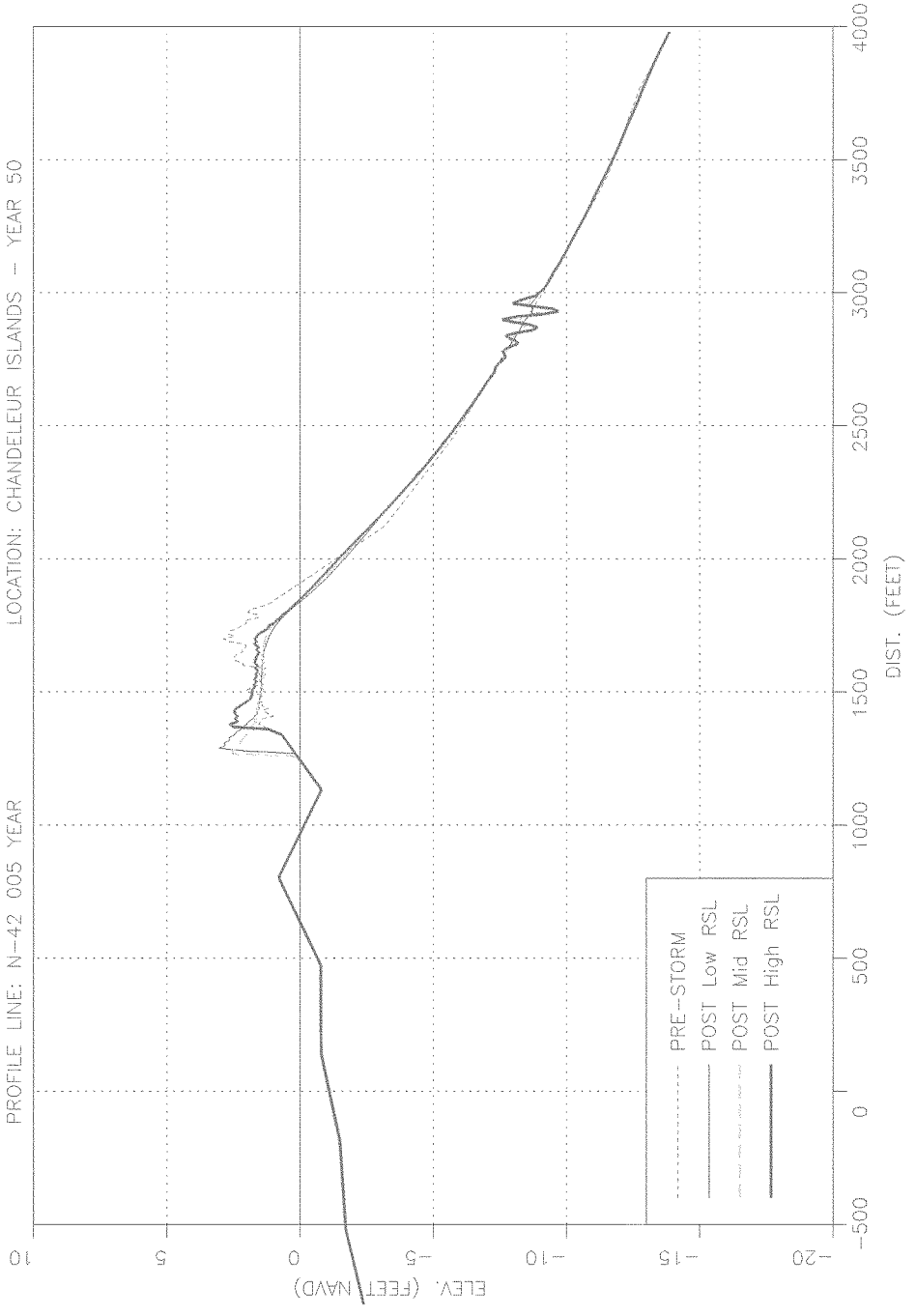

PROFILE LINE: N-41 100 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
POST Mid RSL
POST High RSL
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

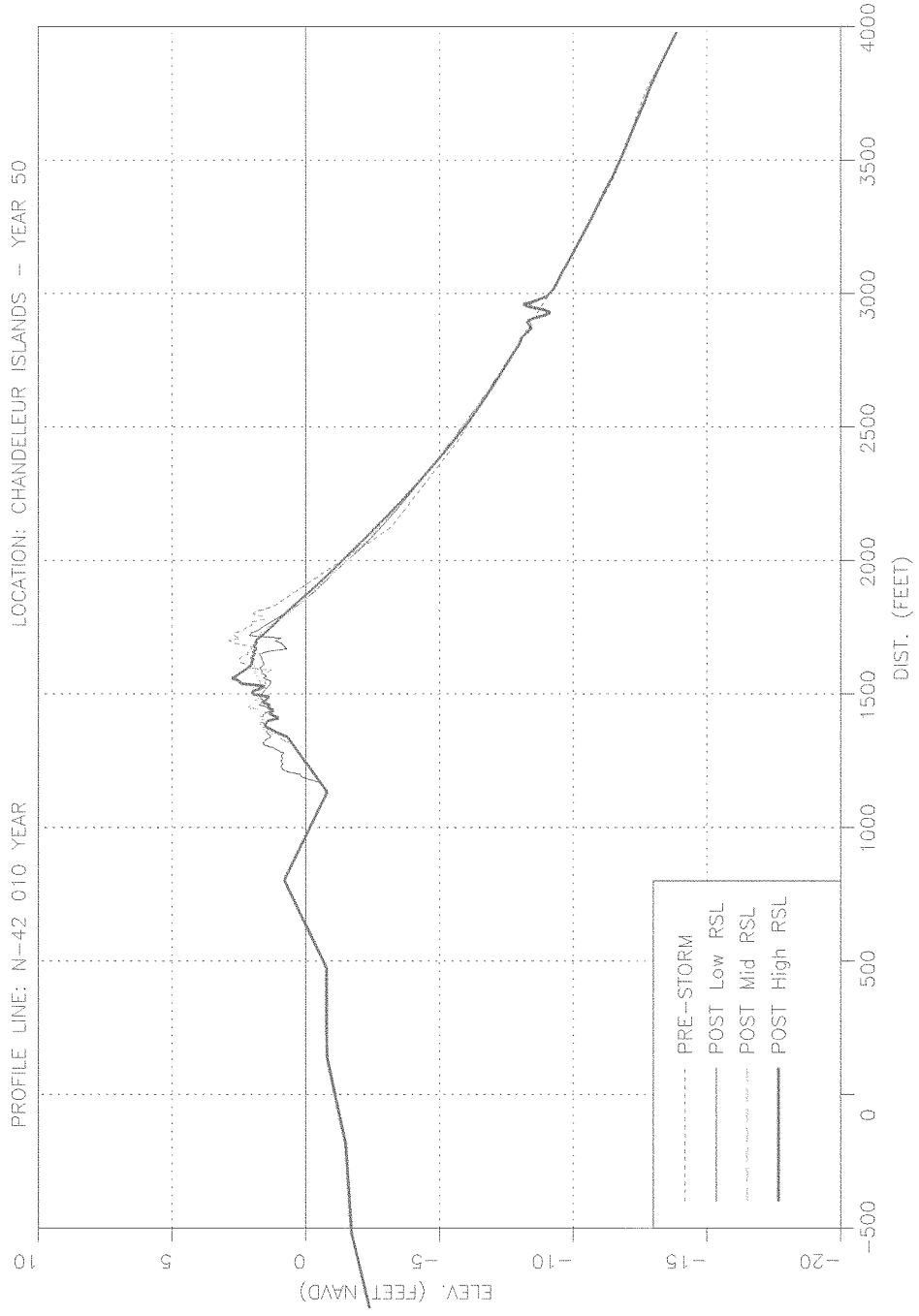

PROFILE LINE: N-42 001 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000
PRE-STORM
POST Low RSL
POST Mid RSL
POST High RSL

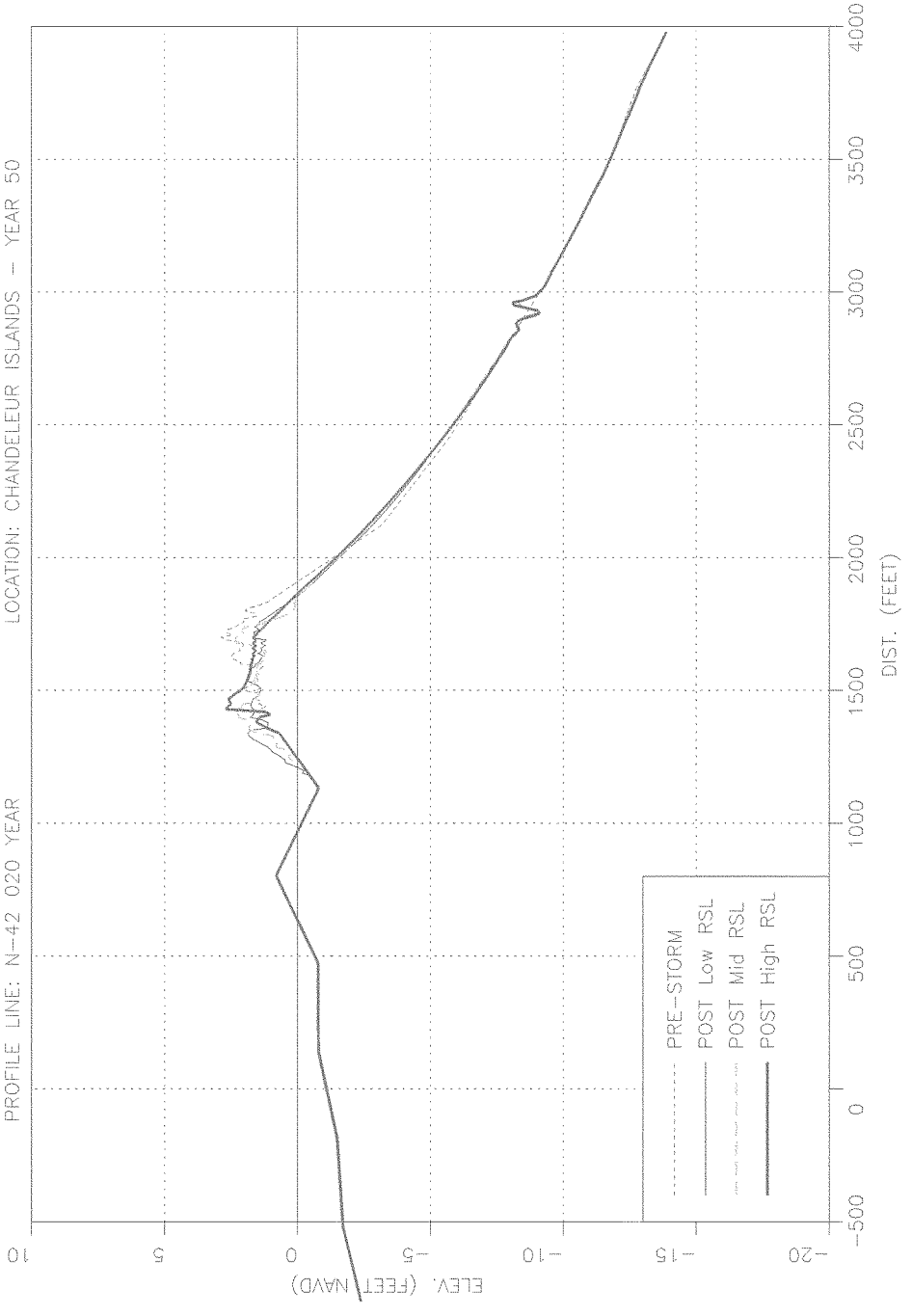

PROFILE LINE: N-42 002 YEAR
LOCATION: CHANDELEUR ISLANDS -- YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
POST Mid RSL
POST High RSL
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

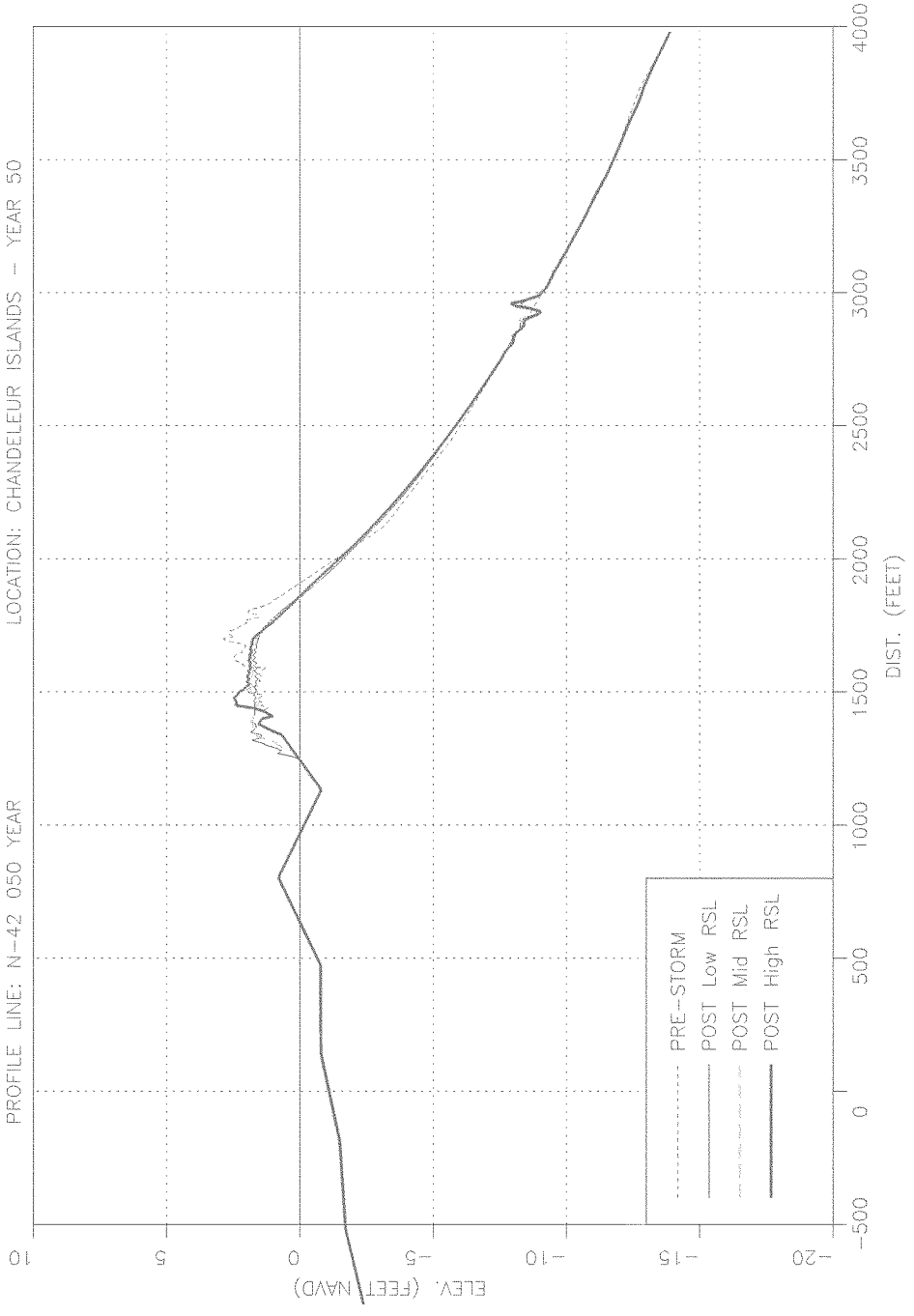

PROFILE LINE: N-42 003 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000
PRE-STORM
POST Low RSL
POST Mid RSL
POST High RSL

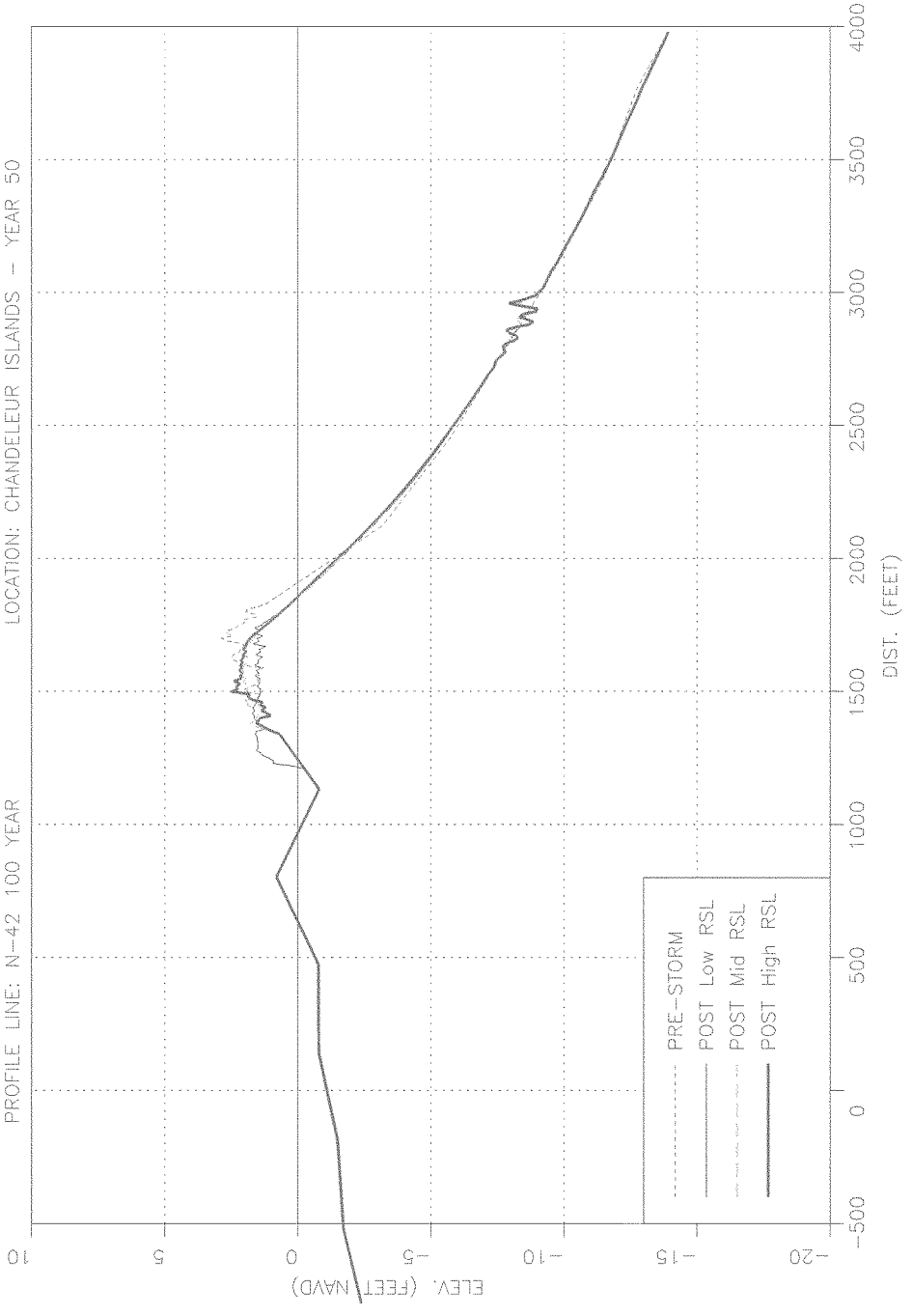

PROFILE LINE: N-42 004 YEAR
LOCATION: CHANDELEUR ISLANDS -- YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
POST Mid RSL
POST High RSL
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

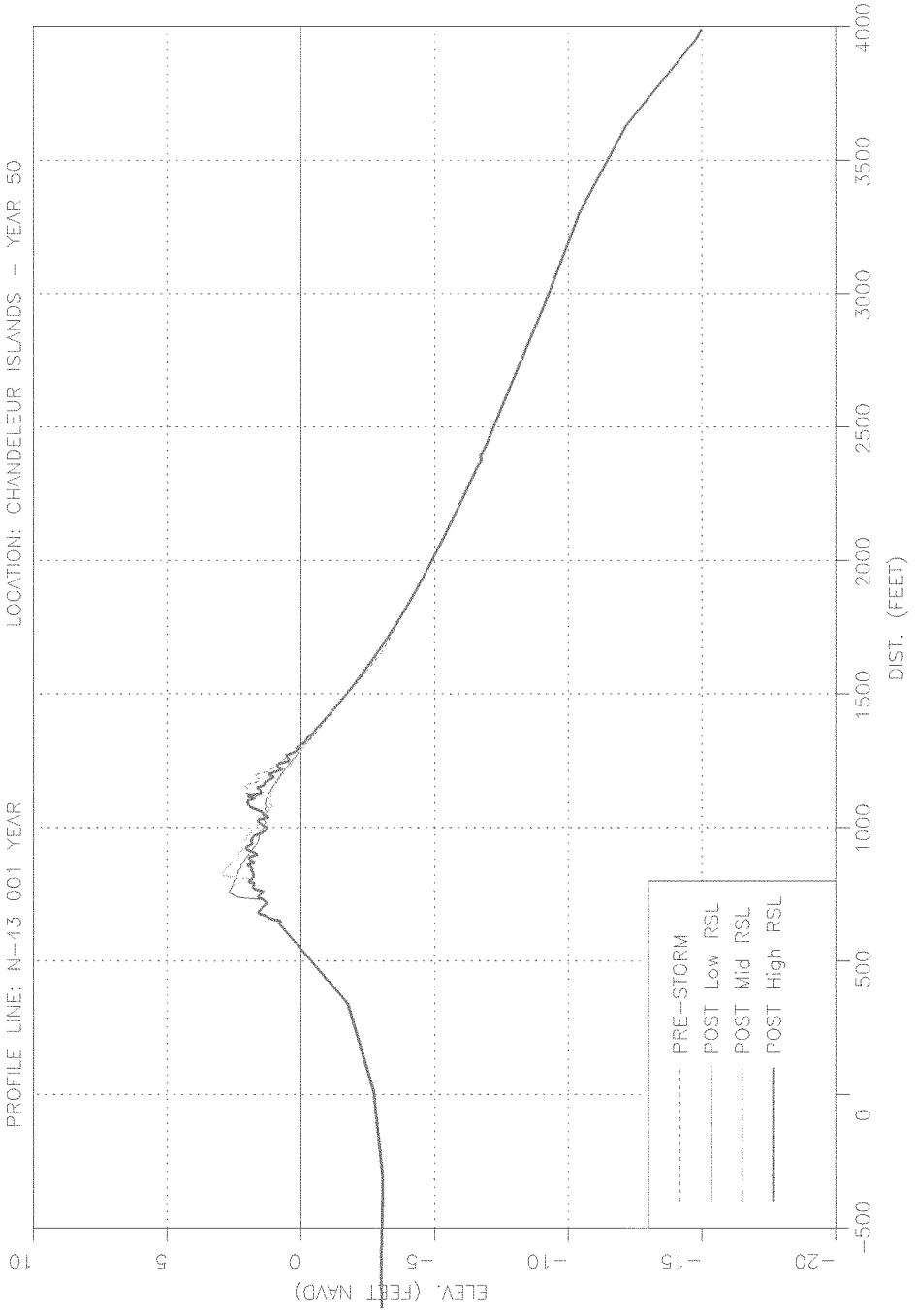

PROFILE LINE: N-42 005 YEAR
LOCATION: CHANDELEUR ISLANDS -- YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000
PRE-STORM
POST Low RSL
POST Mid RSL
POST High RSL

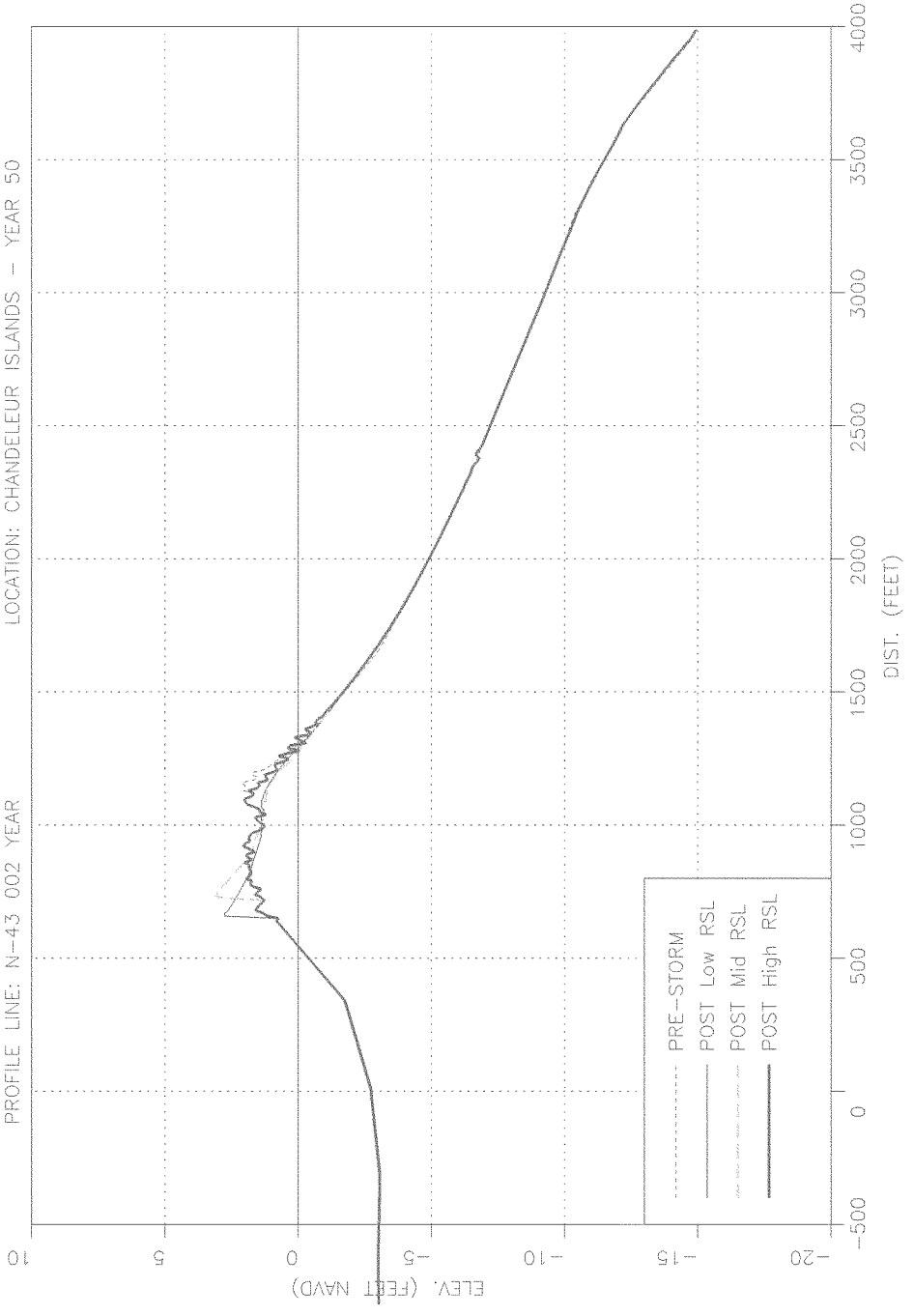

PROFILE LINE: N-42 010 YEAR
LOCATION: CHANDELEUR ISLANDS -- YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
POST Mid RSL
POST High RSL
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

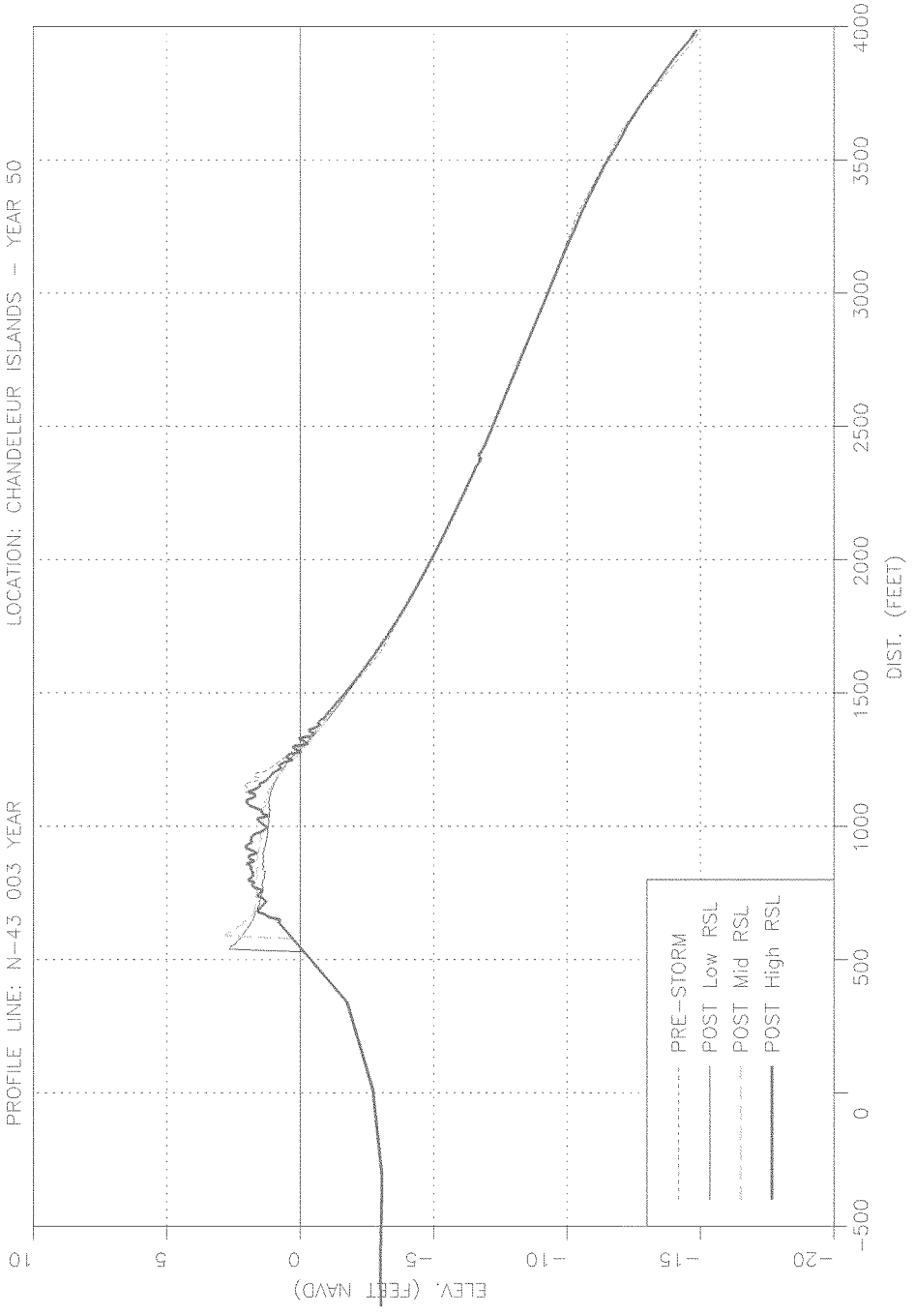

PROFILE LINE: N-42 020 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000
PRE-STORM
POST Low RSL
POST Mid RSL
POST High RSL

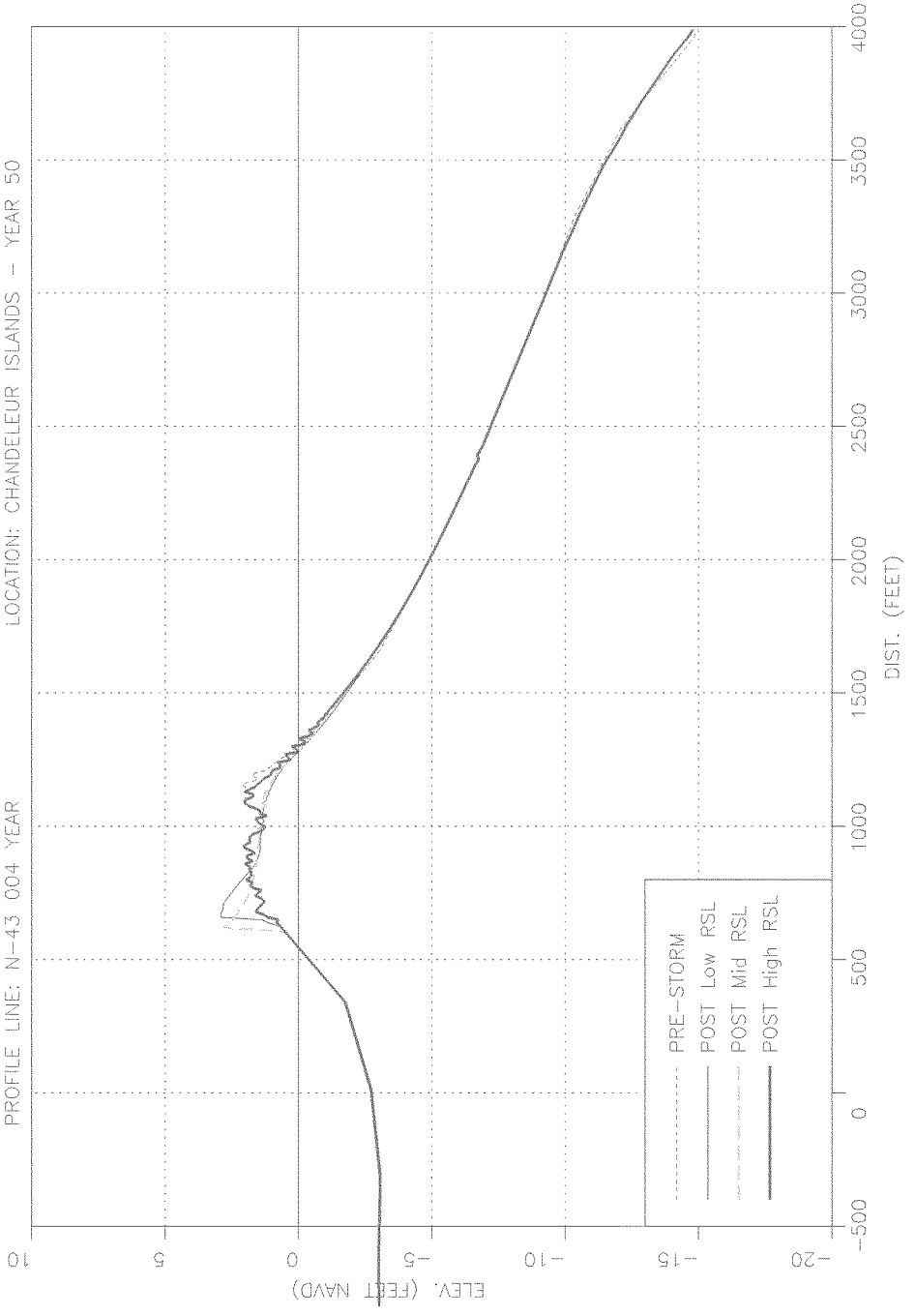

PROFILE LINE: N-42 050 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
POST Mid RSL
POST High RSL
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

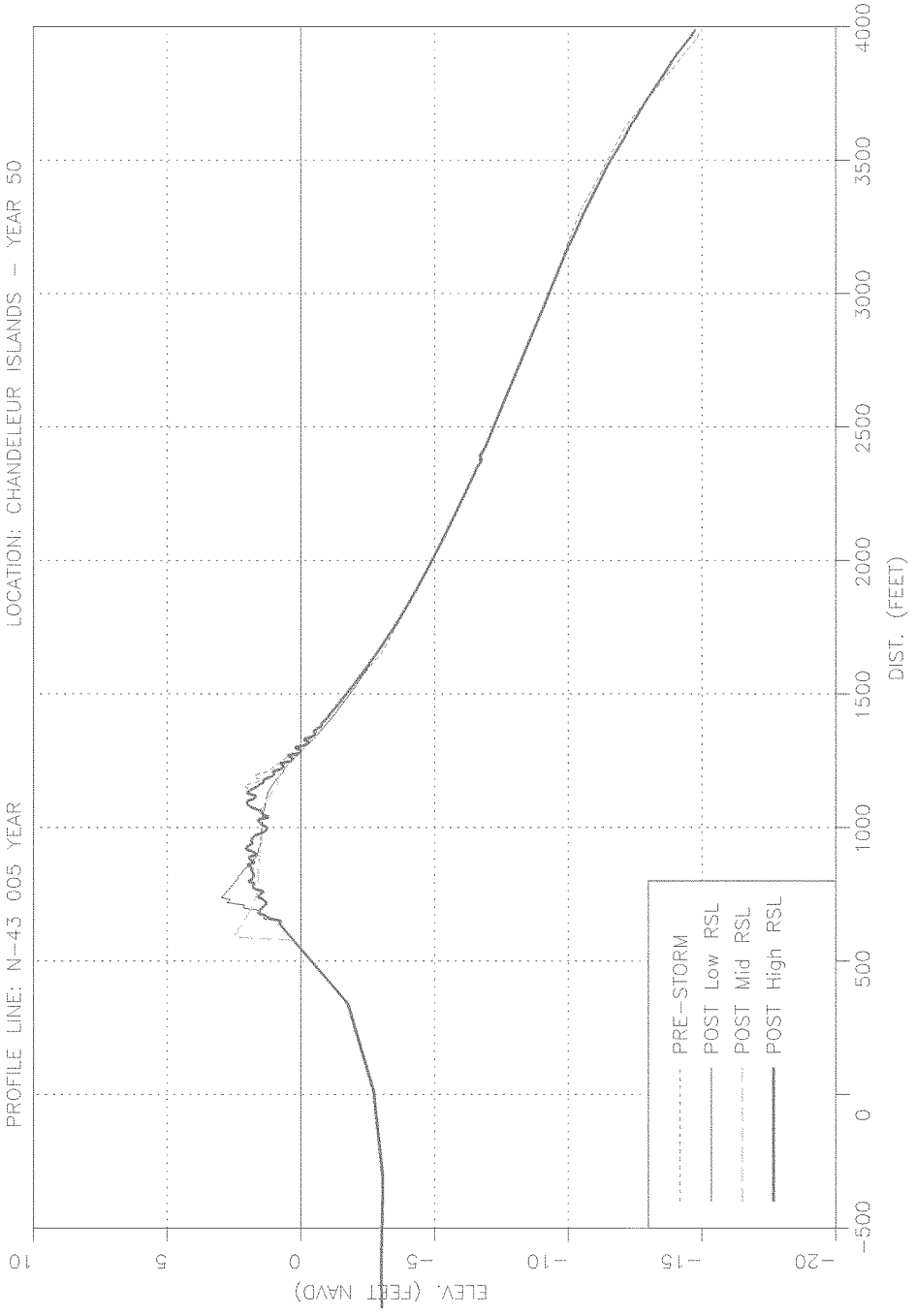

PROFILE LINE: N-42 100 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000
PRE-STORM
POST Low RSL
POST Mid RSL
POST High RSL

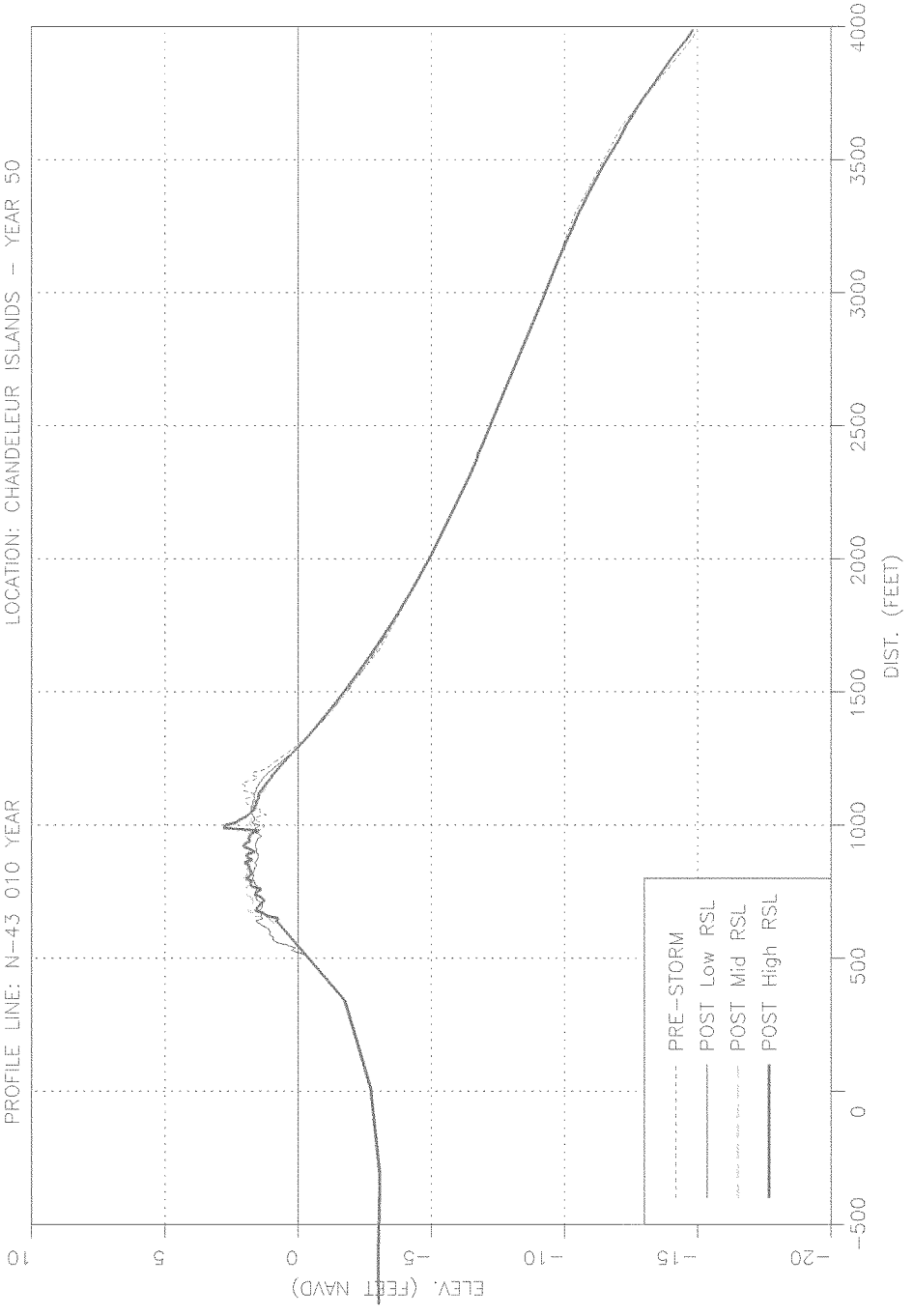

PROFILE LINE: N-43 001 YEAR
LOCATION: CHANDELEUR ISLANDS -- YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000
PRE-STORM
POST Low RSL
POST Mid RSL
POST High RSL

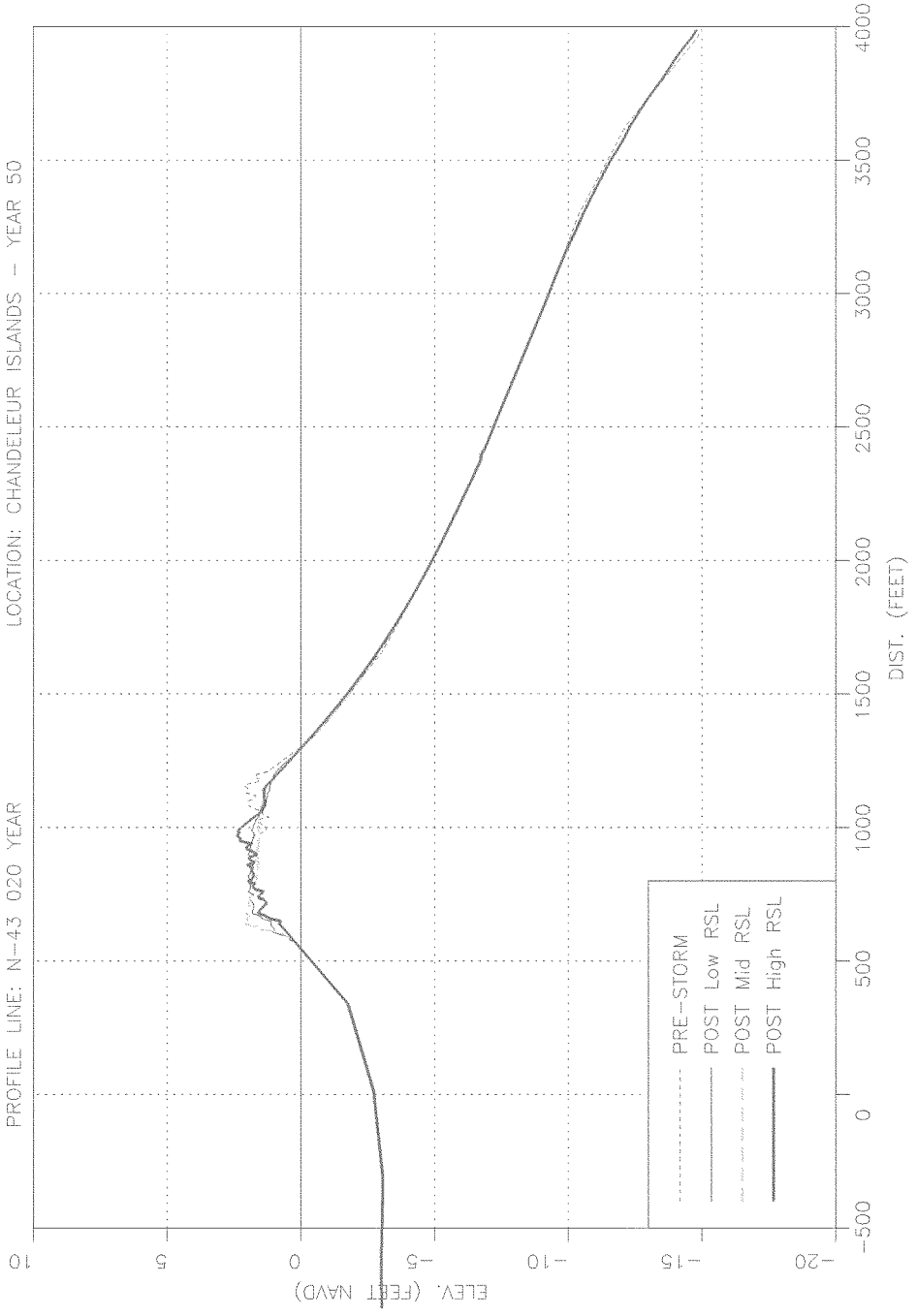

PROFILE LINE: N-43 002 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000
PRE-STORM
POST Low RSL
POST Mid RSL
POST High RSL

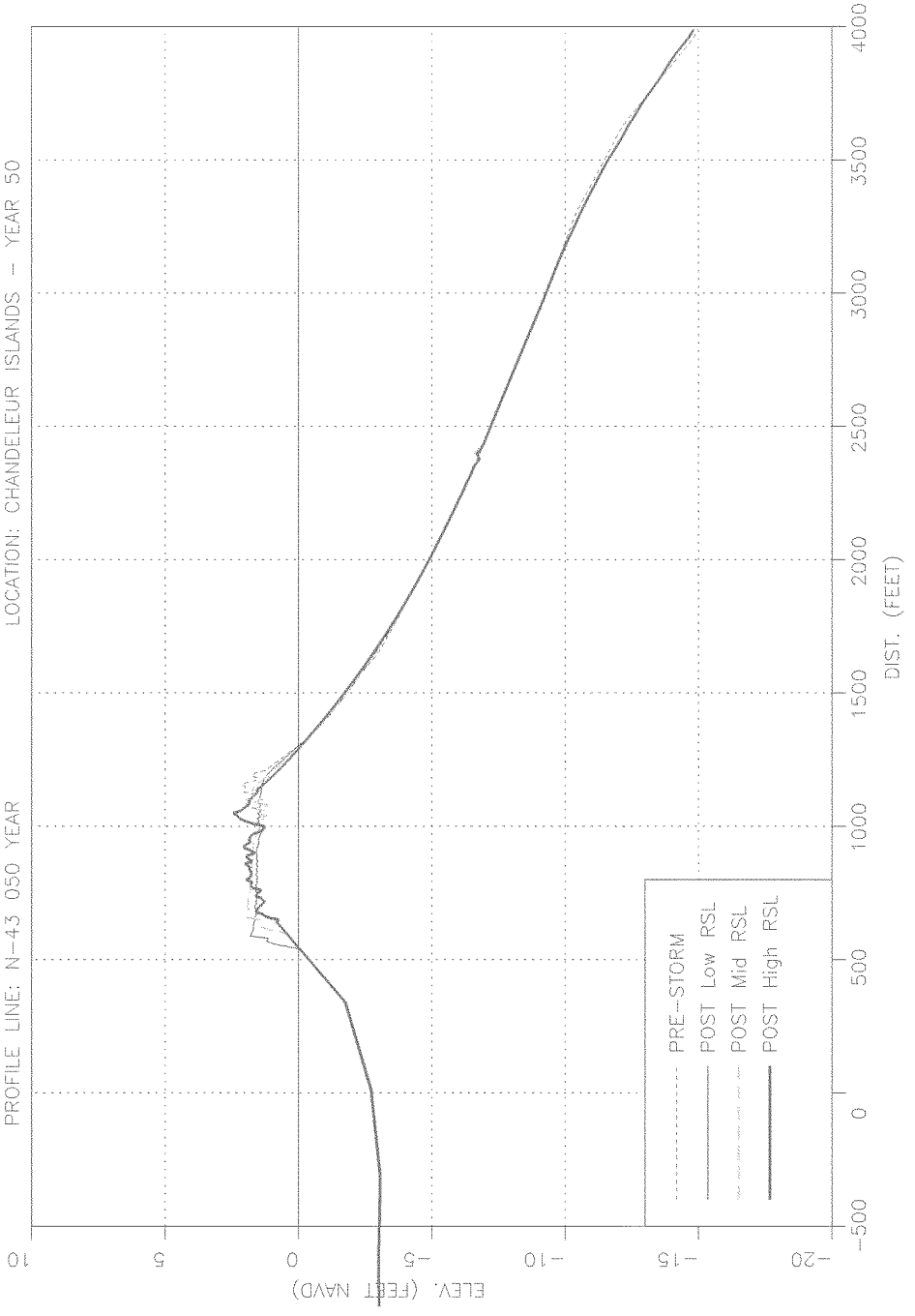

PROFILE LINE: N-43 003 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
POST Mid RSL
POST High RSL
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000


PROFILE LINE: N-43 004 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
POST Mid RSL
POST High RSL
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

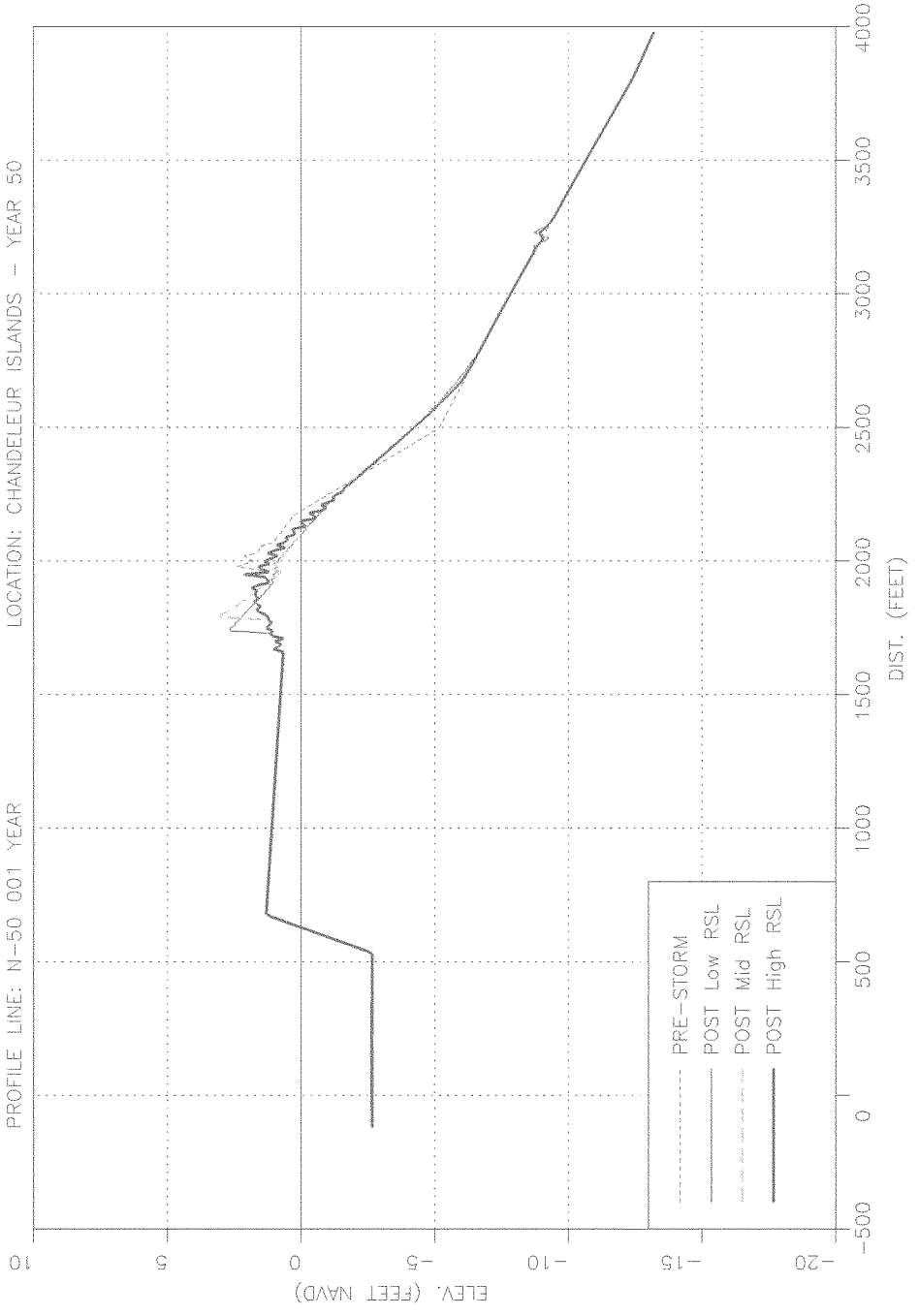

PROFILE LINE: N-43 005 YEAR
LOCATION: CHANDELEUR ISLANDS -- YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
POST Mid RSL
POST High RSL
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

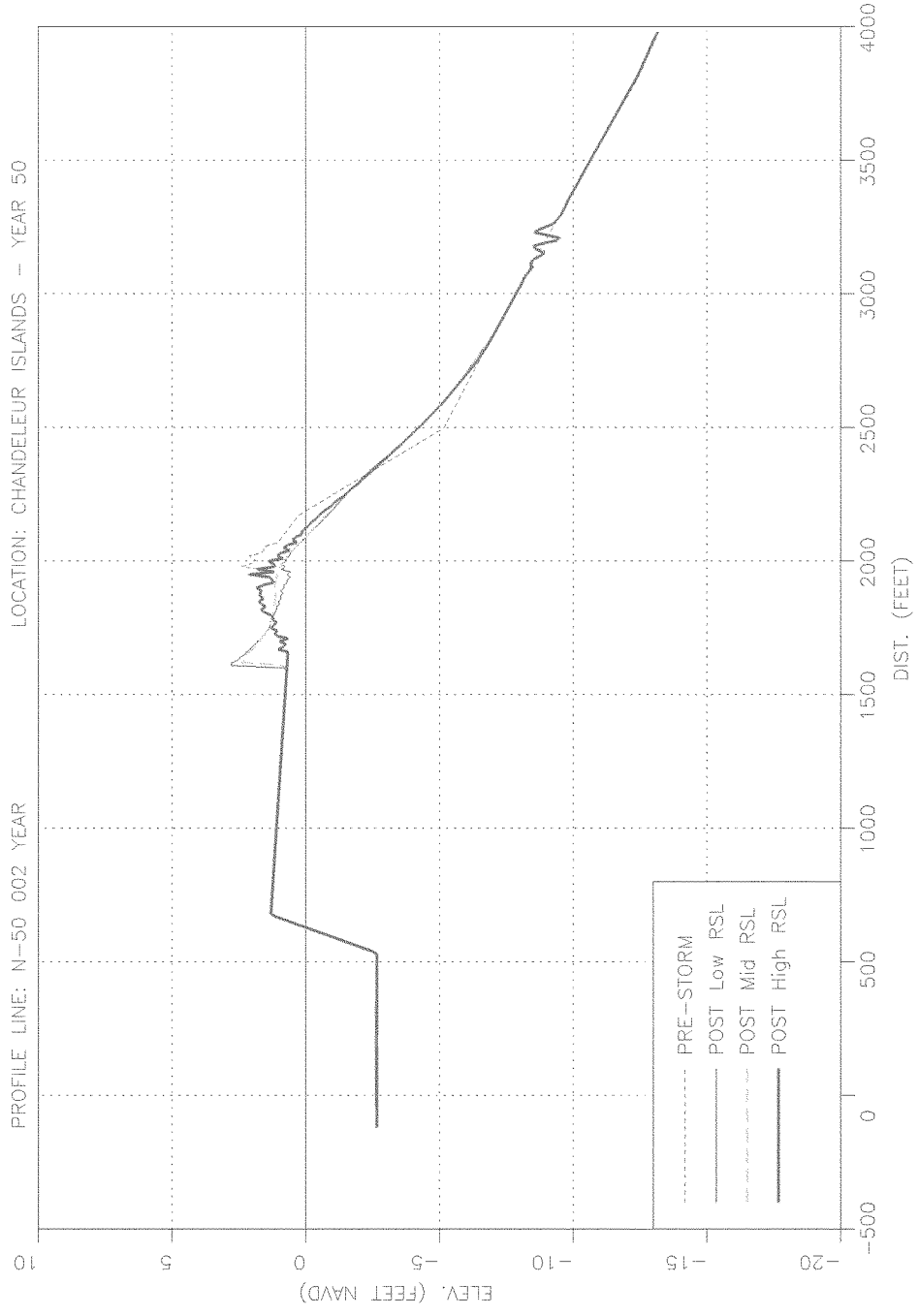

PROFILE LINE: N-43 010 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
POST Mid RSL
POST High RSL
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

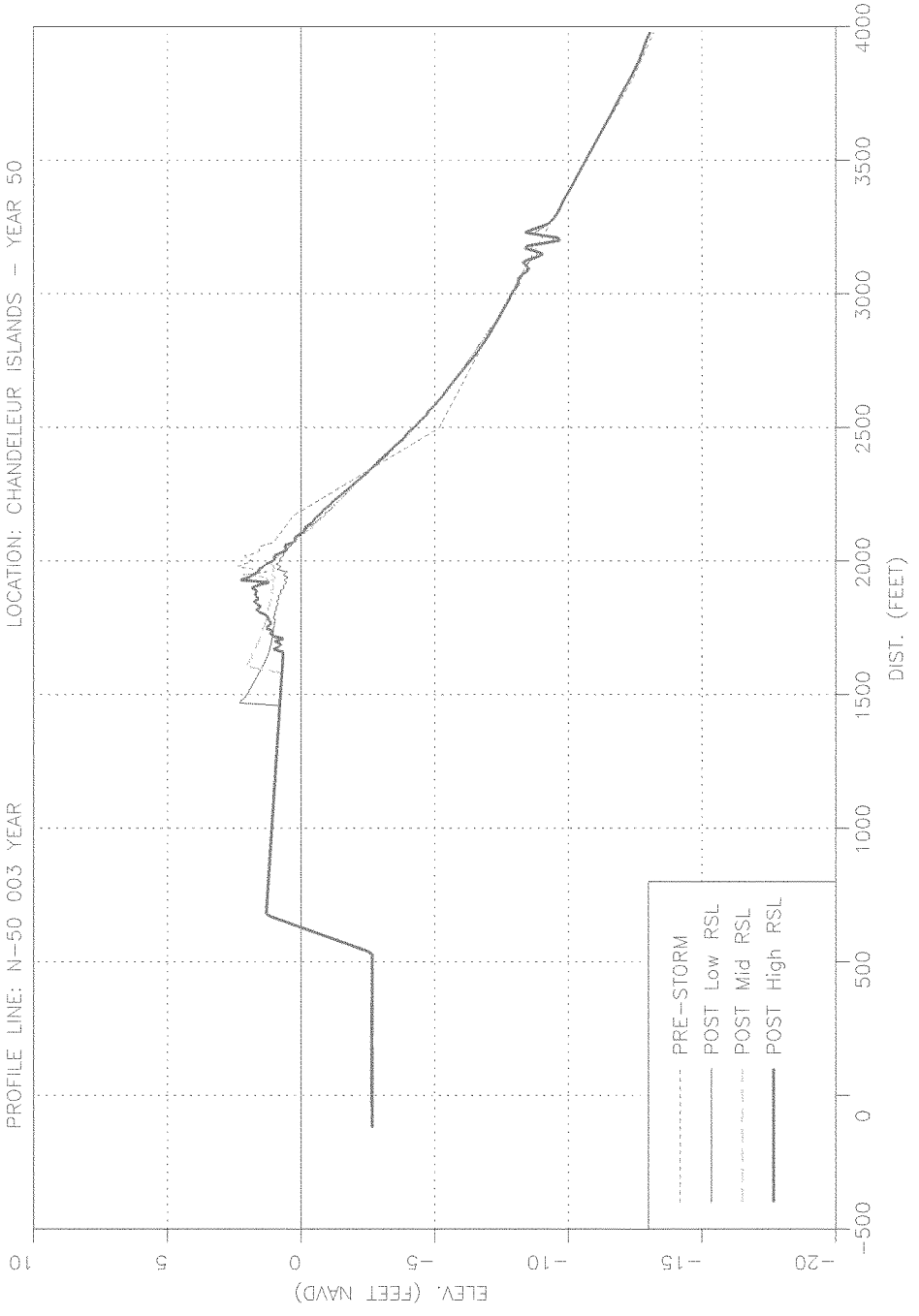

PROFILE LINE: N-43 020 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
POST Mid RSL
POST High RSL
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

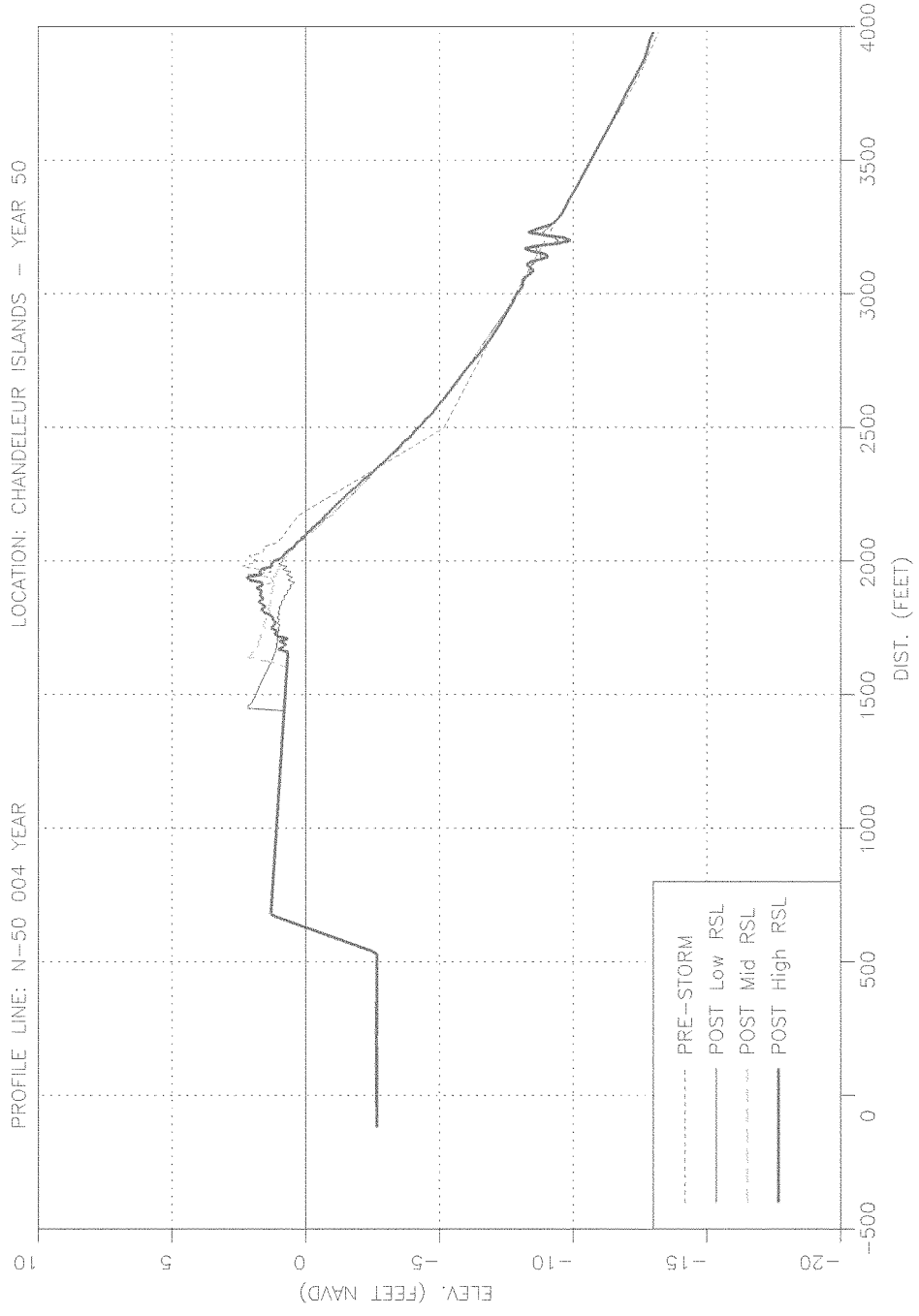

PROFILE LINE: N-43 050 YEAR
LOCATION: CHANDELEUR ISLANDS -- YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000
PRE--STORM
POST Low RSL
POST Mid RSL
POST High RSL

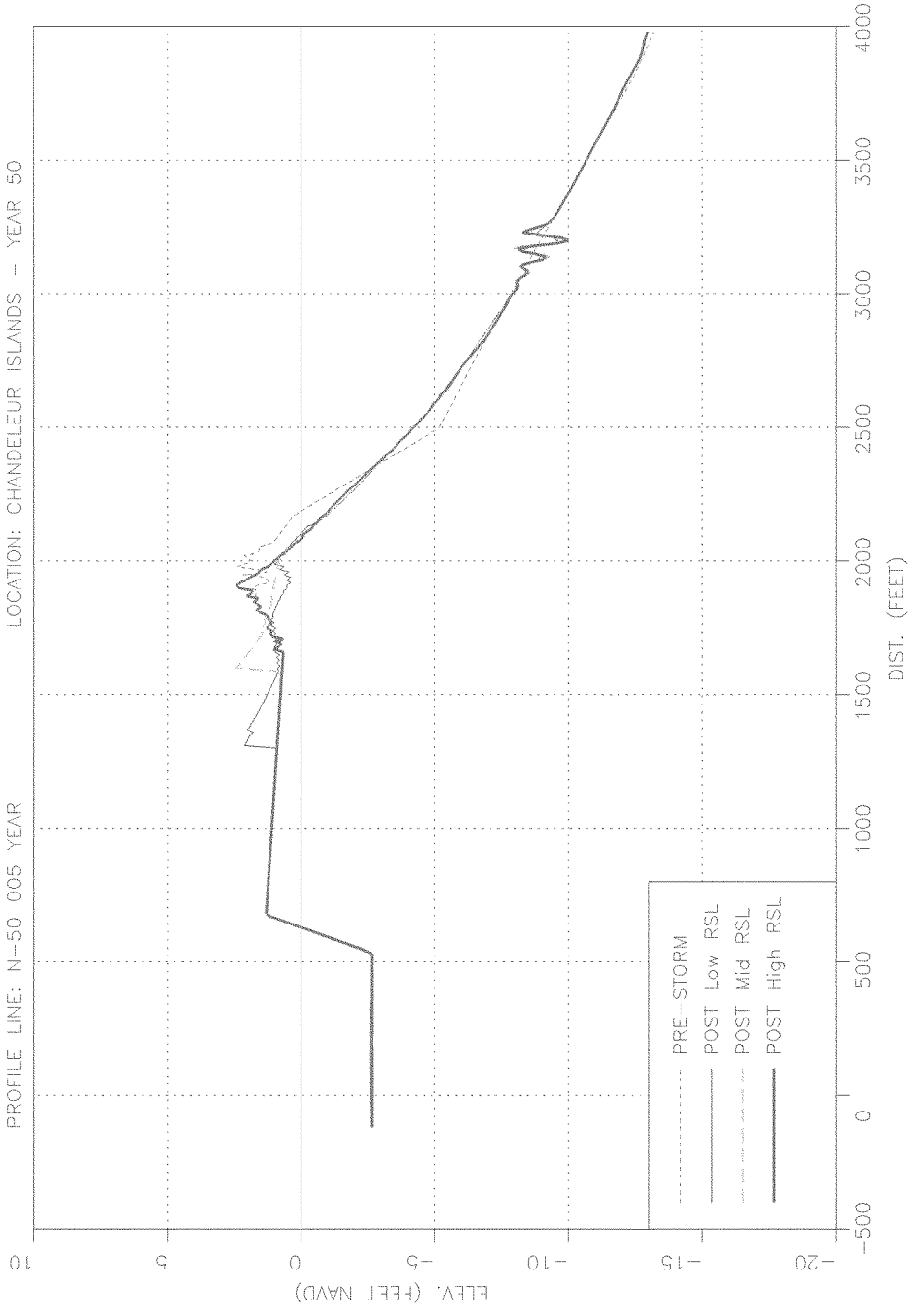

PROFILE LINE: N-43 100 YEAR
LOCATION: CHANDELEUR ISLANDS -- YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
POST Mid RSL
POST High RSL
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

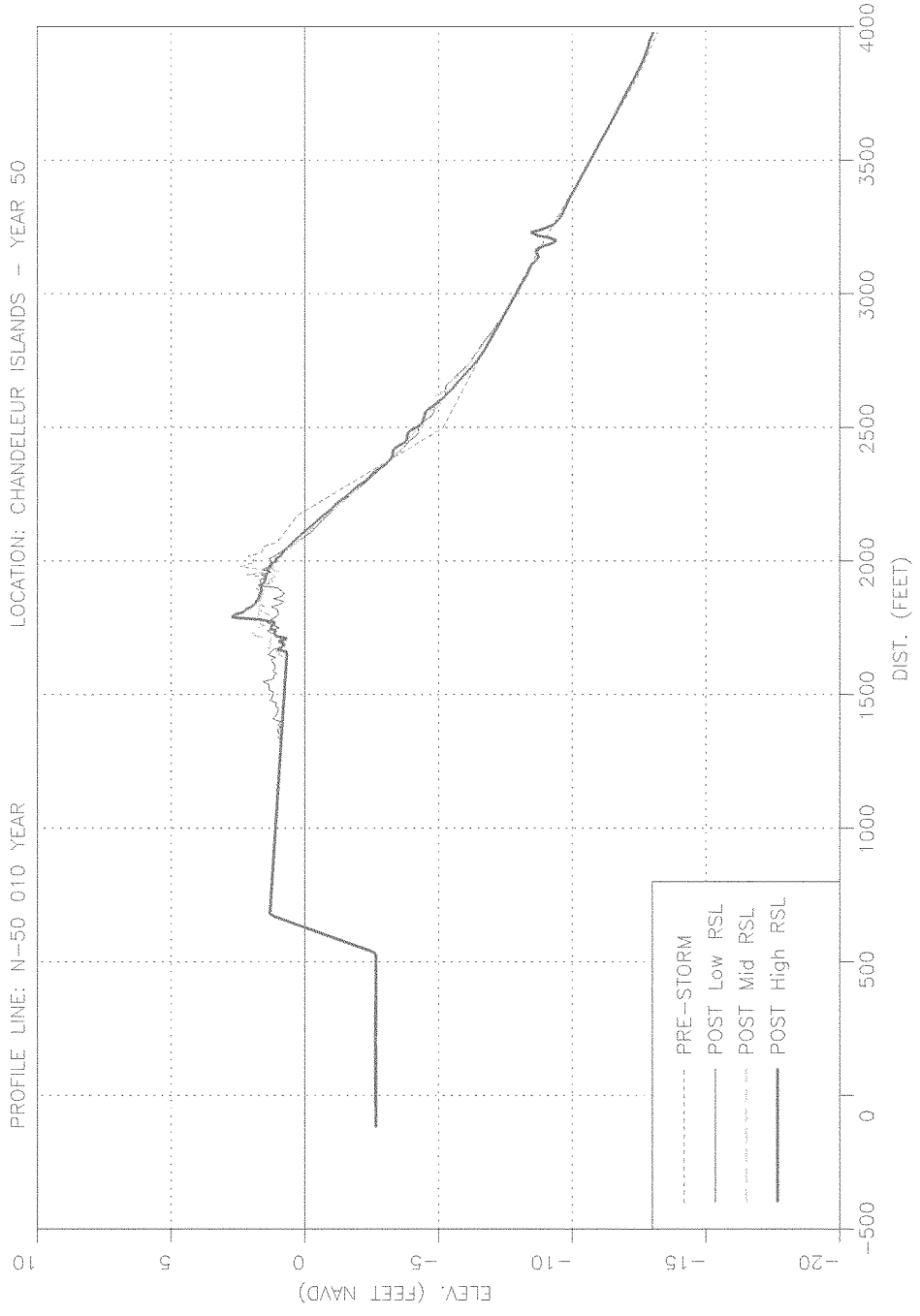

PROFILE LINE: N-50 001 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 50
PRE-STORM
POST Low RSL
POST Mid RSL
POST High RSL
ELEV. (FEET NAVD)
DIST. (FEET)
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

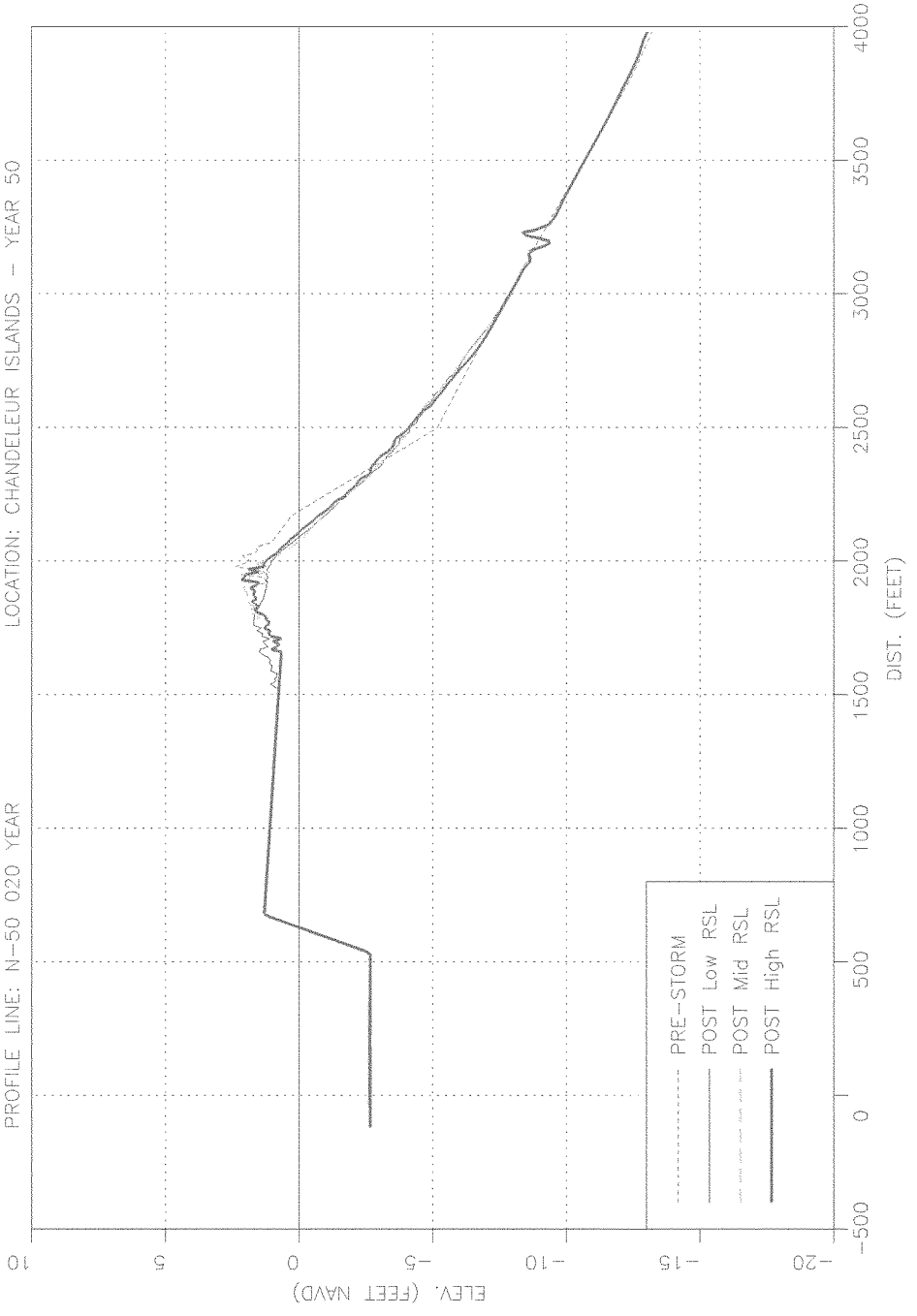

PROFILE LINE: N-50 002 YEAR
LOCATION: CHANDELEUR ISLANDS -- YEAR 50
PRE-STORM
POST Low RSL
POST Mid RSL
POST High RSL
ELEV. (FEET NAVD)
DIST. (FEET)
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

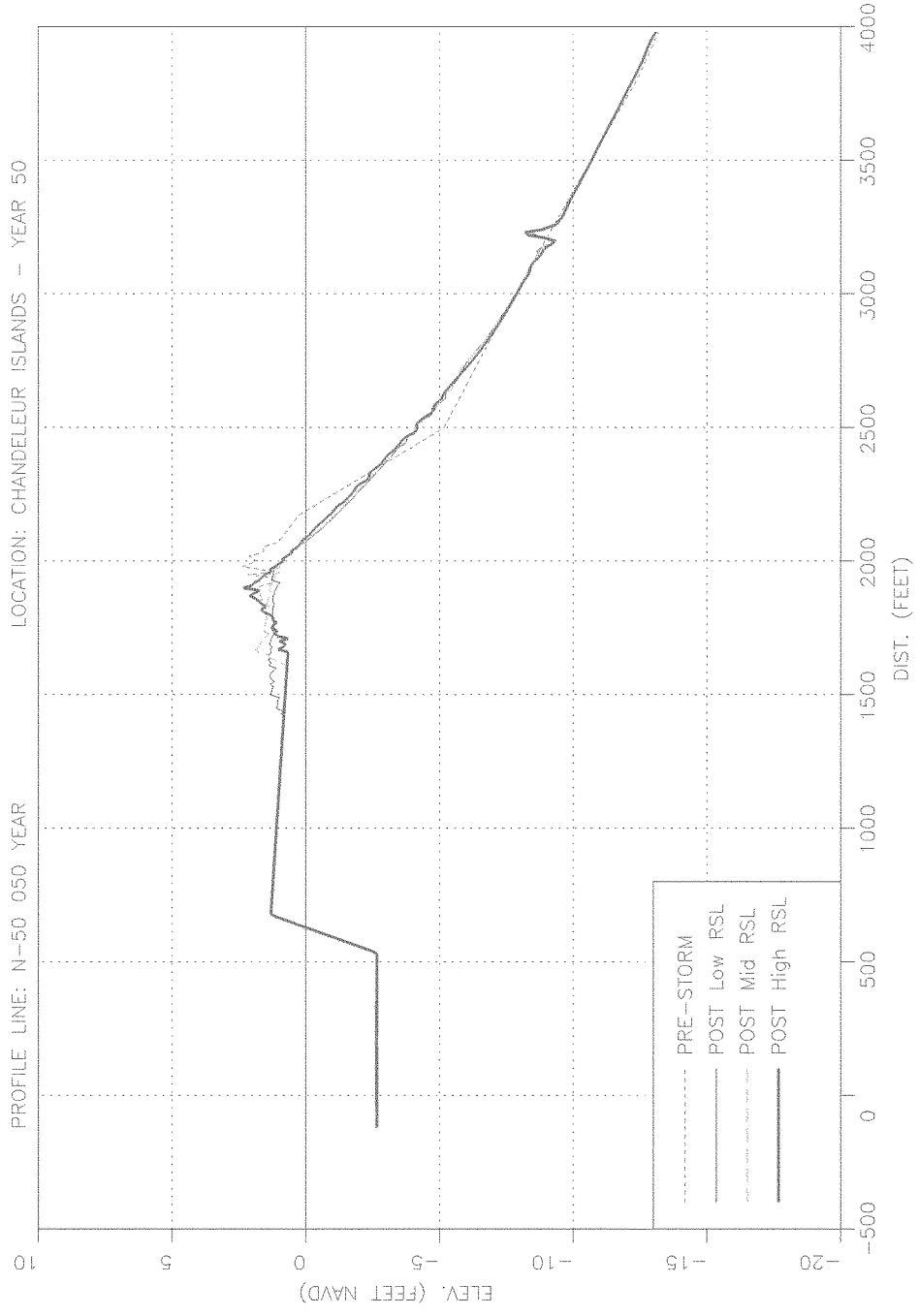

PROFILE LINE: N-50 003 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
POST Mid RSL
POST High RSL
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

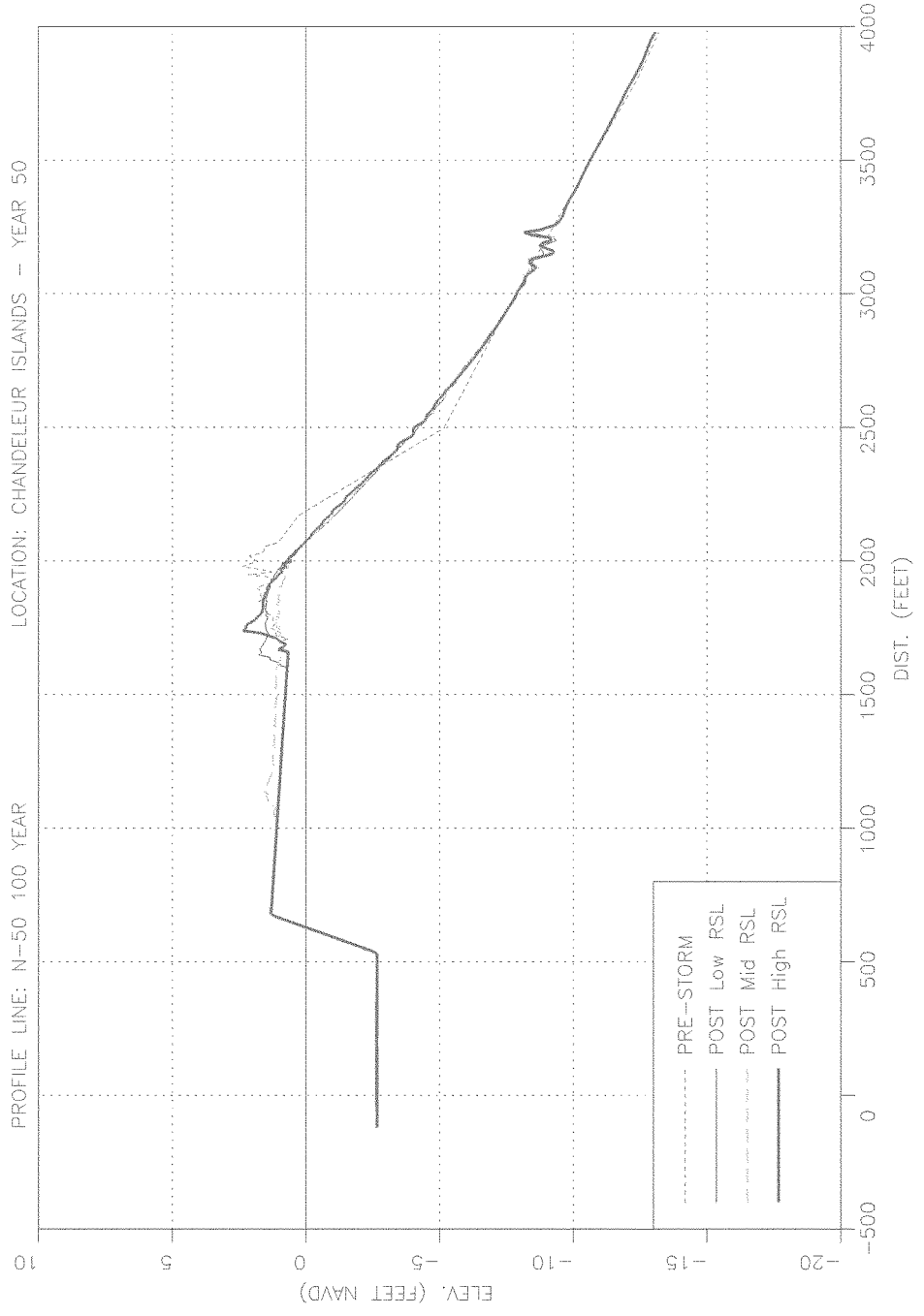

PROFILE LINE: N-50 004 YEAR
LOCATION: CHANDELEUR ISLANDS -- YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
POST Mid RSL
POST High RSL
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

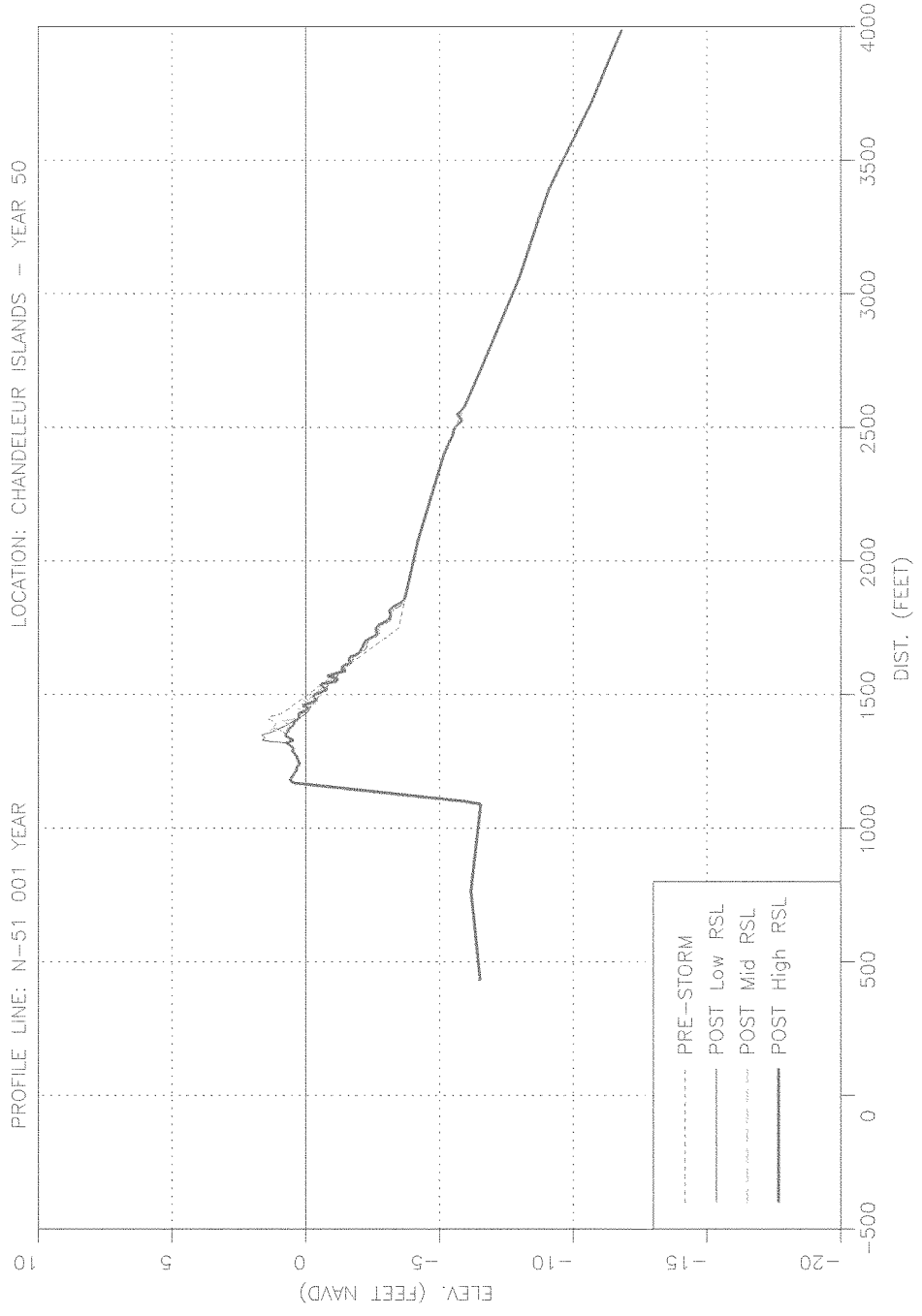

PROFILE LINE: N-50 005 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 50
PRE-STORM
POST Low RSL
POST Mid RSL
POST High RSL
ELEV. (FEET NAVD)
DIST. (FEET)
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

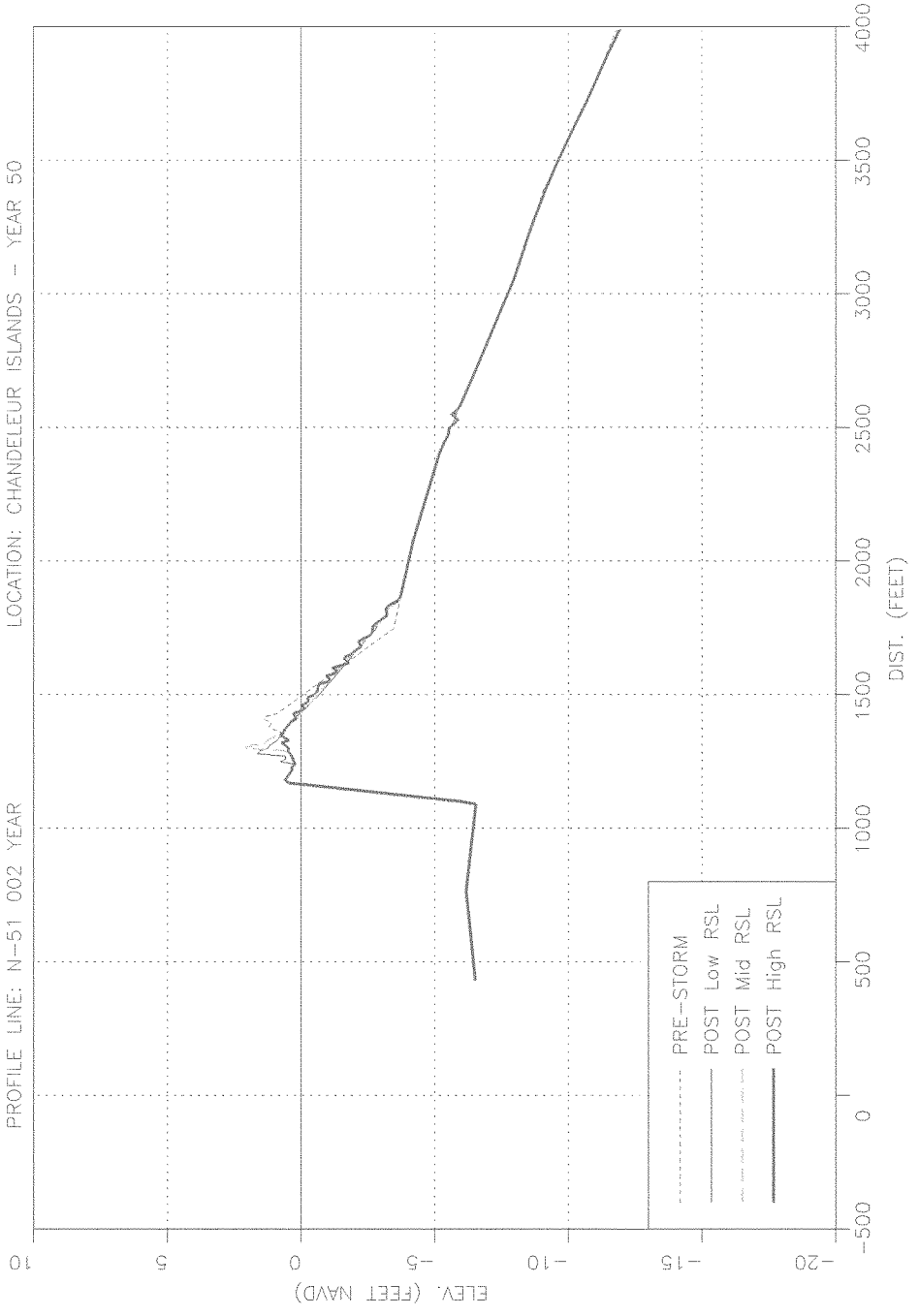

PROFILE LINE: N-50 010 YEAR
LOCATION: CHANDELEUR ISLANDS -- YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
POST Mid RSL
POST High RSL
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

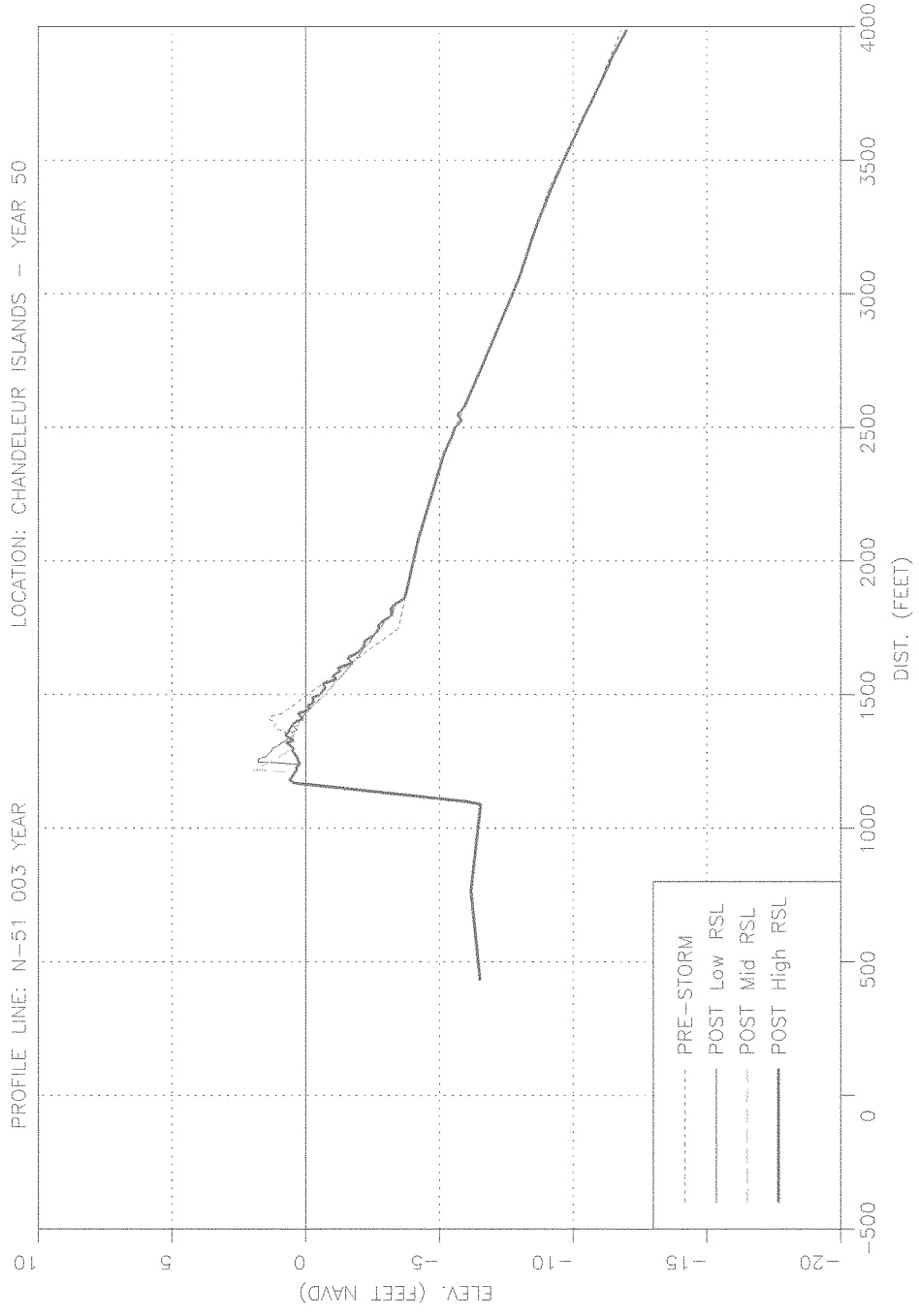

PROFILE LINE: N-50 020 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
POST Mid RSL
POST High RSL
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

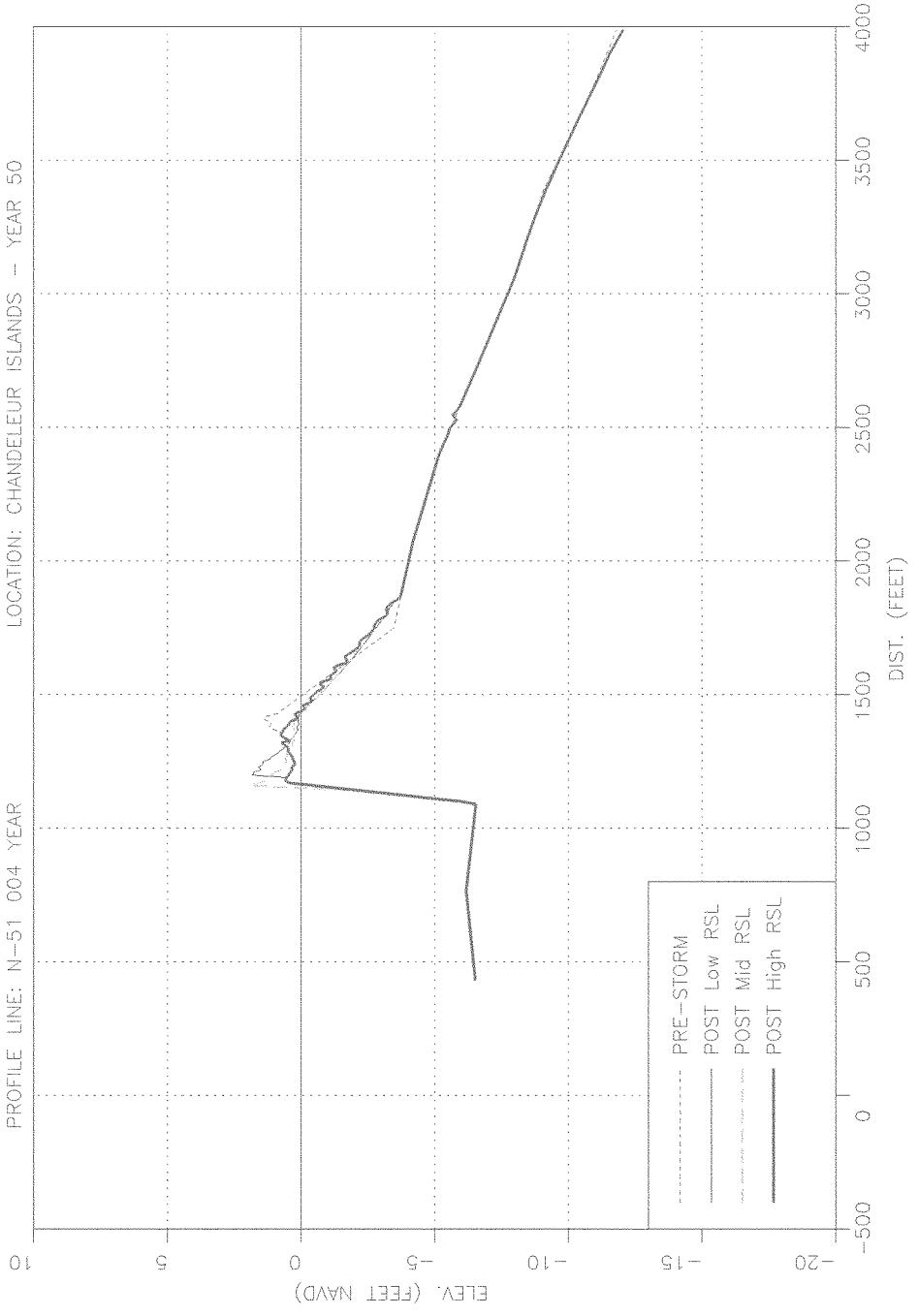

PROFILE LINE: N-50 050 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 50
PRE-STORM
POST Low RSL
POST Mid RSL
POST High RSL
ELEV. (FEET NAVD)
DIST. (FEET)
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

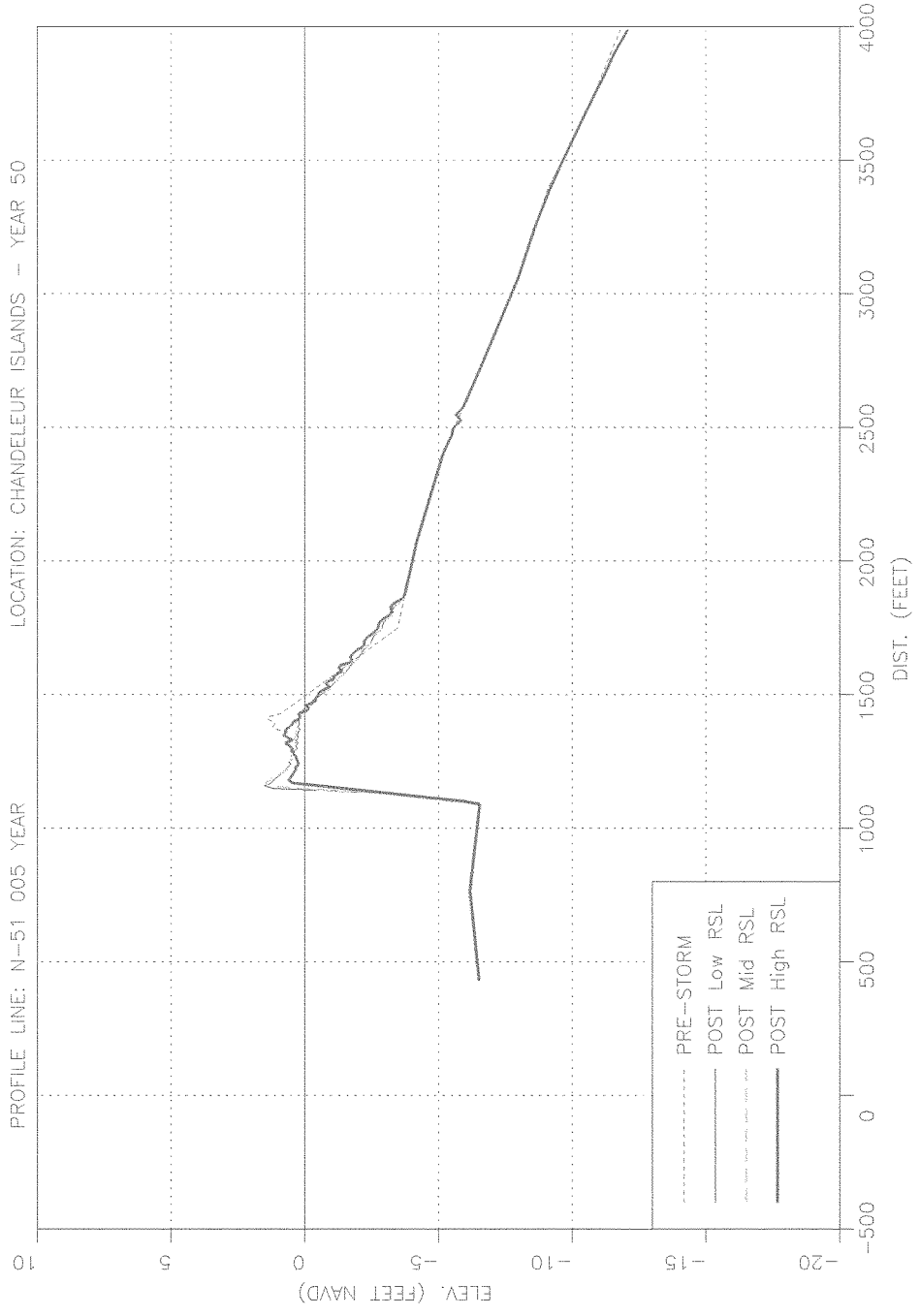

PROFILE LINE: N-50 100 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
POST Mid RSL
POST High RSL
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

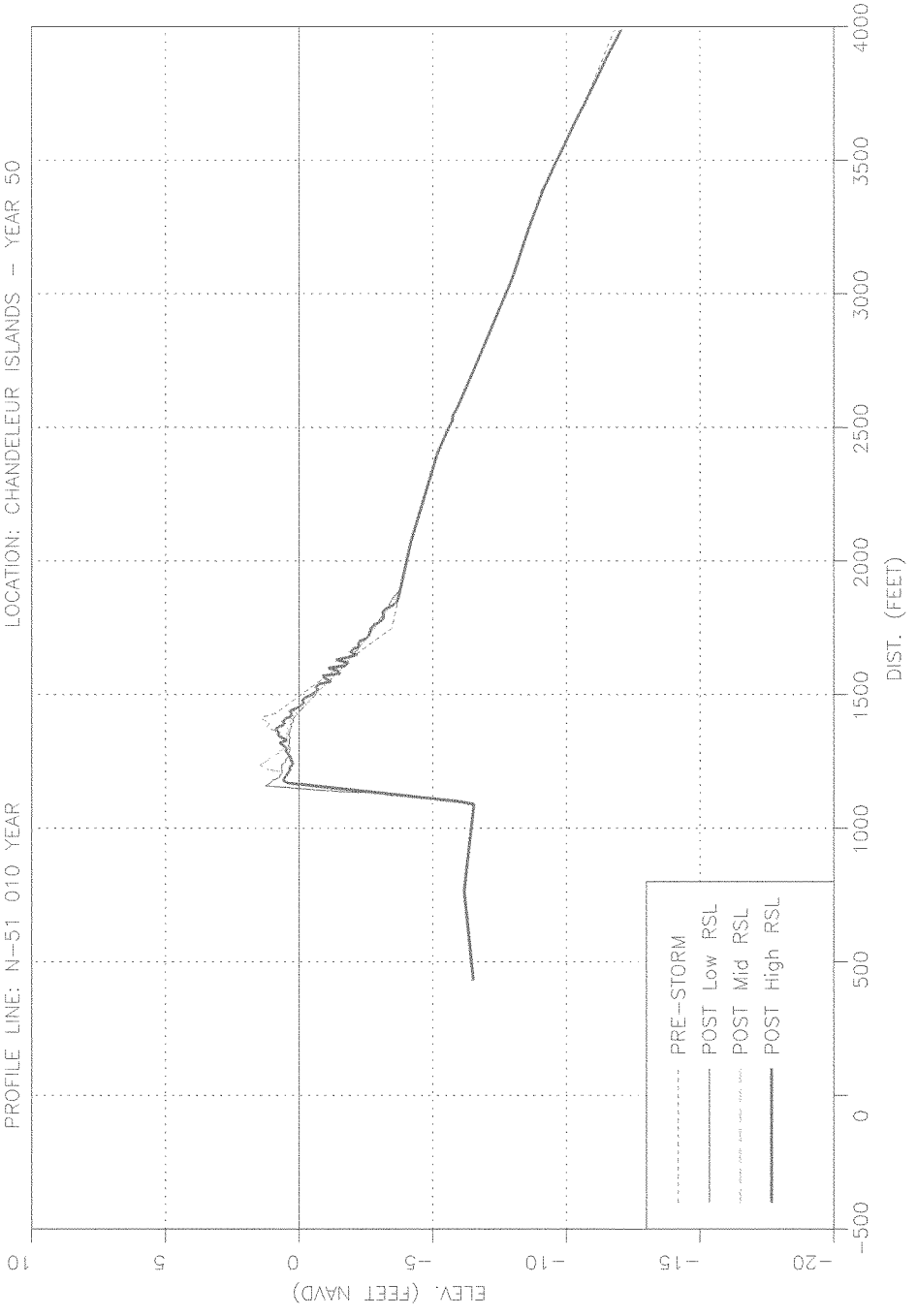

PROFILE LINE: N-51 001 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
POST Mid RSL
POST High RSL
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

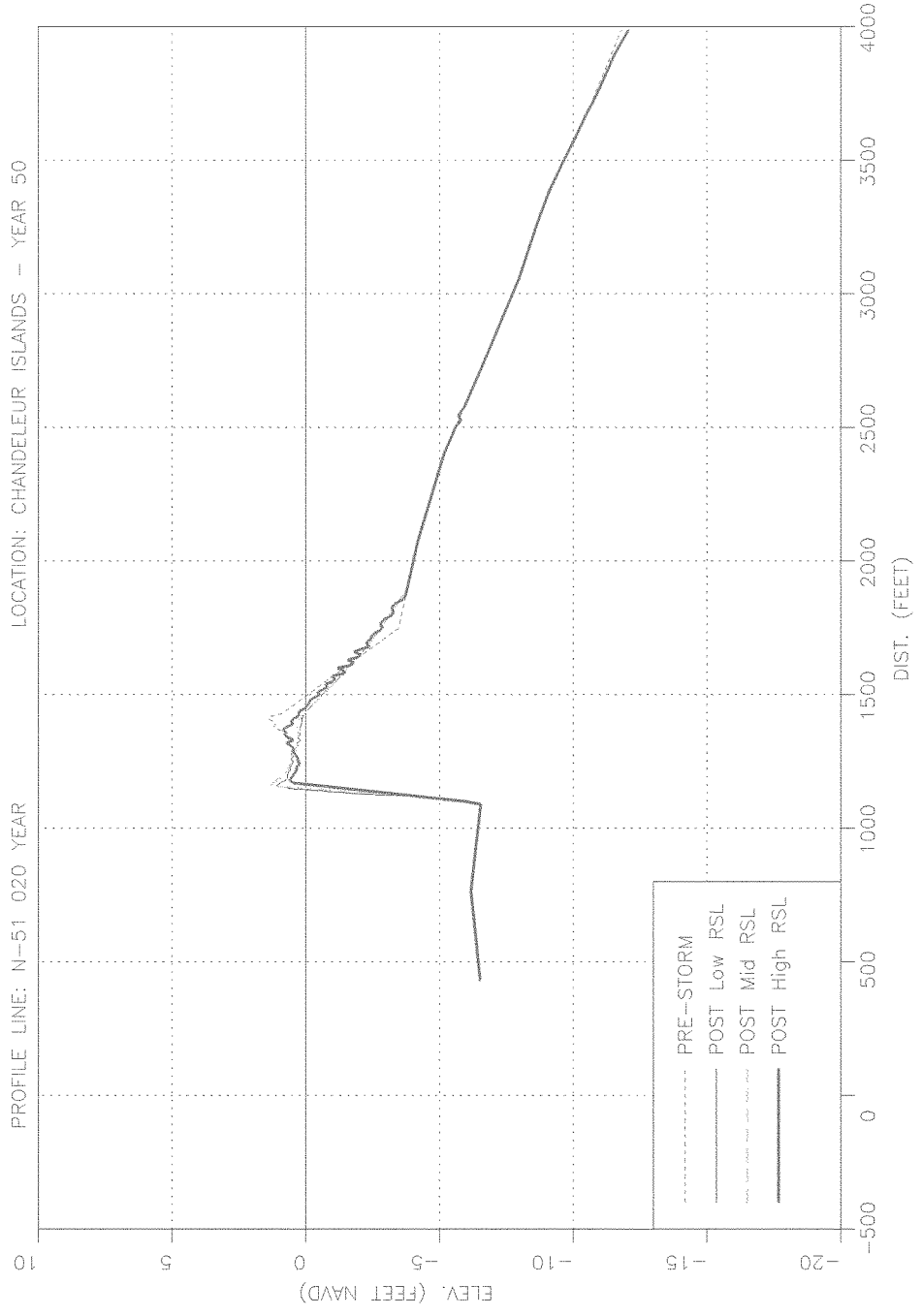

PROFILE LINE: N-51 002 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000
PRE-STORM
POST Low RSL
POST Mid RSL
POST High RSL

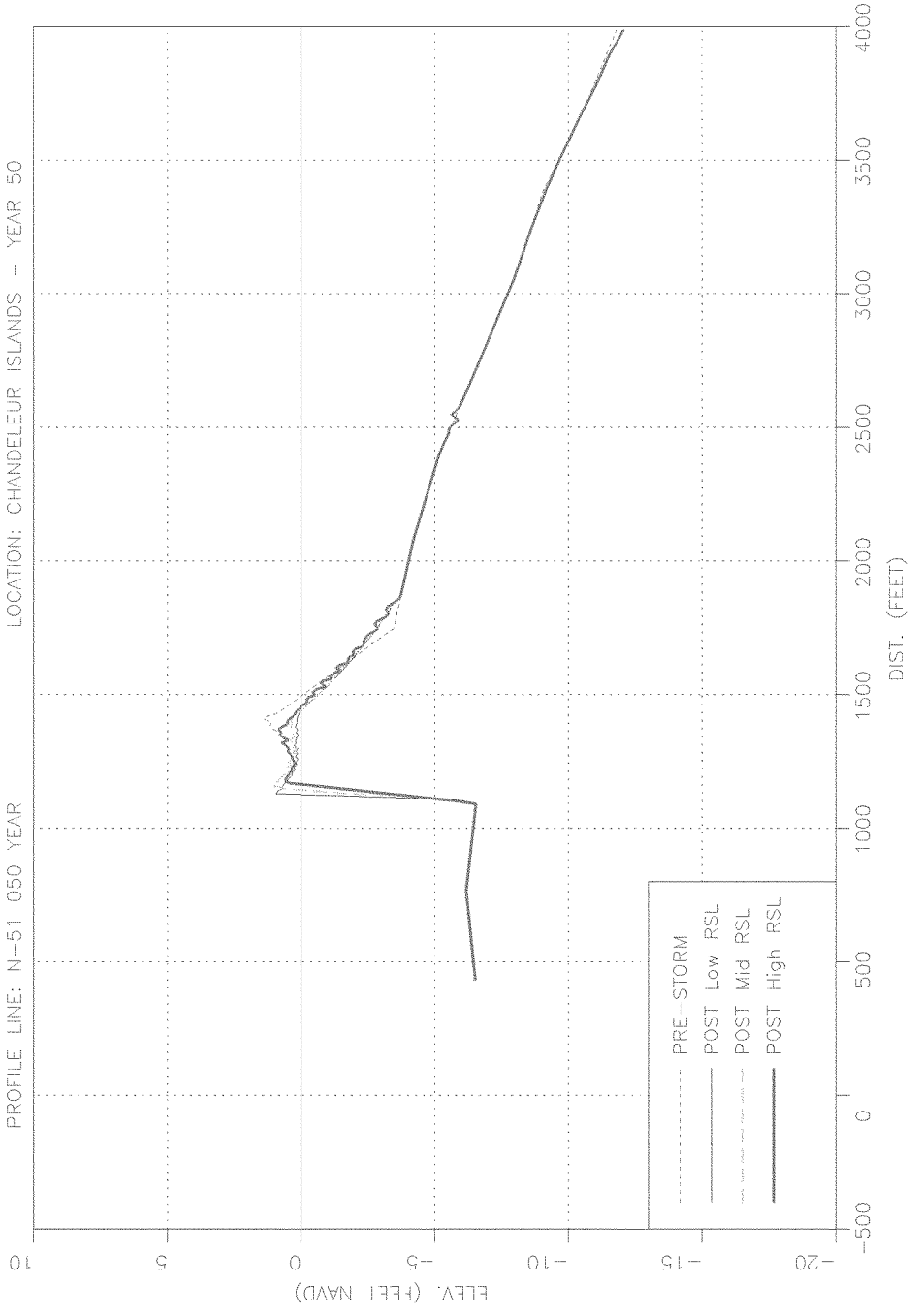

PROFILE LINE: N-51 003 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
POST Mid RSL
POST High RSL
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

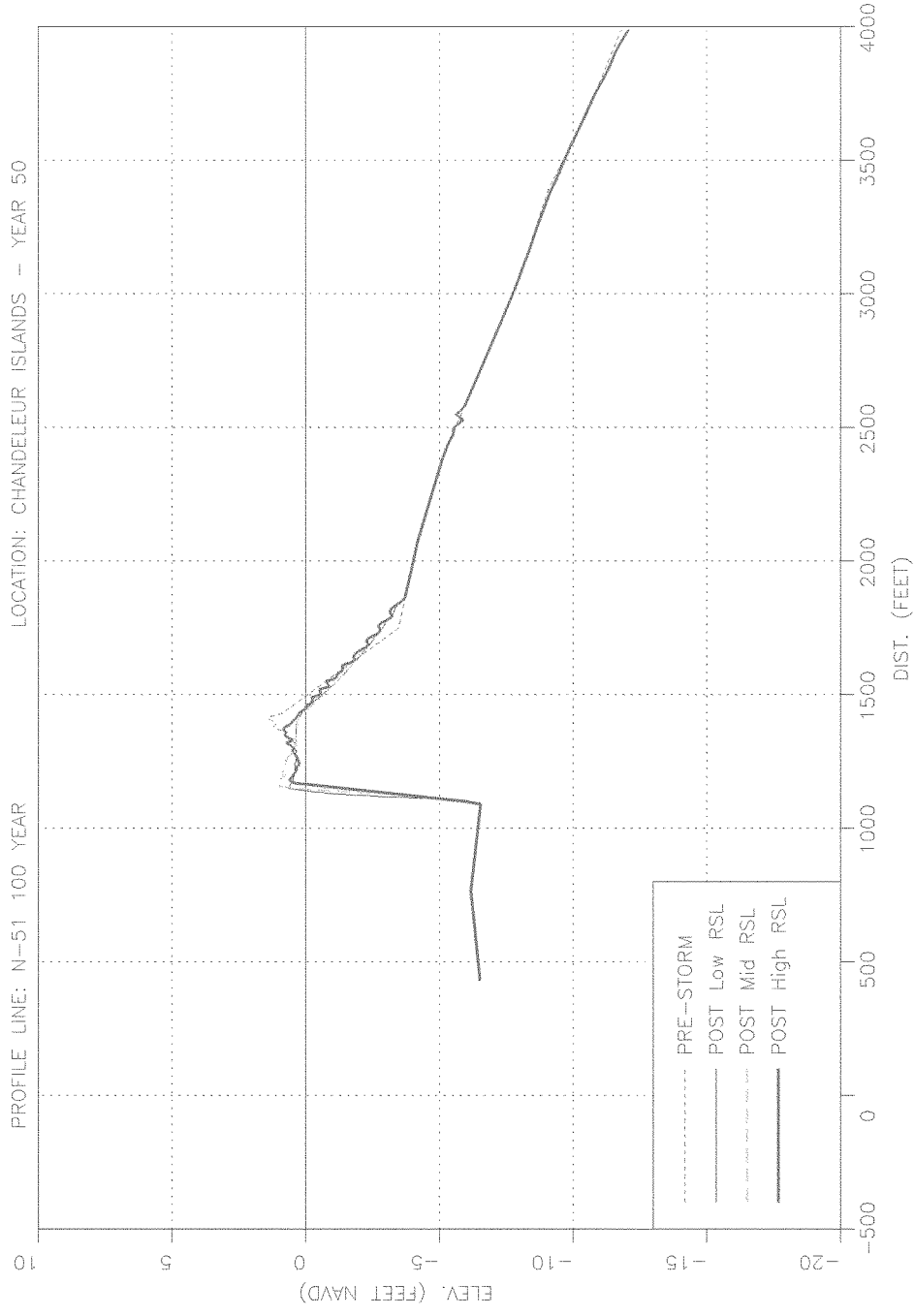

PROFILE LINE: N-51 004 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
POST Mid RSL
POST High RSL
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

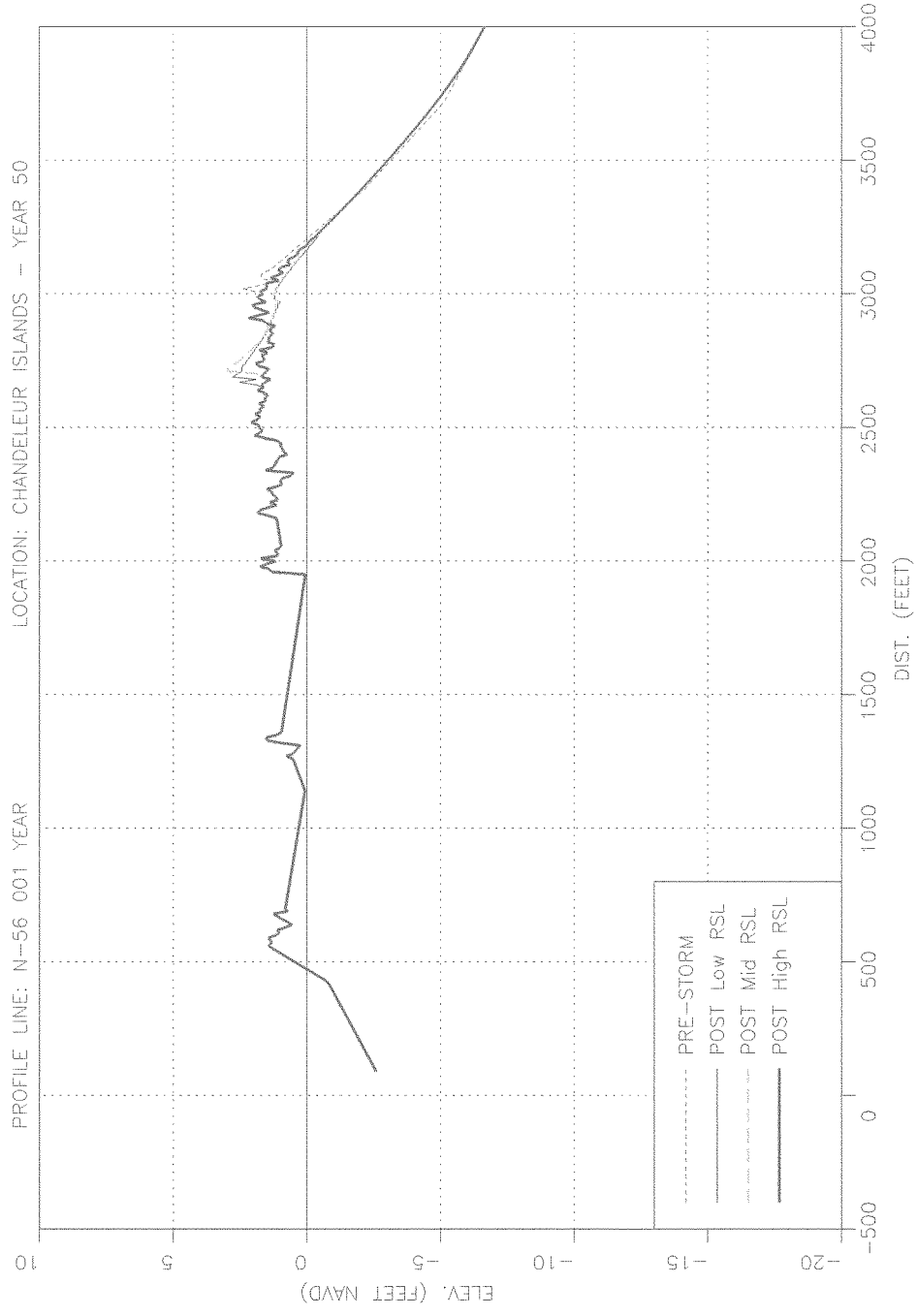

PROFILE LINE: N-51 005 YEAR
LOCATION: CHANDELEUR ISLANDS -- YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
POST Mid RSL
POST High RSL
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

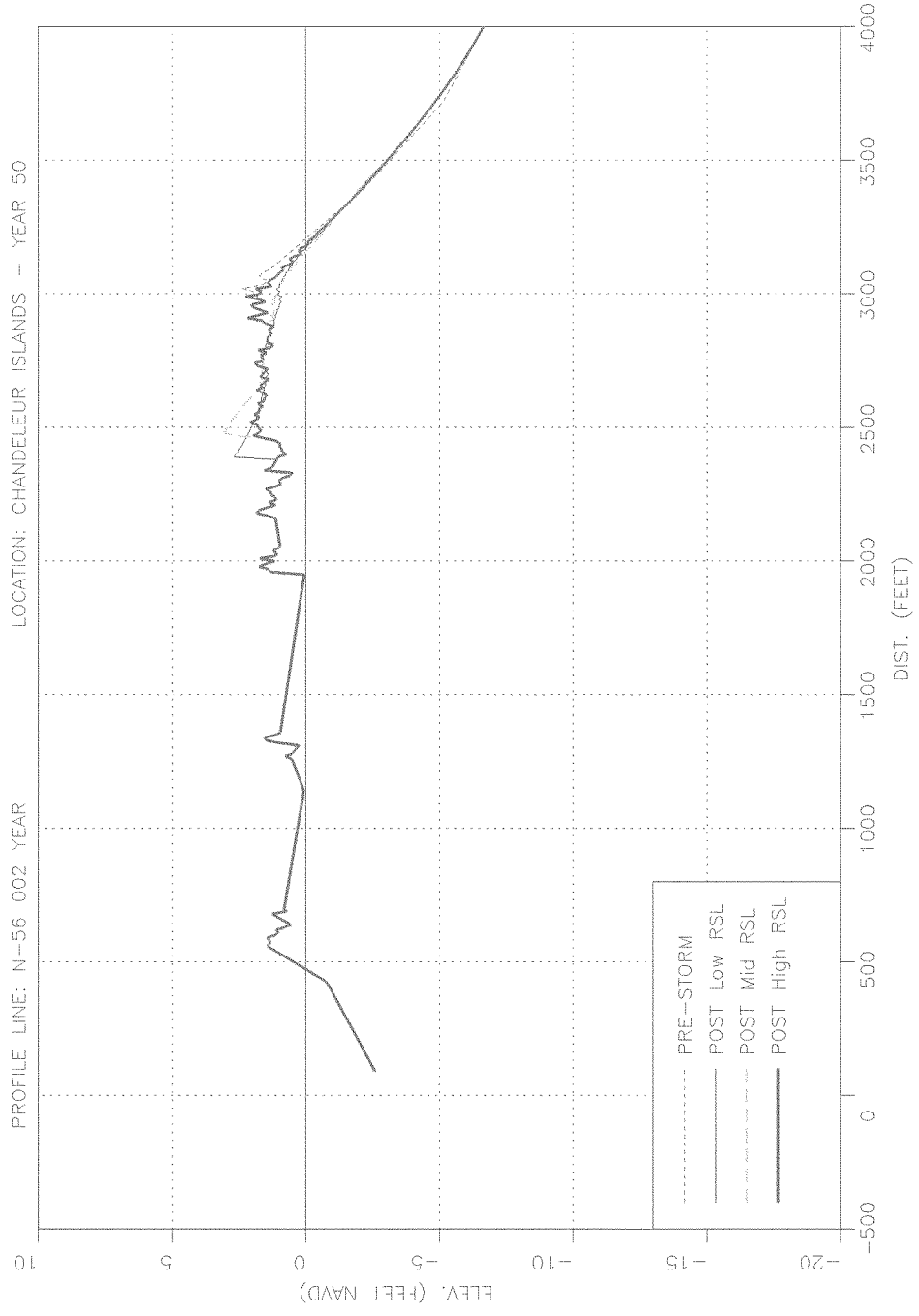

PROFILE LINE: N-51 010 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
POST Mid RSL
POST High RSL
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

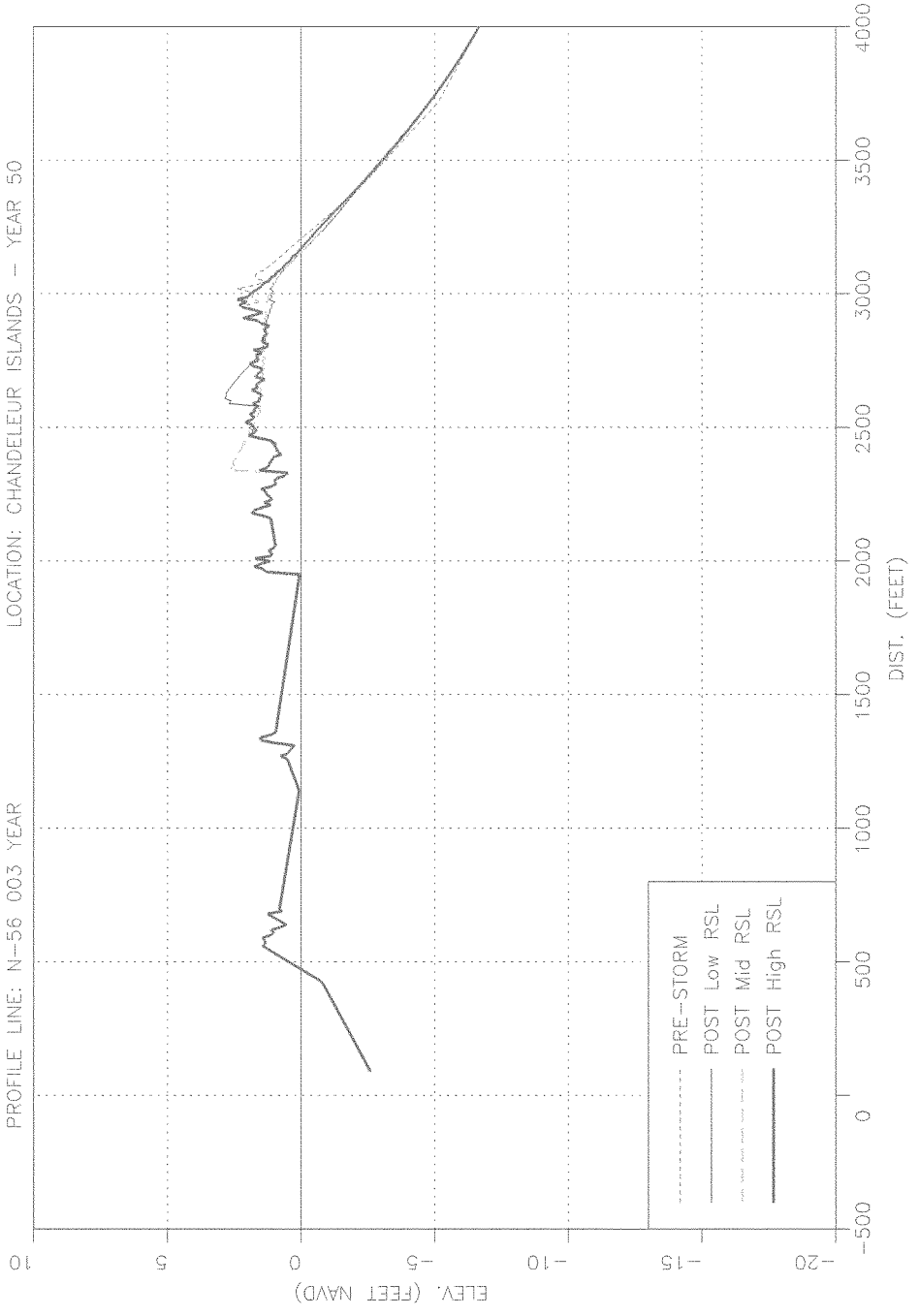

PROFILE LINE: N-51 020 YEAR
LOCATION: CHANDELEUR ISLANDS -- YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
POST Mid RSL
POST High RSL
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

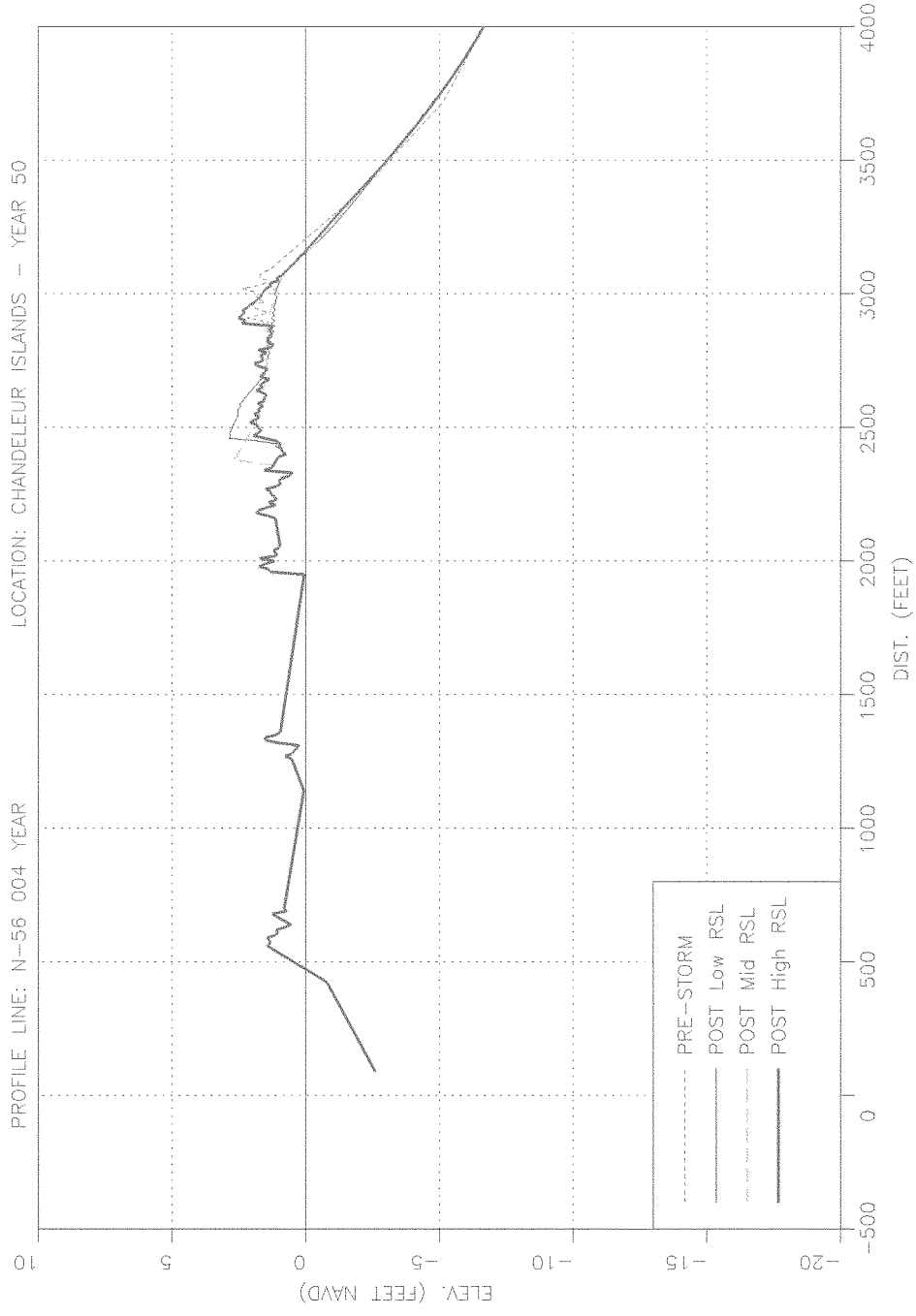

PROFILE LINE: N-51 050 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
POST Mid RSL
POST High RSL
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

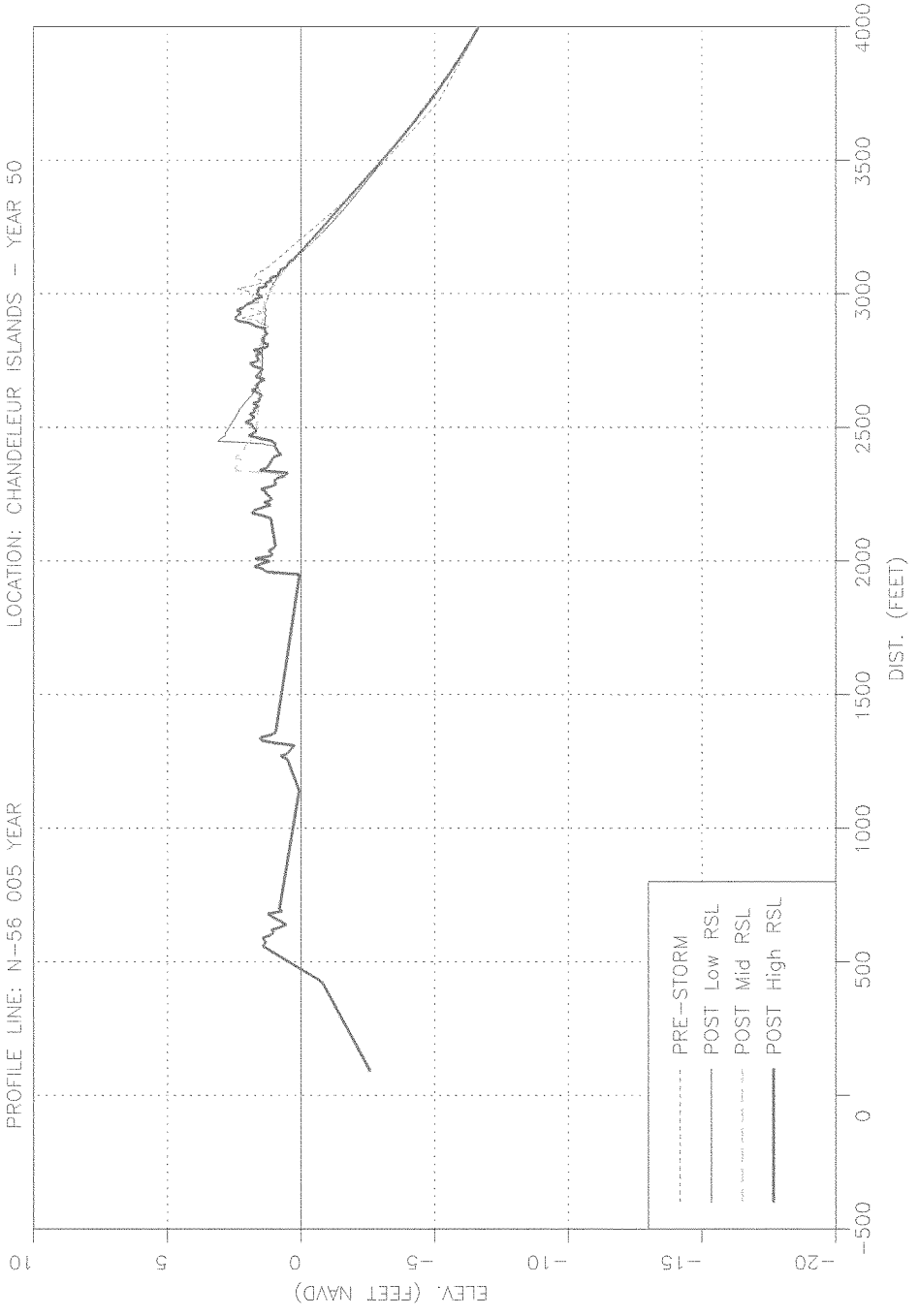

PROFILE LINE: N-51 100 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
POST Mid RSL
POST High RSL
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

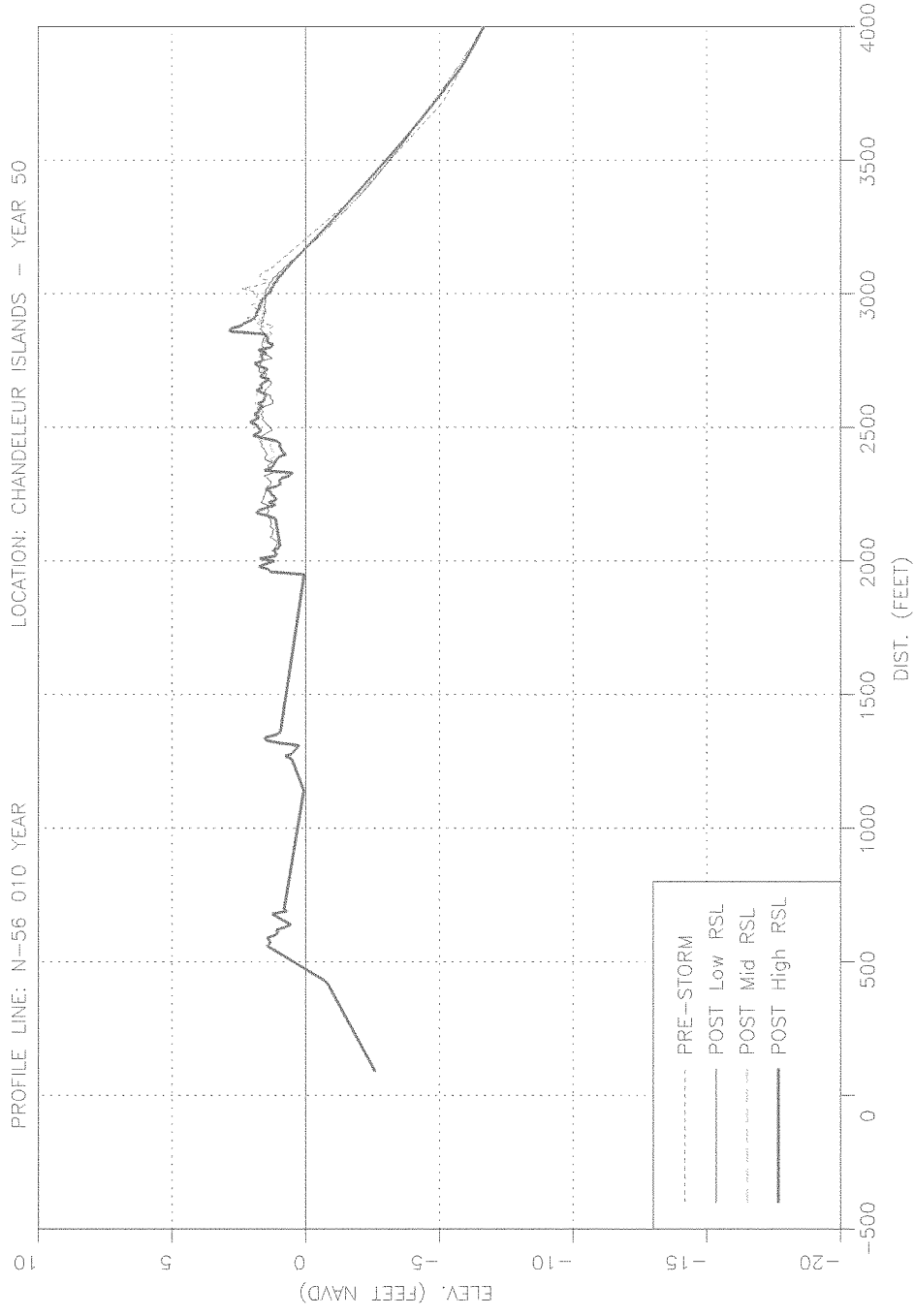

PROFILE LINE: N-56 001 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000
PRE-STORM
POST Low RSL
POST Mid RSL
POST High RSL

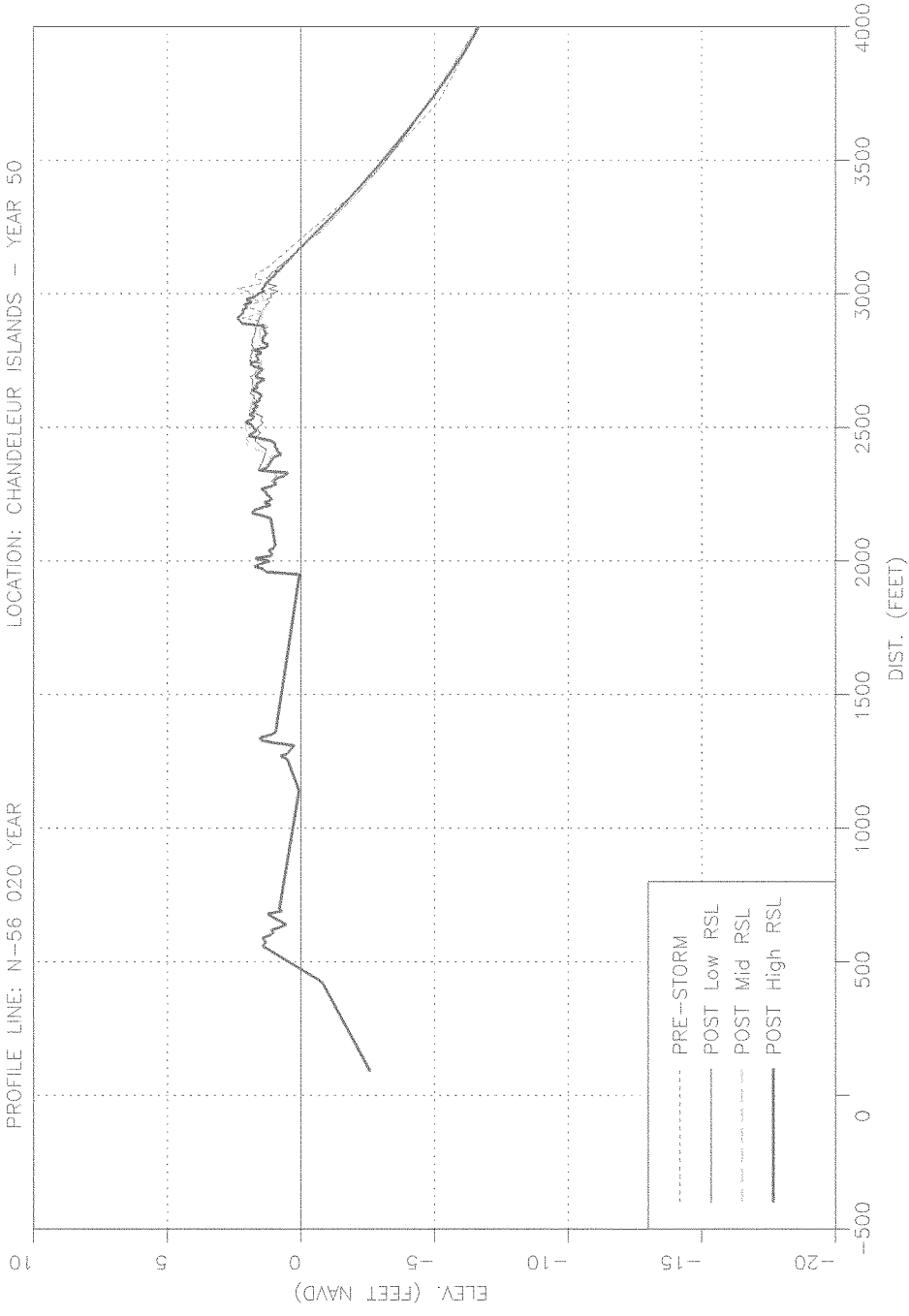

PROFILE LINE: N-56 002 YEAR
LOCATION: CHANDELEUR ISLANDS -- YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
POST Mid RSL
POST High RSL
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

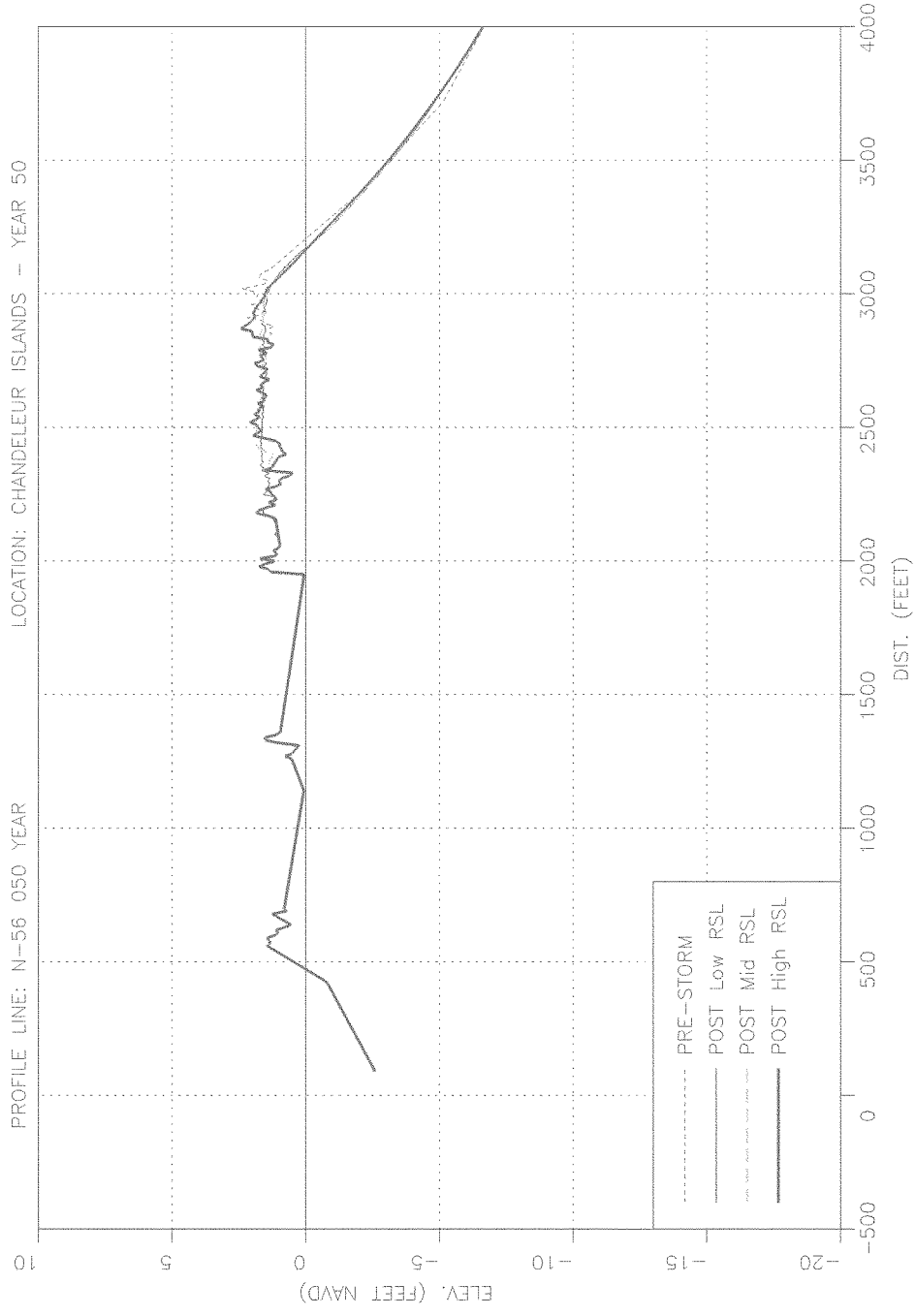

PROFILE LINE: N-56 003 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
POST Mid RSL
POST High RSL
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

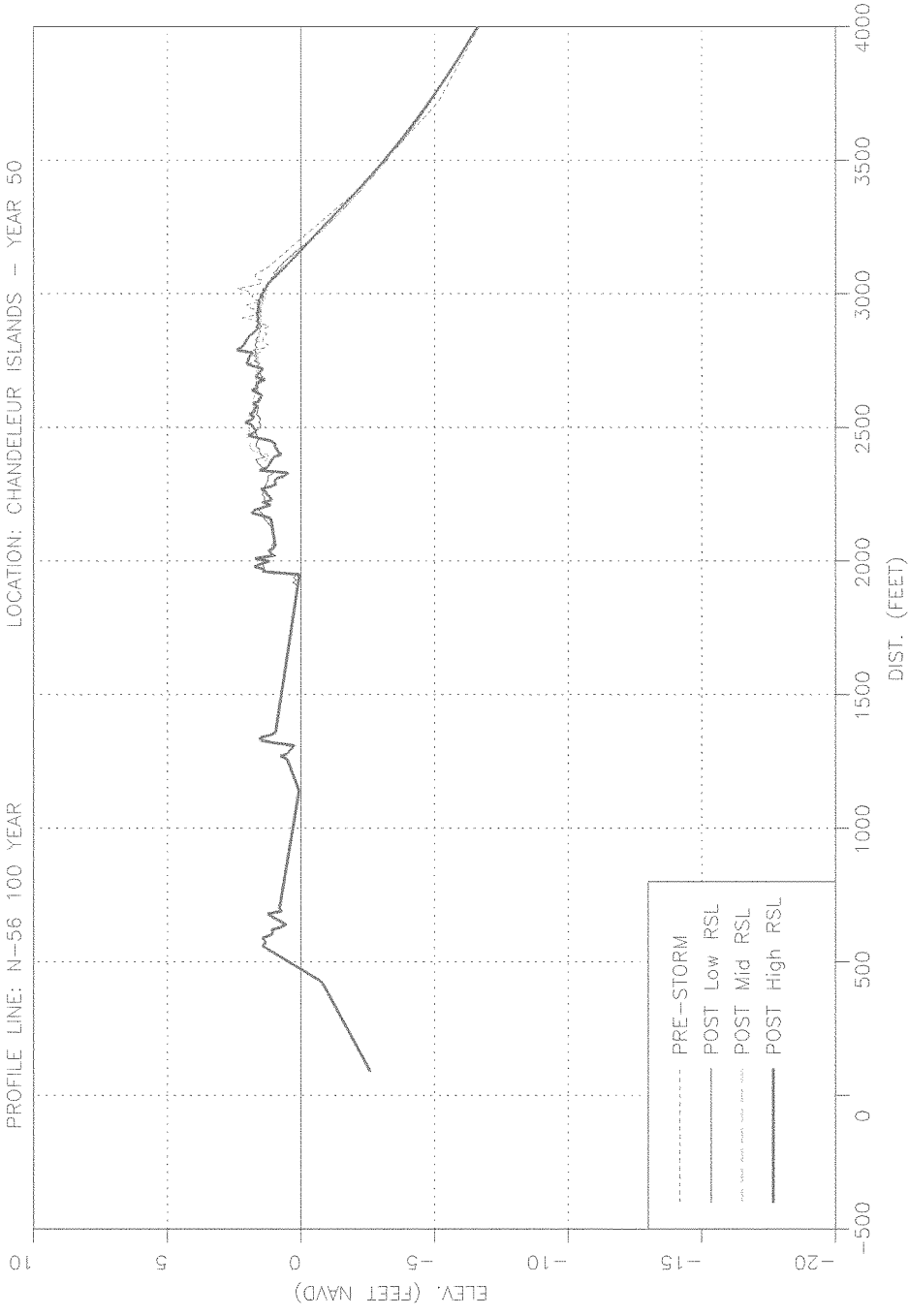

PROFILE LINE: N-56 004 YEAR
LOCATION: CHANDELEUR ISLANDS -- YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
POST Mid RSL
POST High RSL
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

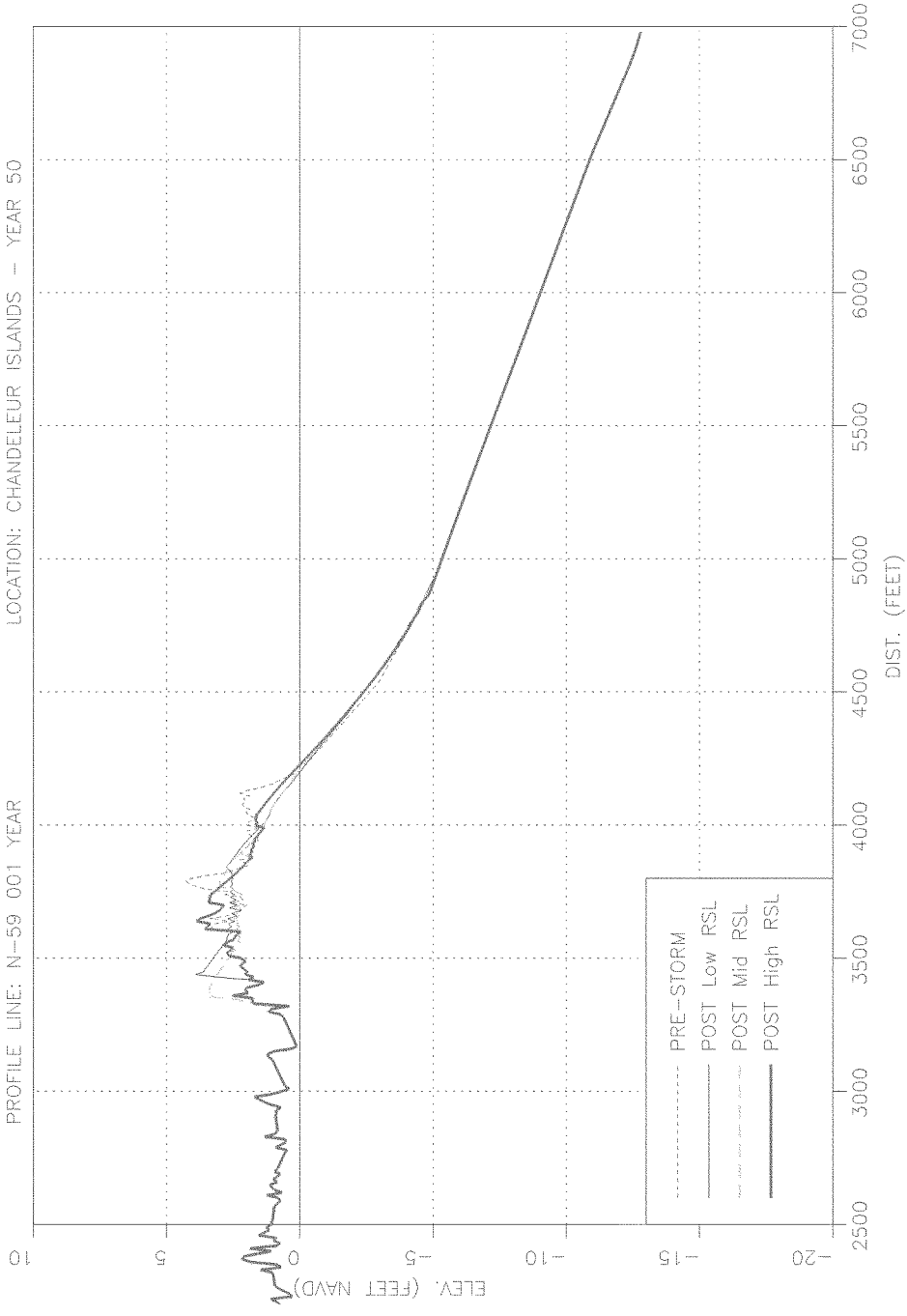

PROFILE LINE: N-56 005 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000
PRE-STORM
POST Low RSL
POST Mid RSL
POST High RSL

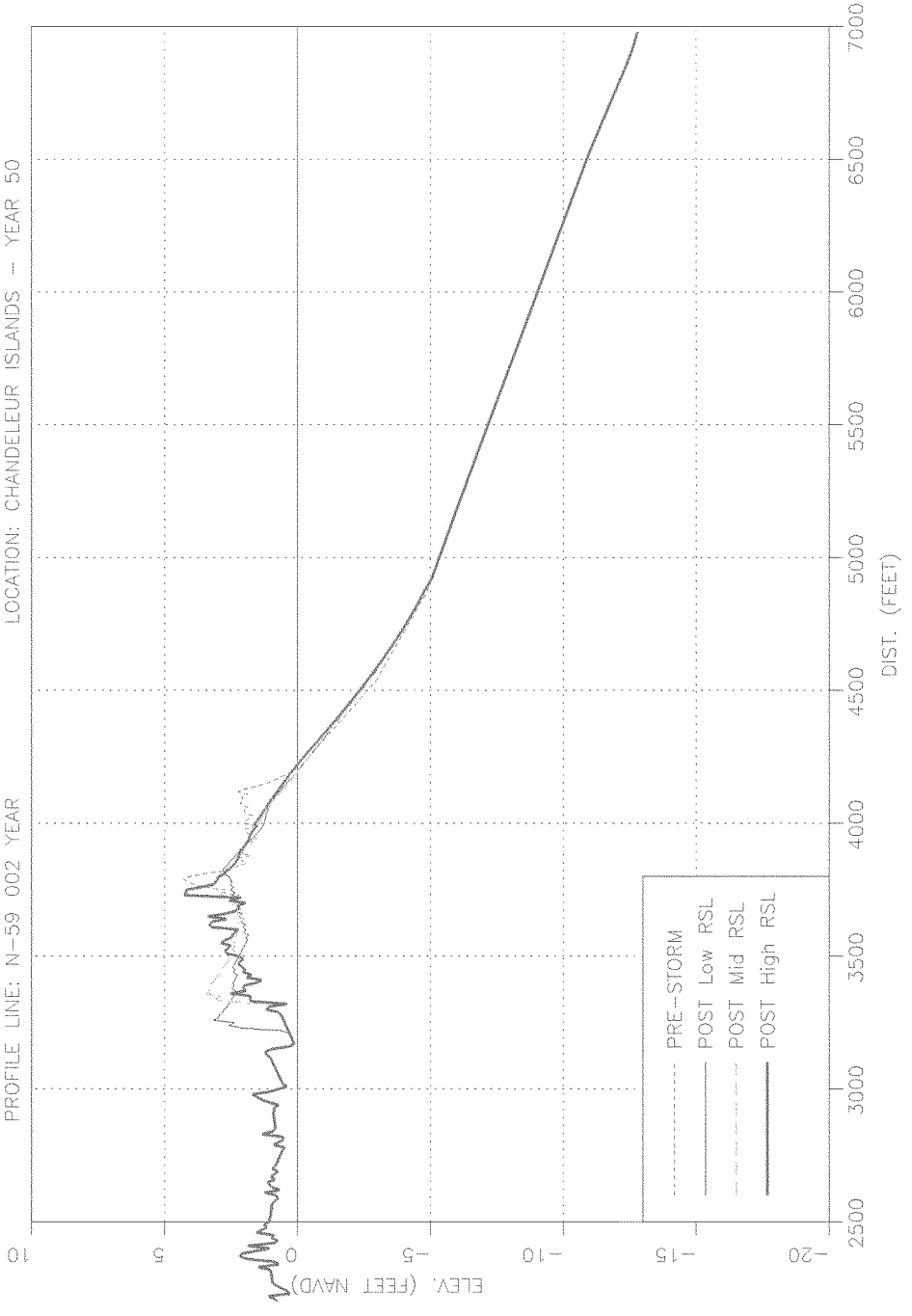

PROFILE LINE: N-56 010 YEAR
LOCATION: CHANDELEUR ISLANDS -- YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
POST Mid RSL
POST High RSL
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

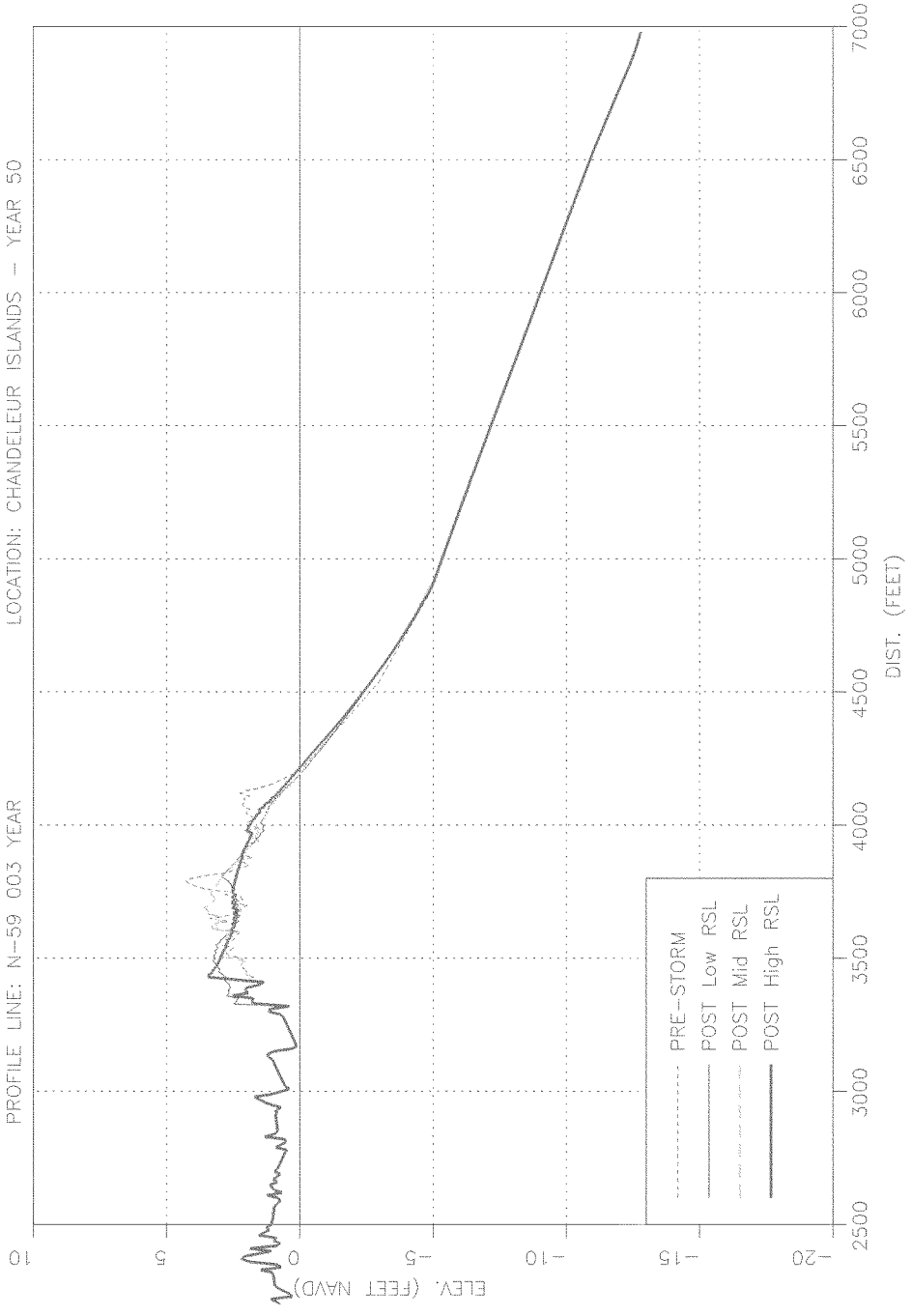

PROFILE LINE: N-56 020 YEAR
LOCATION: CHANDELEUR ISLANDS -- YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000
PRE-STORM
POST Low RSL
POST Mid RSL
POST High RSL

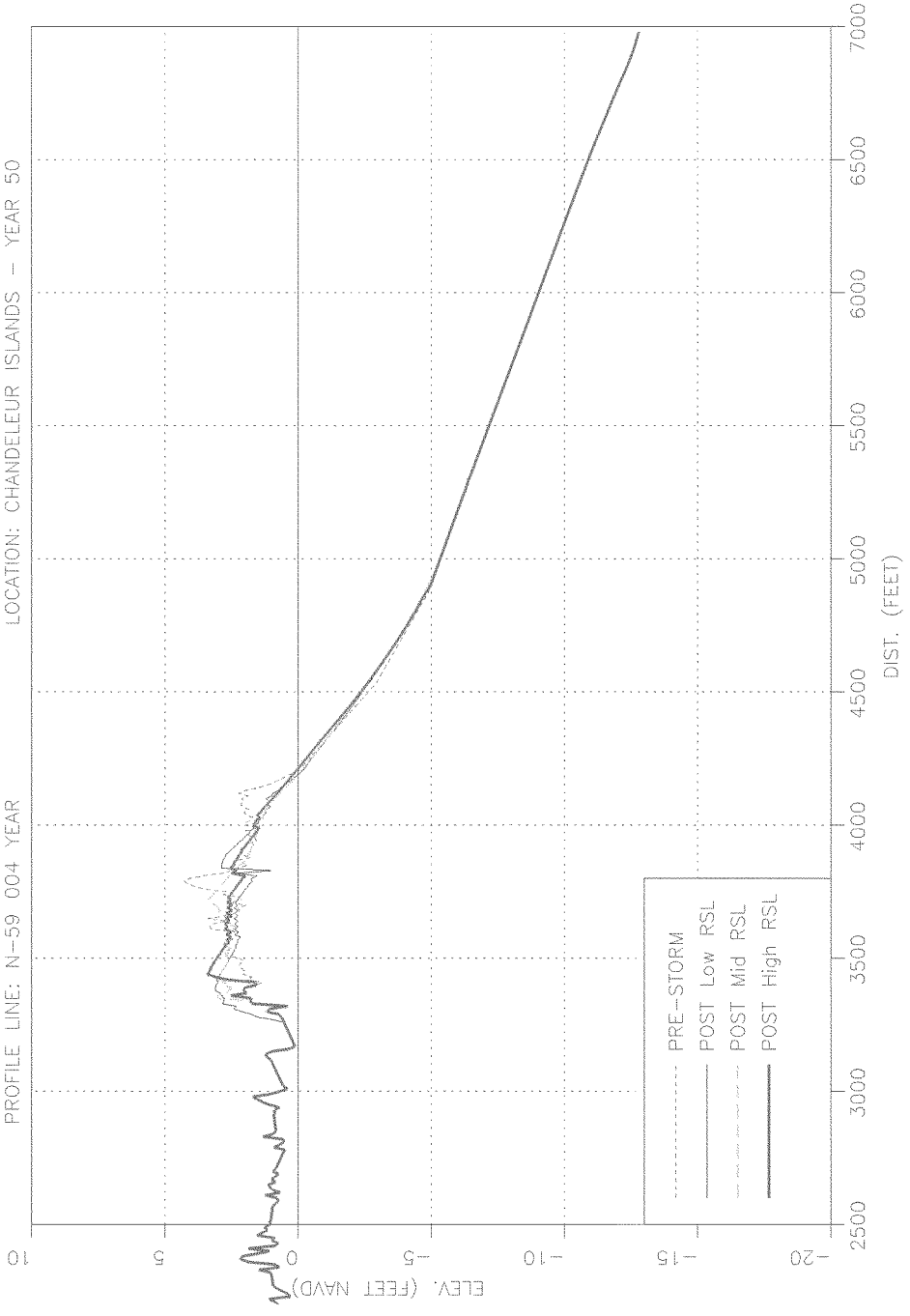

PROFILE LINE: N-56 050 YEAR
LOCATION: CHANDELEUR ISLANDS -- YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
POST Mid RSL
POST High RSL
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

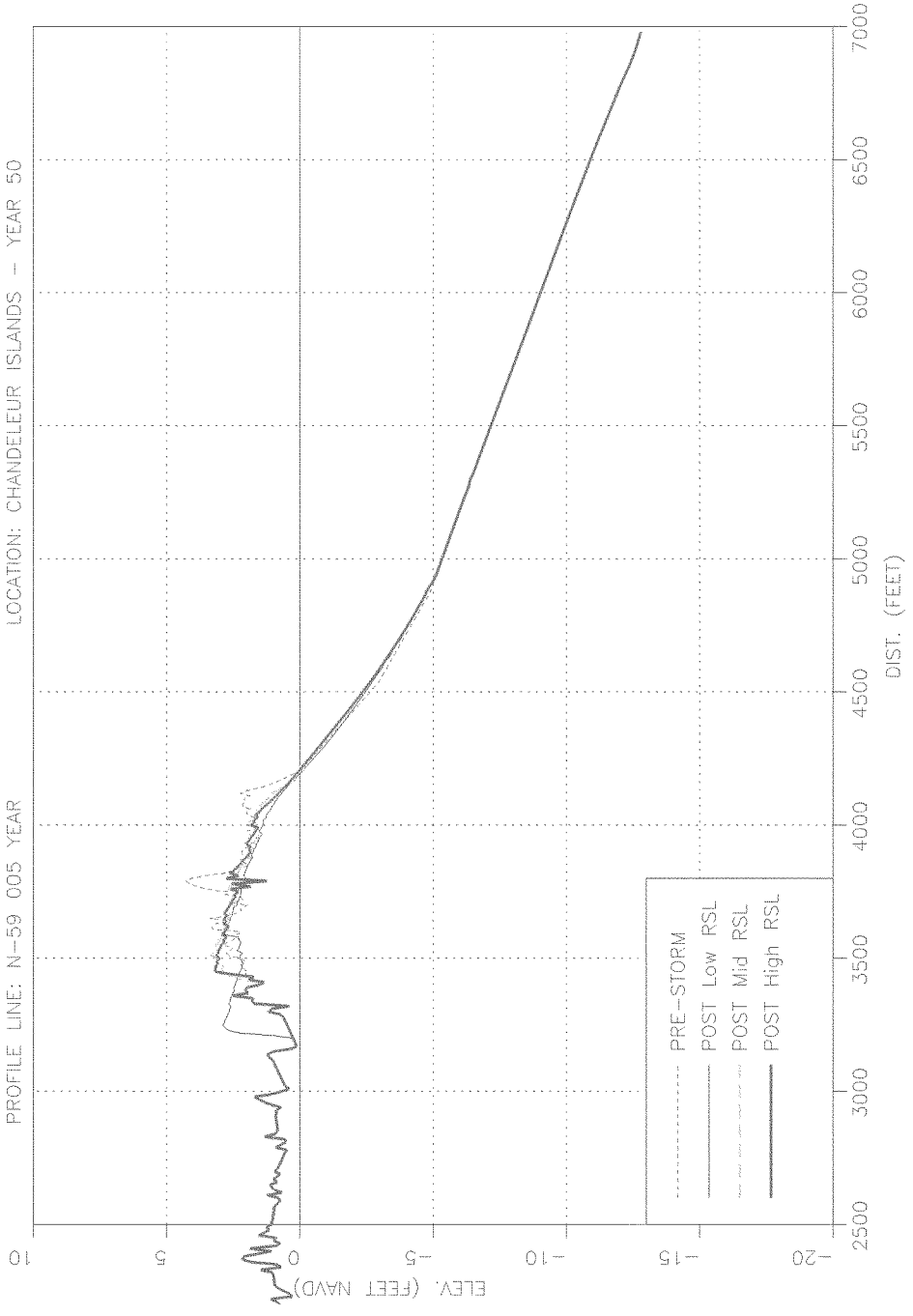

PROFILE LINE: N-56 100 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000
PRE-STORM
POST Low RSL
POST Mid RSL
POST High RSL

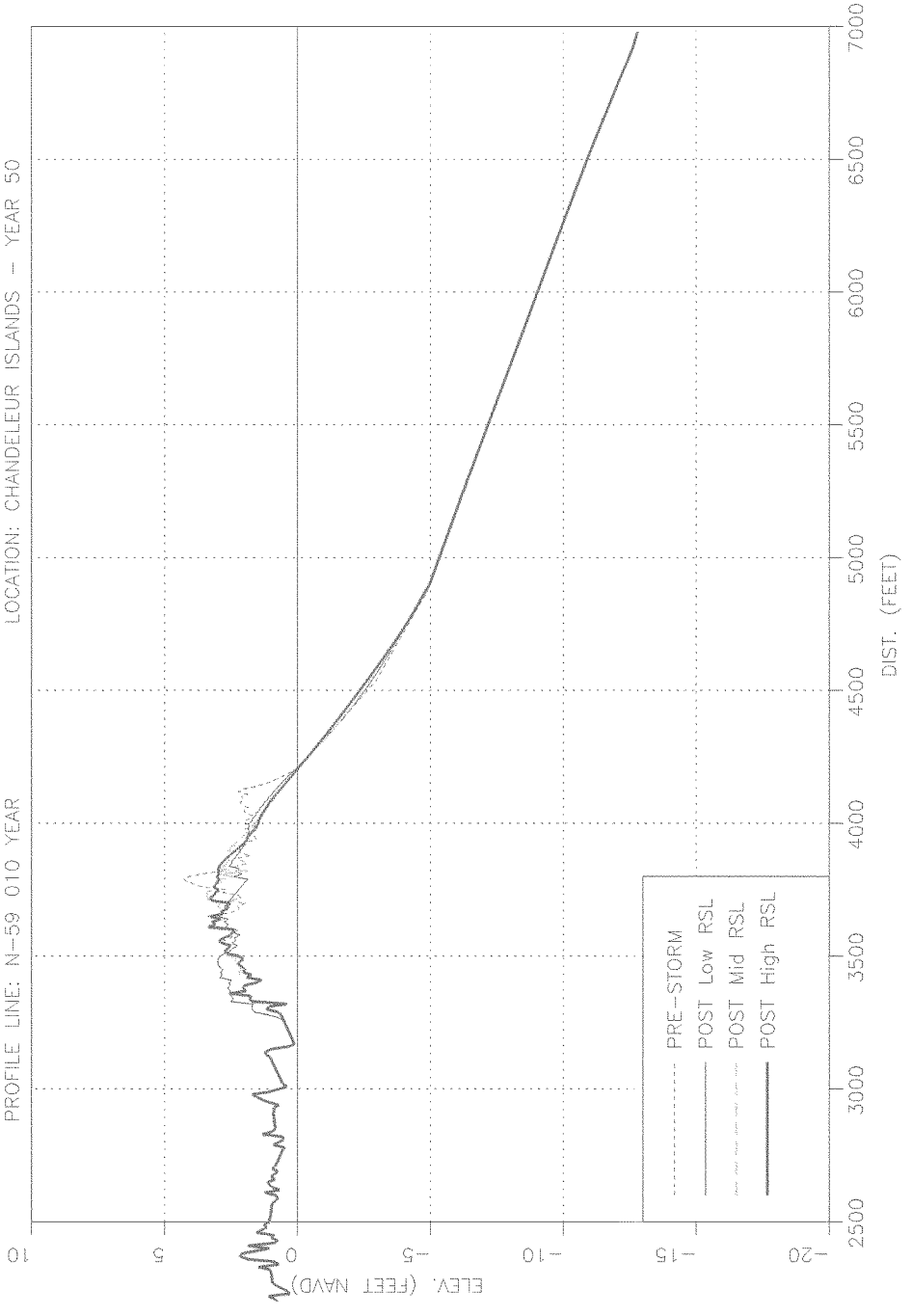

PROFILE LINE: N-59 001 YEAR
LOCATION: CHANDELEUR ISLANDS -- YEAR 50
ELEV. (FEET NAVD)
10
5
0
-5
-10
-15
-20
2500
3000
3500
4000
4500
5000
5500
6000
6500
7000
DIST. (FEET)
PRE-STORM
POST Low RSL
POST Mid RSL
POST High RSL

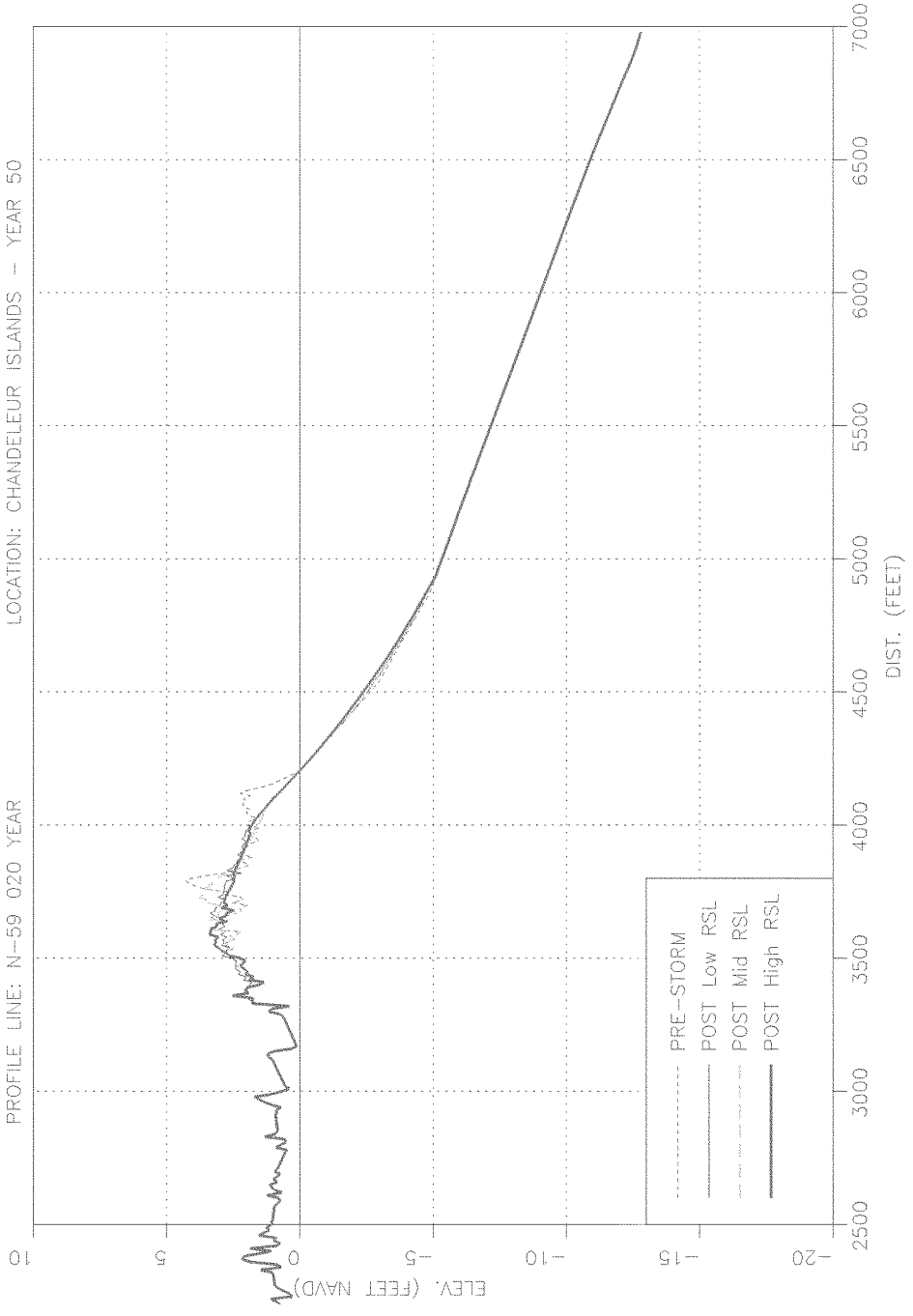

PROFILE LINE: N-59 002 YEAR
LOCATION: CHANDELEUR ISLANDS -- YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
10
5
0
-5
-10
-15
-20
2500
3000
3500
4000
4500
5000
5500
6000
6500
7000
PRE-STORM
POST Low RSL
POST Mid RSL
POST High RSL

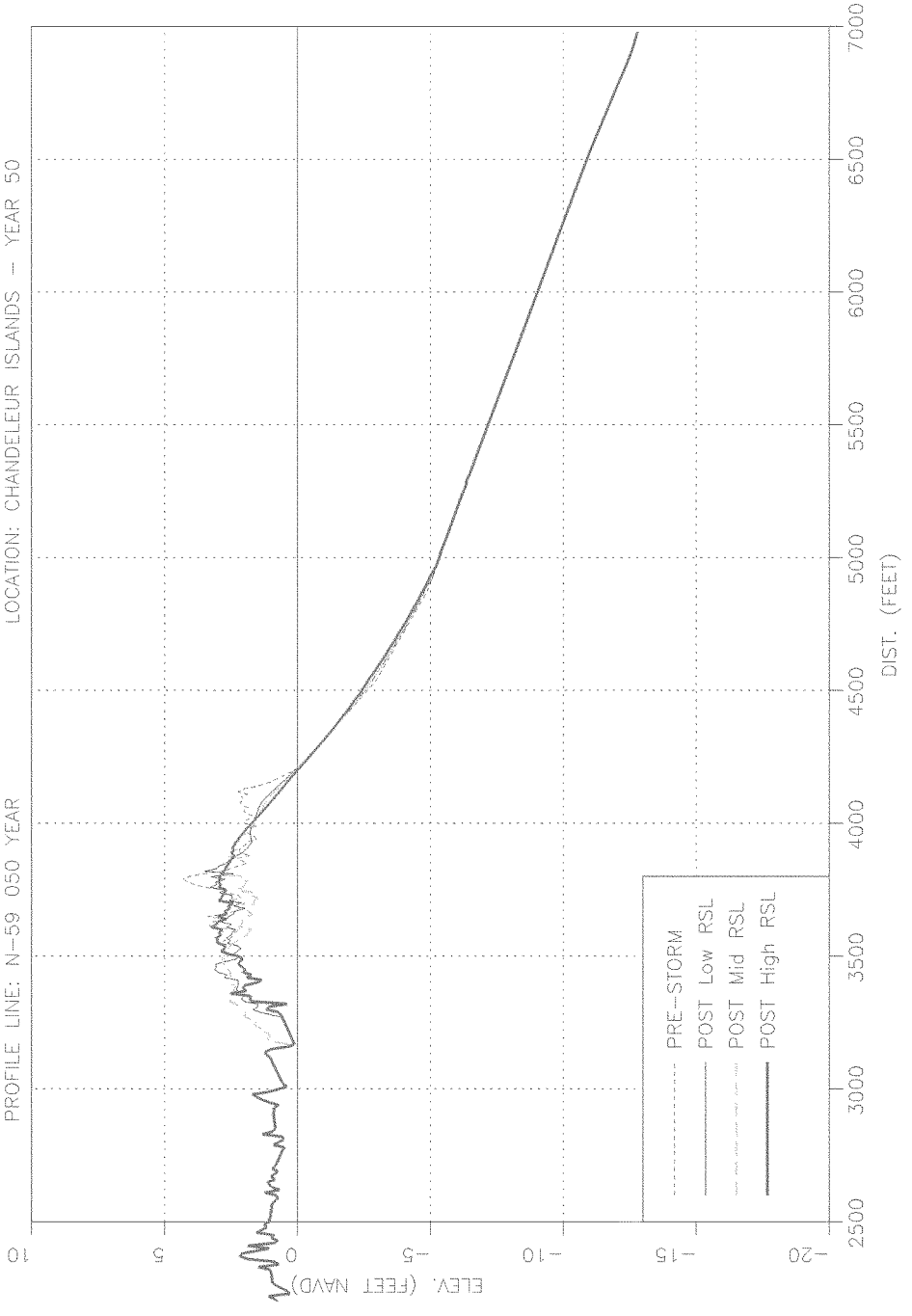

PROFILE LINE: N-59 003 YEAR
LOCATION: CHANDELEUR ISLANDS -- YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
POST Mid RSL
POST High RSL
10
5
0
-5
-10
-15
-20
2500
3000
3500
4000
4500
5000
5500
6000
6500
7000

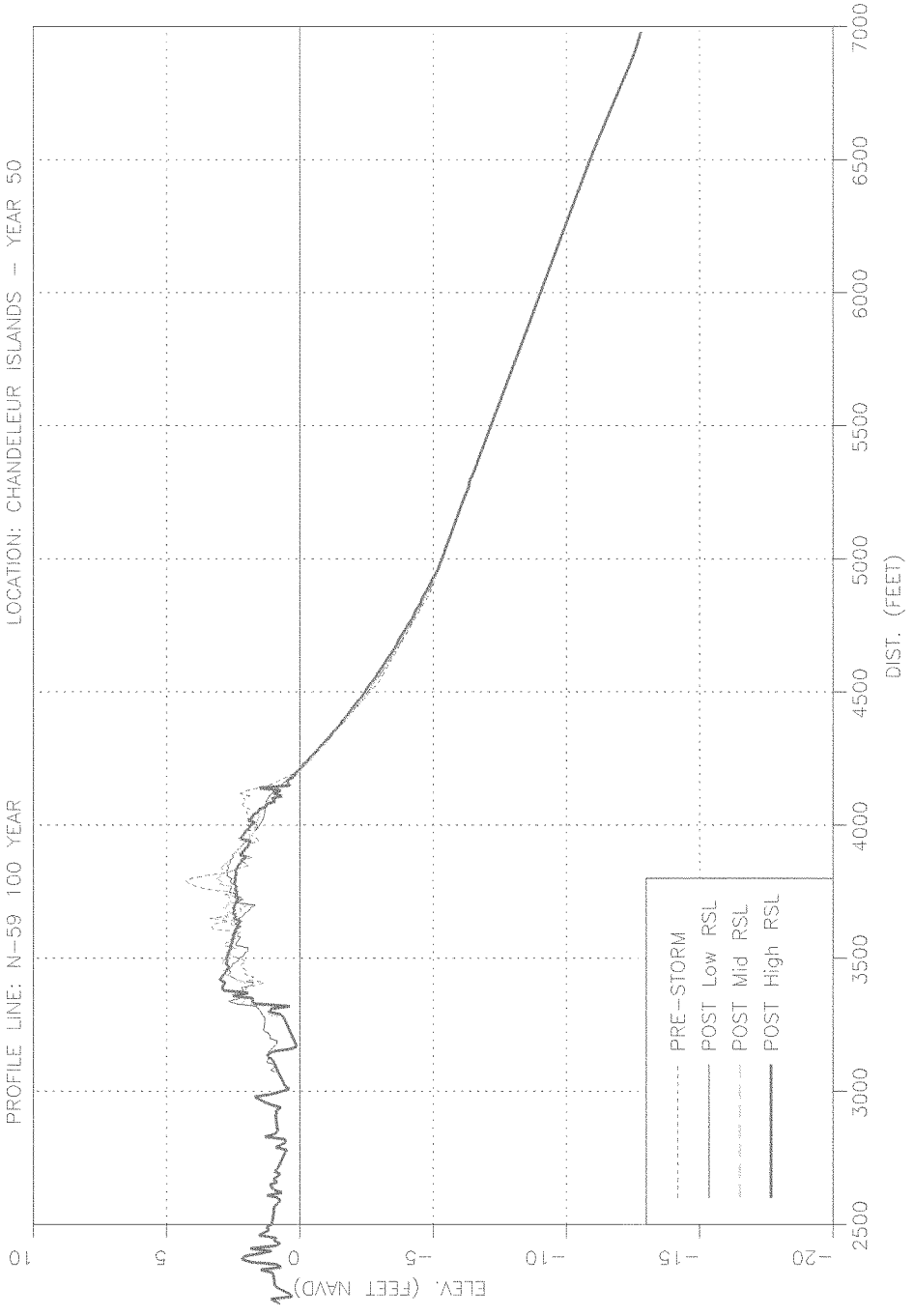

PROFILE LINE: N-59 004 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
POST Mid RSL
POST High RSL
10
5
0
-5
-10
-15
-20
2500
3000
3500
4000
4500
5000
5500
6000
6500
7000

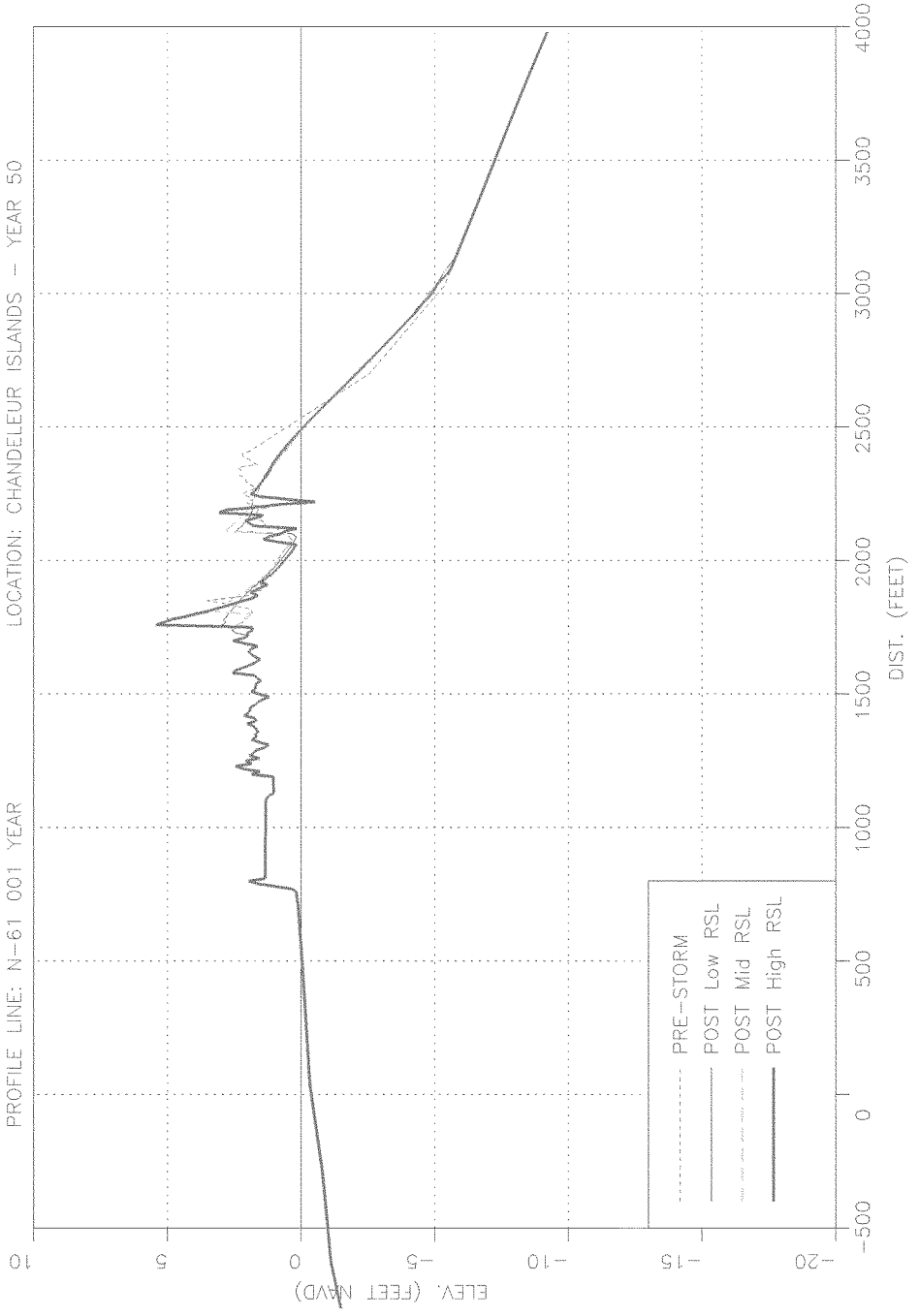

PROFILE LINE: N-59 005 YEAR
LOCATION: CHANDELEUR ISLANDS -- YEAR 50
ELEV. (FEET NAVD)
10
5
0
-5
-10
-15
-20
2500
3000
3500
4000
4500
5000
5500
6000
6500
7000
DIST. (FEET)
PRE-STORM
POST Low RSL
POST Mid RSL
POST High RSL

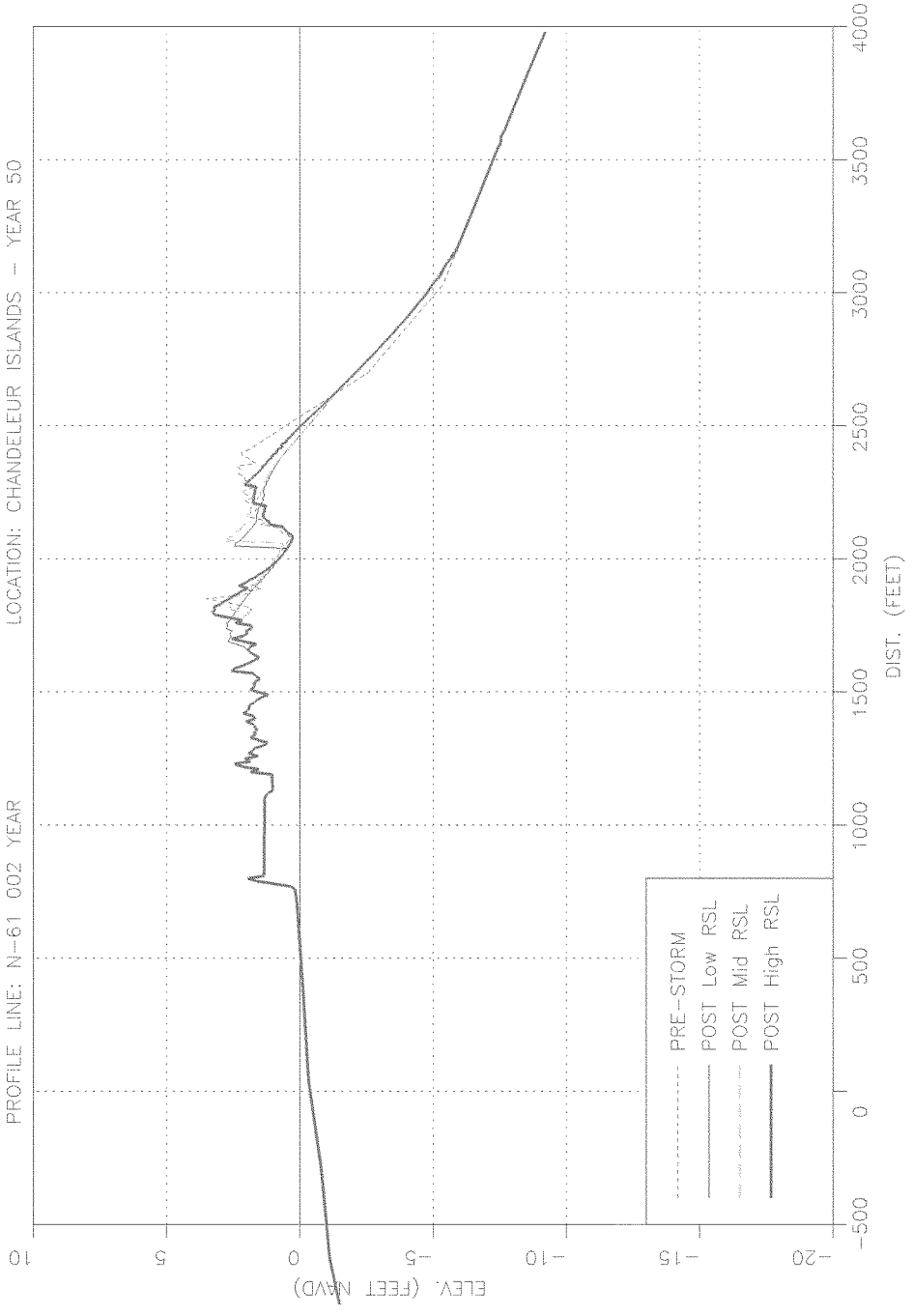

PROFILE LINE: N-59 010 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
10
5
0
-5
-10
-15
-20
2500
3000
3500
4000
4500
5000
5500
6000
6500
7000
PRE-STORM
POST Low RSL
POST Mid RSL
POST High RSL

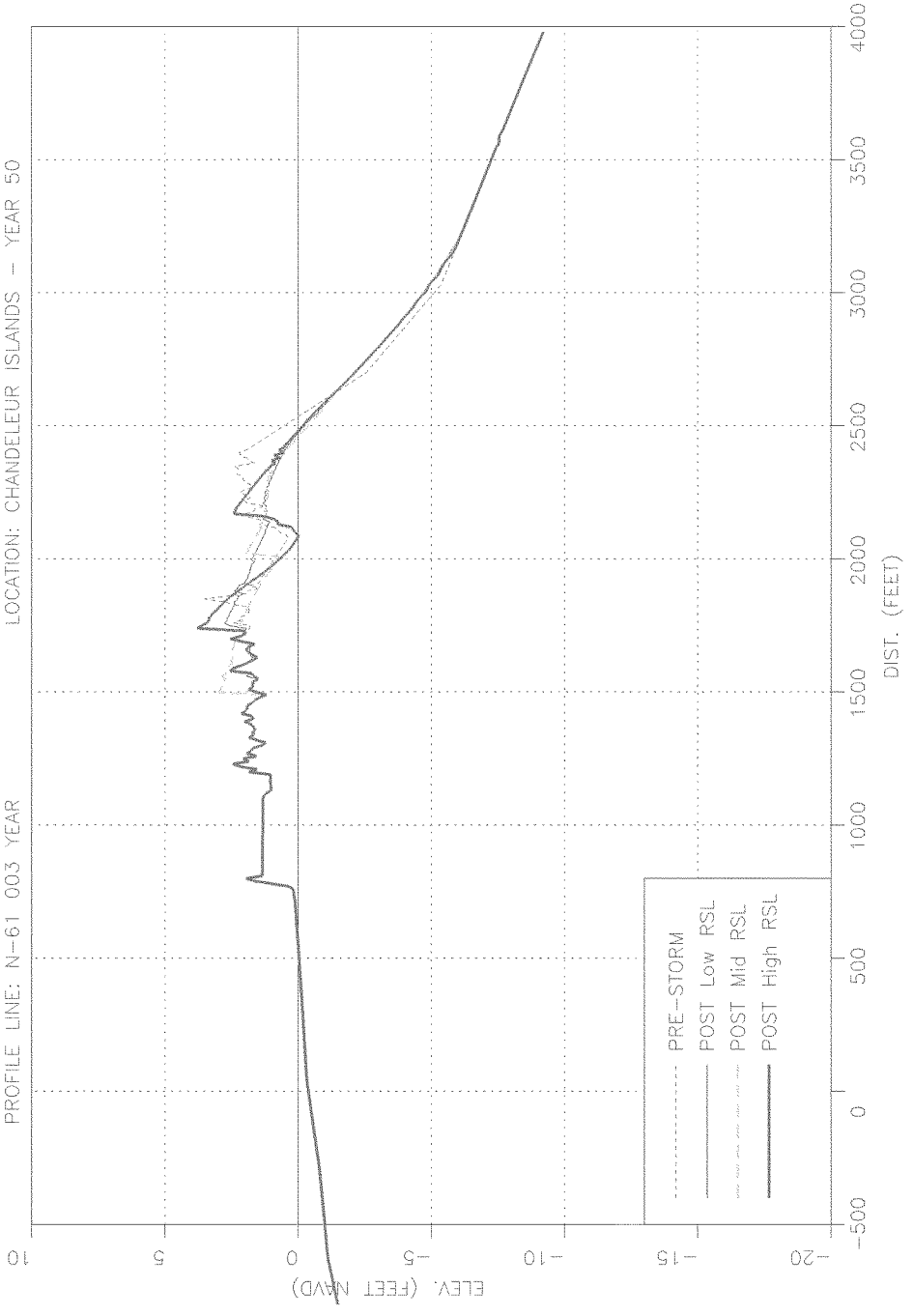

PROFILE LINE: N-59 020 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
POST Mid RSL
POST High RSL
10
5
0
-5
-10
-15
-20
2500
3000
3500
4000
4500
5000
5500
6000
6500
7000

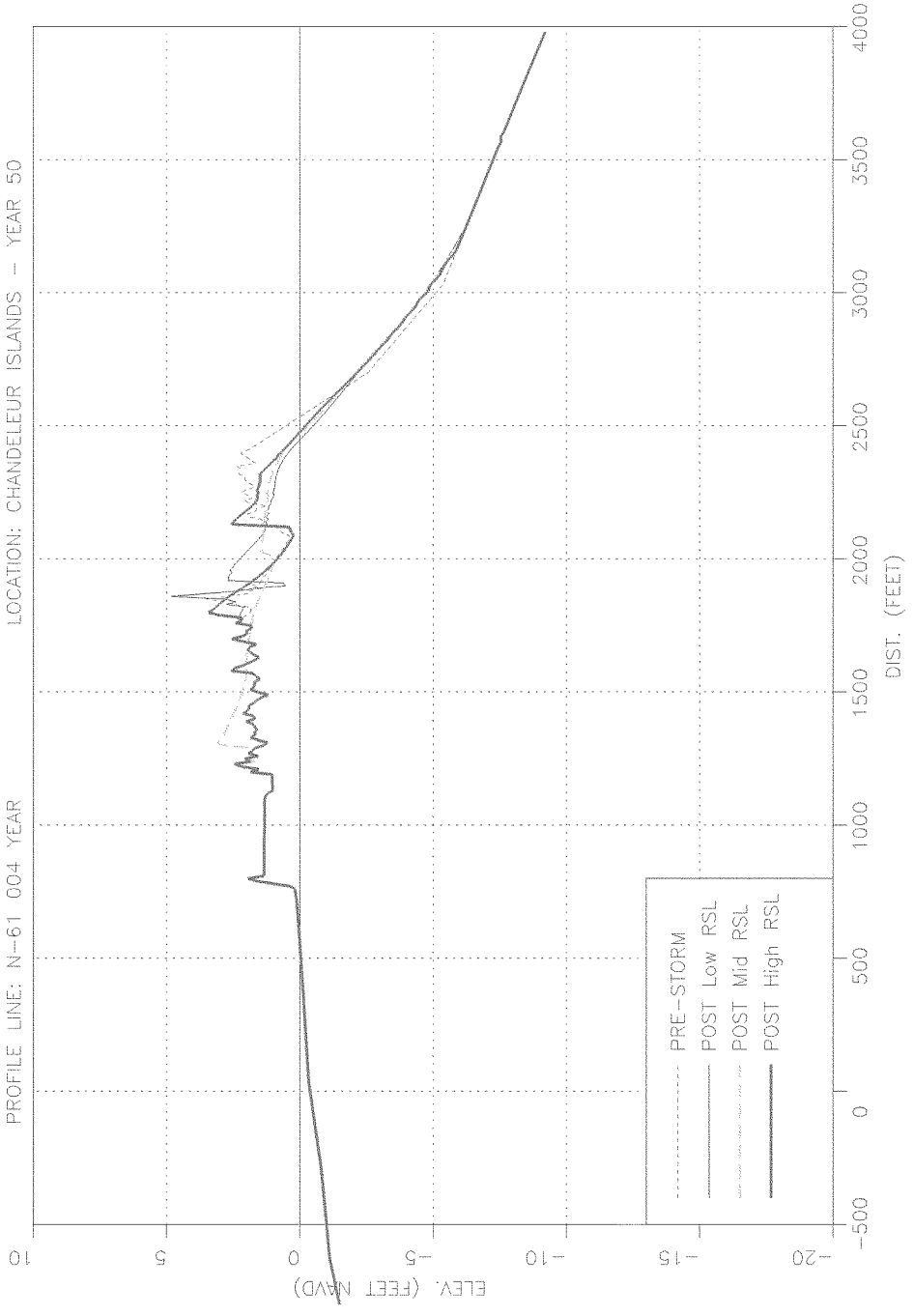

PROFILE LINE: N-59 050 YEAR
LOCATION: CHANDELEUR ISLANDS -- YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
10
5
0
-5
-10
-15
-20
2500
3000
3500
4000
4500
5000
5500
6000
6500
7000
PRE-STORM
POST Low RSL
POST Mid RSL
POST High RSL

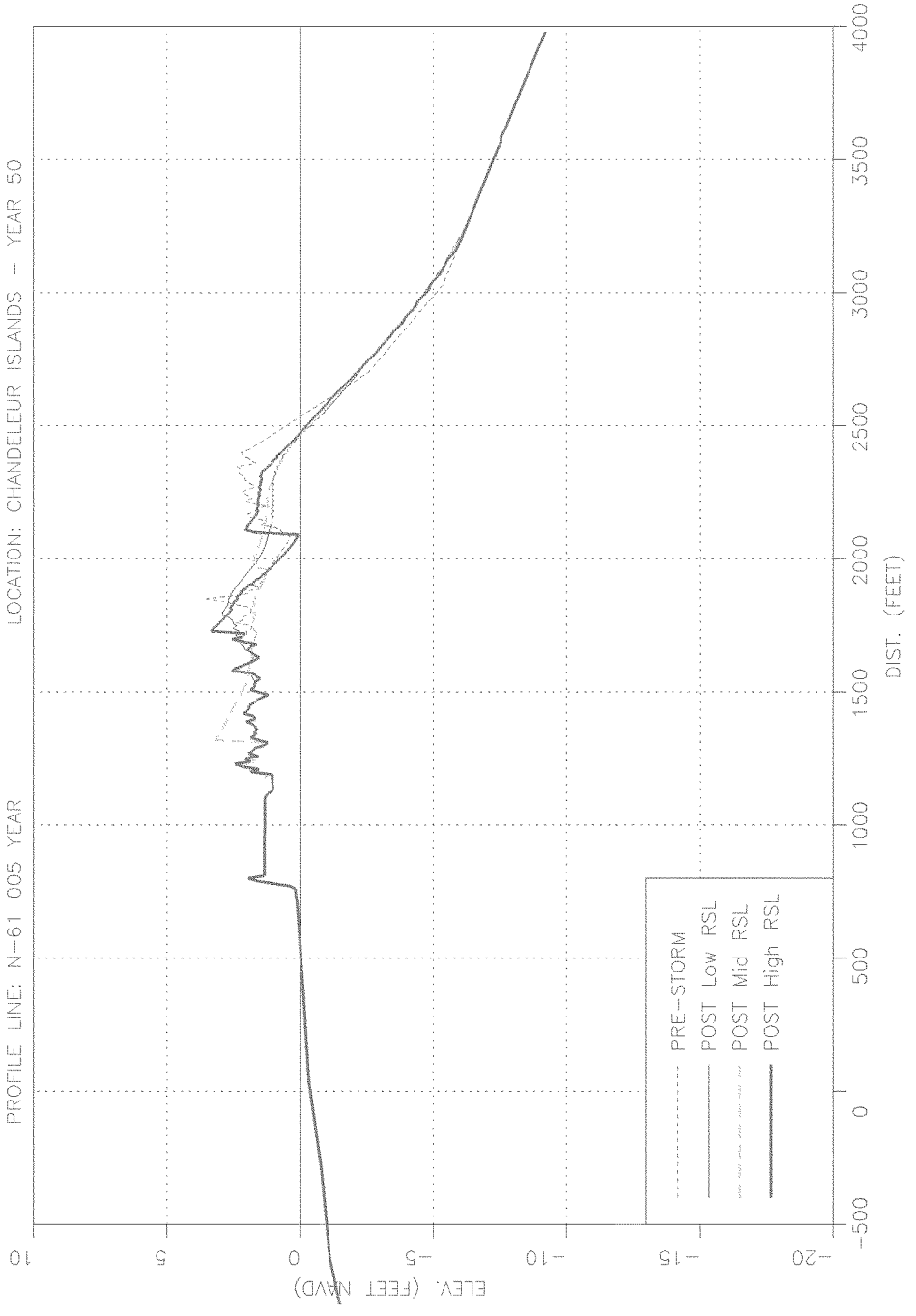

PROFILE LINE: N-59 100 YEAR
LOCATION: CHANDELEUR ISLANDS -- YEAR 50
ELEV. (FEET NAVD)
10
5
0
-5
-10
-15
-20
2500
3000
3500
4000
4500
5000
5500
6000
6500
7000
DIST. (FEET)
PRE-STORM
POST Low RSL
POST Mid RSL
POST High RSL

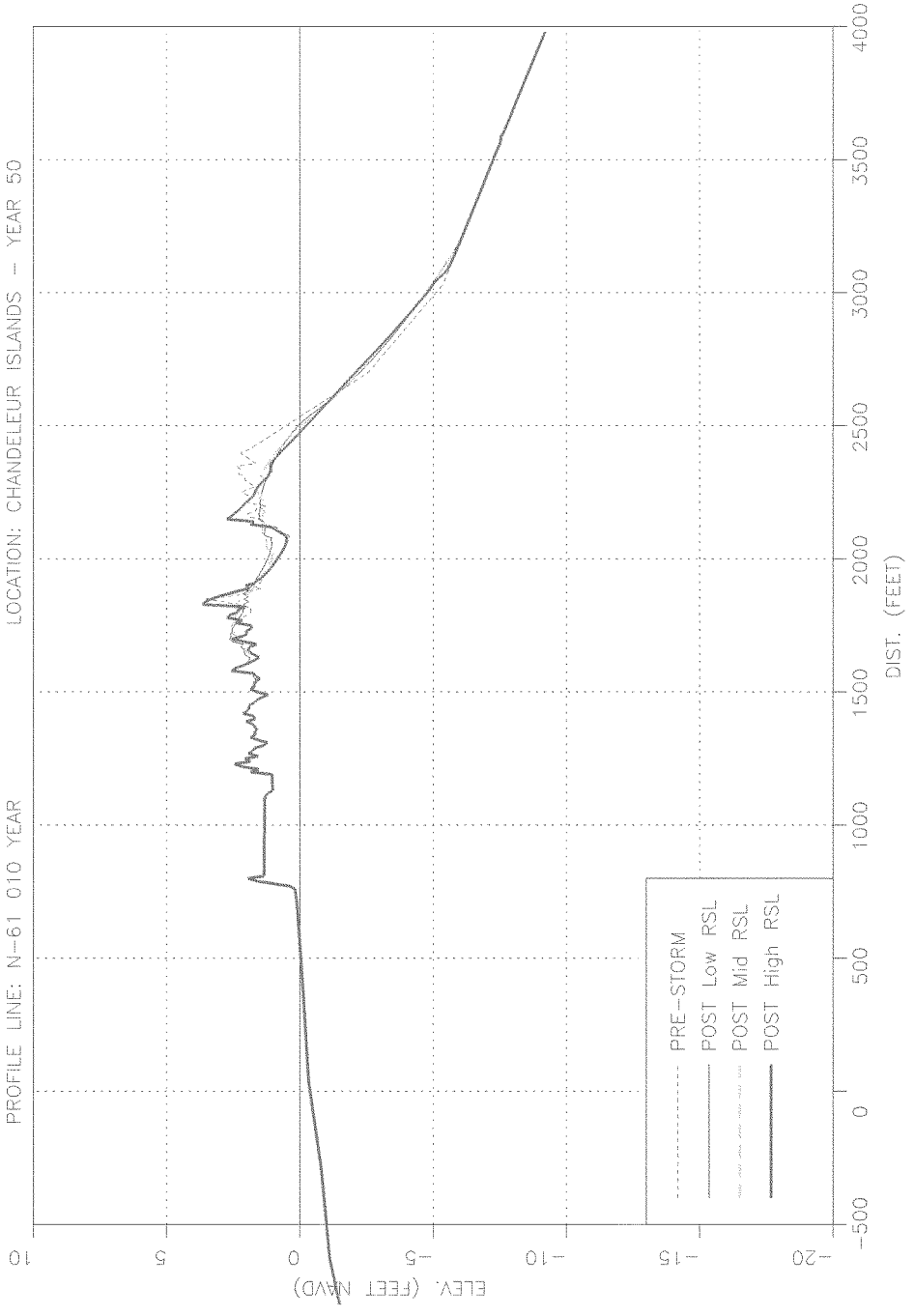

PROFILE LINE: N-61 001 YEAR
LOCATION: CHANDELEUR ISLANDS -- YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
POST Mid RSL
POST High RSL
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

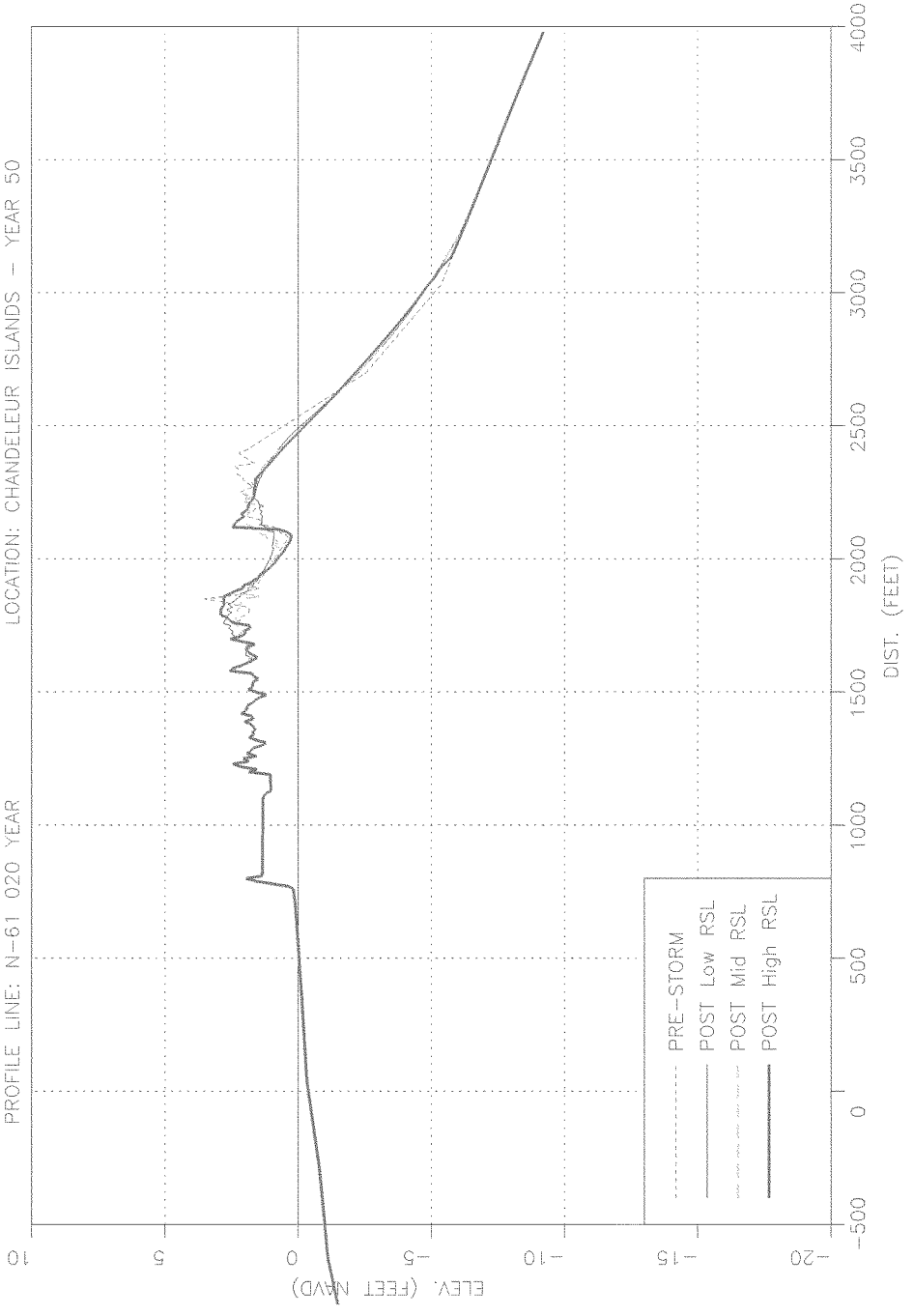

PROFILE LINE: N-61 002 YEAR
LOCATION: CHANDELEUR ISLANDS -- YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
POST Mid RSL
POST High RSL
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

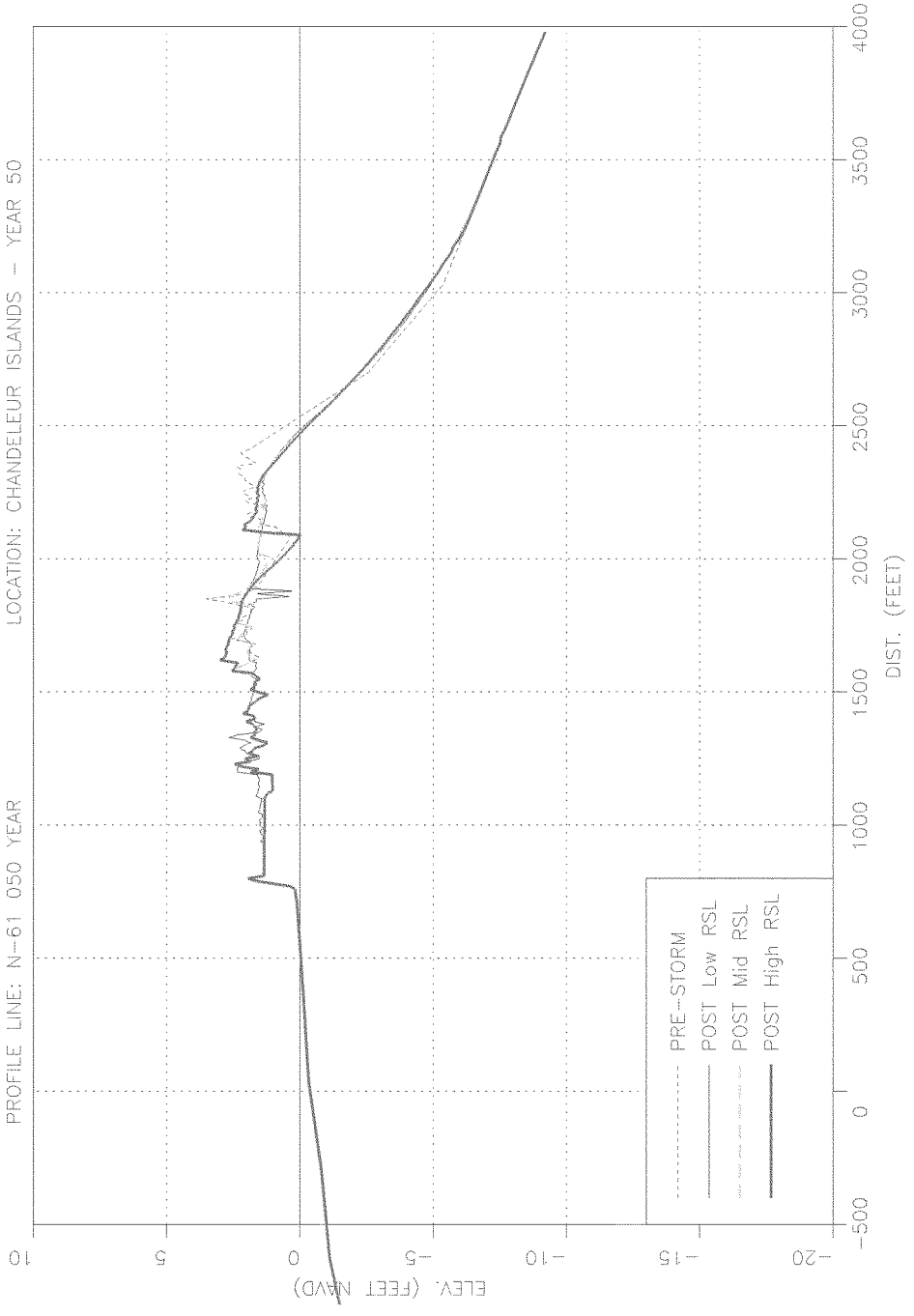

PROFILE LINE: N-61 003 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000
PRE-STORM
POST Low RSL
POST Mid RSL
POST High RSL

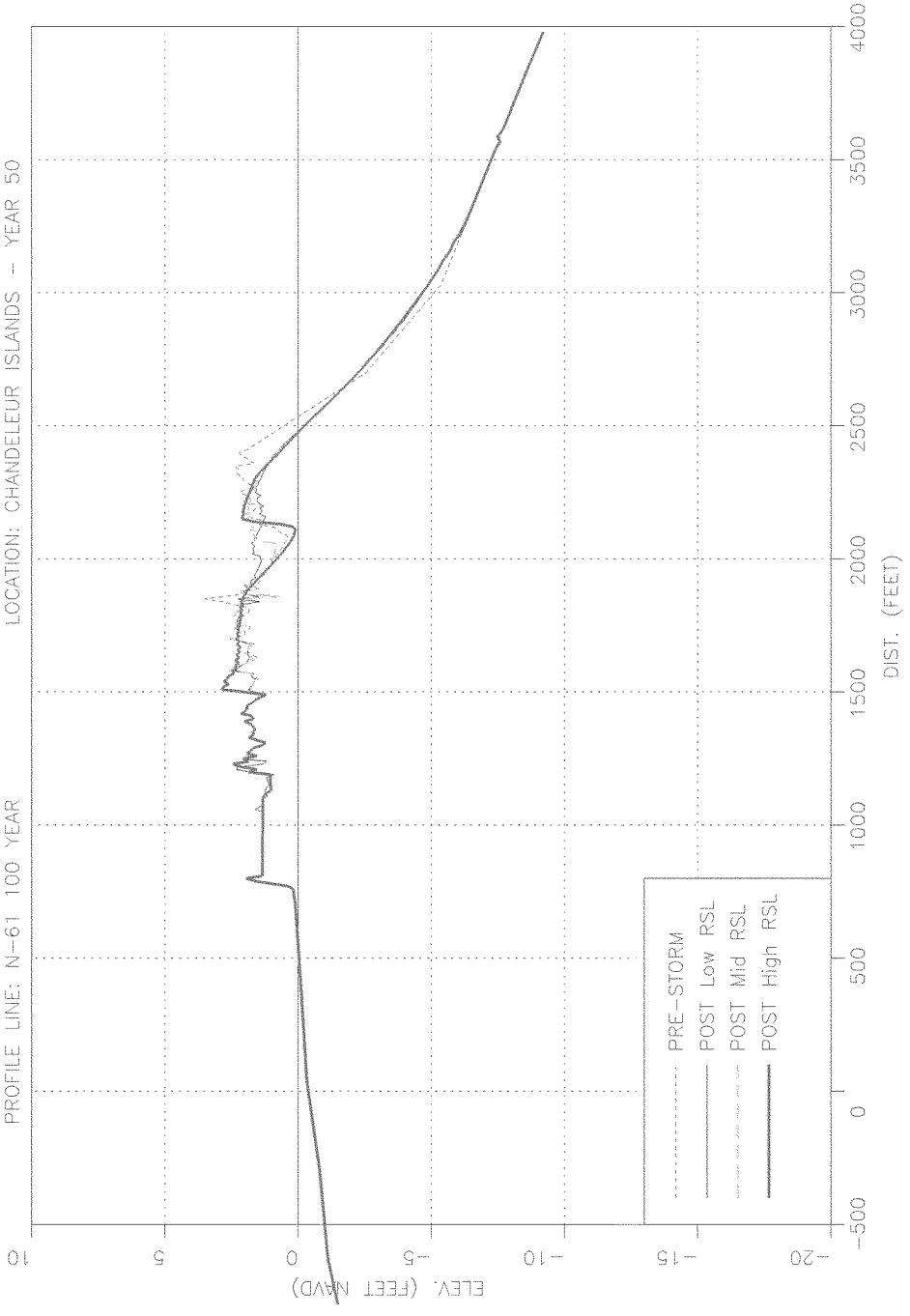

PROFILE LINE: N-61 004 YEAR
LOCATION: CHANDELEUR ISLANDS -- YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
POST Mid RSL
POST High RSL
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

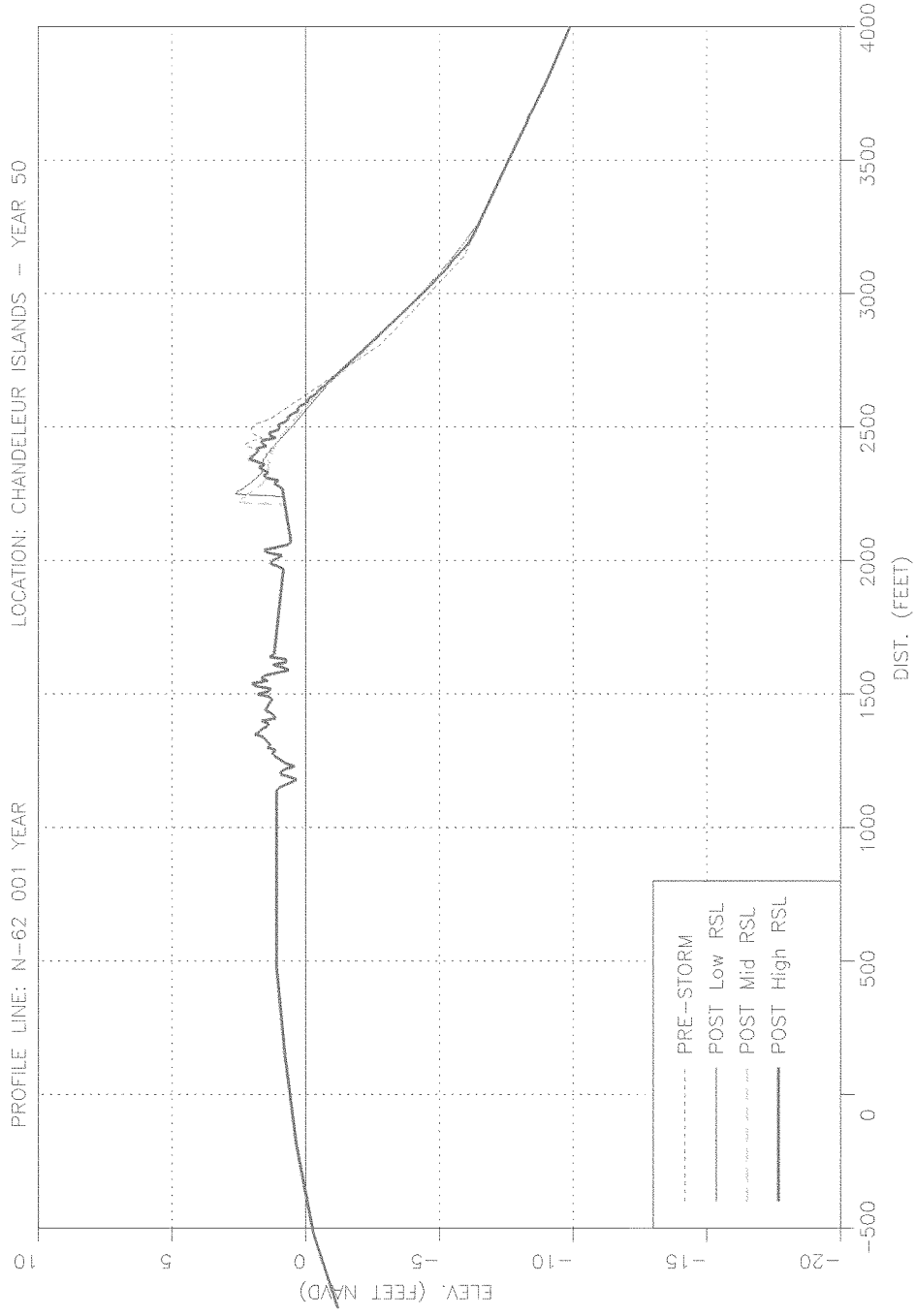

PROFILE LINE: N-61 005 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
POST Mid RSL
POST High RSL
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

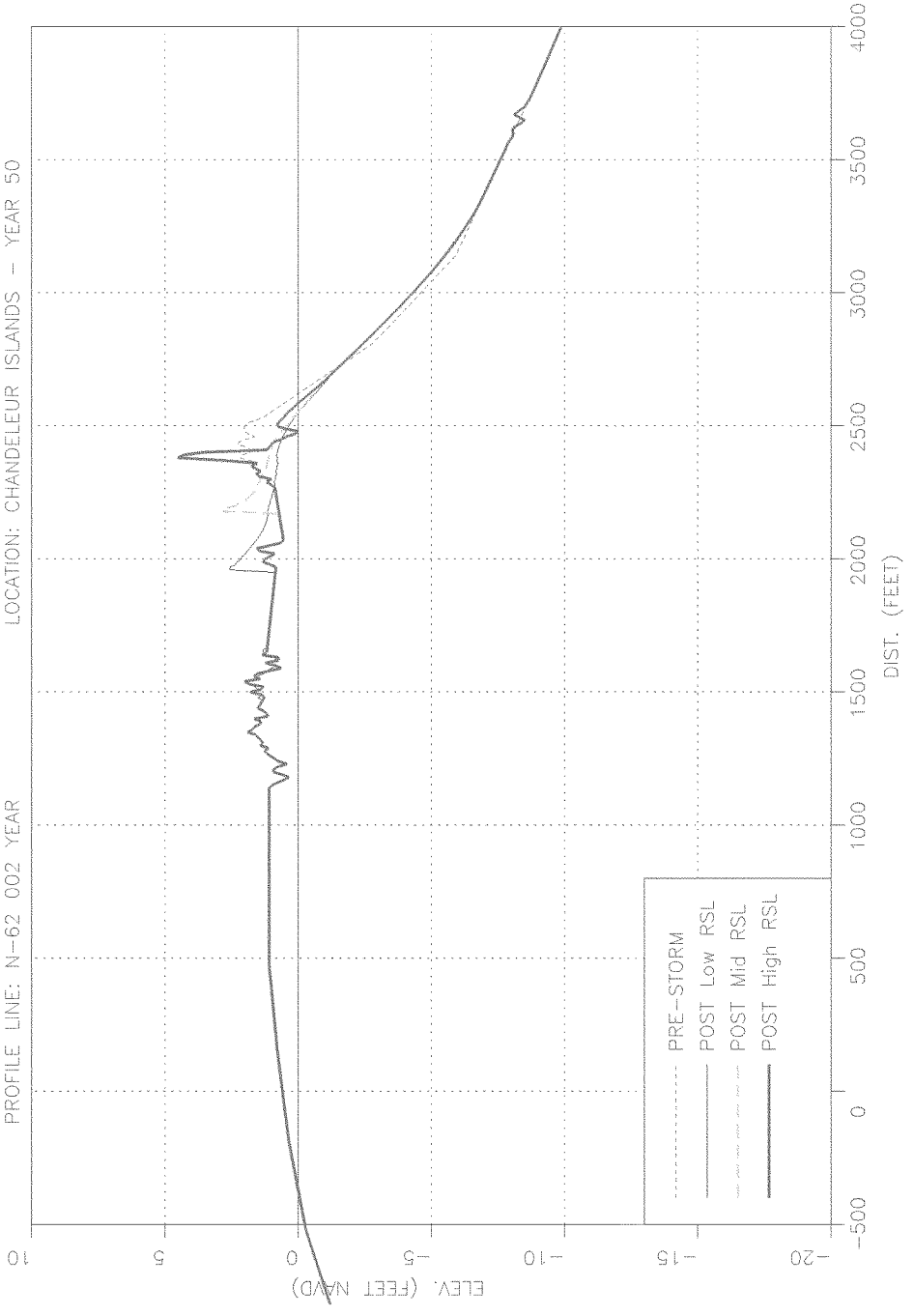

PROFILE LINE: N-61 010 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
POST Mid RSL
POST High RSL
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

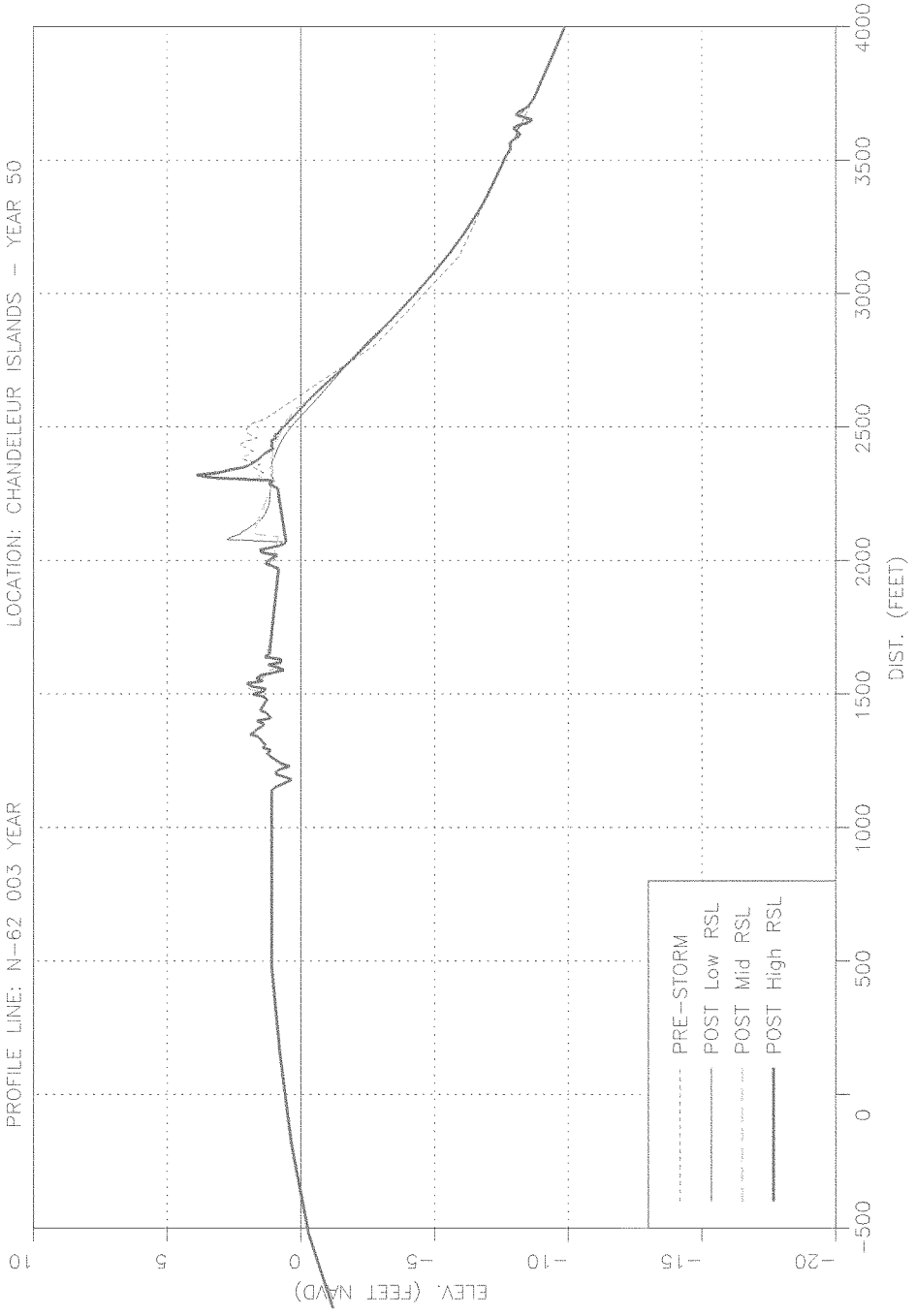

PROFILE LINE: N-61 020 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
POST Mid RSL
POST High RSL
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

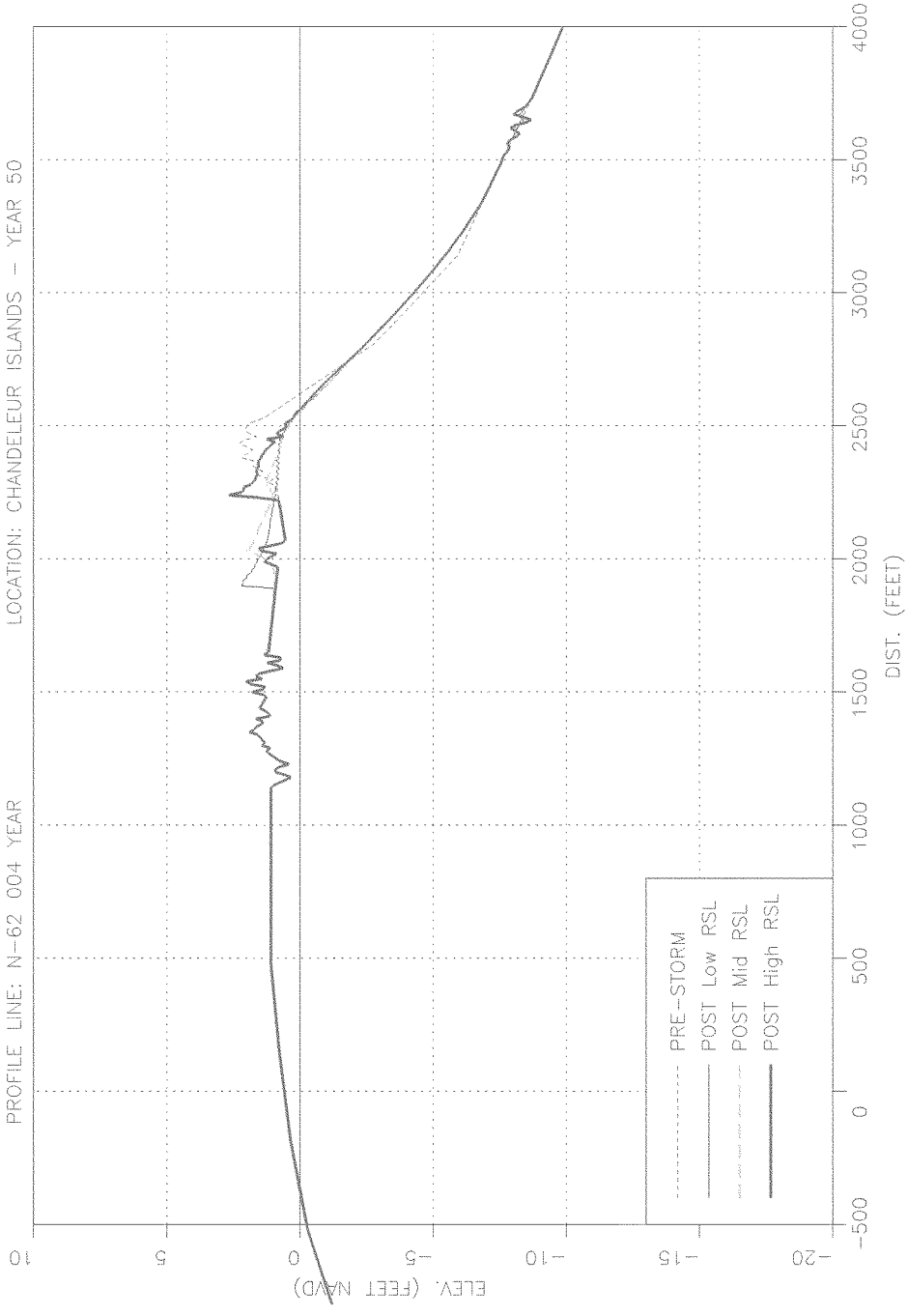

PROFILE LINE: N-61 050 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
POST Mid RSL
POST High RSL
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

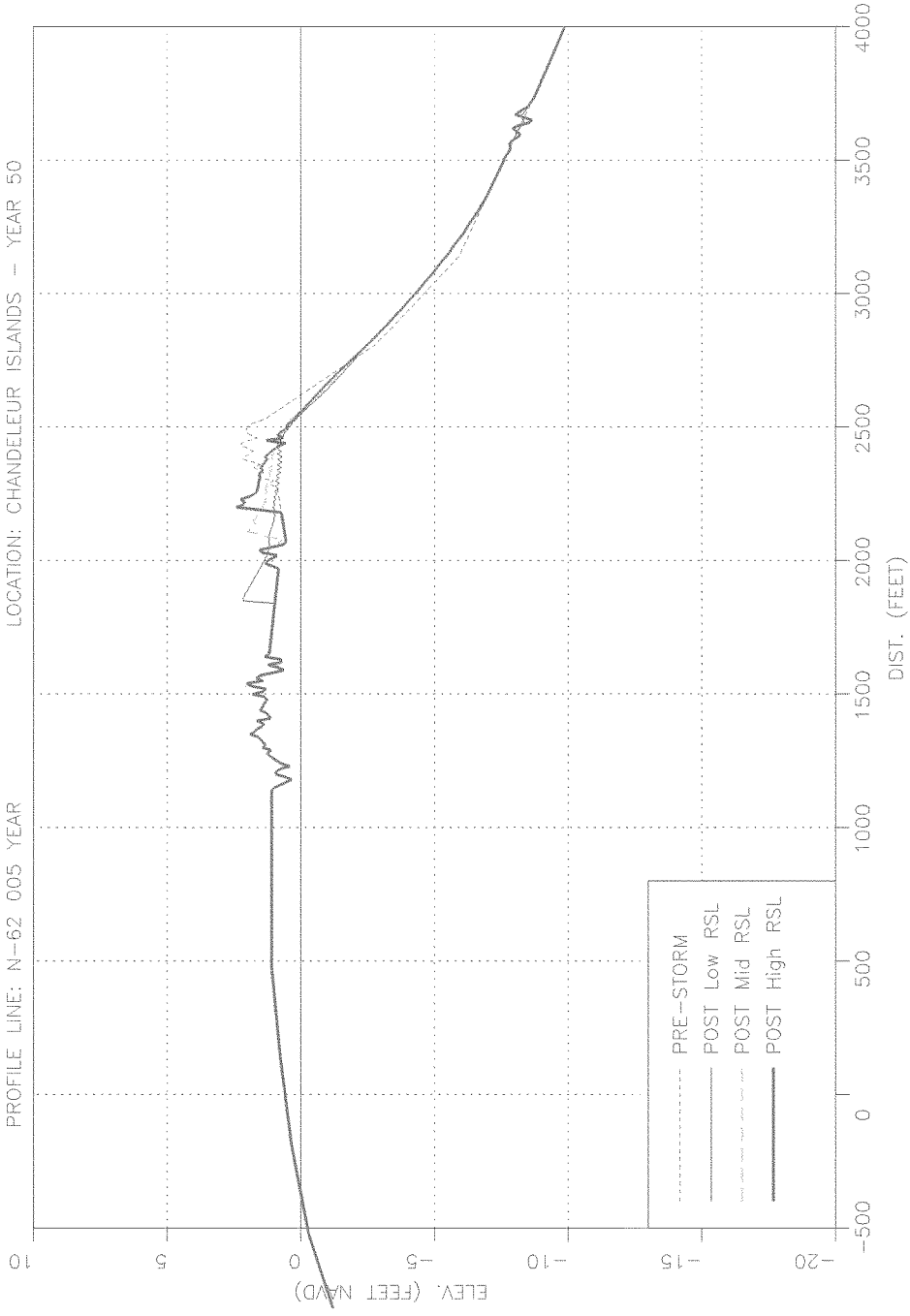

PROFILE LINE: N-61 100 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000
PRE-STORM
POST Low RSL
POST Mid RSL
POST High RSL

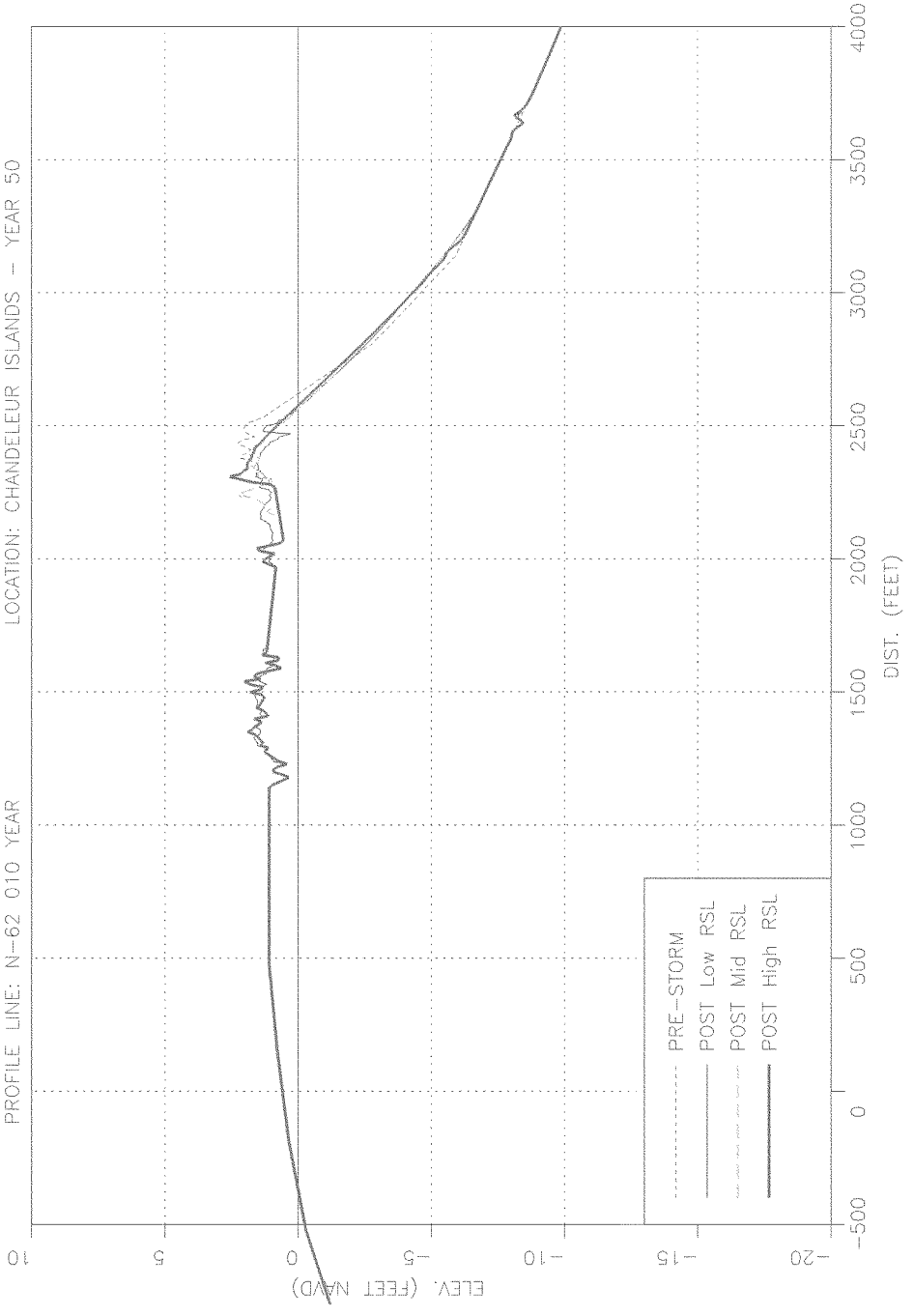

PROFILE LINE: N-62 001 YEAR
LOCATION: CHANDELEUR ISLANDS -- YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
POST Mid RSL
POST High RSL
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

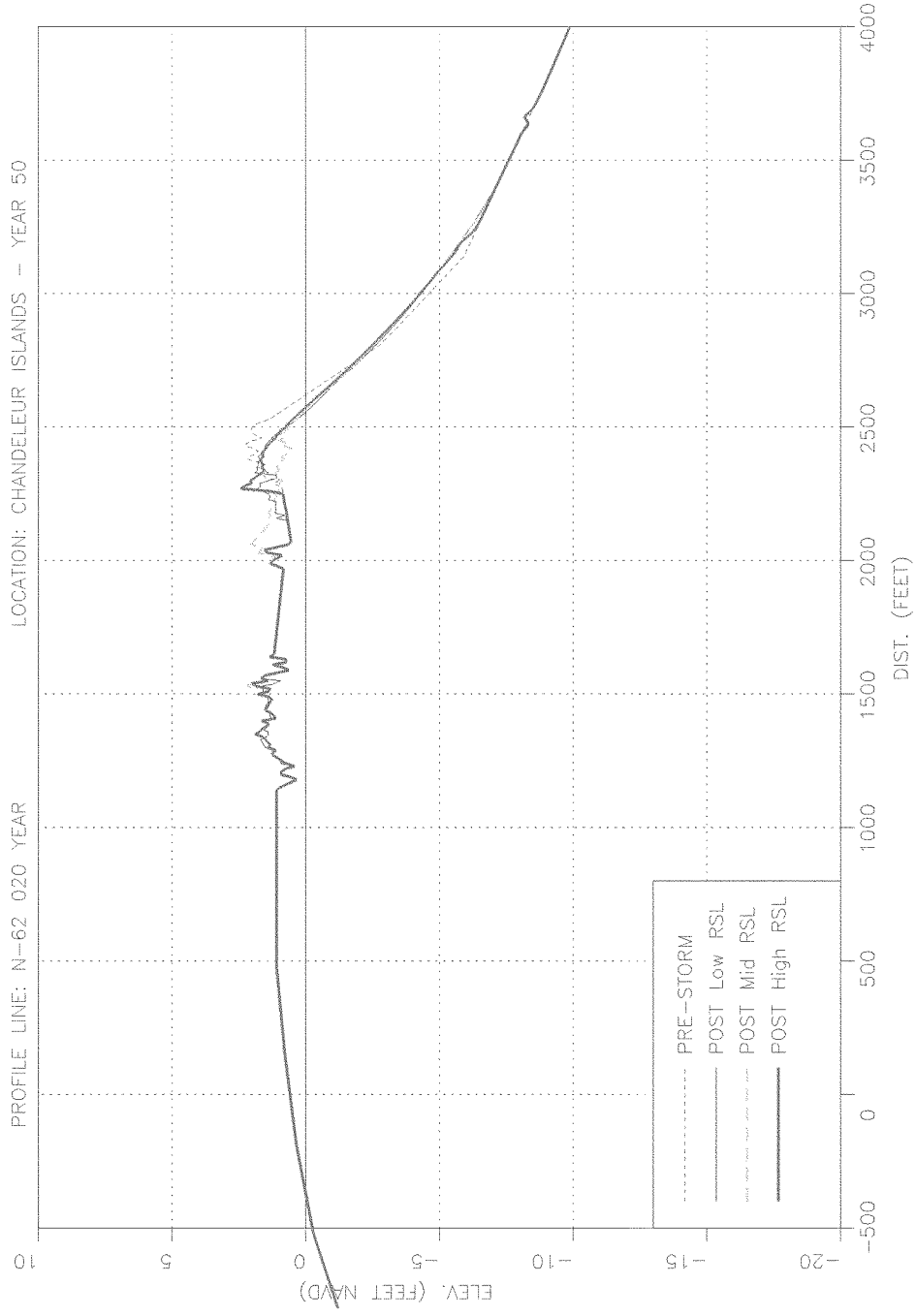

PROFILE LINE: N-62 002 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000
PRE-STORM
POST Low RSL
POST Mid RSL
POST High RSL

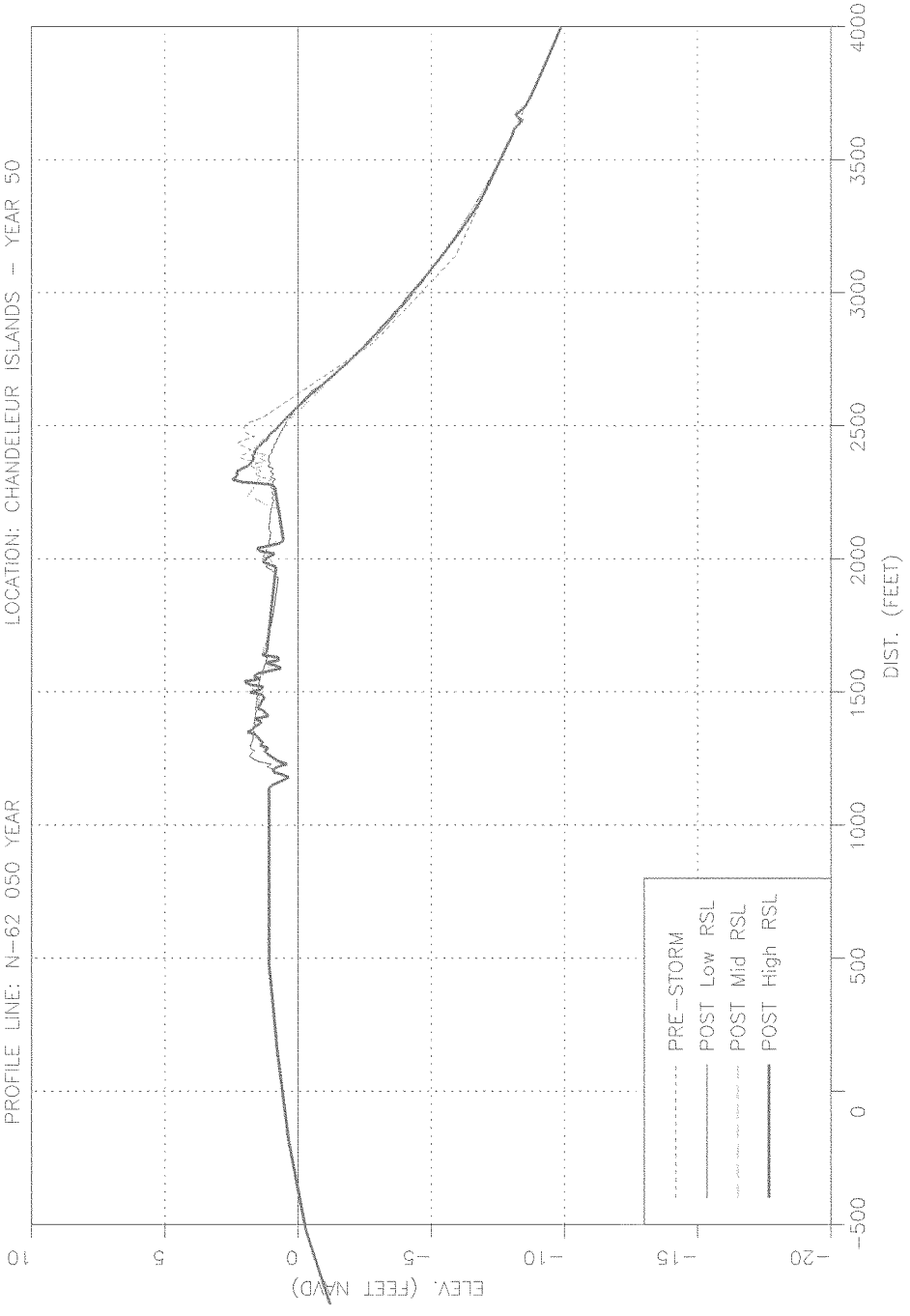

PROFILE LINE: N-62 003 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 50
PRE-STORM
POST Low RSL
POST Mid RSL
POST High RSL
ELEV. (FEET NAVD)
DIST. (FEET)
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

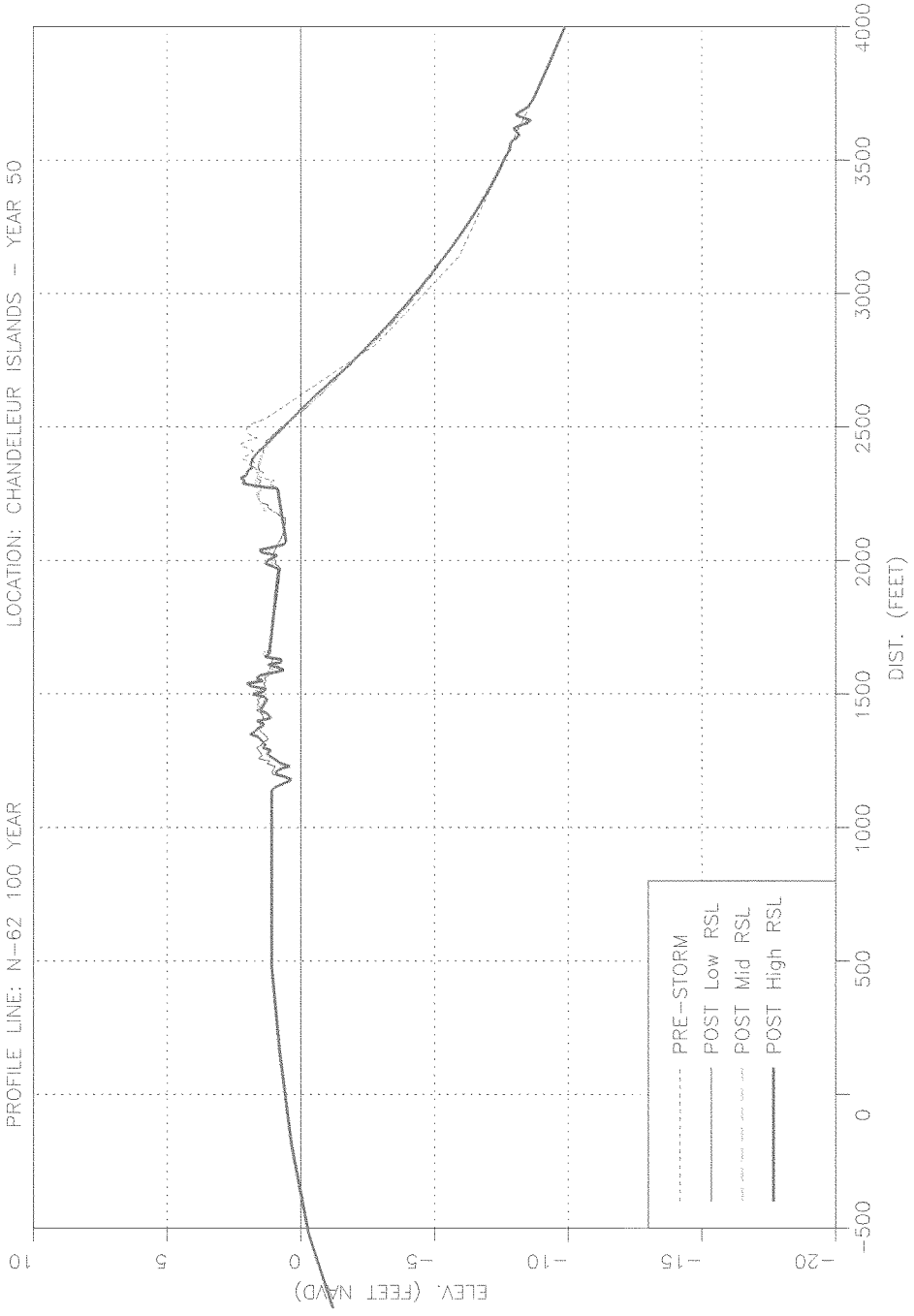

PROFILE LINE: N-62 004 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000
PRE-STORM
POST Low RSL
POST Mid RSL
POST High RSL

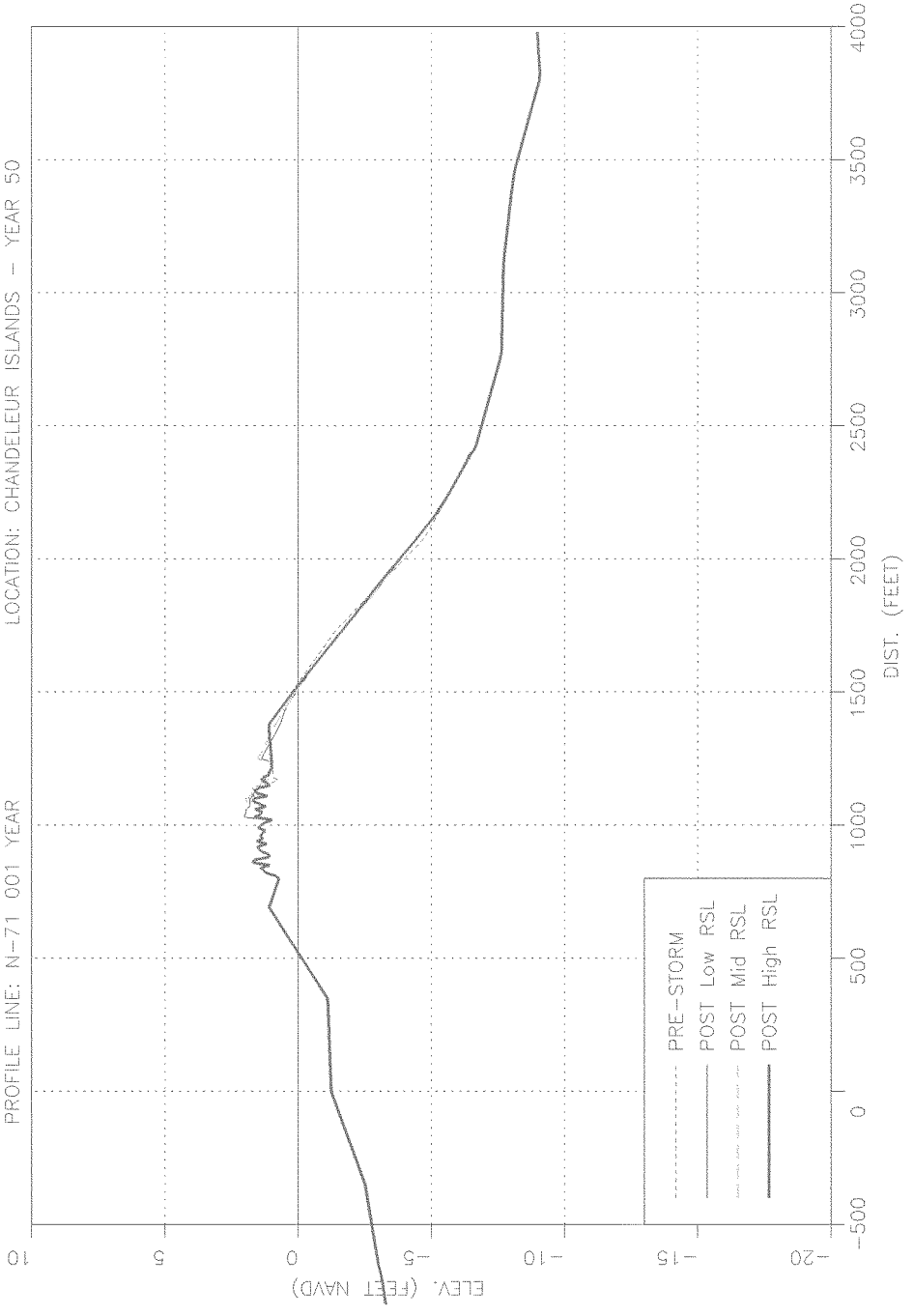

PROFILE LINE: N-62 005 YEAR
LOCATION: CHANDELEUR ISLANDS -- YEAR 50
PRE-STORM
POST Low RSL
POST Mid RSL
POST High RSL
ELEV. (FEET NAVD)
DIST. (FEET)
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

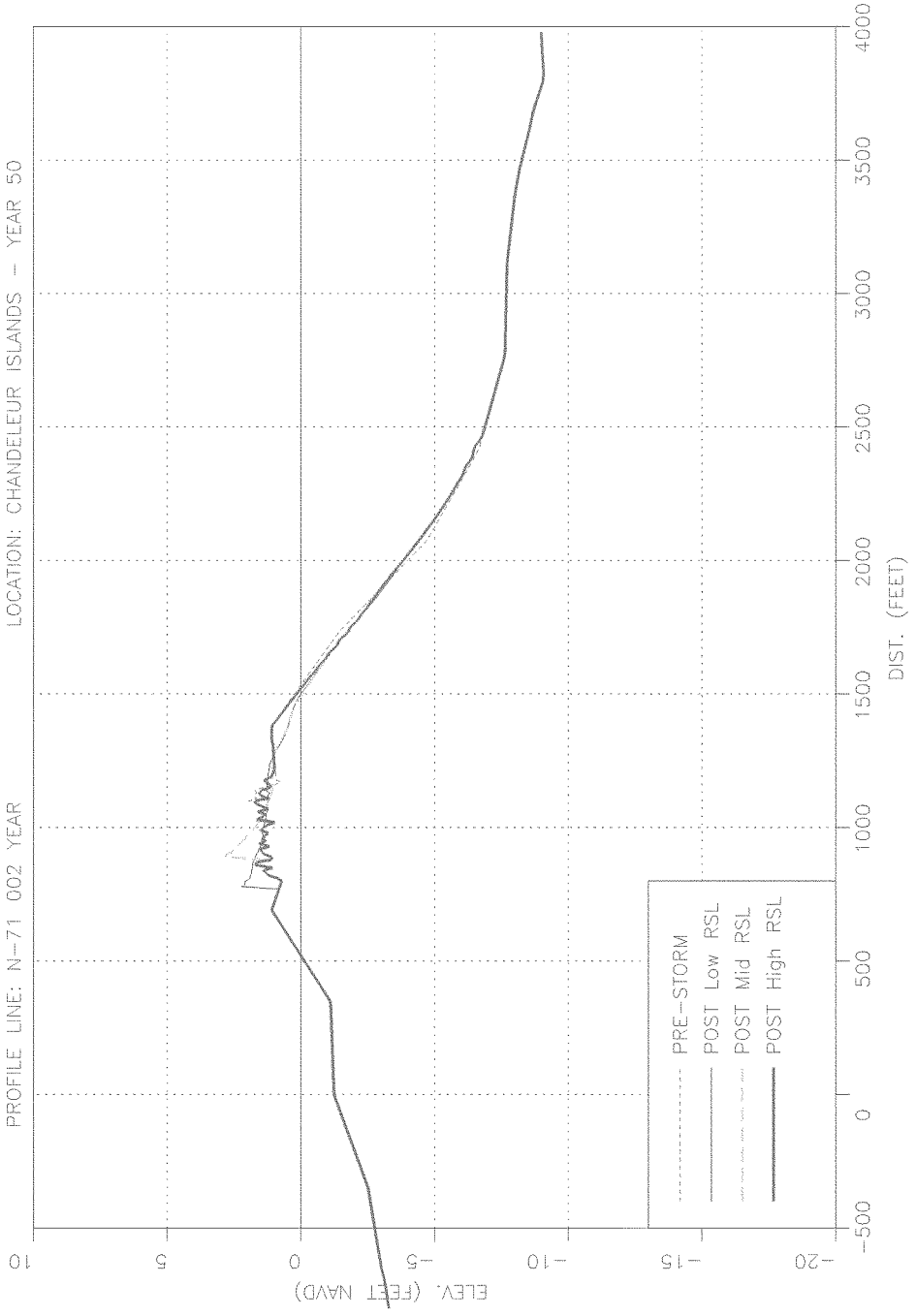

PROFILE LINE: N-62 010 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000
PRE-STORM
POST Low RSL
POST Mid RSL
POST High RSL

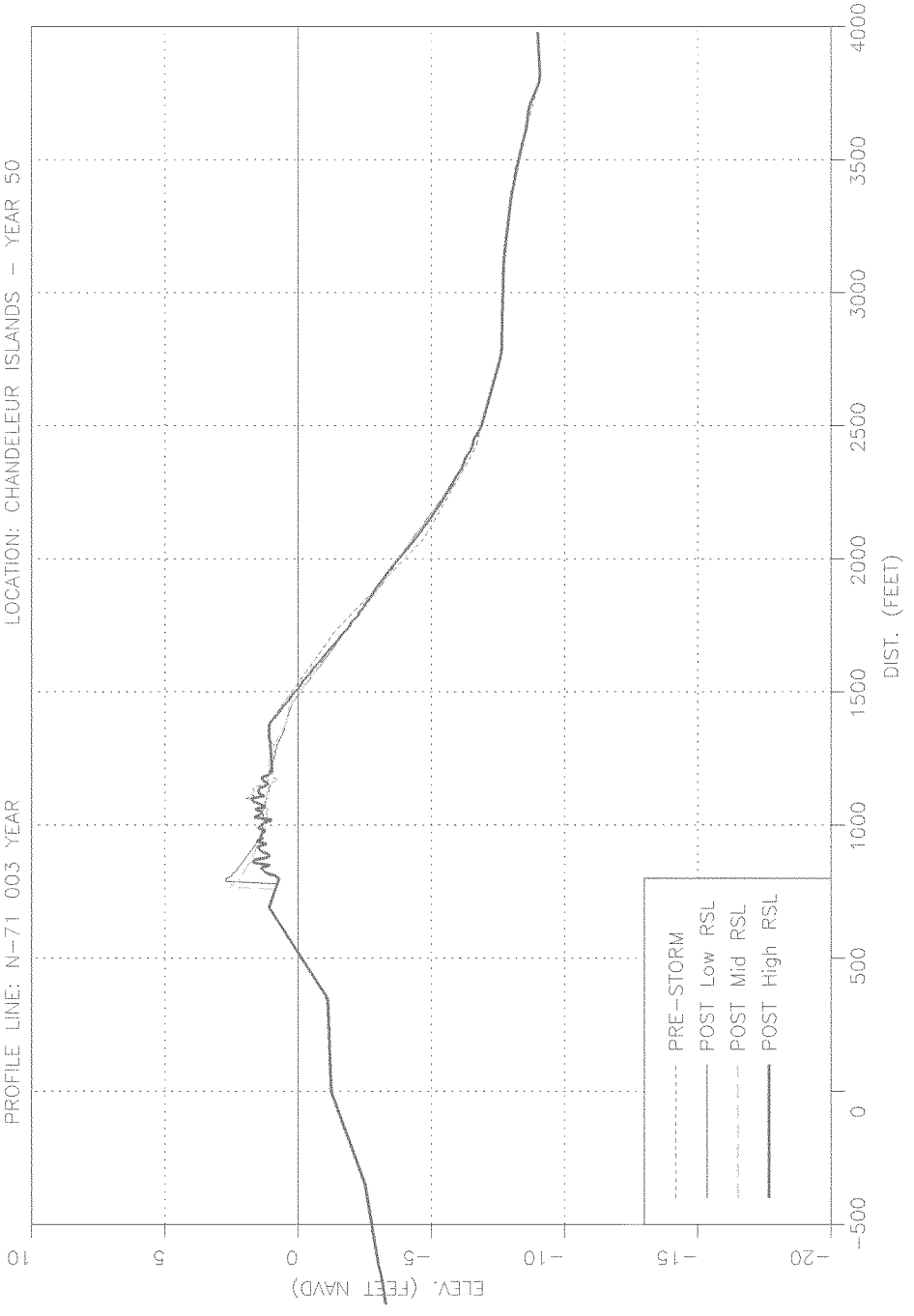

PROFILE LINE: N-62 020 YEAR
LOCATION: CHANDELEUR ISLANDS -- YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
POST Mid RSL
POST High RSL
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

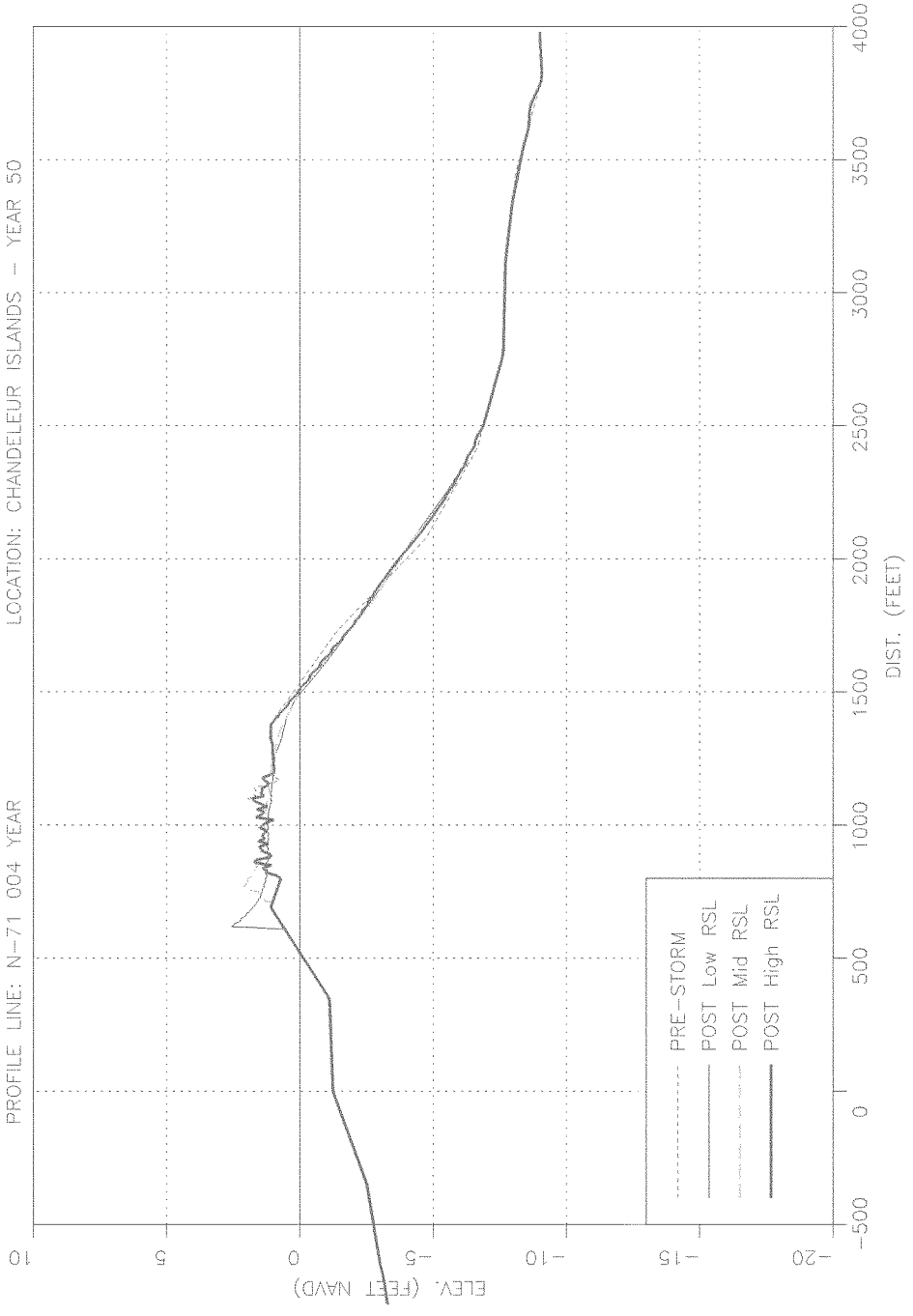

PROFILE LINE: N-62 050 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000
PRE-STORM
POST Low RSL
POST Mid RSL
POST High RSL

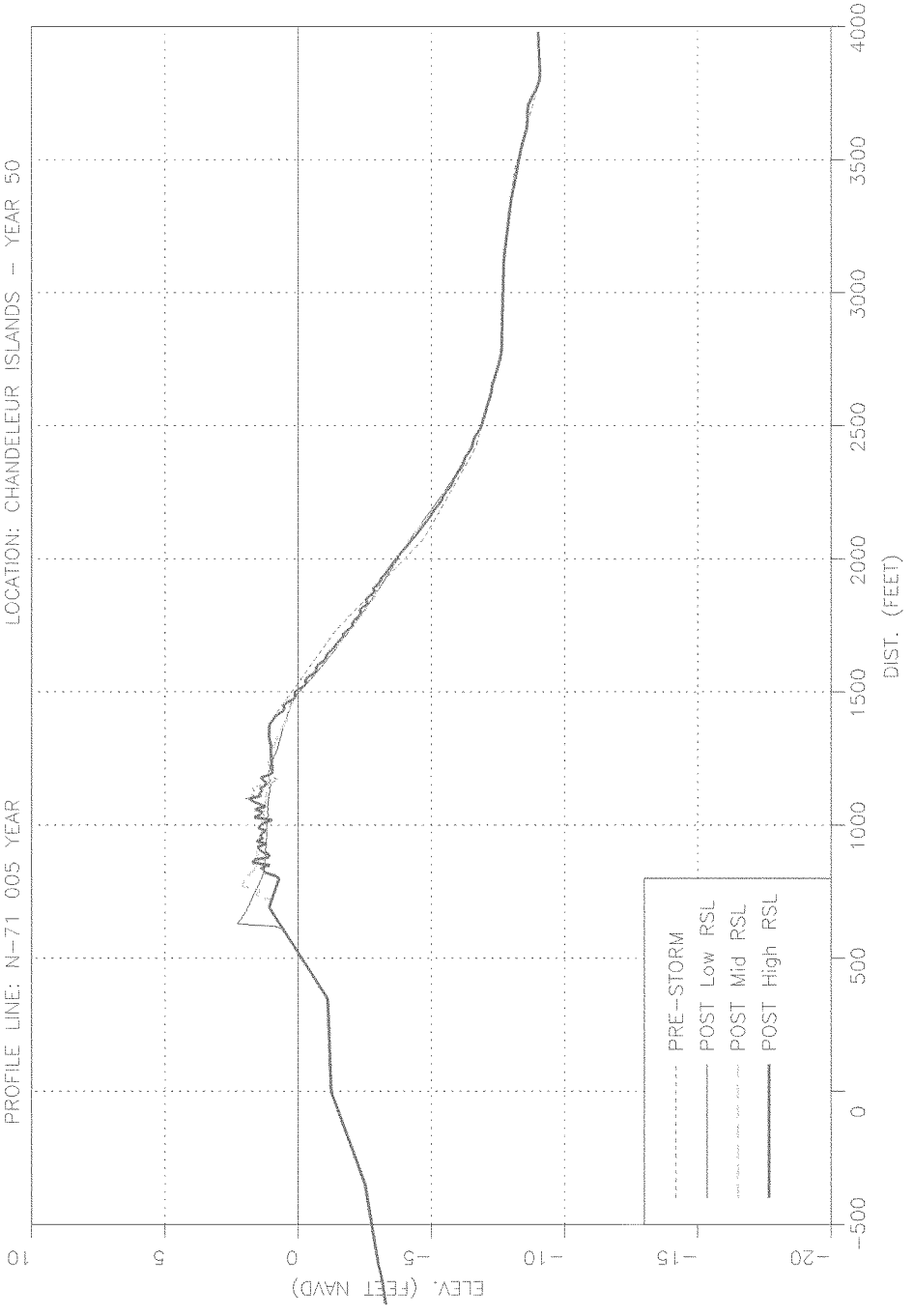

PROFILE LINE: N-62 100 YEAR
LOCATION: CHANDELEUR ISLANDS -- YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
POST Mid RSL
POST High RSL
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

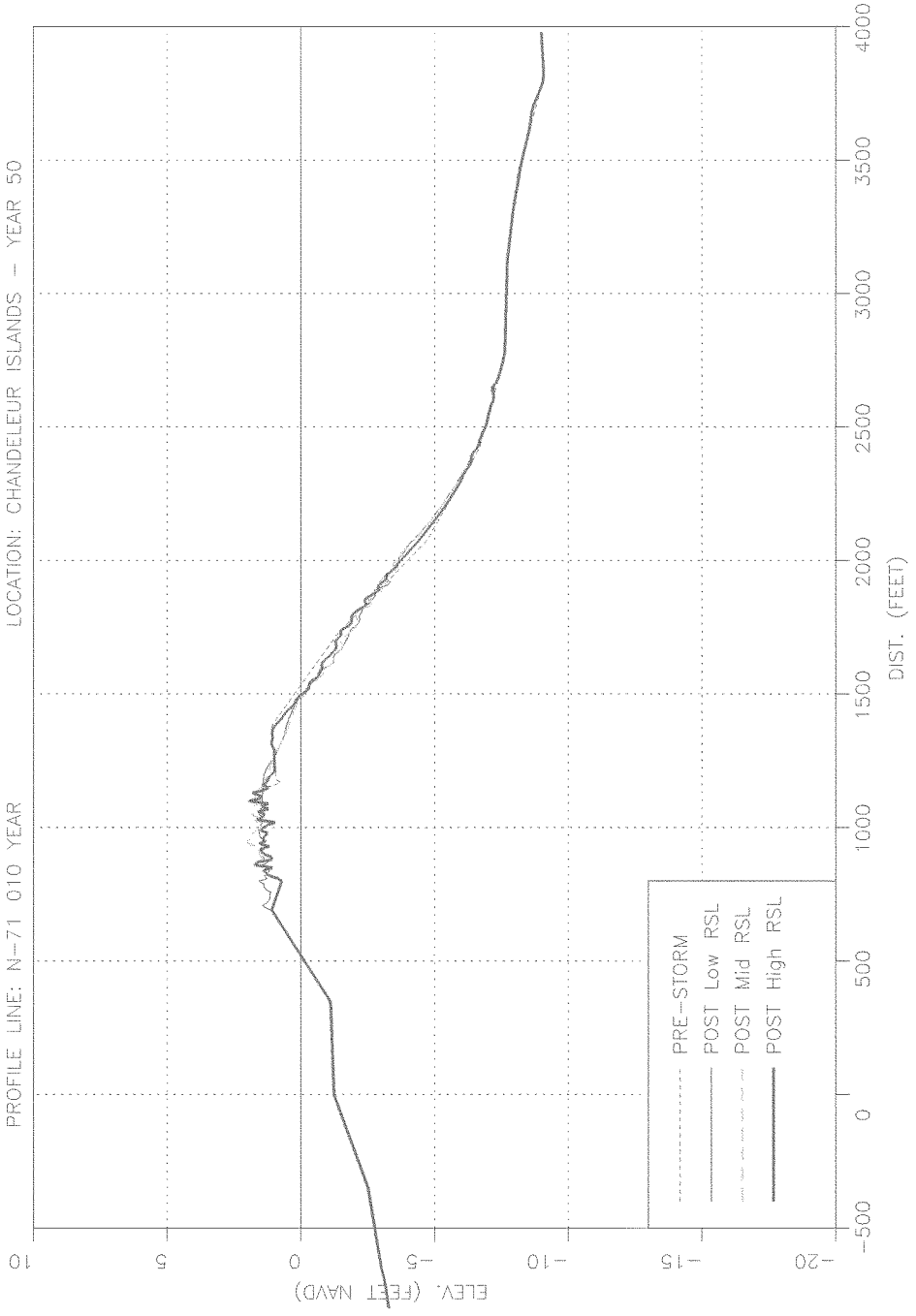

PROFILE LINE: N-71 001 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
POST Mid RSL
POST High RSL
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

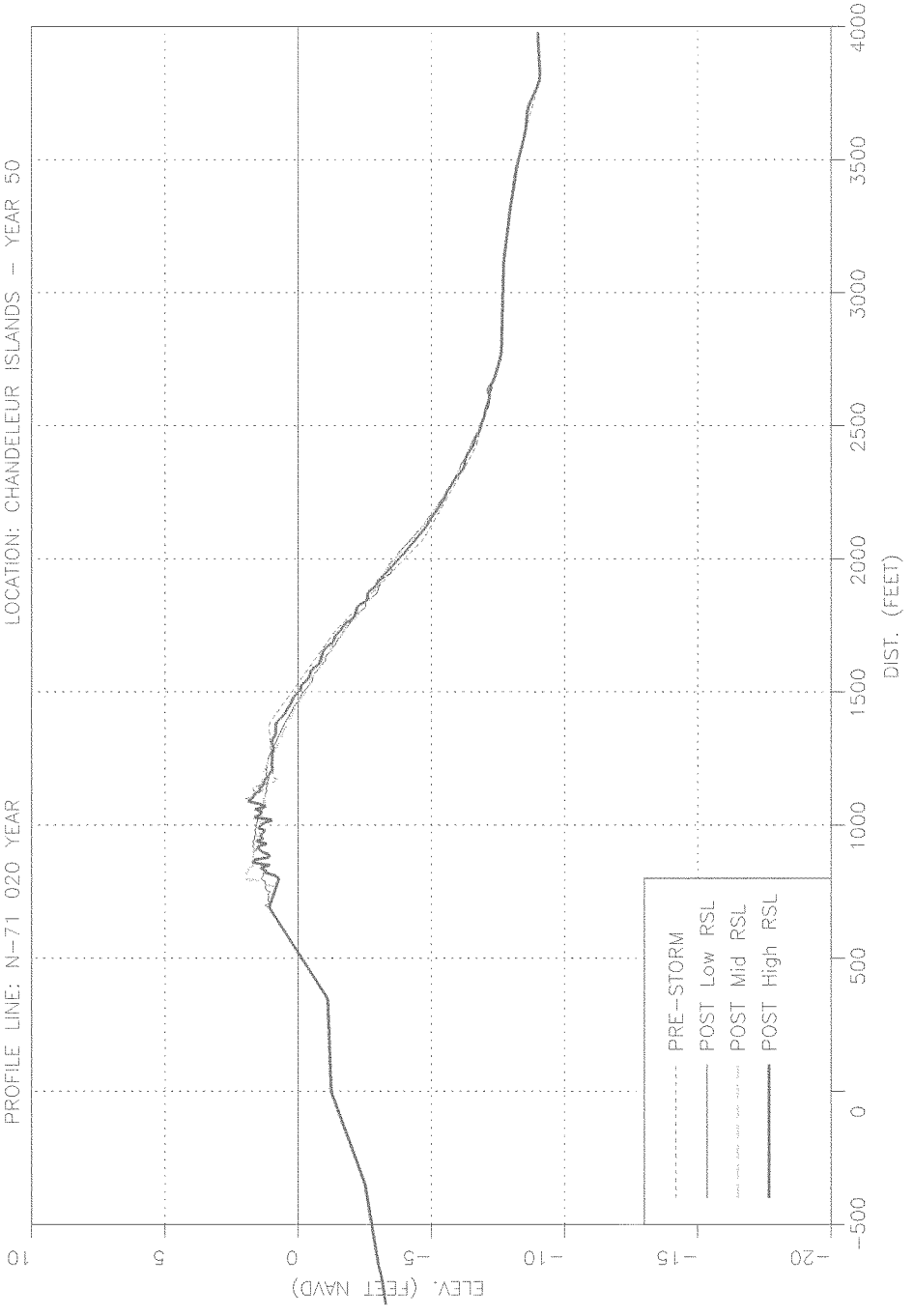

PROFILE LINE: N-71 002 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
POST Mid RSL
POST High RSL
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

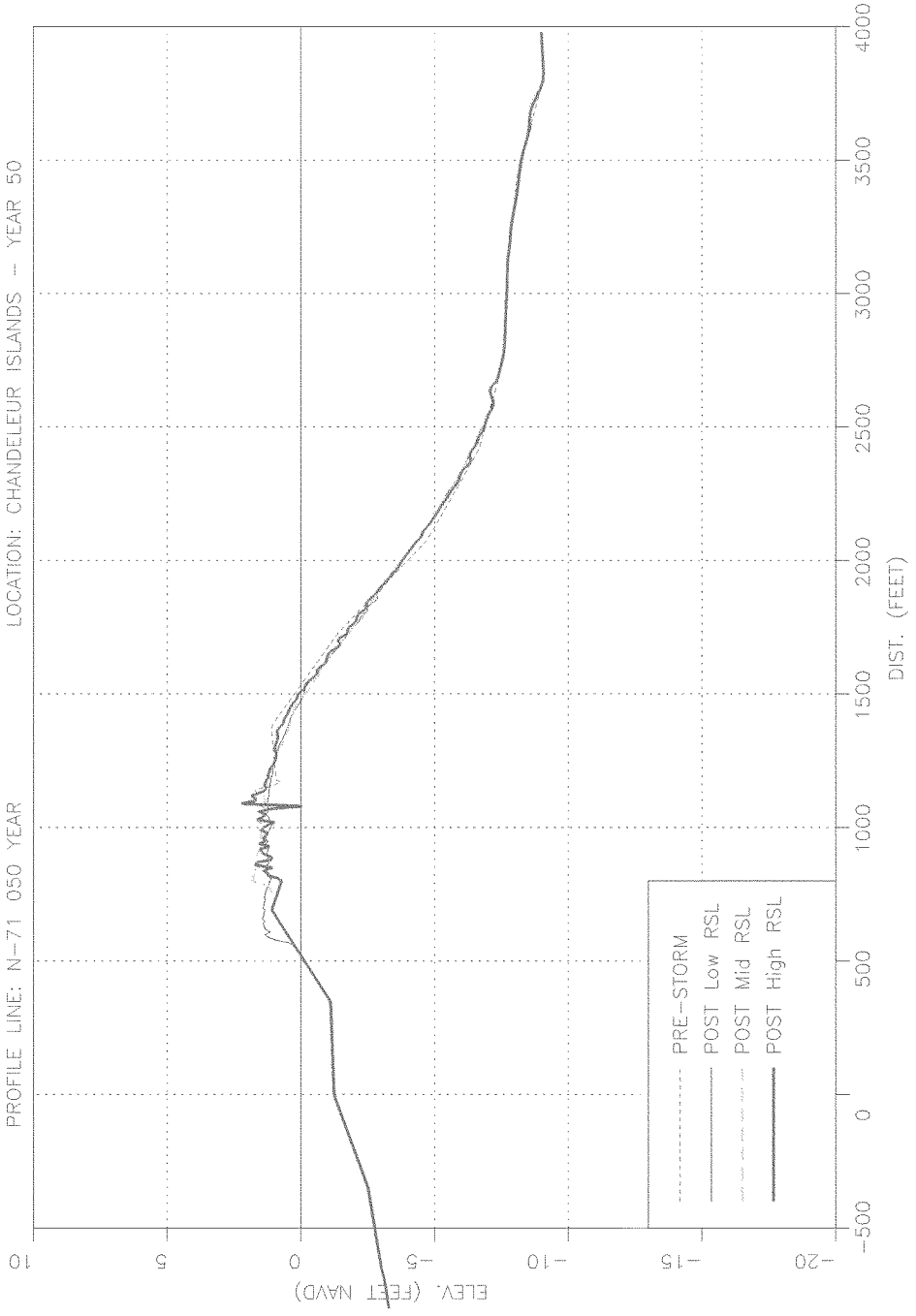

PROFILE LINE: N-71 003 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
POST Mid RSL
POST High RSL
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

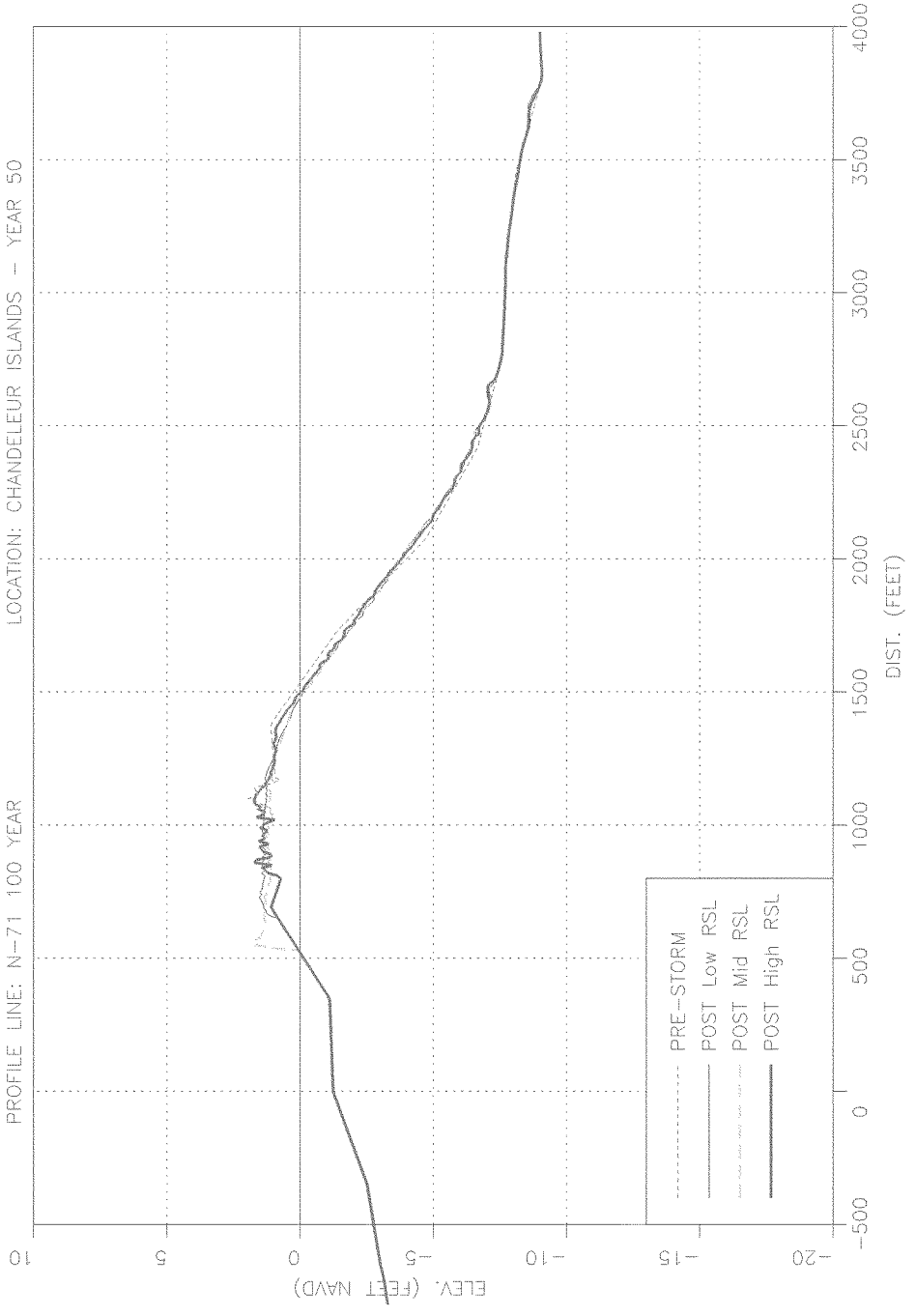

PROFILE LINE: N-71 004 YEAR
LOCATION: CHANDELEUR ISLANDS -- YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
POST Mid RSL
POST High RSL
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000


PROFILE LINE: N-71 005 YEAR
LOCATION: CHANDELEUR ISLANDS -- YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
POST Mid RSL
POST High RSL
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000


PROFILE LINE: N-71 010 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
POST Mid RSL
POST High RSL
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000


PROFILE LINE: N-71 020 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
POST Mid RSL
POST High RSL
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000


PROFILE LINE: N-71 050 YEAR
LOCATION: CHANDELEUR ISLANDS -- YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
POST Mid RSL
POST High RSL
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000


PROFILE LINE: N-71 100 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000
PRE-STORM
POST Low RSL
POST Mid RSL
POST High RSL

SUB-APPENDIX C-2

SBEACH RESULTS GIVEN THE WITH PROJECT CONDITIONS

(Profiles are presented in electronic PDF format only)

SUB-APPENDIX C-2

SBEACH RESULTS - WITH PROJECT CONDITIONS - CHANDELEUR & BRETON ISLANDS, LA

Profile	Return Period	Year 0				Year 50 Low Sea Level Rise				Year 50 Medium Sea Level Rise				Year 50 High Sea Level Rise			
		MHW Change (feet)	Vol. Change Above MHW (c.y. / foot)	Overwash (c.y. / foot)	Dune Elev. (feet NAVD)	MHW Change (feet)	Vol. Change Above MHW (c.y. / foot)	Overwash (c.y. / foot)	Dune Elev. (feet NAVD)	MHW Change (feet)	Vol. Change Above MHW (c.y. / foot)	Overwash (c.y. / foot)	Dune Elev. (feet NAVD)	MHW Change (feet)	Volume Change Above MHW (c.y. / foot)	Overwash (c.y. / foot)	Dune Elev. (feet NAVD)
BRETON ISLAND - ALTERNATIVE 1:																	
S-11	001_YEAR	-75	-8.0	0.0	4.0	-87	-8.2	1.9	4.4	-81	-8.4	2.3	4.4	-35	-8.1	0.4	4.6
S-11	002_YEAR	-81	-8.8	0.0	4.0	-100	-9.1	2.8	4.5	-92	-10.0	2.7	4.5	-49	-10.3	0.2	4.4
S-11	003_YEAR	-91	-8.8	2.0	5.0	-107	-10.1	2.9	4.4	-106	-10.2	4.5	3.5	-64	-11.3	0.5	4.5
S-11	004_YEAR	-92	-9.1	2.0	5.1	-109	-10.0	6.0	4.3	-118	-10.3	4.1	3.9	-94	-11.1	1.9	4.8
S-11	005_YEAR	-95	-9.3	2.6	5.1	-111	-10.6	7.0	4.3	-117	-10.6	8.5	4.1	-100	-11.9	2.6	4.7
S-11	010_YEAR	-68	-8.0	2.6	4.2	-90	-7.8	5.7	3.7	-86	-9.0	5.6	3.6	-83	-10.4	4.2	3.5
S-11	020_YEAR	-63	-10.7	5.3	4.3	-101	-9.8	4.7	4.2	-91	-10.7	6.6	4.5	-61	-12.7	0.9	3.7
S-11	050_YEAR	-62	-11.2	5.0	4.4	-76	-12.4	3.7	4.0	-80	-13.2	6.9	3.9	-87	-13.4	0.5	3.6
S-11	100_YEAR	-72	-12.5	5.8	4.2	-83	-13.5	6.4	3.8	-92	-13.9	7.9	3.5	-100	-15.1	2.3	3.5
BRETON ISLAND - ALTERNATIVE 2:																	
S-11	001_YEAR	-78	-7.8	0.0	6.0	-80	-9.1	0.0	5.5	-70	-10.4	0.0	5.5	0	-12.5	0.0	5.5
S-11	002_YEAR	-83	-8.7	0.0	6.0	-89	-10.3	0.0	5.5	-86	-12.2	0.0	5.5	-23	-15.5	0.0	5.5
S-11	003_YEAR	-84	-9.3	0.0	6.0	-94	-11.2	0.1	5.7	-94	-12.9	0.2	6.2	-42	-17.3	2.7	6.6
S-11	004_YEAR	-88	-9.6	0.0	6.1	-93	-11.5	0.0	5.5	-97	-13.2	0.7	6.3	-56	-17.9	3.8	6.8
S-11	005_YEAR	-85	-10.0	0.0	6.3	-96	-11.8	0.0	5.5	-97	-13.9	0.3	5.9	-65	-18.6	4.1	6.7
S-11	010_YEAR	-50	-8.6	0.1	6.5	-63	-10.1	6.9	5.5	-65	-11.0	3.9	5.8	-54	-12.6	7.8	5.6
S-11	020_YEAR	-42	-12.0	5.2	6.3	-56	-14.9	12.7	5.5	-59	-15.5	11.4	5.5	-29	-15.5	4.5	6.2
S-11	050_YEAR	-55	-13.4	7.5	6.2	-56	-21.1	16.4	5.6	-50	-22.0	16.5	5.5	-31	-19.6	8.2	5.9
S-11	100_YEAR	-59	-19.2	12.6	5.8	-66	-22.8	17.1	5.4	-67	-22.6	12.2	5.6	-46	-22.8	8.9	5.7
BRETON ISLAND - ALTERNATIVE 3:																	
S-11	001_YEAR	-76	-7.8	0.0	10.0	-79	-9.2	0.0	9.5	-69	-10.6	0.0	9.5	1	-12.9	0.0	9.5
S-11	002_YEAR	-80	-8.6	0.0	10.0	-88	-10.4	0.0	9.5	-85	-12.1	0.0	9.5	-19	-16.0	0.0	9.5
S-11	003_YEAR	-82	-9.2	0.0	10.0	-94	-10.8	0.0	9.5	-95	-12.6	0.0	9.5	-31	-17.6	0.0	9.5
S-11	004_YEAR	-83	-9.5	0.0	10.0	-92	-11.5	0.0	9.5	-93	-13.5	0.0	9.5	-41	-18.8	0.0	9.5
S-11	005_YEAR	-83	-9.9	0.0	10.0	-93	-11.8	0.0	9.5	-95	-13.6	0.0	9.5	-55	-19.6	0.0	9.5
S-11	010_YEAR	-53	-9.4	0.0	10.2	-62	-10.6	0.2	10.0	-64	-11.8	0.3	10.1	-41	-13.9	0.2	9.8
S-11	020_YEAR	-50	-12.6	0.2	10.5	-57	-14.1	0.1	9.9	-52	-15.3	0.3	9.8	-17	-18.3	2.1	9.7
S-11	050_YEAR	-42	-13.7	1.9	10.3	-29	-17.0	7.8	9.8	-30	-18.0	4.0	9.7	-2	-20.9	2.6	9.9
S-11	100_YEAR	-31	-15.4	3.3	10.2	-45	-16.8	2.5	9.8	-43	-18.5	6.9	10.2	-24	-21.6	8.6	10.2

SUB-APPENDIX C-2

SBEACH RESULTS - WITH PROJECT CONDITIONS - CHANDELEUR & BRETON ISLANDS, LA

Profile	Return Period	Year 0				Year 50 Low Sea Level Rise				Year 50 Medium Sea Level Rise				Year 50 High Sea Level Rise			
		MHW Change (feet)	Vol. Change Above MHW (c.y. / foot)	Overwash (c.y. / foot)	Dune Elev. (feet NAVD)	MHW Change (feet)	Vol. Change Above MHW (c.y. / foot)	Overwash (c.y. / foot)	Dune Elev. (feet NAVD)	MHW Change (feet)	Vol. Change Above MHW (c.y. / foot)	Overwash (c.y. / foot)	Dune Elev. (feet NAVD)	MHW Change (feet)	Volume Change Above MHW (c.y. / foot)	Overwash (c.y. / foot)	Dune Elev. (feet NAVD)
CHANDELEUR ISLANDS SOUTH REACH:																	
N-31	001_YEAR	-82	-5.9	2.9	3.9	-105	-6.0	1.7	3.2	-102	-5.9	1.7	3.4	-64	-6.1	0.0	2.5
N-31	002_YEAR	-79	-5.9	9.4	3.5	-117	-5.6	7.1	2.9	-116	-5.9	3.7	3.2	-81	-6.4	0.1	2.5
N-31	003_YEAR	-104	-4.3	11.9	3.4	-115	-5.3	7.4	3.1	-102	-5.5	6.1	2.6	-99	-6.3	0.1	2.5
N-31	004_YEAR	-81	-5.8	9.8	2.7	-100	-5.7	3.1	3.0	-119	-5.2	7.0	3.4	-116	-5.6	0.3	3.8
N-31	005_YEAR	-90	-5.5	16.1	3.1	-99	-6.1	4.6	3.2	-120	-5.1	8.8	3.3	-113	-5.0	0.4	3.1
N-31	010_YEAR	-56	-4.4	11.1	3.0	-89	-4.5	5.0	2.8	-92	-5.2	5.2	2.8	-52	-6.1	1.2	3.0
N-31	020_YEAR	-60	-5.1	9.0	3.3	-103	-5.8	12.7	2.8	-102	-6.0	7.5	2.6	-91	-5.8	1.3	3.0
N-31	050_YEAR	-71	-6.0	6.1	3.4	-93	-6.9	6.9	2.8	-98	-6.3	4.8	2.5	-114	-6.2	1.4	2.8
N-31	100_YEAR	-71	-7.0	11.0	3.6	-98	-6.3	4.3	2.8	-110	-6.3	7.4	2.4	-130	-6.1	0.8	2.9
N-32	001_YEAR	-88	-6.0	1.6	2.8	-114	-5.8	2.7	2.8	-108	-6.3	1.6	3.3	-65	-6.3	0.0	2.5
N-32	002_YEAR	-121	-4.2	2.2	2.5	-116	-7.3	2.4	2.9	-133	-7.2	0.4	3.2	-54	-6.7	0.1	2.5
N-32	003_YEAR	-105	-4.8	12.7	3.0	-131	-6.6	8.6	2.9	-121	-7.1	0.4	2.7	-102	-6.6	0.1	2.5
N-32	004_YEAR	-106	-4.1	12.6	3.1	-150	-5.8	6.4	2.9	-128	-5.9	0.6	3.5	-100	-6.4	0.1	2.5
N-32	005_YEAR	-139	-4.3	15.6	3.0	-143	-6.5	2.4	2.9	-121	-6.5	0.7	2.7	-121	-5.7	0.4	3.7
N-32	010_YEAR	-62	-4.6	8.9	2.8	-111	-5.9	6.9	2.6	-93	-6.5	7.3	2.3	-90	-5.3	0.5	3.2
N-32	020_YEAR	-66	-5.0	8.4	3.2	-91	-6.7	3.1	2.0	-94	-6.9	4.4	2.5	-105	-5.4	0.6	3.0
N-32	050_YEAR	-64	-6.1	2.9	2.7	-118	-6.7	5.3	2.5	-93	-7.5	4.8	1.9	-113	-5.9	0.6	2.9
N-32	100_YEAR	-85	-5.4	12.5	2.9	-112	-6.9	1.5	1.8	-103	-7.6	6.1	2.1	-116	-6.0	1.3	2.4
N-36	001_YEAR	-73	-6.2	1.8	2.9	-103	-6.8	1.3	2.9	-96	-7.2	1.3	3.2	-61	-6.5	0.1	2.6
N-36	002_YEAR	-75	-5.4	8.7	2.9	-97	-6.8	1.5	3.0	-107	-6.9	0.3	3.2	-103	-6.1	0.6	3.5
N-36	003_YEAR	-81	-5.3	8.9	2.9	-115	-6.5	1.0	2.8	-133	-5.6	0.7	3.4	-105	-6.0	0.2	3.5
N-36	004_YEAR	-75	-5.2	10.4	3.1	-112	-6.0	9.4	2.9	-106	-6.0	1.9	3.3	-105	-6.1	0.3	3.7
N-36	005_YEAR	-67	-5.6	9.9	3.5	-106	-5.5	8.9	3.0	-100	-6.1	1.1	3.0	-104	-5.6	0.5	3.7
N-36	010_YEAR	-44	-4.2	6.4	2.9	-81	-5.1	3.3	2.8	-74	-5.6	5.5	2.2	-73	-5.7	1.4	3.2
N-36	020_YEAR	-42	-4.9	4.5	2.8	-73	-5.6	7.3	2.3	-83	-5.7	3.4	2.5	-88	-5.9	1.1	3.0
N-36	050_YEAR	-22	-5.0	6.6	3.0	-75	-5.7	3.8	2.6	-76	-6.2	2.0	2.3	-93	-5.8	0.6	2.8
N-36	100_YEAR	-33	-4.9	9.5	3.1	-77	-5.6	2.8	2.1	-93	-5.7	5.8	2.4	-95	-5.8	1.9	2.7

SUB-APPENDIX C-2

SBEACH RESULTS - WITH PROJECT CONDITIONS - CHANDELEUR & BRETON ISLANDS, LA

Profile	Return Period	Year 0				Year 50 Low Sea Level Rise				Year 50 Medium Sea Level Rise				Year 50 High Sea Level Rise			
		MHW Change (feet)	Vol. Change Above MHW (c.y. / foot)	Overwash (c.y. / foot)	Dune Elev. (feet NAVD)	MHW Change (feet)	Vol. Change Above MHW (c.y. / foot)	Overwash (c.y. / foot)	Dune Elev. (feet NAVD)	MHW Change (feet)	Vol. Change Above MHW (c.y. / foot)	Overwash (c.y. / foot)	Dune Elev. (feet NAVD)	MHW Change (feet)	Volume Change Above MHW (c.y. / foot)	Overwash (c.y. / foot)	Dune Elev. (feet NAVD)
CHANDELEUR ISLANDS MIDDLE REACH:																	
N-40	001_YEAR	-69	-5.2	2.6	4.0	-94	-5.7	2.7	3.1	-94	-5.9	1.8	3.4	-59	-5.6	0.0	2.5
N-40	002_YEAR	-65	-4.9	9.4	3.0	-92	-5.5	3.1	3.1	-93	-5.8	1.7	3.3	-66	-5.8	0.1	2.5
N-40	003_YEAR	-77	-4.3	11.0	3.2	-88	-5.8	2.4	3.1	-98	-5.8	0.4	3.1	-104	-4.9	0.4	3.4
N-40	004_YEAR	-65	-4.7	12.9	3.0	-96	-4.6	4.1	3.2	-100	-5.1	8.1	3.3	-100	-4.9	0.2	3.5
N-40	005_YEAR	-64	-4.6	15.2	3.0	-82	-5.4	3.3	3.1	-100	-4.7	6.7	3.4	-103	-4.9	0.3	3.9
N-40	010_YEAR	-48	-3.9	10.0	3.2	-72	-4.4	4.3	2.6	-77	-5.1	5.6	2.7	-76	-5.0	1.7	3.1
N-40	020_YEAR	-43	-4.4	7.6	3.7	-81	-4.3	8.7	2.5	-77	-5.1	6.6	2.6	-82	-5.4	1.4	3.0
N-40	050_YEAR	-44	-4.6	6.6	3.4	-70	-4.7	5.4	2.7	-76	-5.3	4.7	2.5	-95	-5.2	1.2	2.7
N-40	100_YEAR	-41	-4.6	11.0	3.7	-65	-4.8	3.8	2.7	-75	-5.0	4.6	2.4	-84	-5.5	1.1	2.5
N-41	001_YEAR	-92	-6.3	0.8	3.1	-120	-5.7	1.8	3.1	-118	-5.7	1.1	3.5	-61	-6.0	0.0	2.5
N-41	002_YEAR	-97	-5.6	6.9	2.8	-138	-4.8	5.2	2.9	-124	-6.7	0.4	3.0	-97	-6.6	0.0	2.5
N-41	003_YEAR	-112	-5.0	13.1	2.9	-127	-6.1	3.0	2.9	-139	-4.9	4.0	3.4	-118	-5.8	0.3	3.5
N-41	004_YEAR	-112	-4.7	12.6	3.1	-139	-5.8	8.0	3.0	-138	-4.8	4.2	3.4	-118	-5.8	0.4	3.6
N-41	005_YEAR	-113	-4.8	13.8	3.1	-133	-5.0	6.3	3.5	-129	-5.0	1.9	3.4	-120	-5.2	0.7	3.2
N-41	010_YEAR	-78	-4.8	6.5	3.1	-101	-5.7	5.2	2.6	-89	-5.8	5.2	2.2	-86	-4.8	0.6	3.0
N-41	020_YEAR	-67	-5.4	6.7	2.9	-111	-5.4	9.2	2.2	-102	-5.7	3.6	2.5	-99	-5.3	1.1	3.0
N-41	050_YEAR	-86	-6.2	12.0	2.6	-105	-6.3	6.0	2.3	-108	-6.6	2.3	2.1	-116	-5.6	0.5	2.8
N-41	100_YEAR	-83	-6.3	3.4	2.5	-101	-6.6	6.4	2.0	-112	-6.8	4.5	2.2	-121	-5.6	1.2	2.5
N-42	001_YEAR	-72	-5.3	0.6	3.2	-97	-5.5	1.8	2.9	-93	-5.9	0.3	3.1	-69	-4.9	0.1	3.1
N-42	002_YEAR	-84	-4.4	8.6	3.2	-101	-6.0	1.8	2.8	-106	-7.2	0.6	2.7	-93	-5.1	0.3	3.5
N-42	003_YEAR	-70	-5.4	8.8	3.2	-95	-5.1	3.1	3.1	-109	-6.5	0.6	3.2	-98	-5.1	0.6	3.4
N-42	004_YEAR	-83	-6.7	12.5	3.0	-110	-6.8	5.7	2.9	-106	-4.9	0.5	3.4	-100	-5.2	0.4	3.6
N-42	005_YEAR	-80	-7.6	8.1	2.9	-103	-6.0	5.0	3.0	-109	-4.2	1.0	3.5	-99	-5.0	0.4	3.5
N-42	010_YEAR	-59	-5.3	7.5	2.8	-80	-5.3	5.0	2.5	-74	-6.5	5.9	2.3	-76	-5.1	1.3	2.9
N-42	020_YEAR	-52	-5.7	6.0	3.2	-87	-9.2	9.8	2.2	-84	-5.4	3.9	2.5	-85	-5.2	1.3	2.9
N-42	050_YEAR	-52	-11.2	7.8	2.3	-93	-6.9	6.5	2.3	-80	-7.1	1.8	1.9	-97	-5.4	1.0	2.8
N-42	100_YEAR	-69	-11.5	14.5	2.4	-76	-7.6	4.8	1.9	-88	-6.1	5.4	2.1	-96	-4.8	1.2	2.5
N-43	001_YEAR	-71	-5.4	2.9	4.0	-103	-6.1	2.1	3.1	-93	-5.9	2.2	3.4	-60	-5.7	0.1	2.5
N-43	002_YEAR	-73	-5.5	7.9	2.9	-99	-5.8	1.7	2.8	-99	-6.2	1.9	3.2	-70	-6.0	0.0	2.5
N-43	003_YEAR	-70	-5.9	8.9	3.3	-91	-5.9	3.5	3.3	-103	-6.9	1.5	3.2	-91	-5.9	0.1	2.5
N-43	004_YEAR	-67	-8.6	10.8	3.3	-100	-4.7	3.2	3.3	-105	-5.3	7.8	3.3	-103	-5.3	0.3	3.8
N-43	005_YEAR	-73	-7.2	13.6	3.0	-89	-5.7	2.2	3.0	-106	-4.8	7.1	3.4	-105	-4.9	0.4	5.5
N-43	010_YEAR	-54	-5.4	8.7	3.2	-80	-4.5	3.5	2.7	-78	-5.6	3.9	2.7	-79	-4.9	0.8	3.2
N-43	020_YEAR	-52	-4.9	5.0	3.7	-89	-5.6	5.9	2.8	-82	-5.7	4.3	2.5	-86	-5.3	1.2	3.0
N-43	050_YEAR	-53	-6.5	4.7	3.3	-77	-8.0	7.6	2.5	-80	-6.2	4.8	2.4	-96	-5.3	0.7	2.8
N-43	100_YEAR	-46	-8.6	9.0	3.6	-76	-6.0	3.9	2.6	-79	-5.6	5.7	2.5	-99	-6.3	1.2	3.0

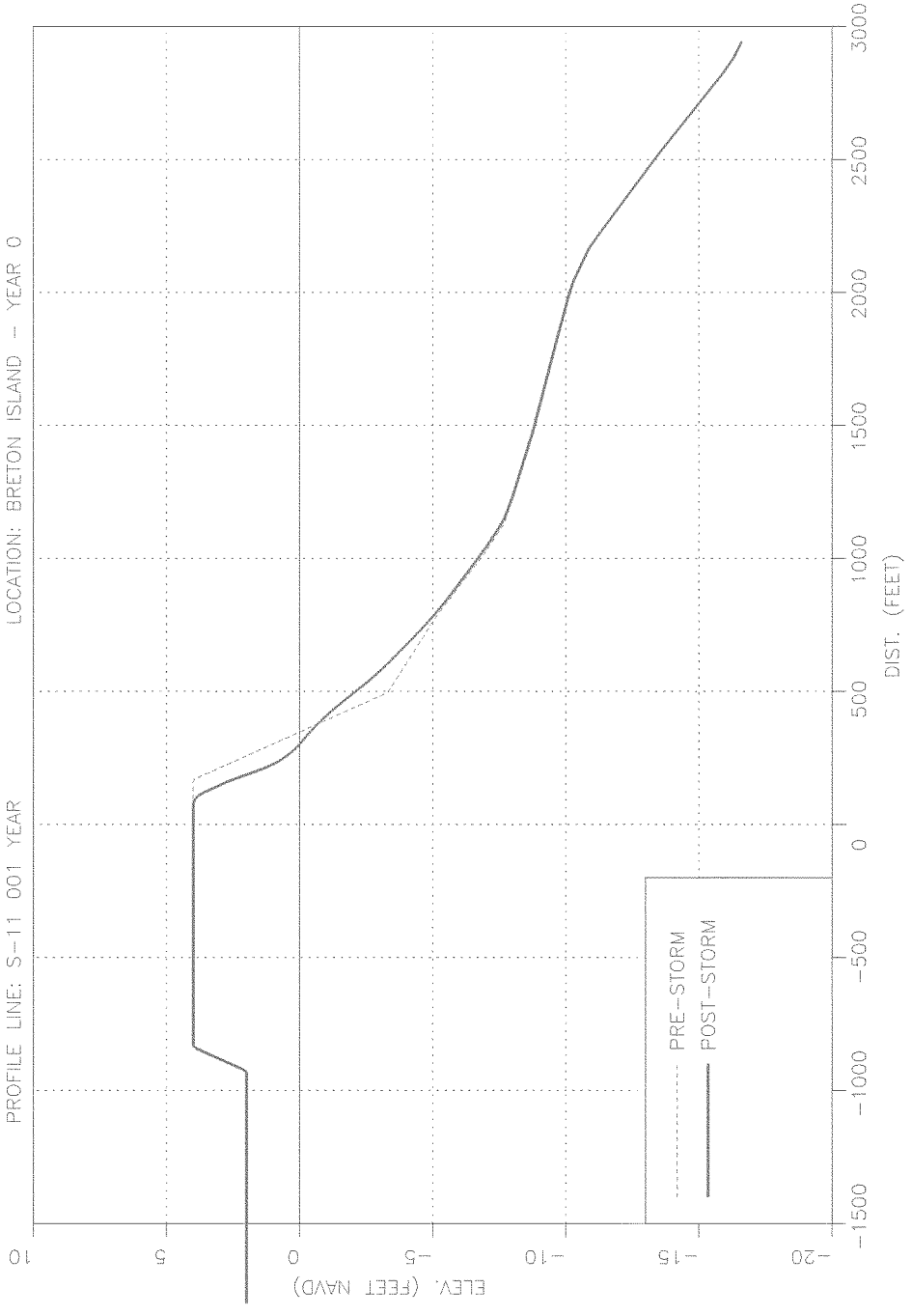
SUB-APPENDIX C-2

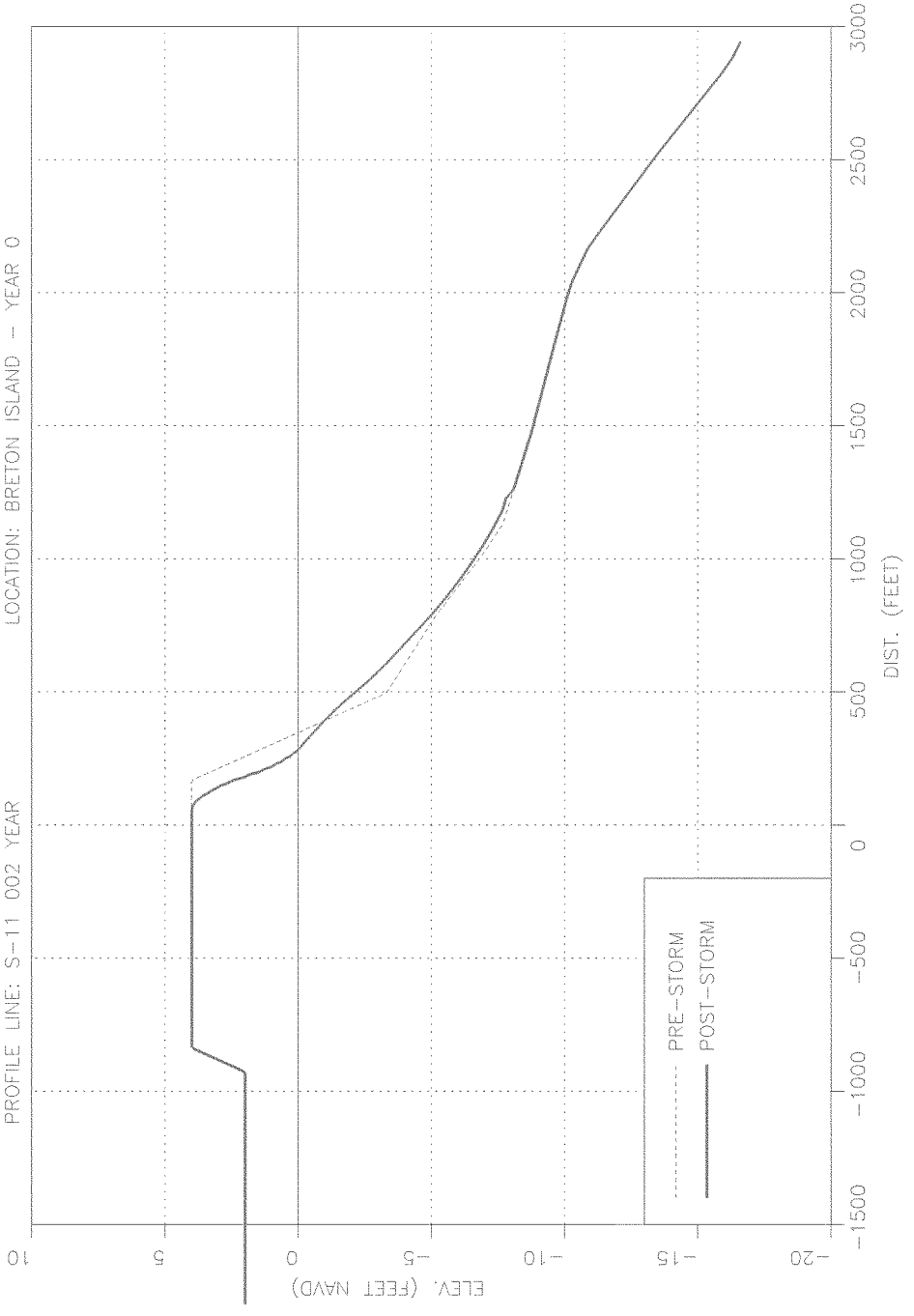
SBEACH RESULTS - WITH PROJECT CONDITIONS - CHANDELEUR & BRETON ISLANDS, LA

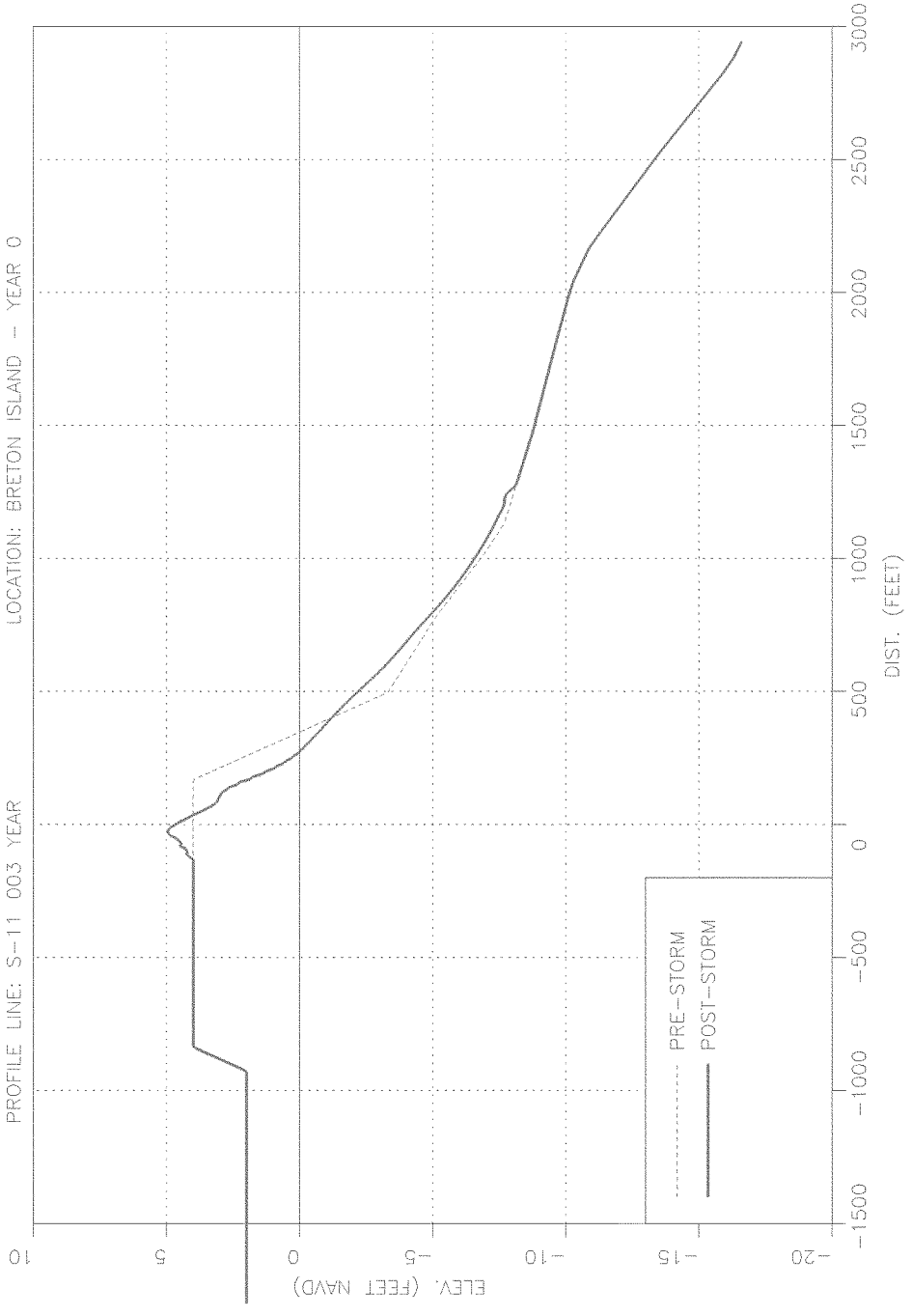
Profile	Return Period	Year 0				Year 50 Low Sea Level Rise				Year 50 Medium Sea Level Rise				Year 50 High Sea Level Rise			
		MHW Change (feet)	Vol. Change Above MHW (c.y. / foot)	Overwash (c.y. / foot)	Dune Elev. (feet NAVD)	MHW Change (feet)	Vol. Change Above MHW (c.y. / foot)	Overwash (c.y. / foot)	Dune Elev. (feet NAVD)	MHW Change (feet)	Vol. Change Above MHW (c.y. / foot)	Overwash (c.y. / foot)	Dune Elev. (feet NAVD)	MHW Change (feet)	Volume Change Above MHW (c.y. / foot)	Overwash (c.y. / foot)	Dune Elev. (feet NAVD)
CHAN. IS. SOUTH REACH AVERAGE	001_YEAR	-81	-6.0	2.1	3.2	-108	-6.2	1.9	2.9	-102	-6.5	1.5	3.3	-64	-6.3	0.0	2.5
	002_YEAR	-92	-5.2	6.7	3.1	-110	-6.6	3.7	2.9	-119	-6.6	1.5	3.2	-89	-6.4	0.2	2.8
	003_YEAR	-97	-4.8	11.2	3.1	-120	-6.1	5.7	2.9	-119	-6.1	2.4	2.9	-102	-6.3	0.1	2.8
	004_YEAR	-87	-5.0	11.0	3.0	-121	-5.9	6.3	2.9	-117	-5.7	3.2	3.4	-107	-6.1	0.2	3.3
	005_YEAR	-99	-5.1	13.9	3.2	-116	-6.0	5.3	3.0	-114	-5.9	3.5	3.0	-113	-5.4	0.4	3.5
N-31 to N-36	010_YEAR	-54	-4.4	8.8	2.9	-94	-5.1	5.0	2.7	-86	-5.8	6.0	2.4	-71	-5.7	1.1	3.1
	020_YEAR	-56	-5.0	7.3	3.1	-89	-6.0	7.7	2.4	-93	-6.2	5.1	2.6	-95	-5.7	1.0	3.0
	050_YEAR	-52	-5.7	5.2	3.1	-95	-6.4	5.3	2.7	-89	-6.7	3.9	2.2	-107	-5.9	0.8	2.8
	100_YEAR	-63	-5.8	11.0	3.2	-96	-6.3	2.9	2.2	-102	-6.5	6.4	2.3	-114	-6.0	1.3	2.7
CHAN. IS. MIDDLE REACH AVERAGE	001_YEAR	-76	-5.5	1.7	3.6	-104	-5.8	2.1	3.1	-99	-5.8	1.4	3.4	-62	-5.5	0.1	2.6
	002_YEAR	-80	-5.1	8.2	3.0	-107	-5.5	2.9	2.9	-105	-6.5	1.2	3.1	-82	-5.9	0.1	2.8
	003_YEAR	-82	-5.2	10.4	3.1	-100	-5.7	3.0	3.1	-112	-6.0	1.8	3.2	-103	-5.4	0.3	3.2
	004_YEAR	-82	-5.7	12.2	3.1	-111	-5.6	5.3	3.1	-112	-5.0	5.1	3.4	-105	-5.3	0.3	3.6
	005_YEAR	-83	-6.0	12.7	3.0	-102	-5.5	4.2	3.2	-111	-4.7	4.2	3.4	-107	-5.0	0.4	3.5
N-40 to N-43	010_YEAR	-60	-4.8	8.2	3.1	-83	-5.0	4.6	2.6	-79	-5.8	5.1	2.5	-79	-5.0	1.1	3.1
	020_YEAR	-54	-5.1	6.3	3.4	-92	-6.1	8.4	2.4	-86	-5.5	4.6	2.5	-88	-5.3	1.2	3.0
	050_YEAR	-59	-7.1	7.8	2.9	-86	-6.5	7.1	2.5	-86	-6.4	3.4	2.2	-101	-5.4	0.9	2.8
	100_YEAR	-60	-7.7	9.5	3.1	-80	-6.3	4.7	2.3	-88	-5.9	5.0	2.3	-100	-5.6	1.2	2.6

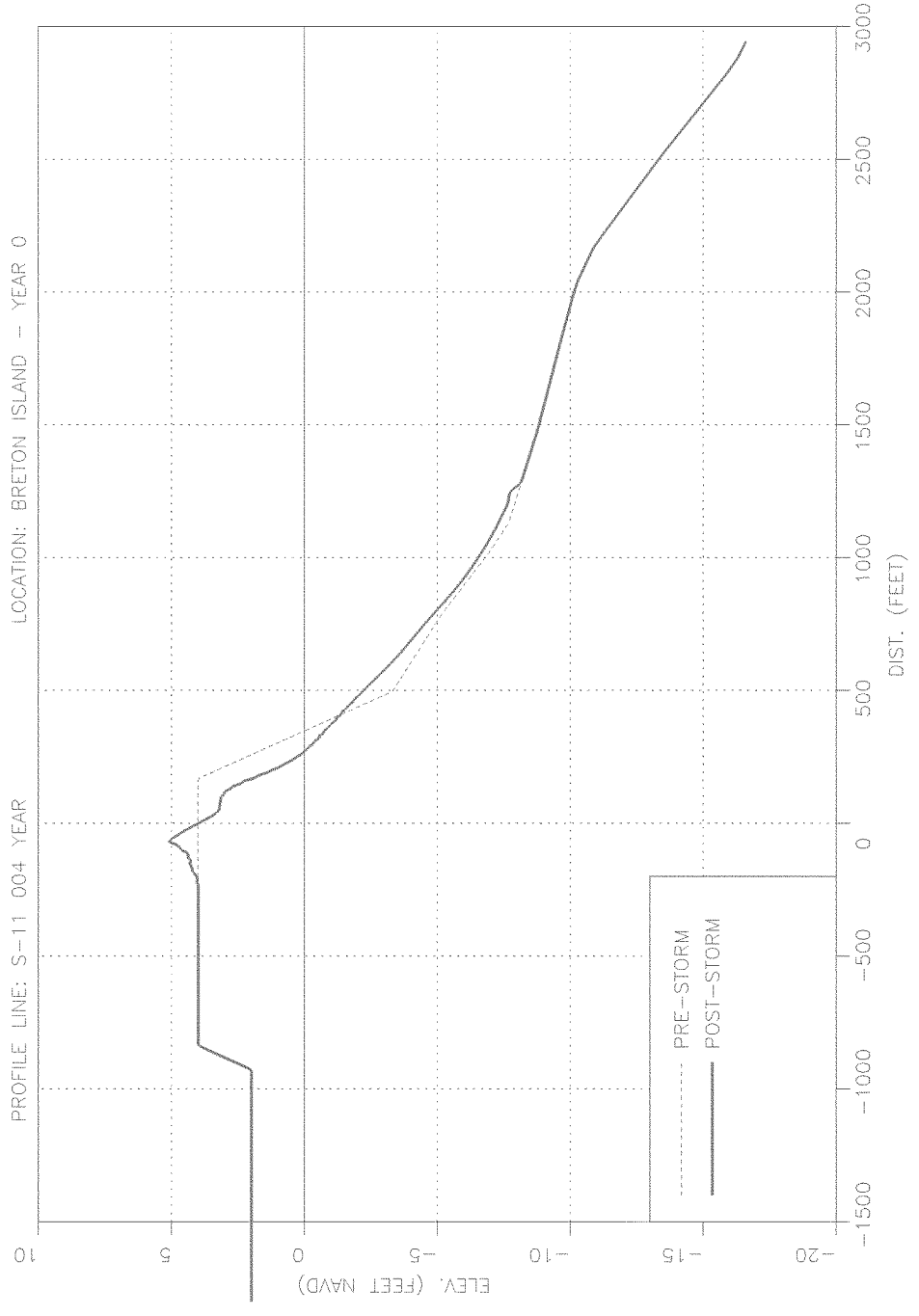
Breton Island Profile S-11

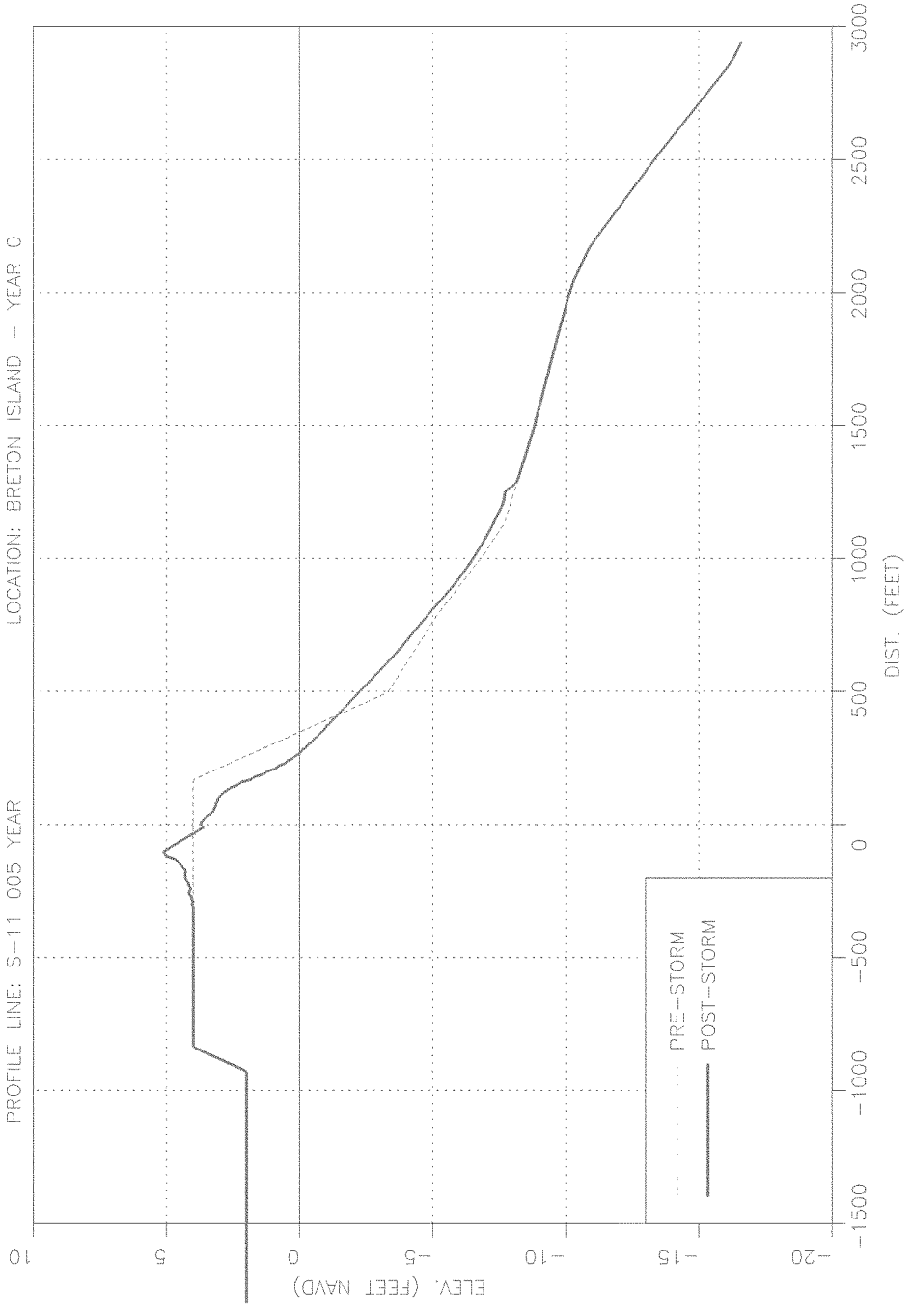
Alternative 1

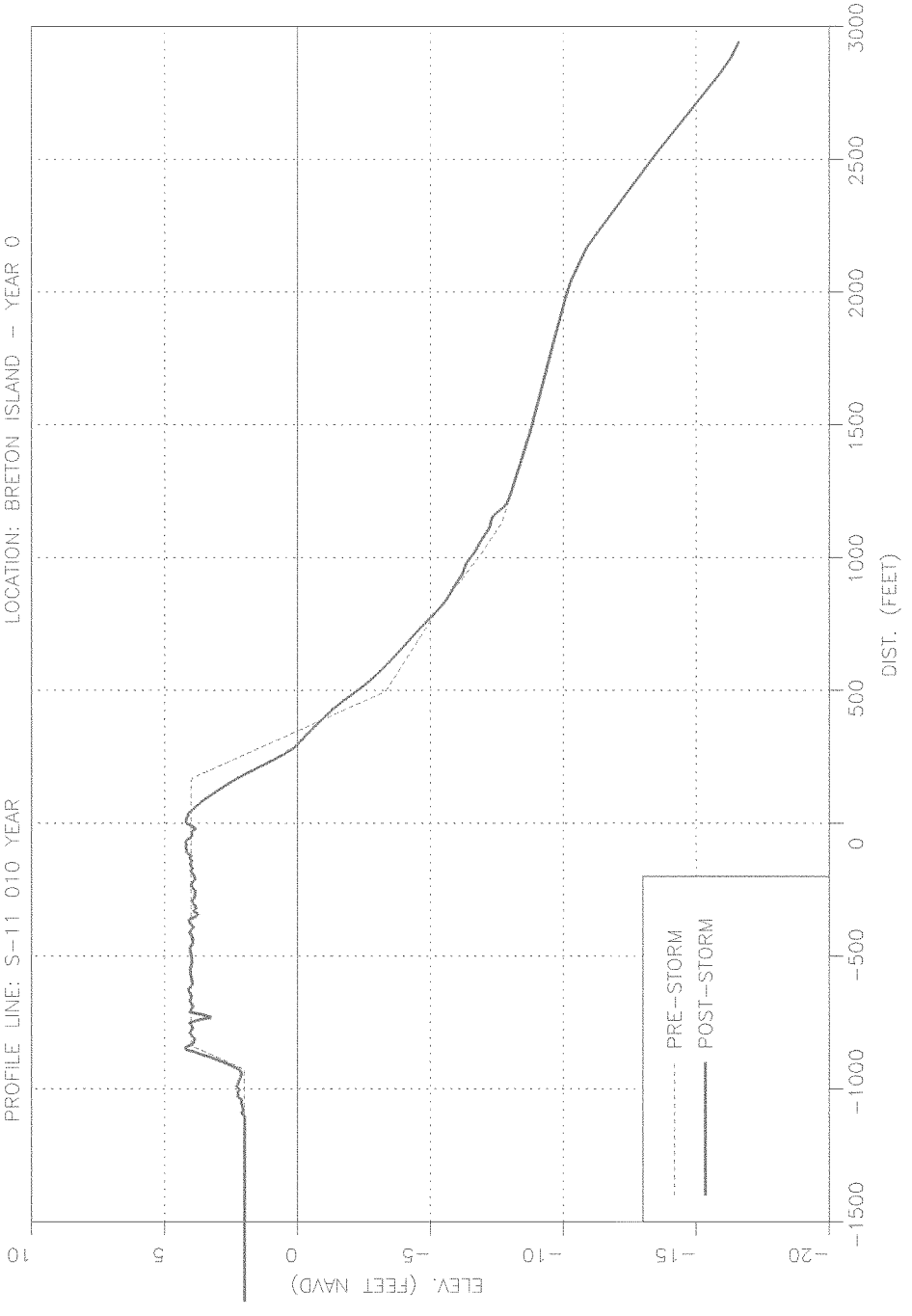

PROFILE LINE: S-11 001 YEAR
LOCATION: BRETON ISLAND -- YEAR 0
ELEV. (FEET NAVD)
10
5
0
-5
-10
-15
-20
DIST. (FEET)
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000
PRE-STORM
POST-STORM

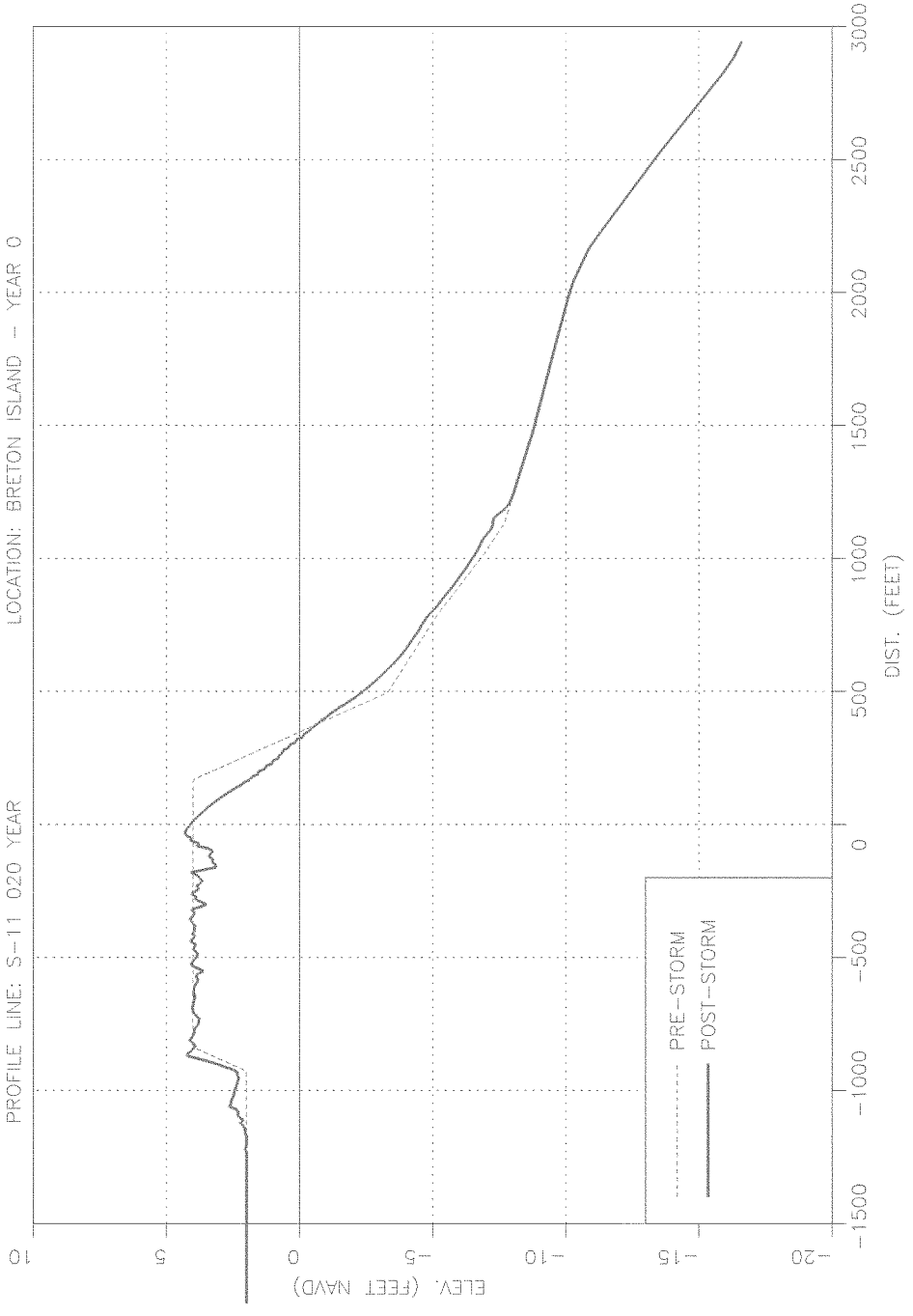

PROFILE LINE: S-11 002 YEAR
LOCATION: BRETON ISLAND -- YEAR 0
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

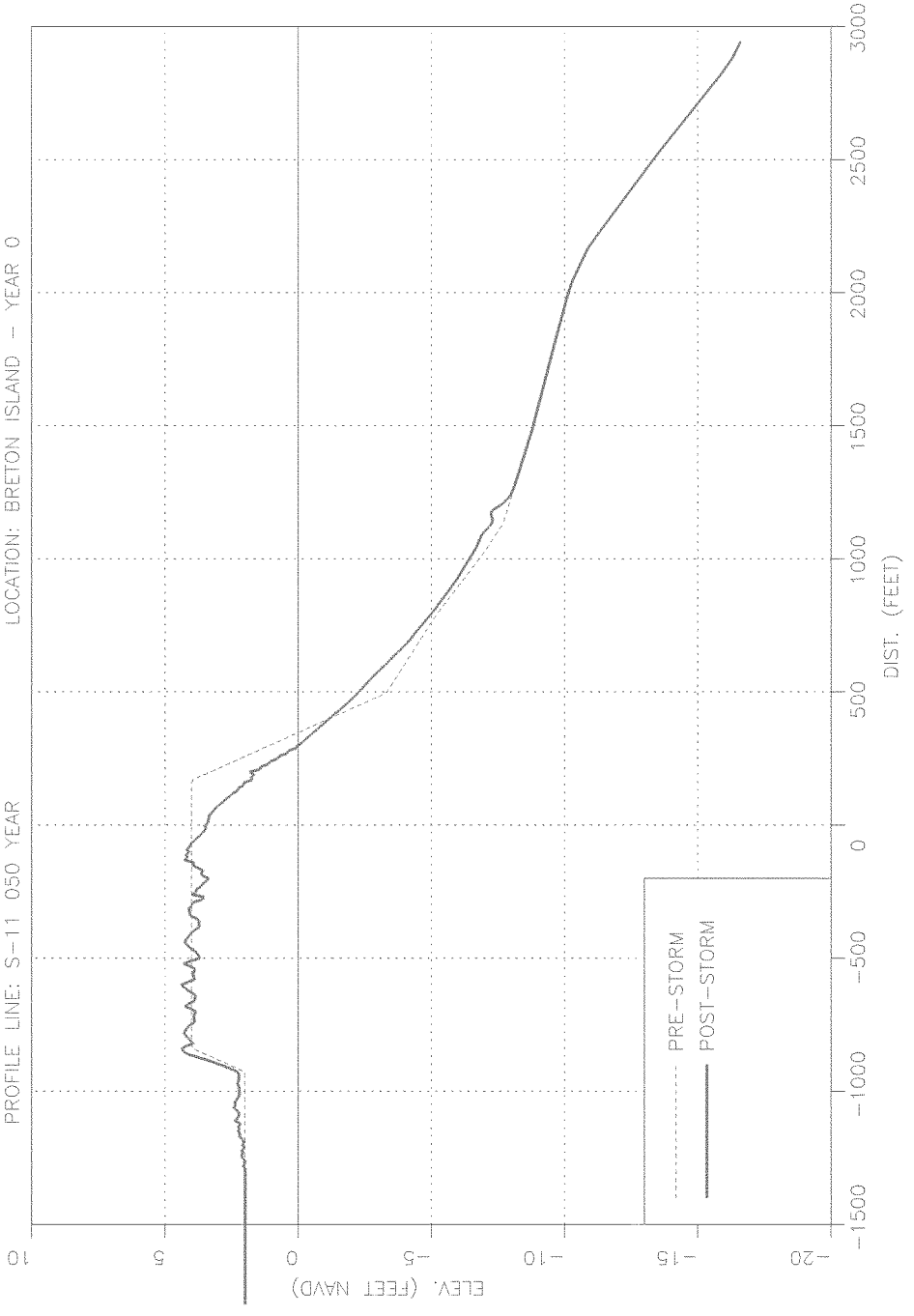

PROFILE LINE: S-11 003 YEAR
LOCATION: BRETON ISLAND -- YEAR 0
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

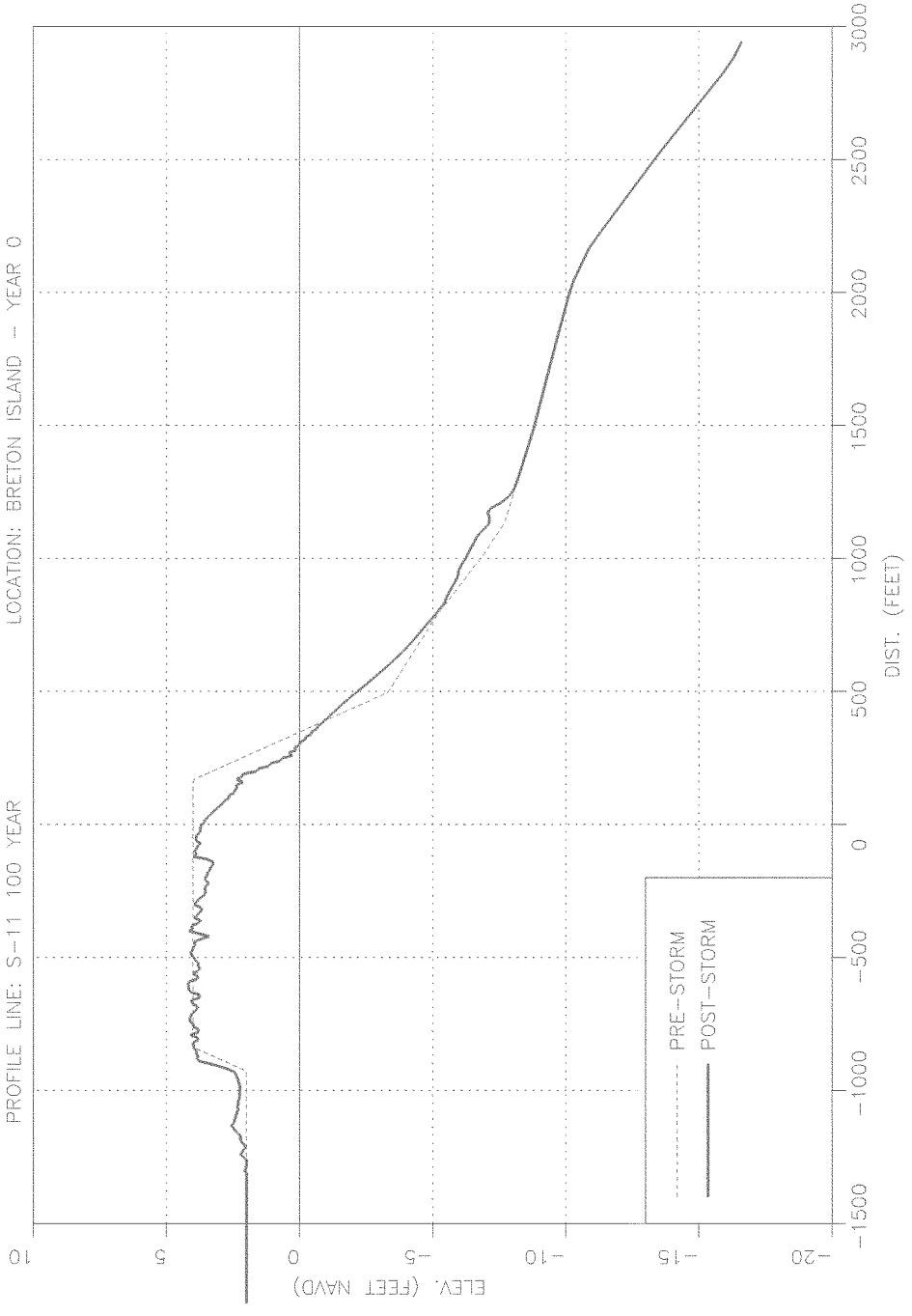

PROFILE LINE: S-11 004 YEAR
LOCATION: BRETON ISLAND -- YEAR 0
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

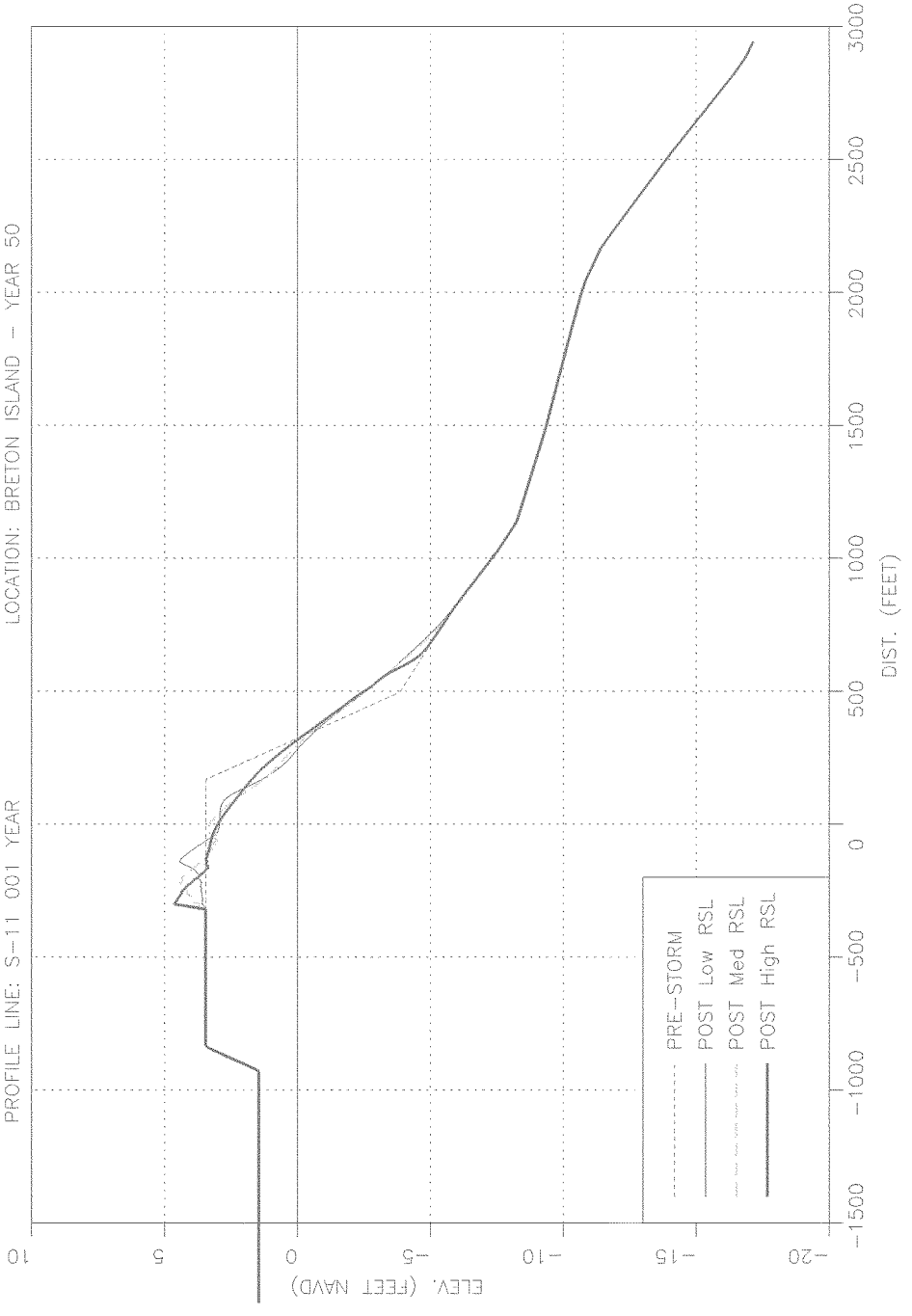

PROFILE LINE: S-11 005 YEAR
LOCATION: BRETON ISLAND -- YEAR 0
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

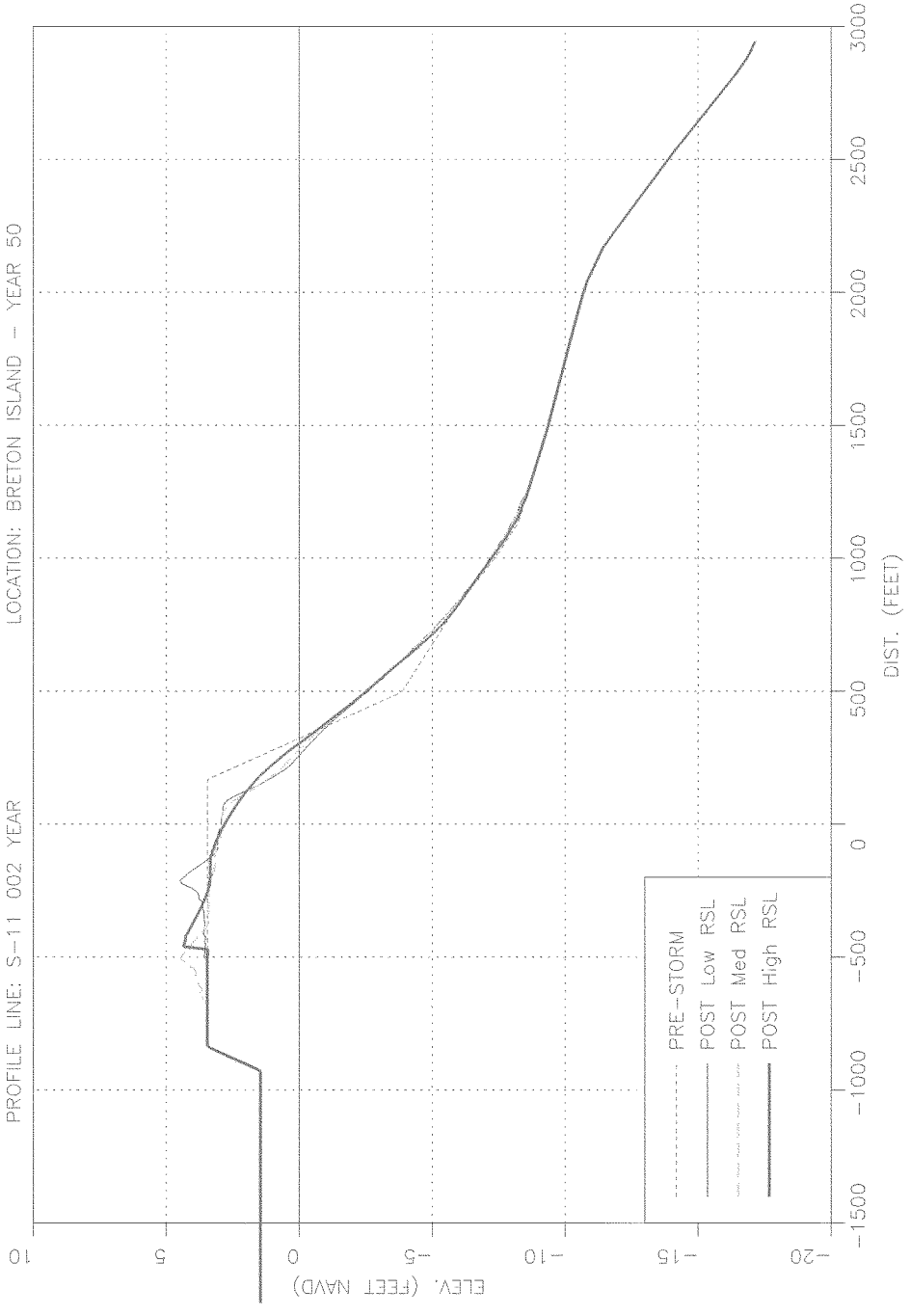

PROFILE LINE: S-11 010 YEAR
LOCATION: BRETON ISLAND -- YEAR 0
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

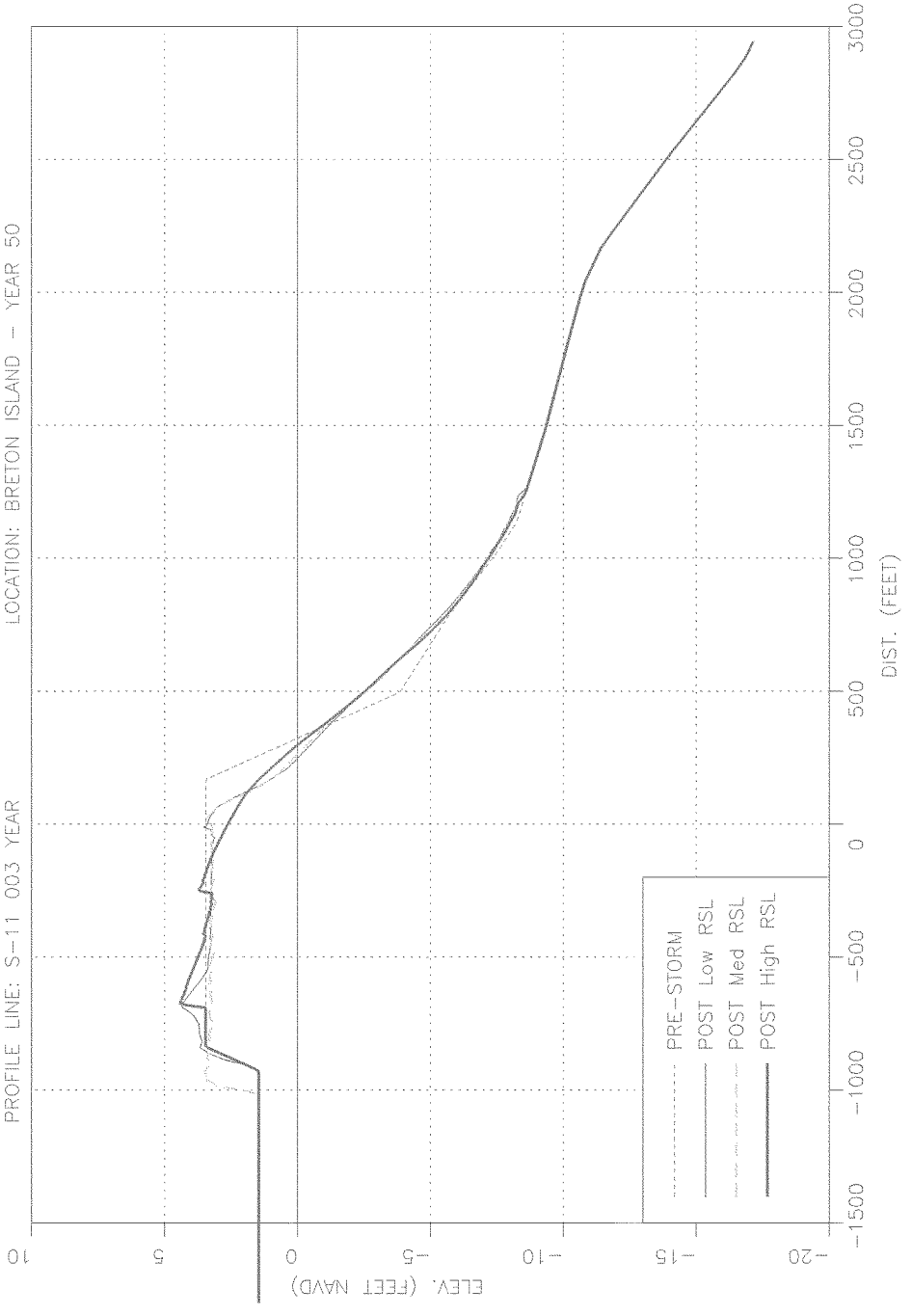

PROFILE LINE: S-11 020 YEAR
LOCATION: BRETON ISLAND -- YEAR 0
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

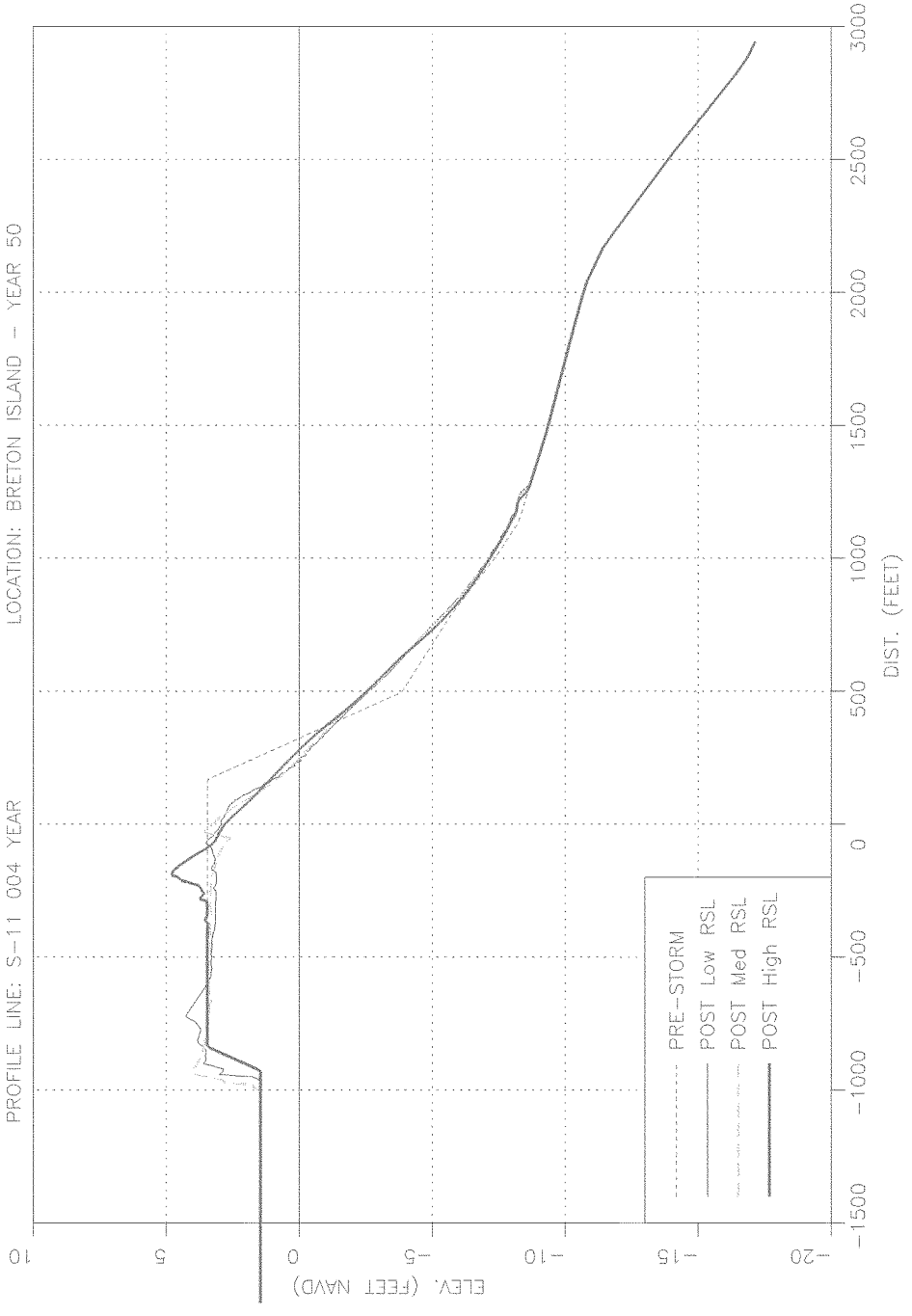

PROFILE LINE: S-11 050 YEAR
LOCATION: BRETON ISLAND -- YEAR 0
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

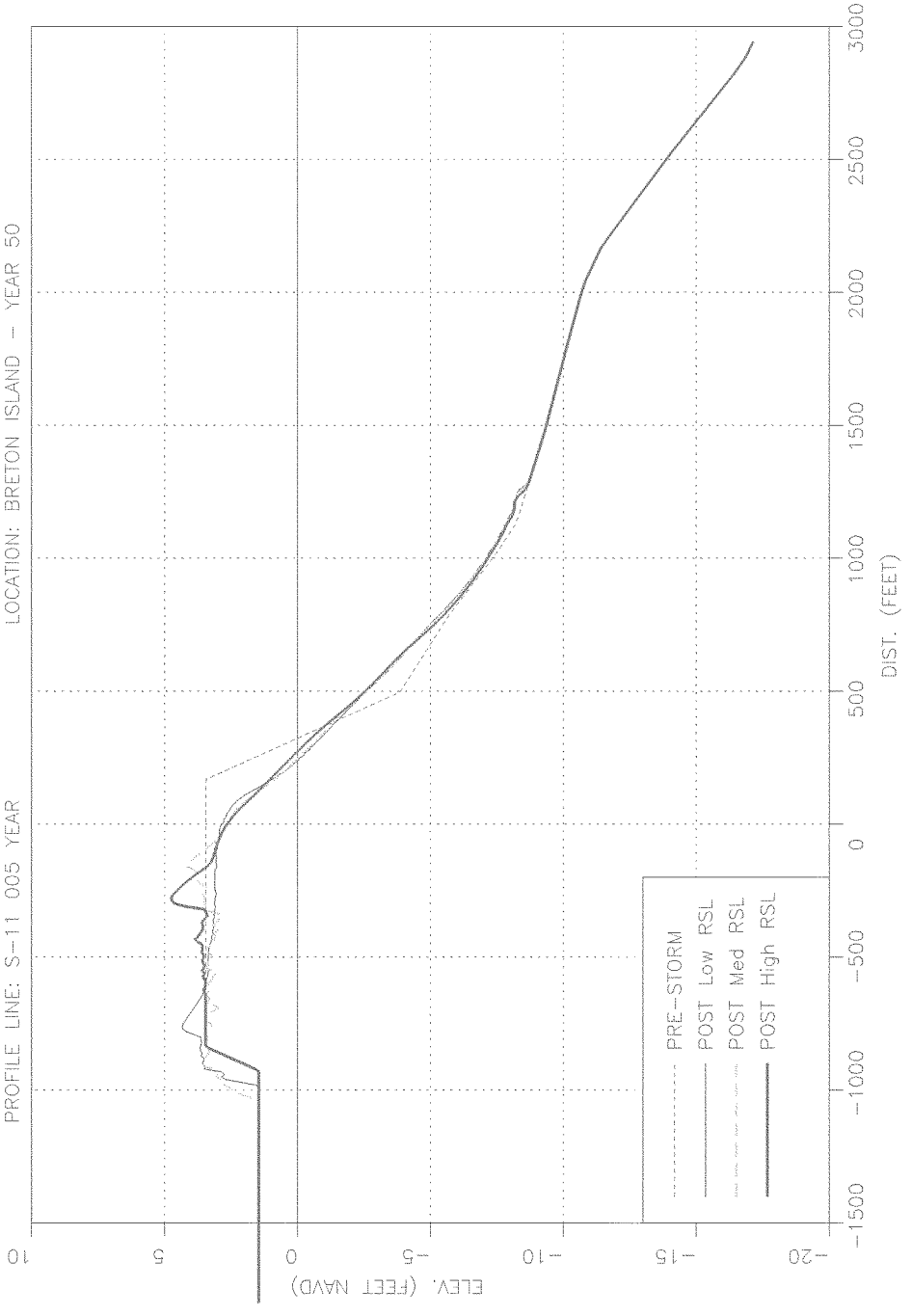

PROFILE LINE: S-11 100 YEAR
LOCATION: BRETON ISLAND -- YEAR 0
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

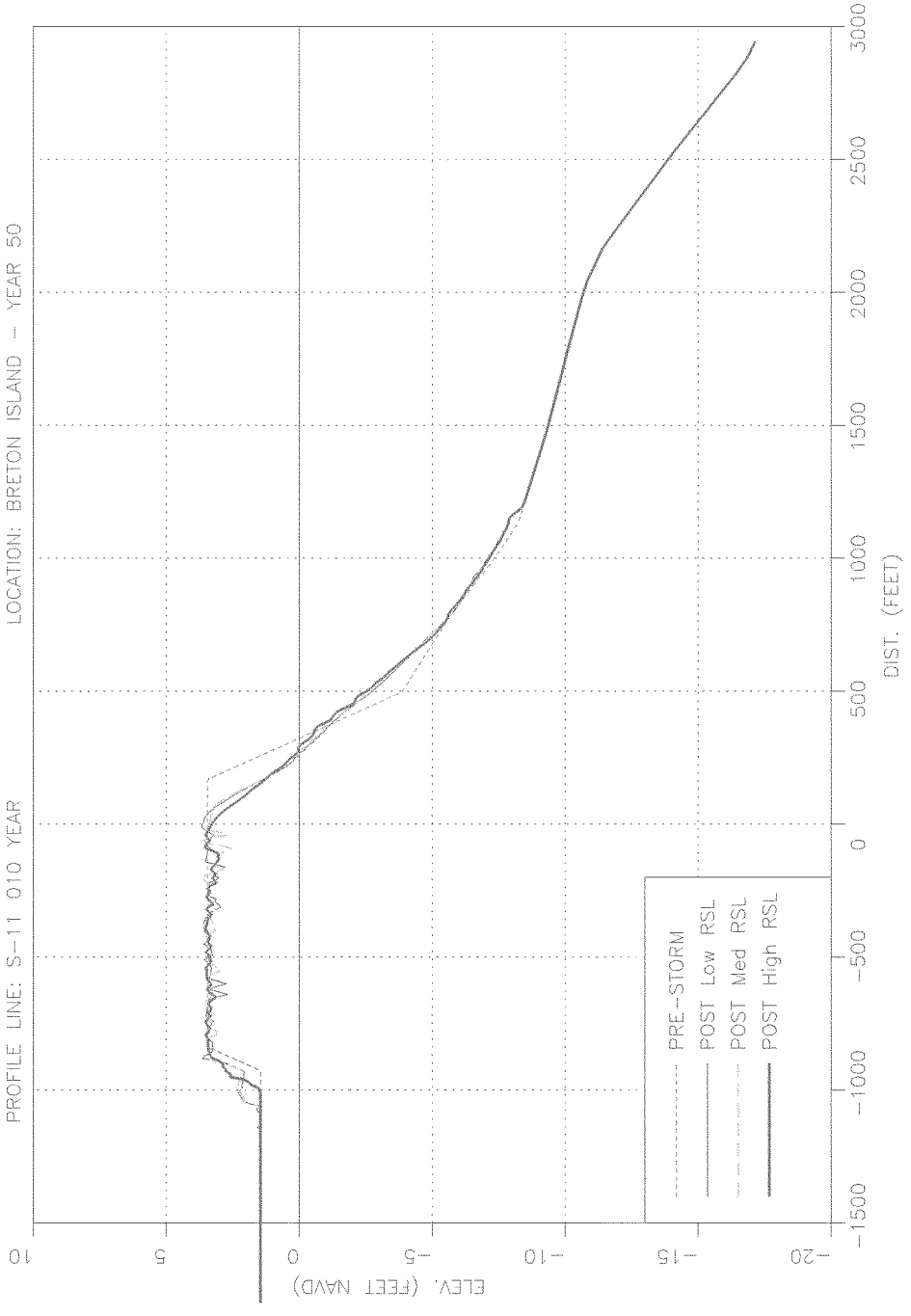

PROFILE LINE: S-11 001 YEAR
LOCATION: BRETON ISLAND -- YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
POST Med RSL
POST High RSL
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

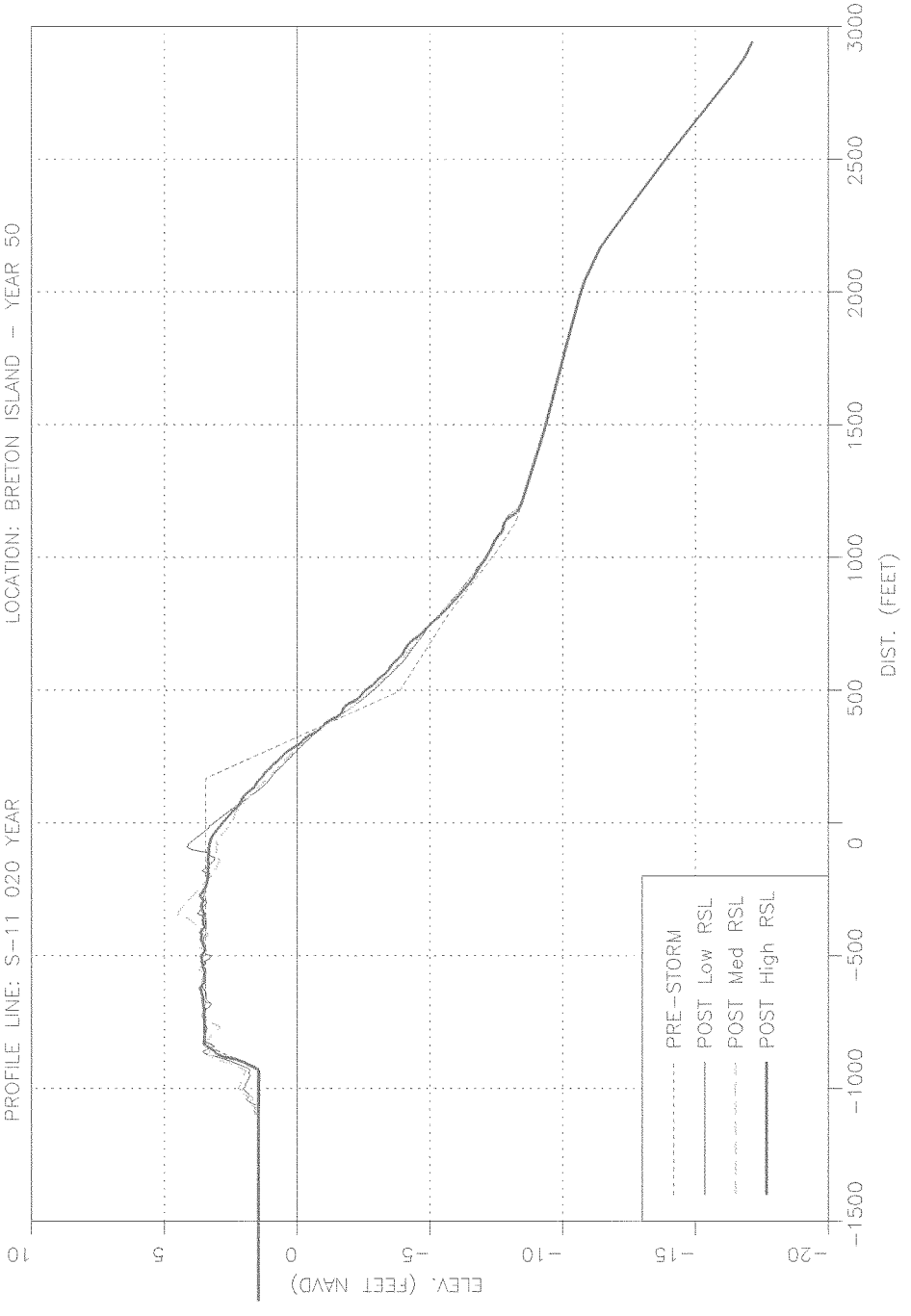

PROFILE LINE: S-11 002 YEAR
LOCATION: BRETON ISLAND -- YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
POST Med RSL
POST High RSL
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

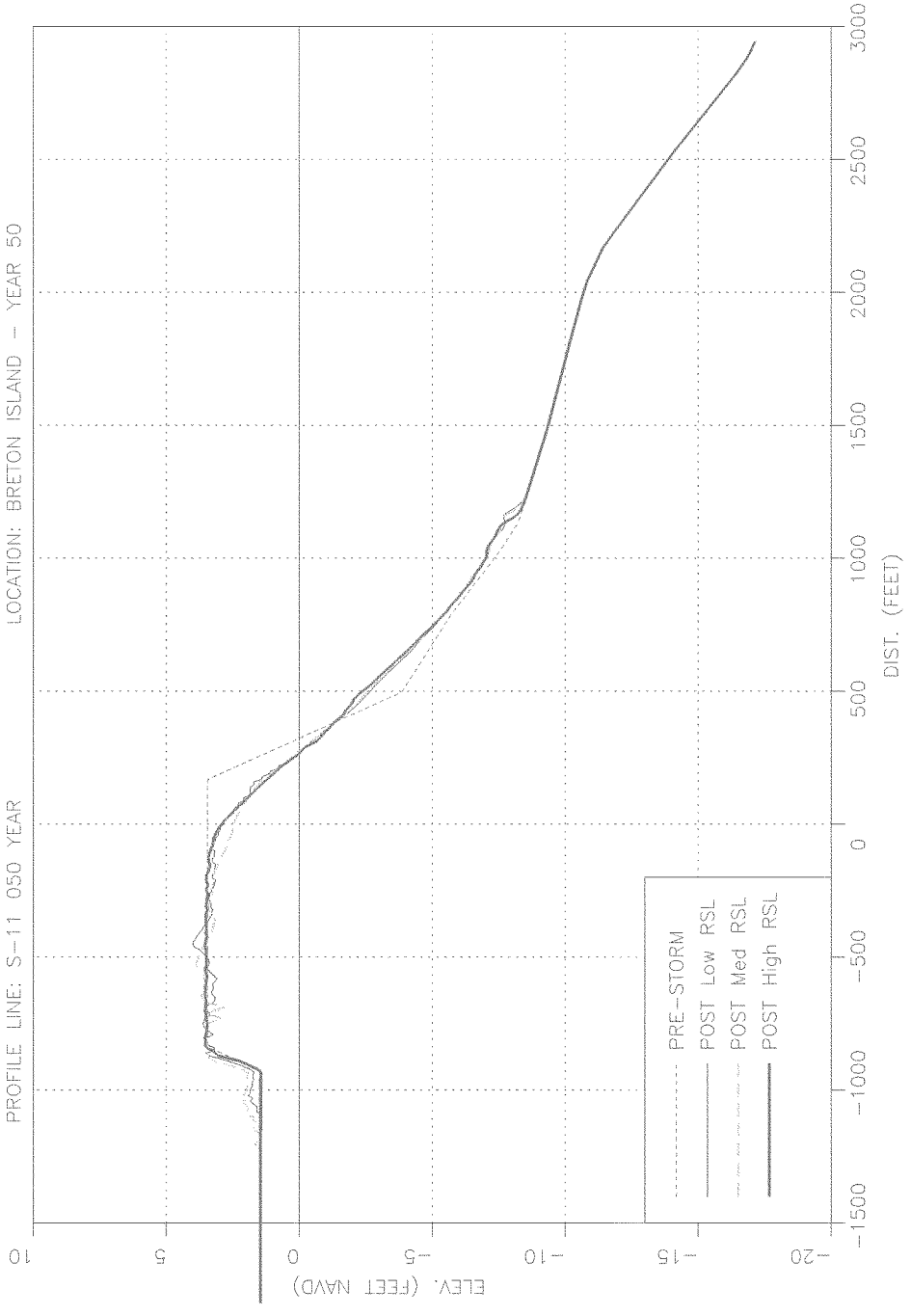

PROFILE LINE: S-11 003 YEAR
LOCATION: BRETON ISLAND -- YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000
PRE-STORM
POST Low RSL
POST Med RSL
POST High RSL

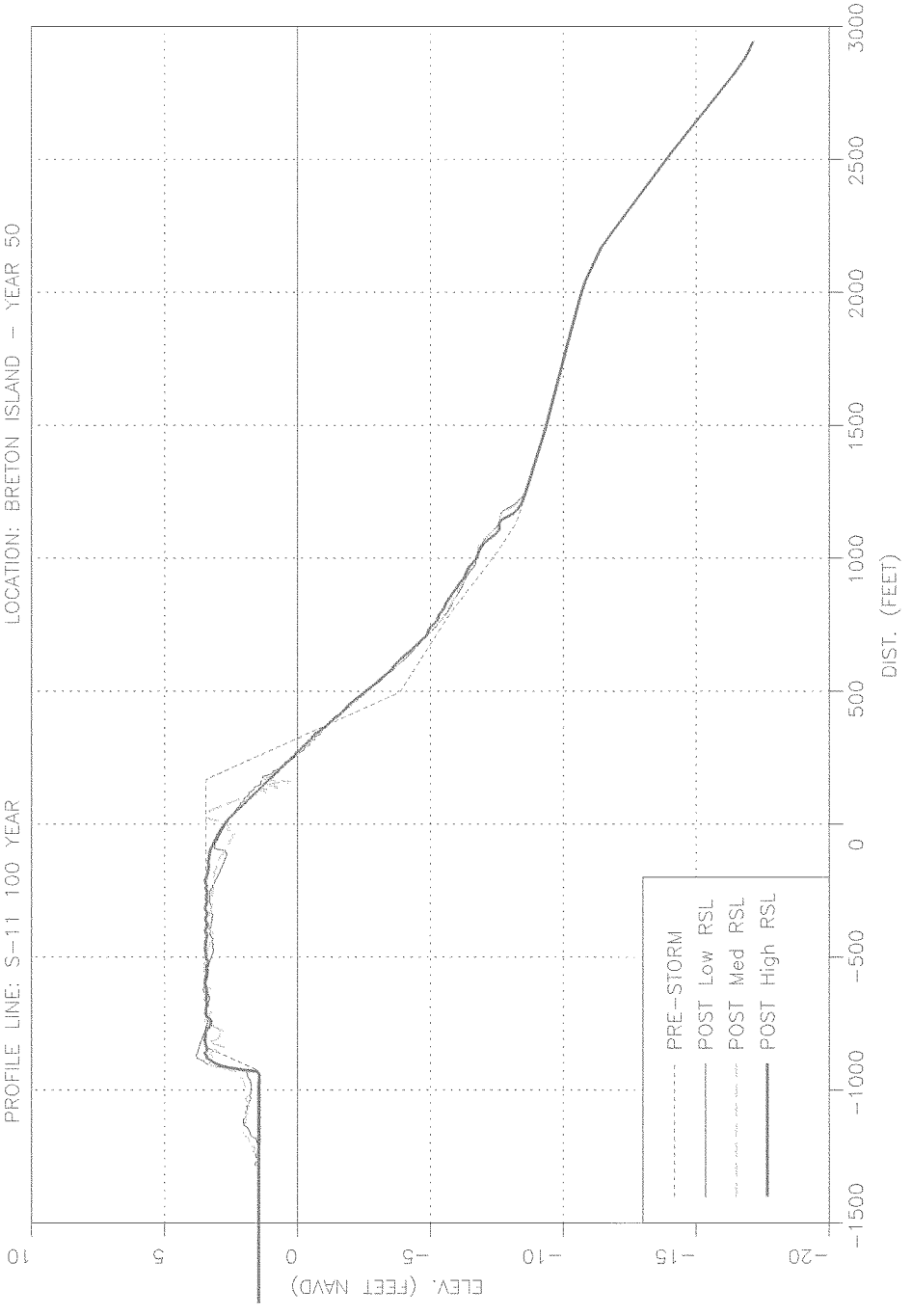

PROFILE LINE: S-11 004 YEAR
LOCATION: BRETON ISLAND -- YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
POST Med RSL
POST High RSL
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000


PROFILE LINE: S-11 005 YEAR
LOCATION: BRETON ISLAND -- YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
POST Med RSL
POST High RSL
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000


PROFILE LINE: S-11 010 YEAR
LOCATION: BRETON ISLAND -- YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
POST Med RSL
POST High RSL
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

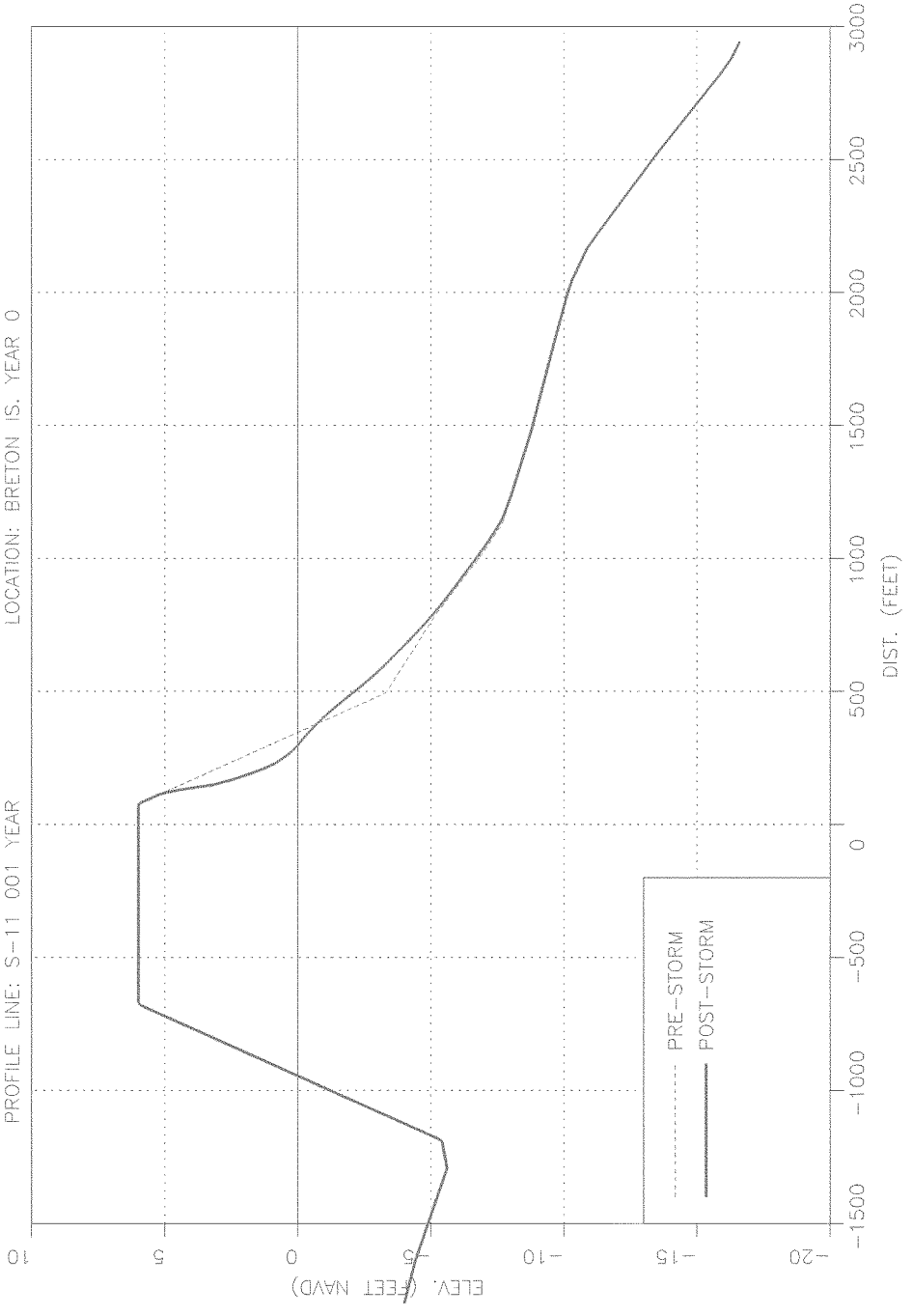

PROFILE LINE: S-11 020 YEAR
LOCATION: BRETON ISLAND -- YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000
PRE-STORM
POST Low RSL
POST Med RSL
POST High RSL

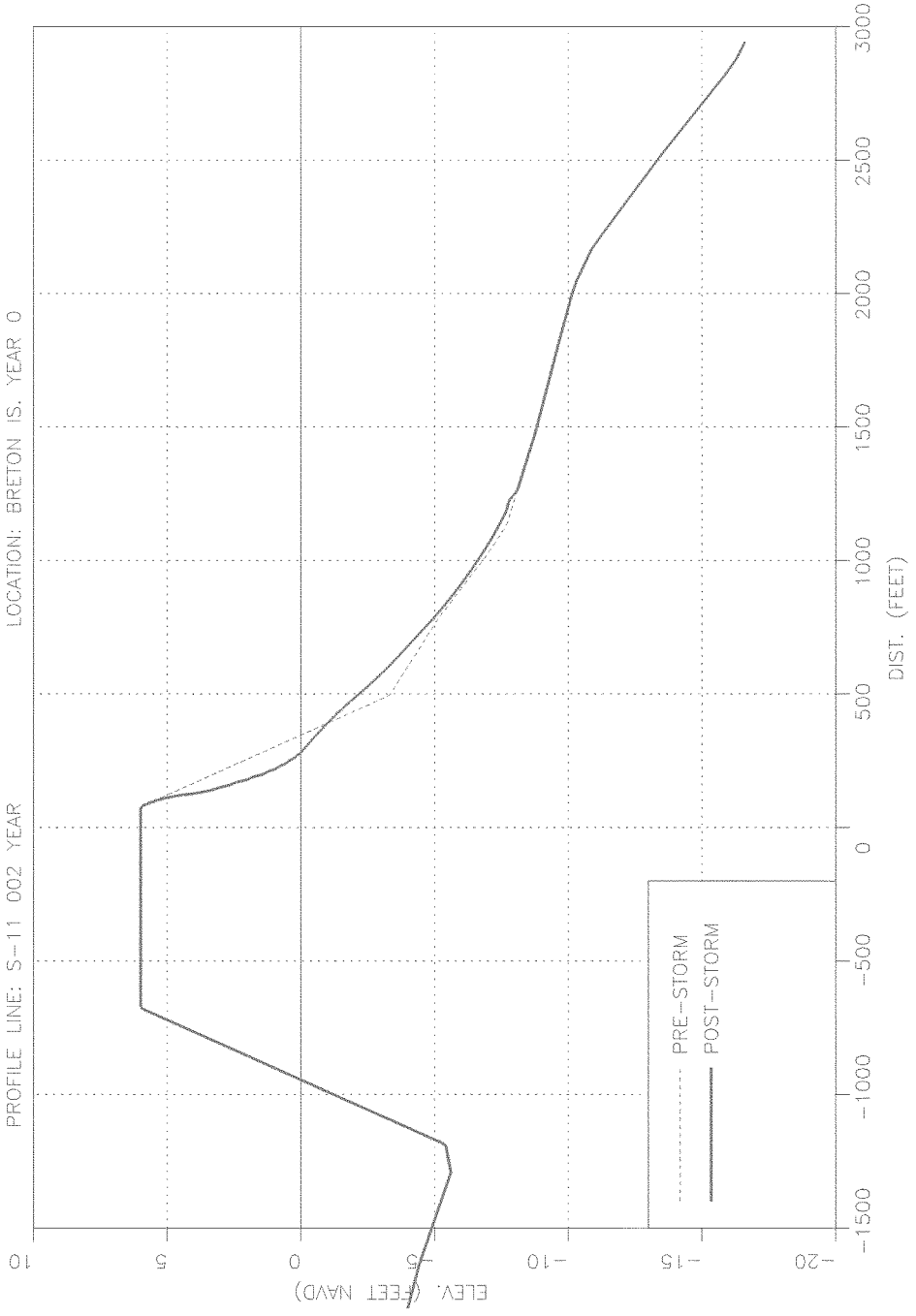

PROFILE LINE: S-11 050 YEAR
LOCATION: BRETON ISLAND -- YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
POST Med RSL
POST High RSL
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

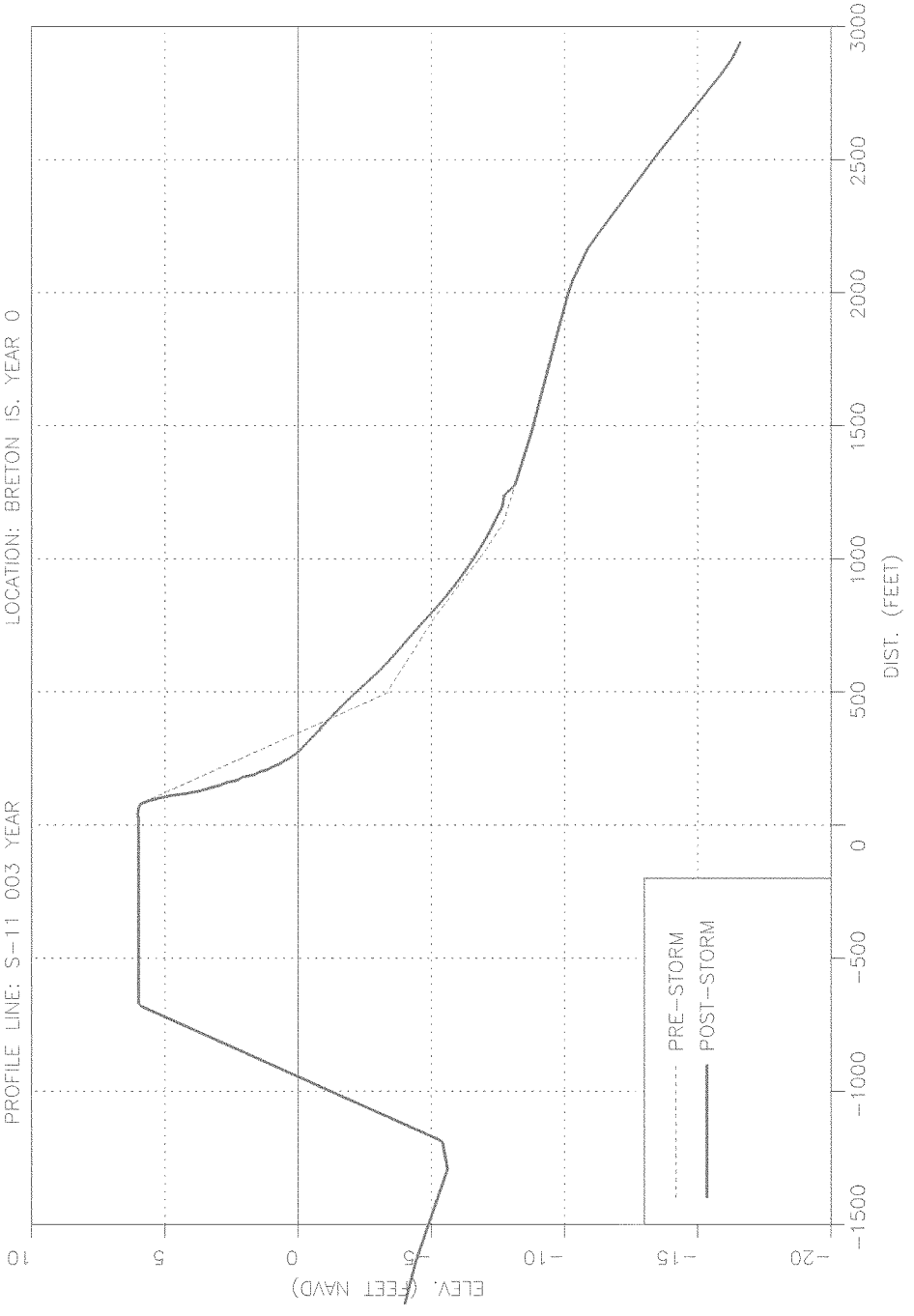

PROFILE LINE: S-11 100 YEAR
LOCATION: BRETON ISLAND -- YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
POST Med RSL
POST High RSL
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

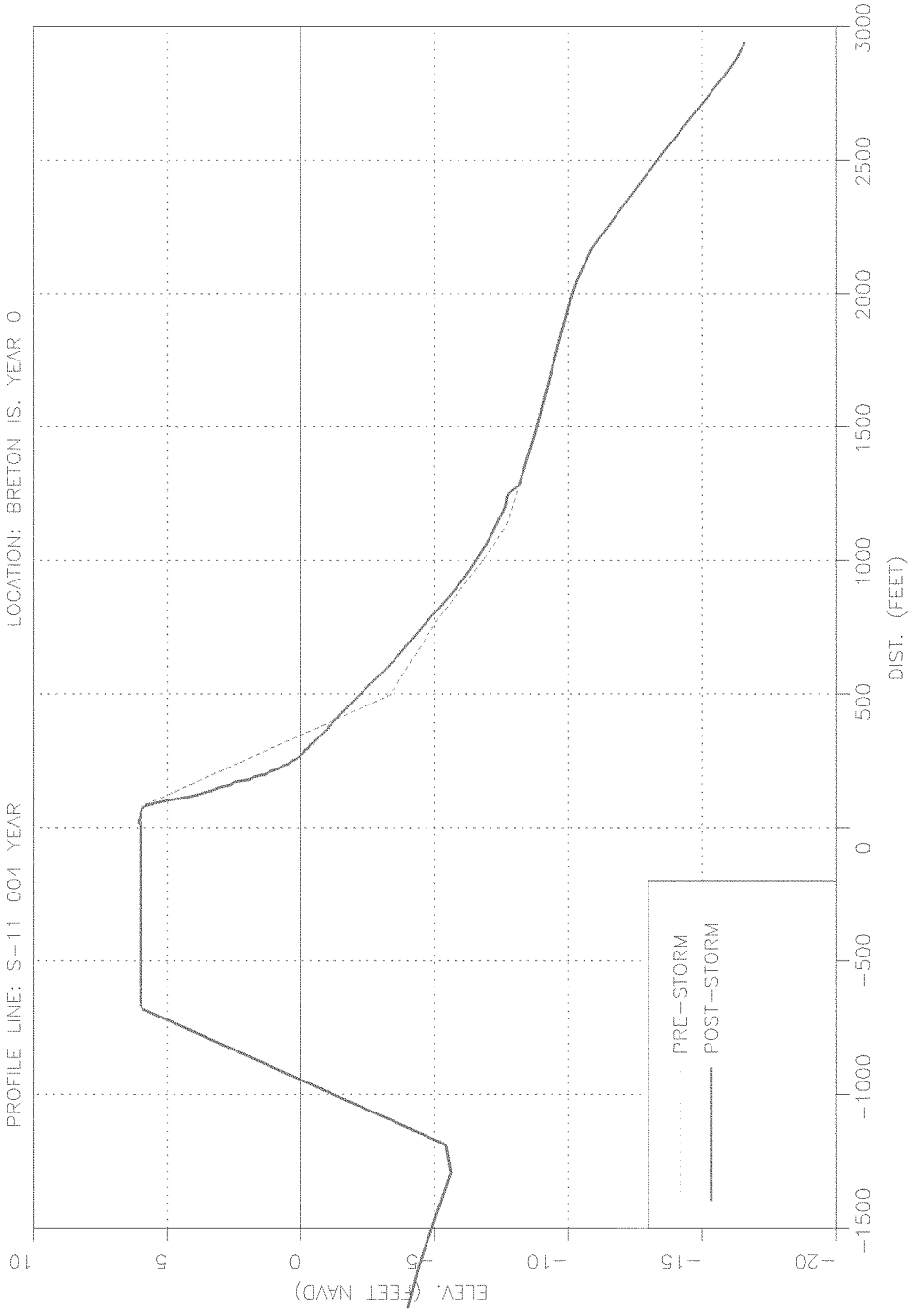
Breton Island Profile S-11

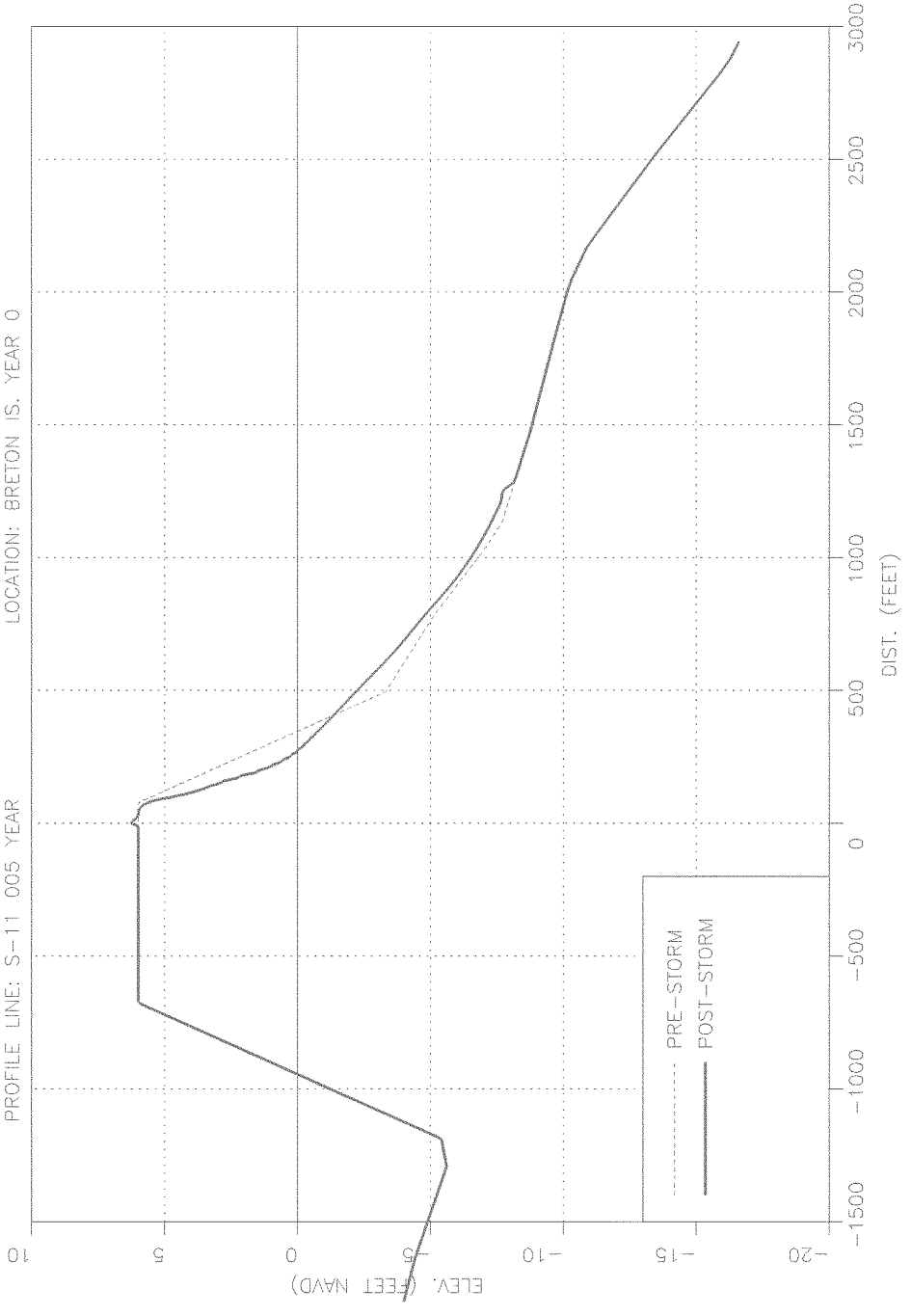
Alternative 2

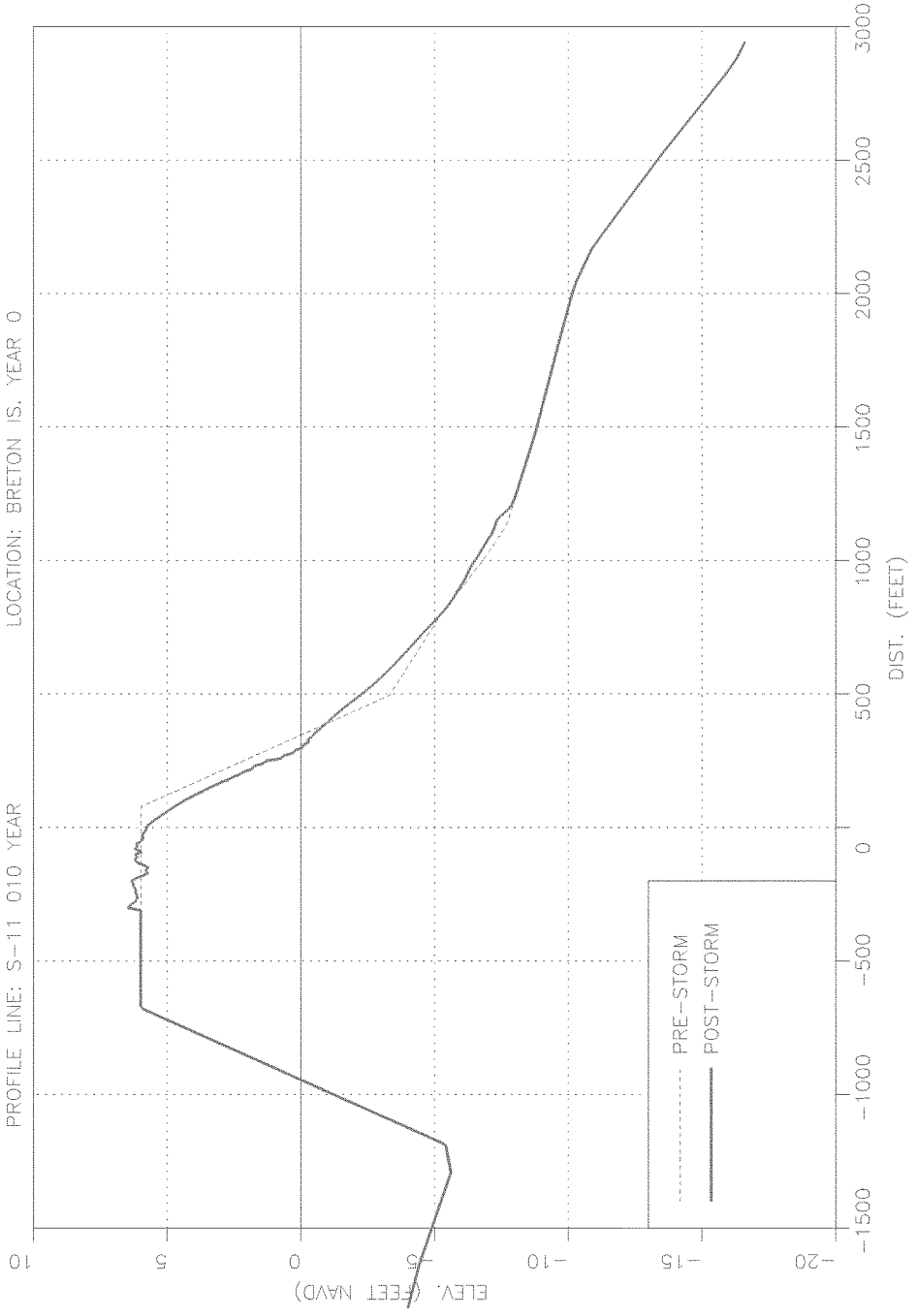

PROFILE LINE: S-11 001 YEAR
LOCATION: BRETON IS. YEAR 0
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

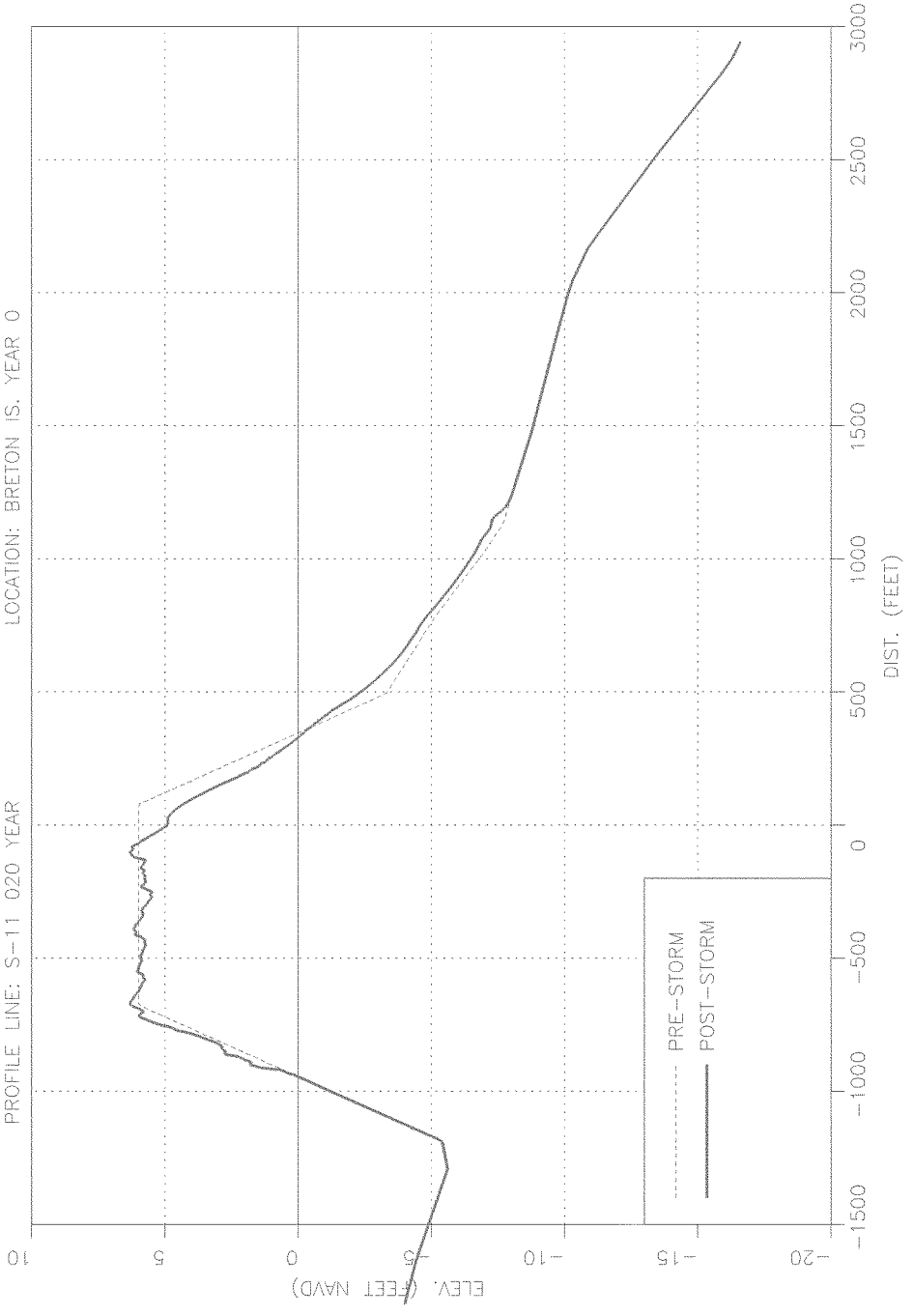

PROFILE LINE: S-11 002 YEAR
LOCATION: BRETON IS. YEAR 0
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

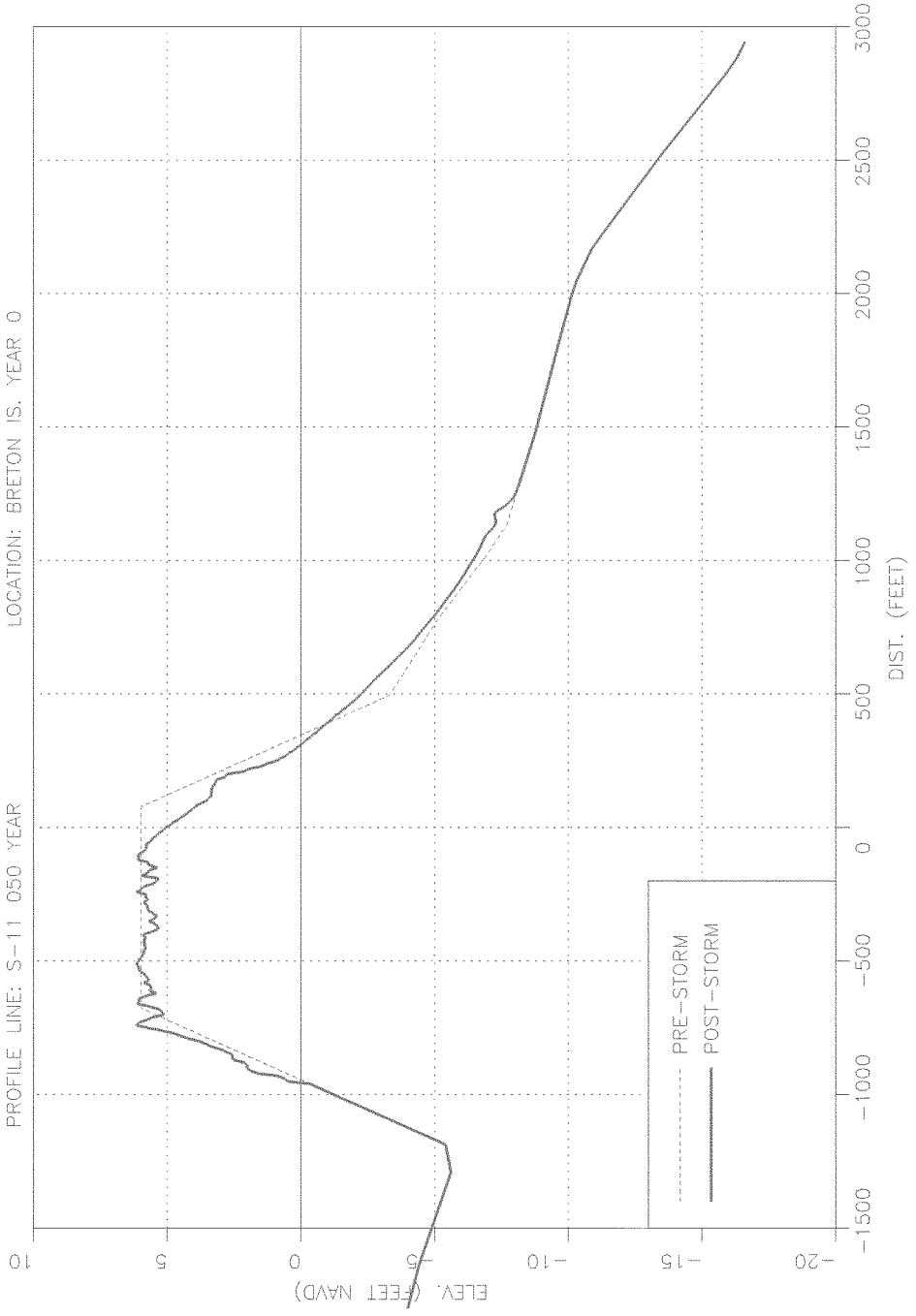

PROFILE LINE: S-11 003 YEAR
LOCATION: BRETON IS. YEAR 0
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

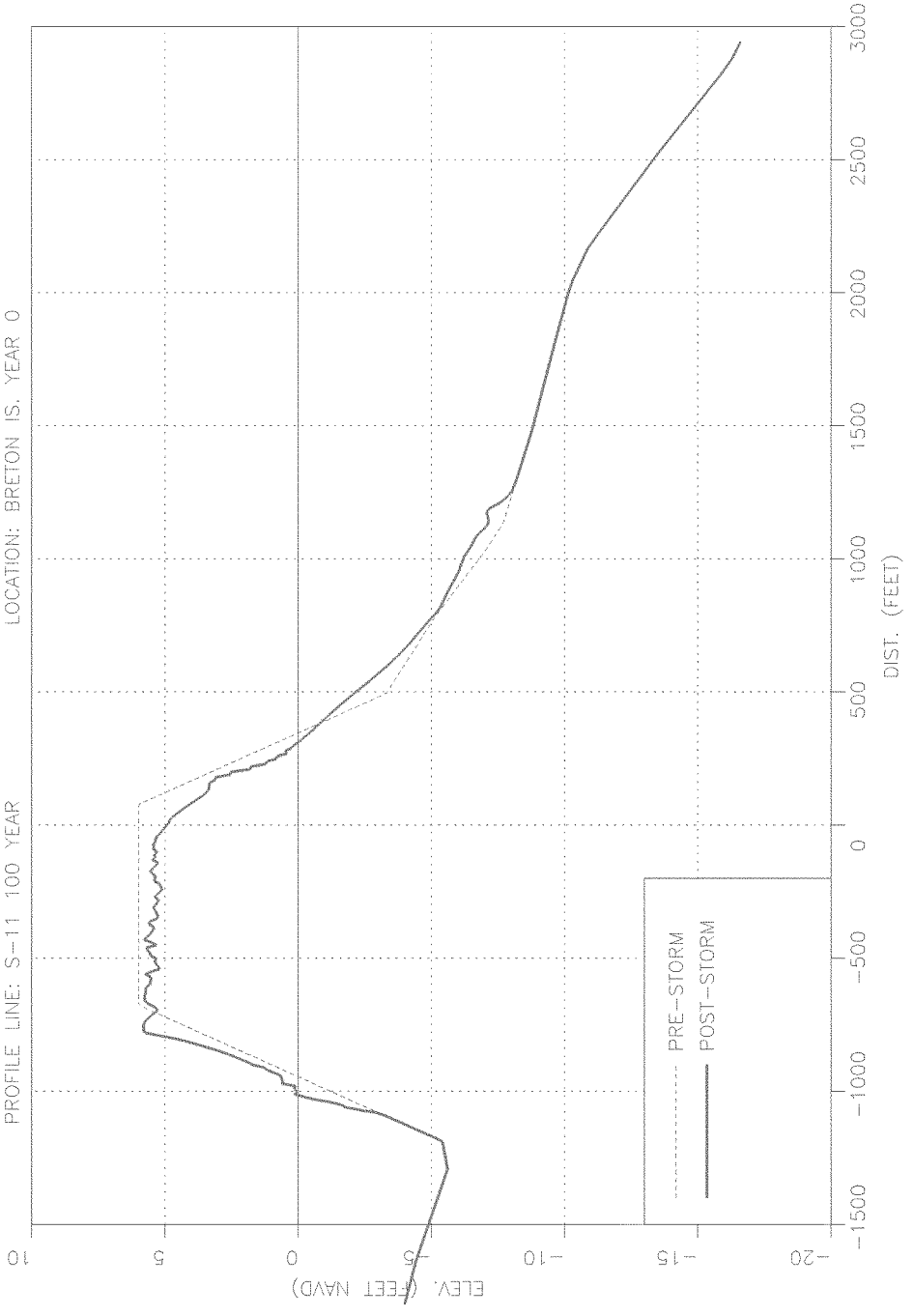

PROFILE LINE: S-11 004 YEAR
LOCATION: BRETON IS. YEAR 0
PRE-STORM
POST-STORM
ELEV. (FEET NAVD)
DIST. (FEET)
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

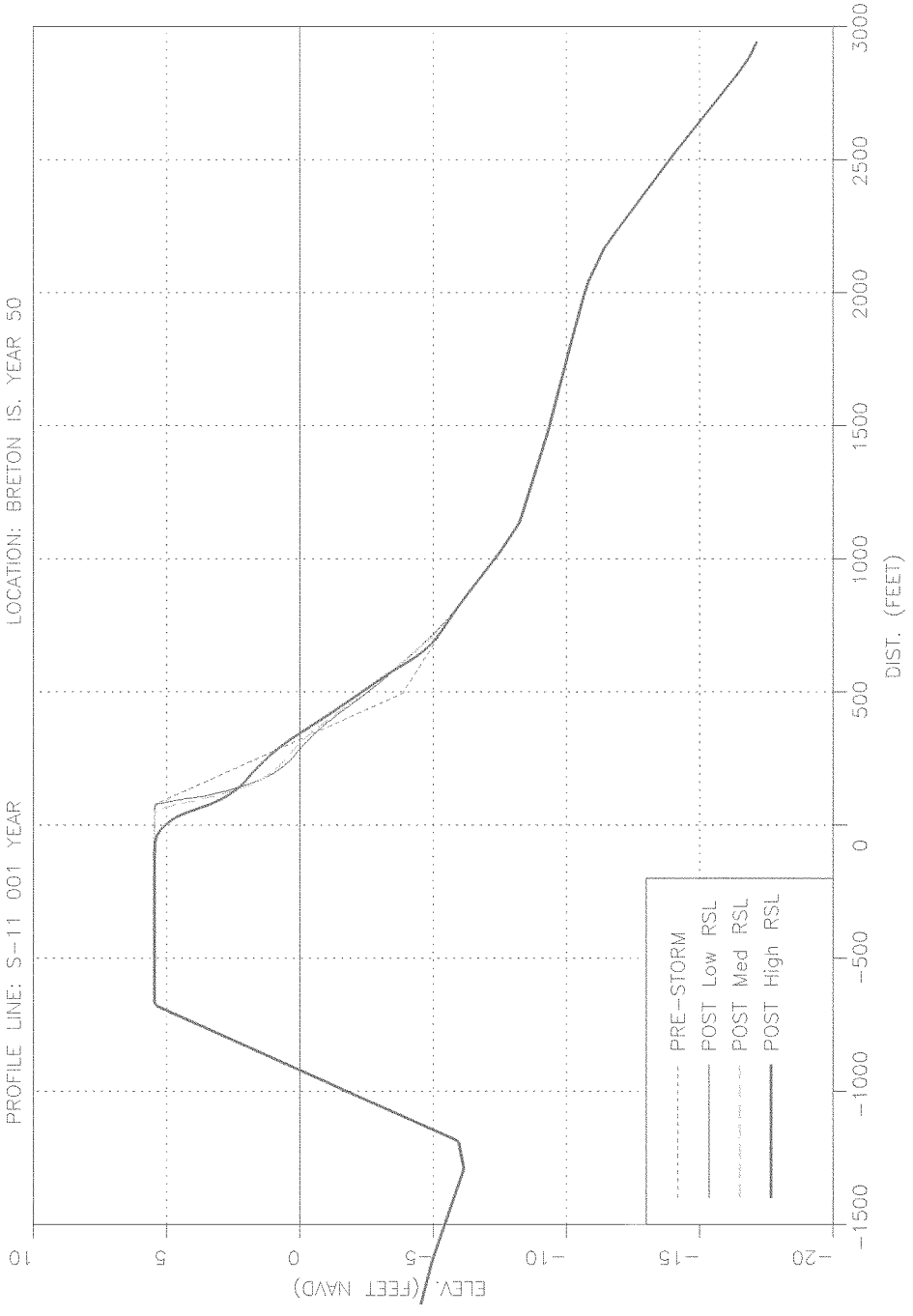

PROFILE LINE: S-11 005 YEAR
LOCATION: BRETON IS. YEAR 0
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

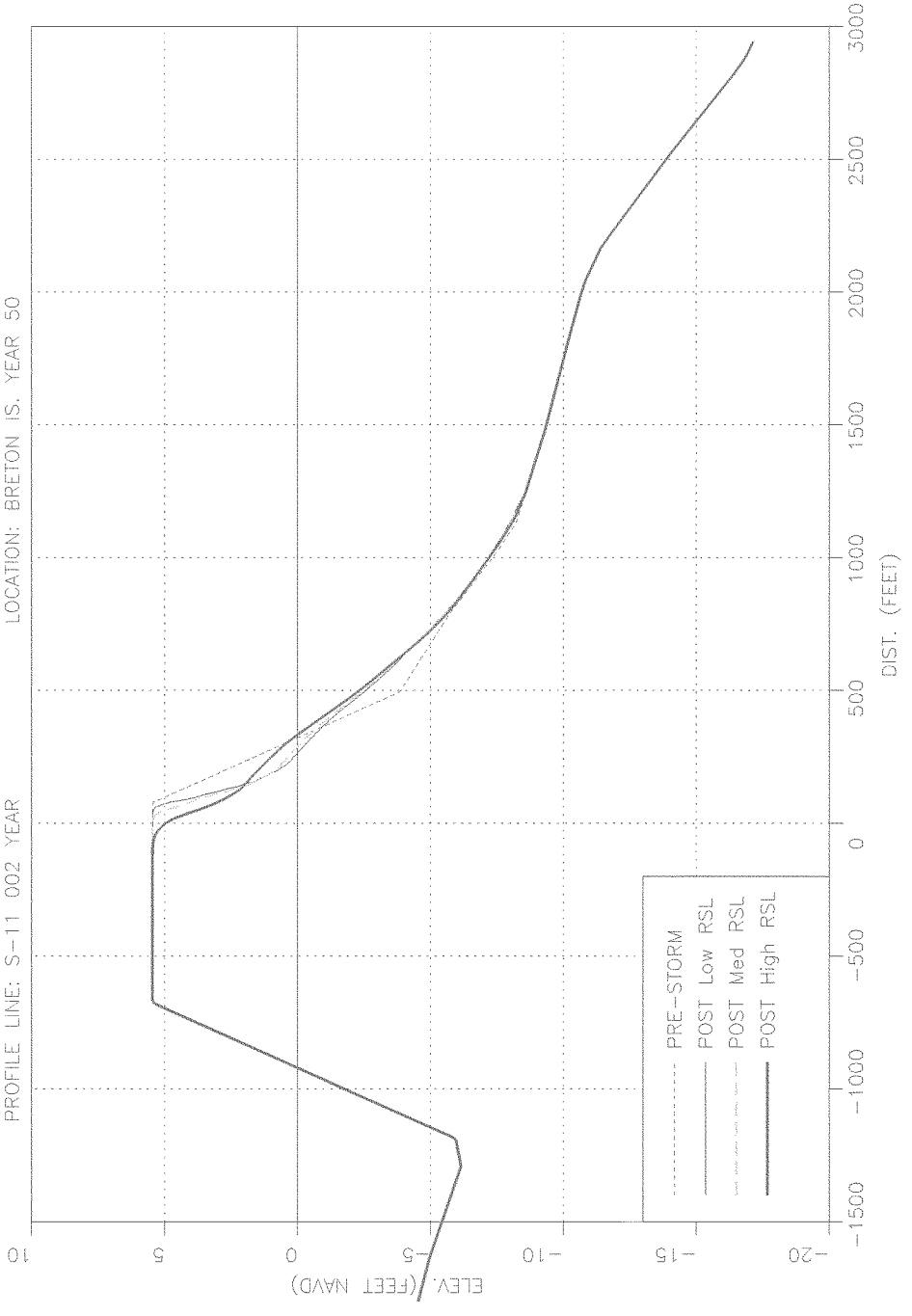

PROFILE LINE: S-11 010 YEAR
LOCATION: BRETON IS. YEAR 0
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

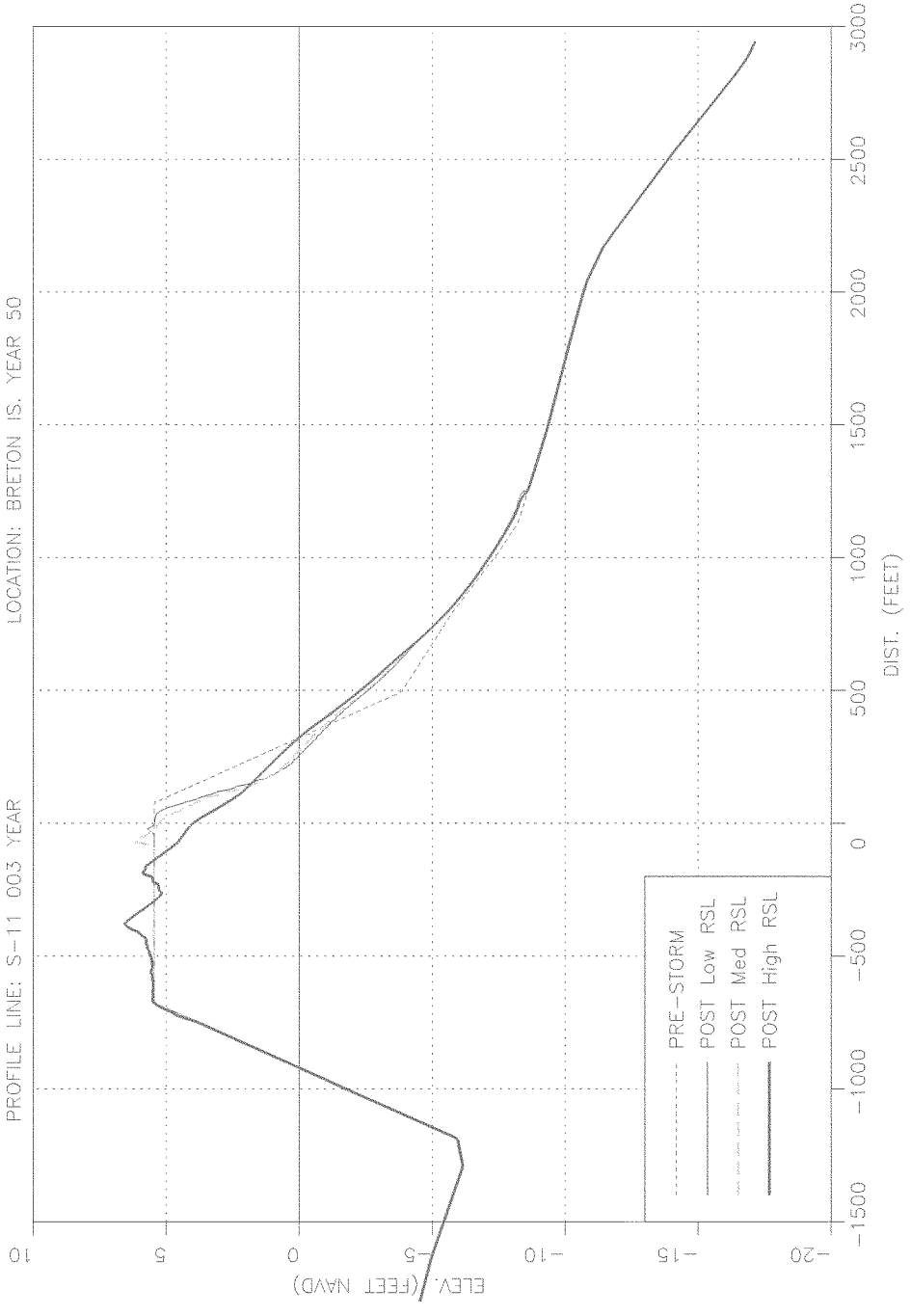

PROFILE LINE: S-11 020 YEAR
LOCATION: BRETON IS. YEAR 0
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

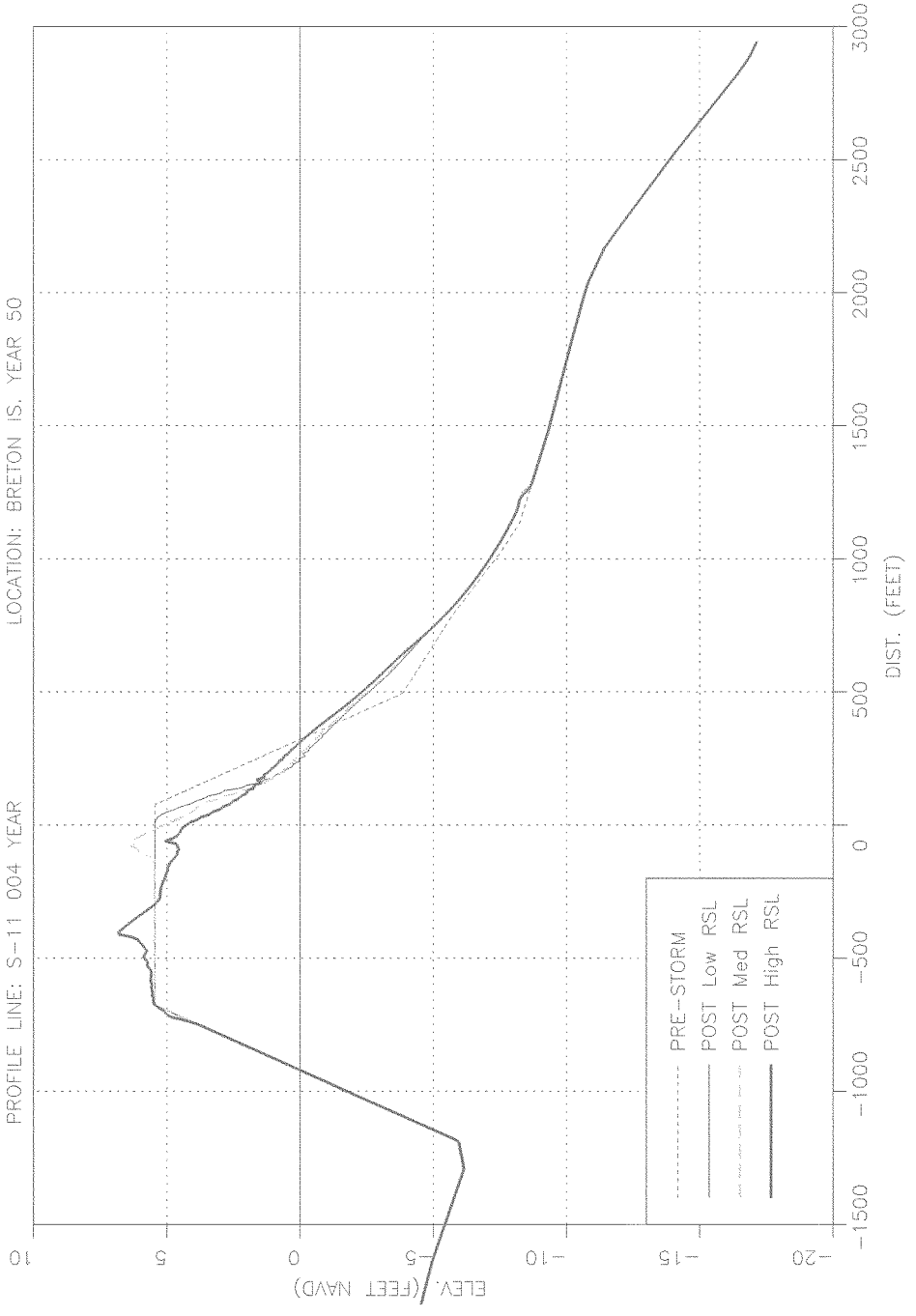

PROFILE LINE: S-11 050 YEAR
LOCATION: BRETON IS. YEAR 0
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

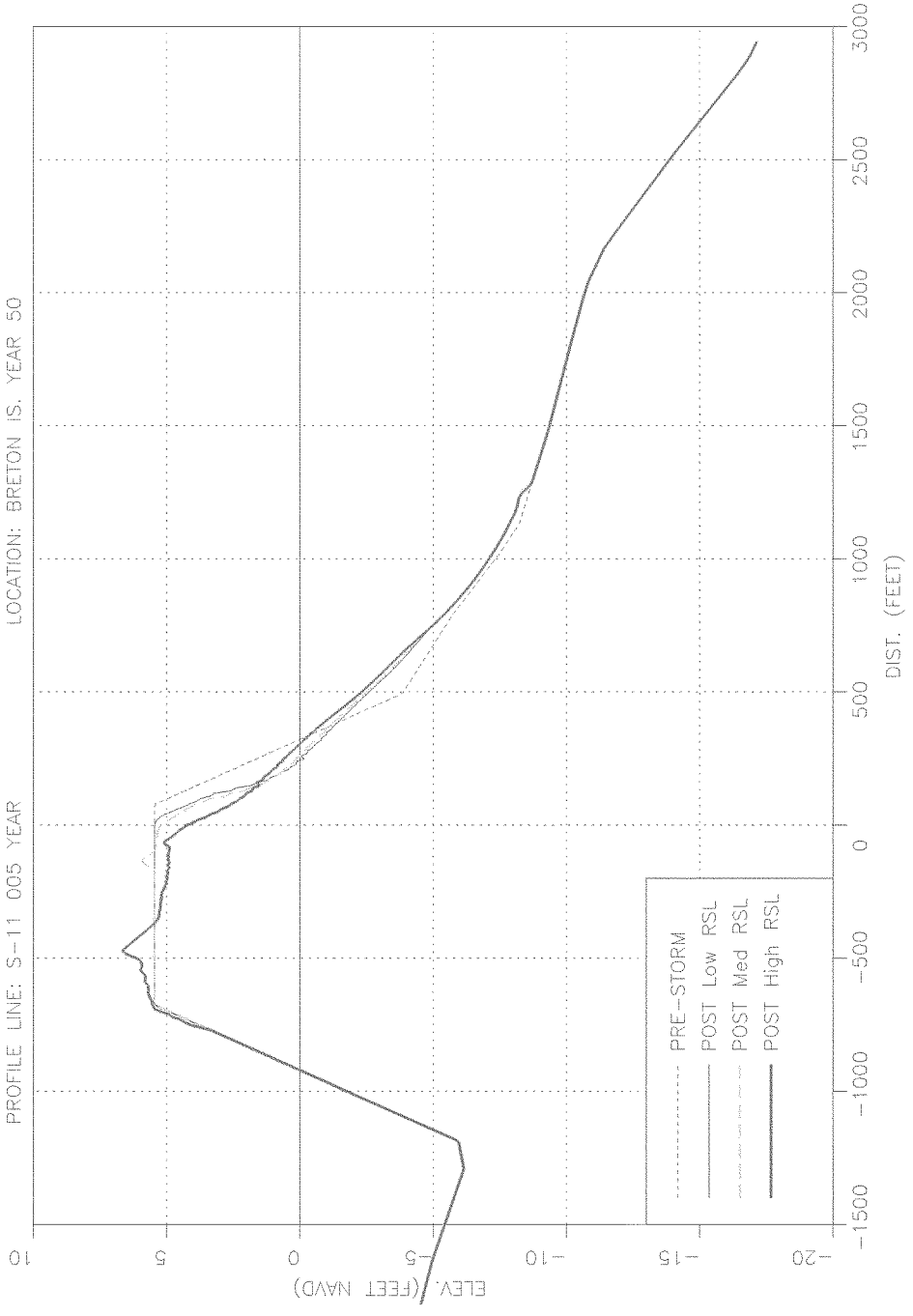

PROFILE LINE: S-11 100 YEAR
LOCATION: BRETON IS. YEAR 0
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

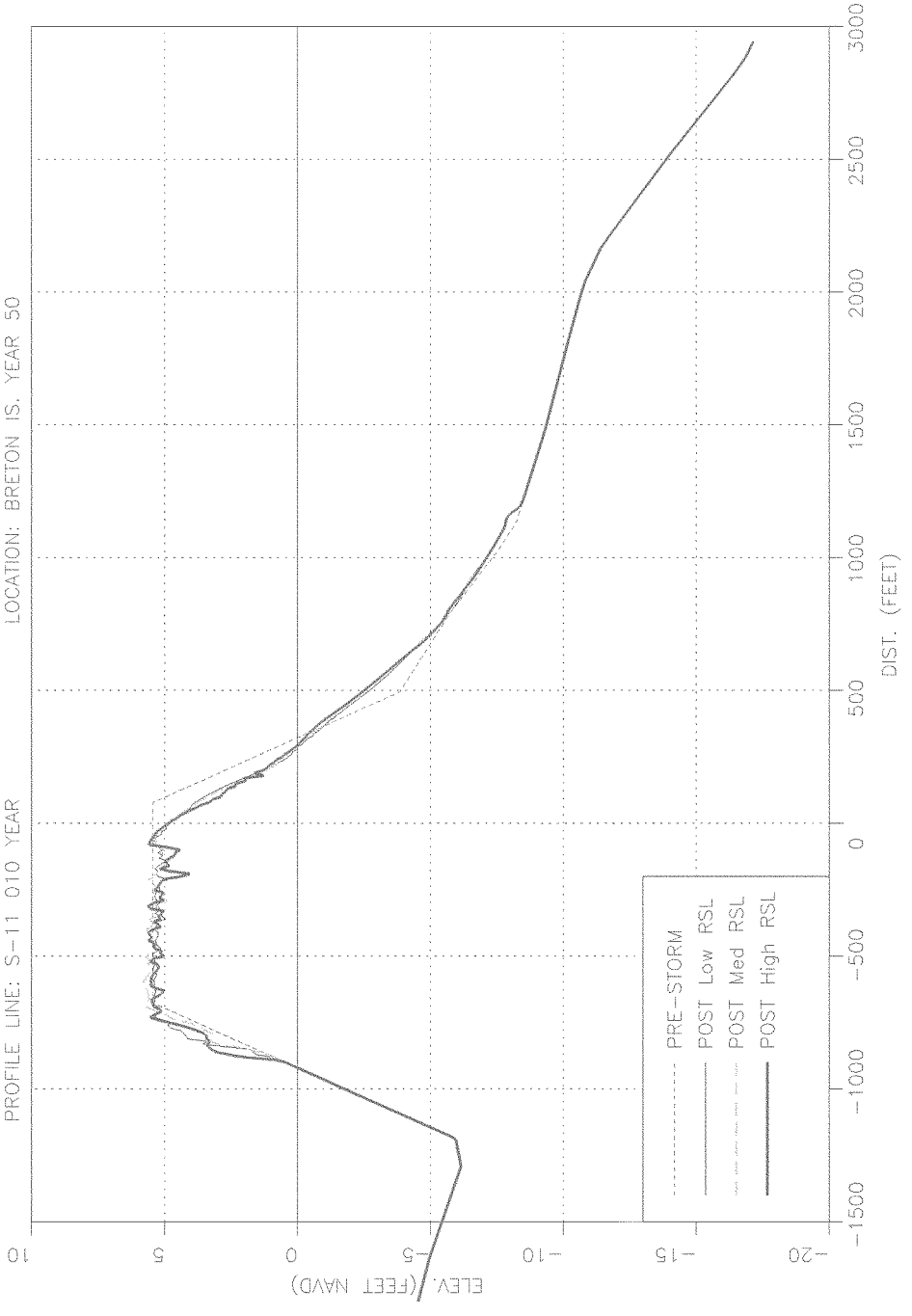

PROFILE LINE: S-11 001 YEAR
LOCATION: BRETON IS. YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
POST Med RSL
POST High RSL
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

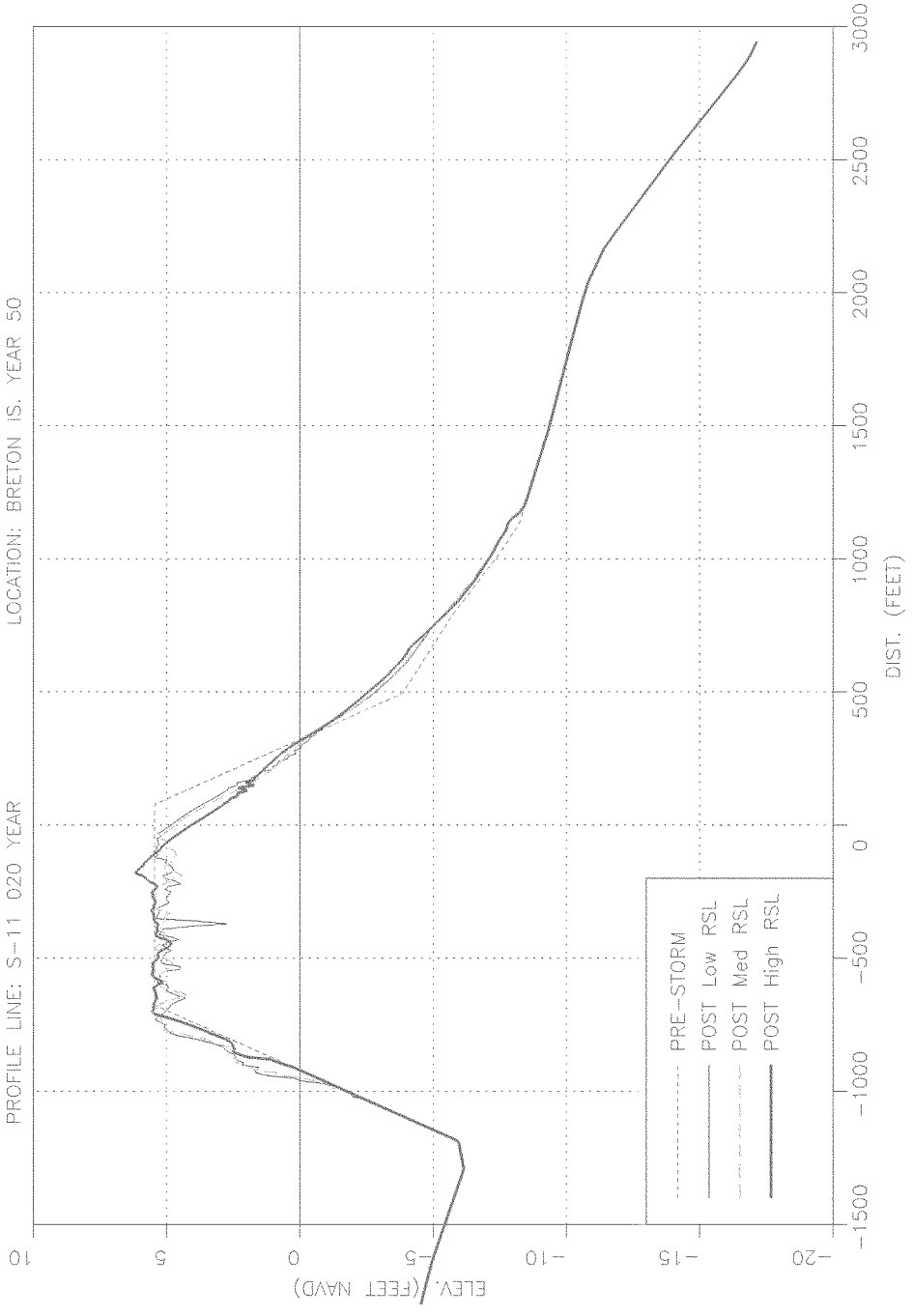

PROFILE LINE: S-11 002 YEAR
LOCATION: BRETON IS. YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
POST Med RSL
POST High RSL
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

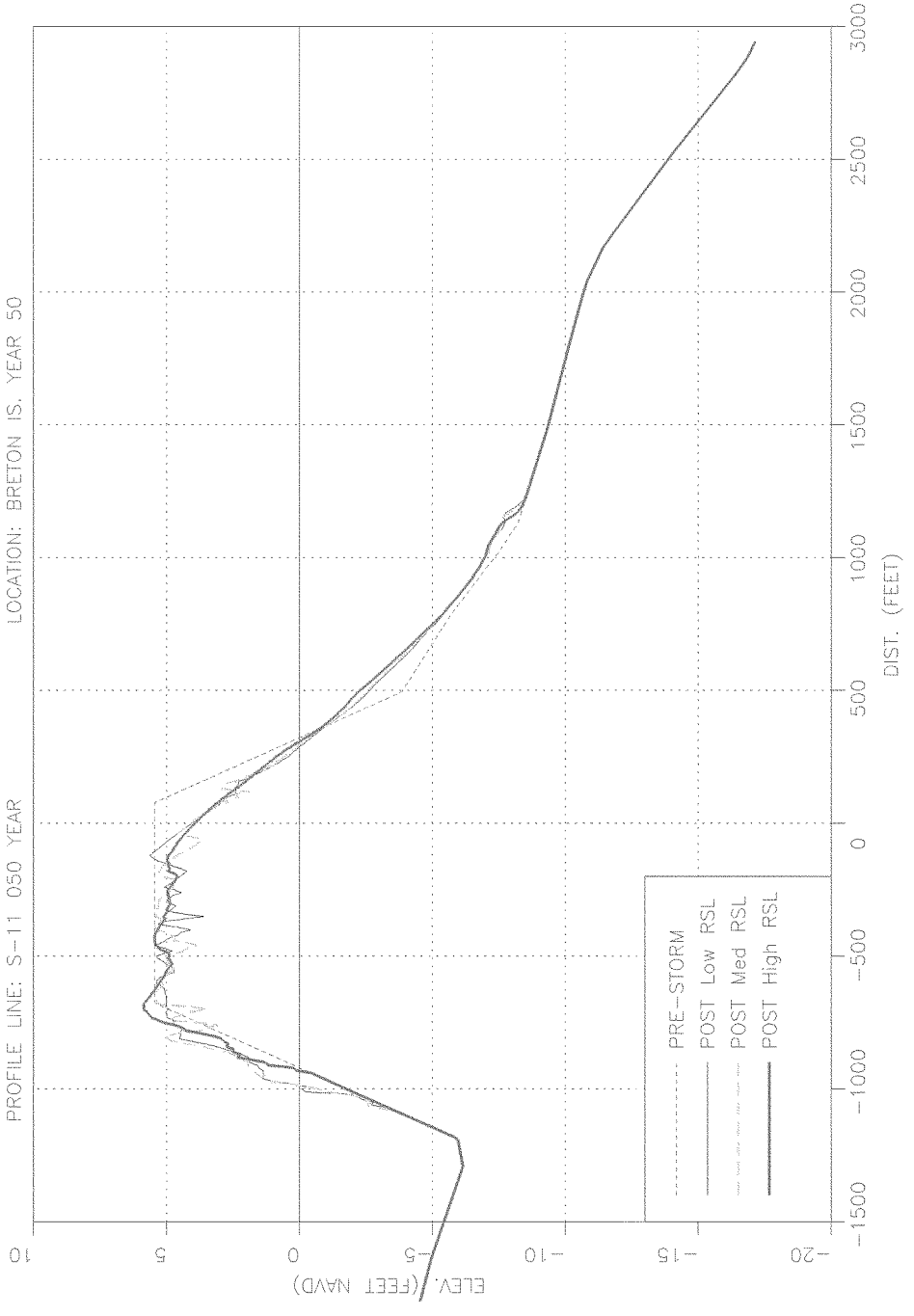

PROFILE LINE: S-11 003 YEAR
LOCATION: BRETON IS. YEAR 50
PRE-STORM
POST Low RSL
POST Med RSL
POST High RSL
ELEV. (FEET NAVD)
DIST. (FEET)
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

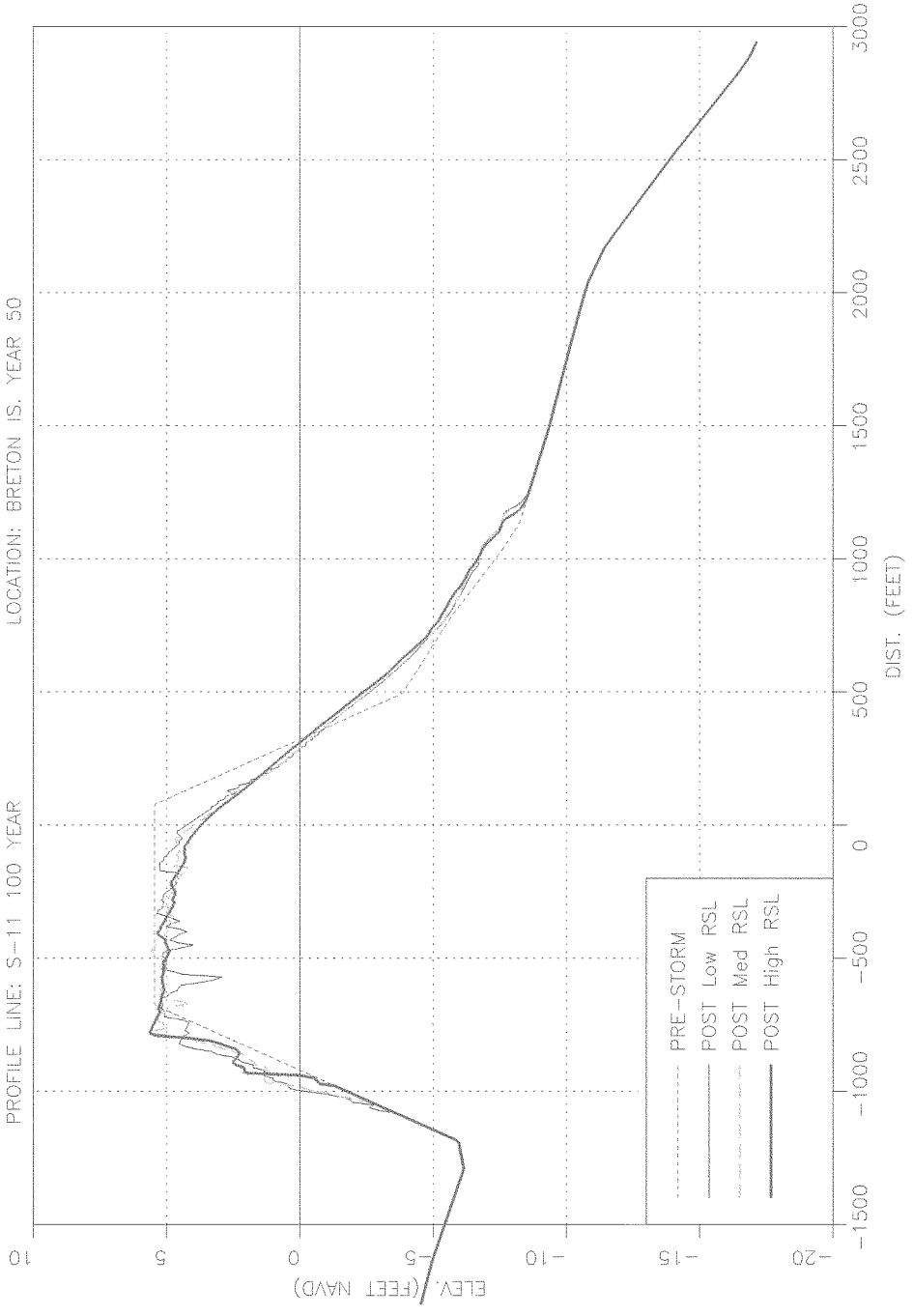

PROFILE LINE: S-11 004 YEAR
LOCATION: BRETON IS. YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
POST Med RSL
POST High RSL
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000


PROFILE LINE: S-11 005 YEAR
LOCATION: BRETON IS. YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
POST Med RSL
POST High RSL
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000


PROFILE LINE: S-11 010 YEAR
LOCATION: BRETON IS. YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
POST Med RSL
POST High RSL
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

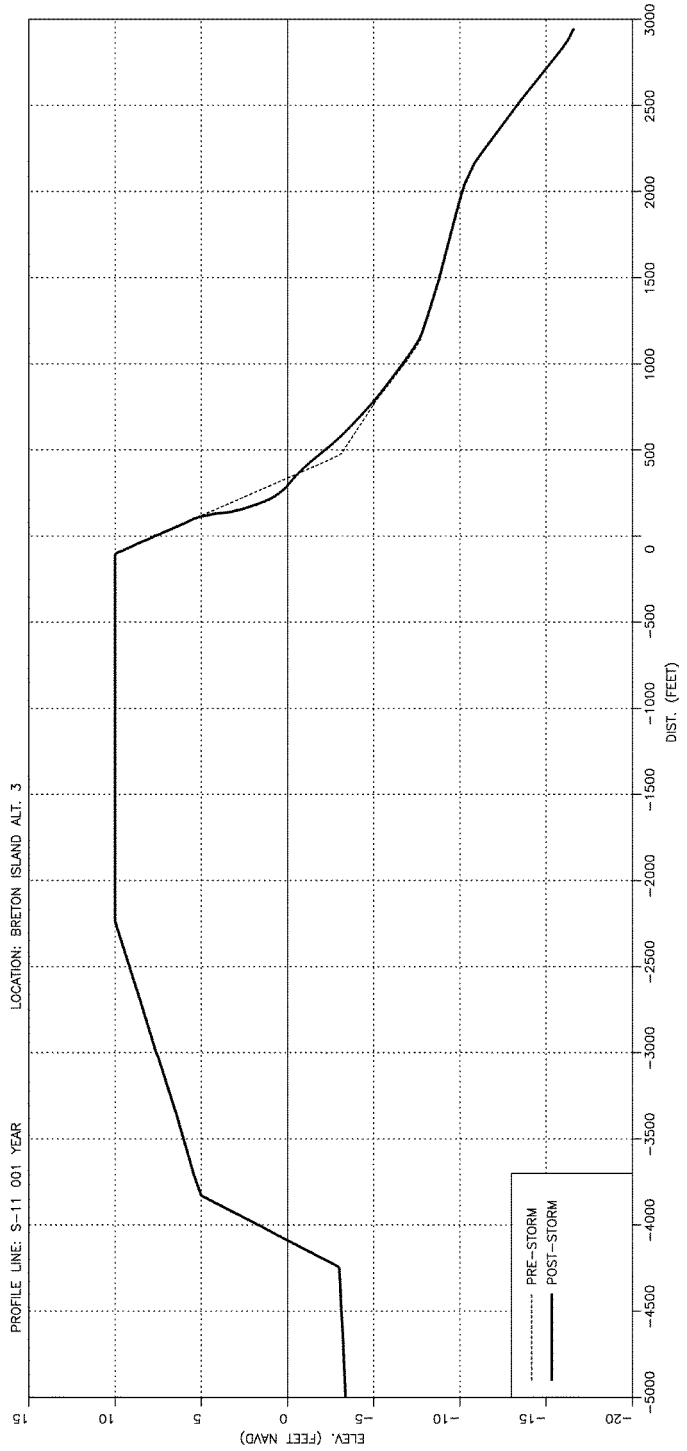

PROFILE LINE: S-11 020 YEAR
LOCATION: BRETON IS. YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
POST Med RSL
POST High RSL
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

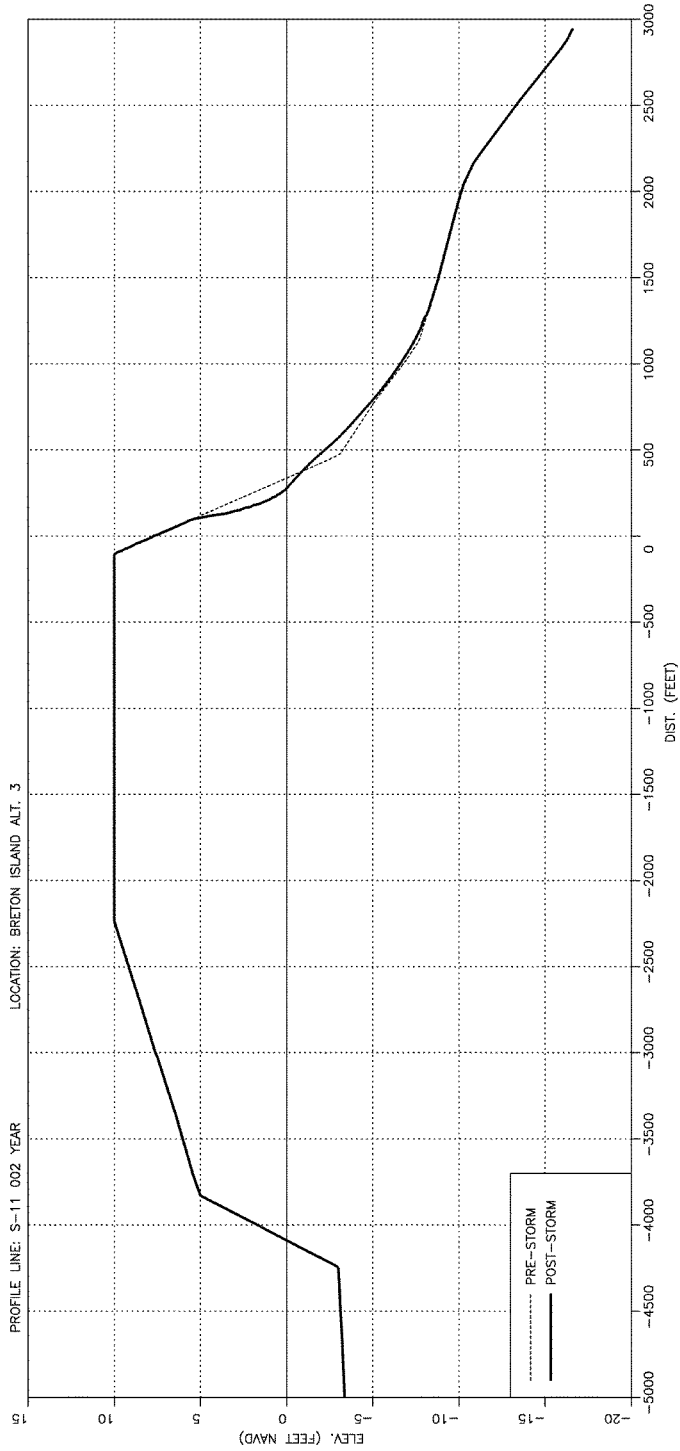

PROFILE LINE: S-11 050 YEAR
LOCATION: BRETON IS. YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
POST Med RSL
POST High RSL
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

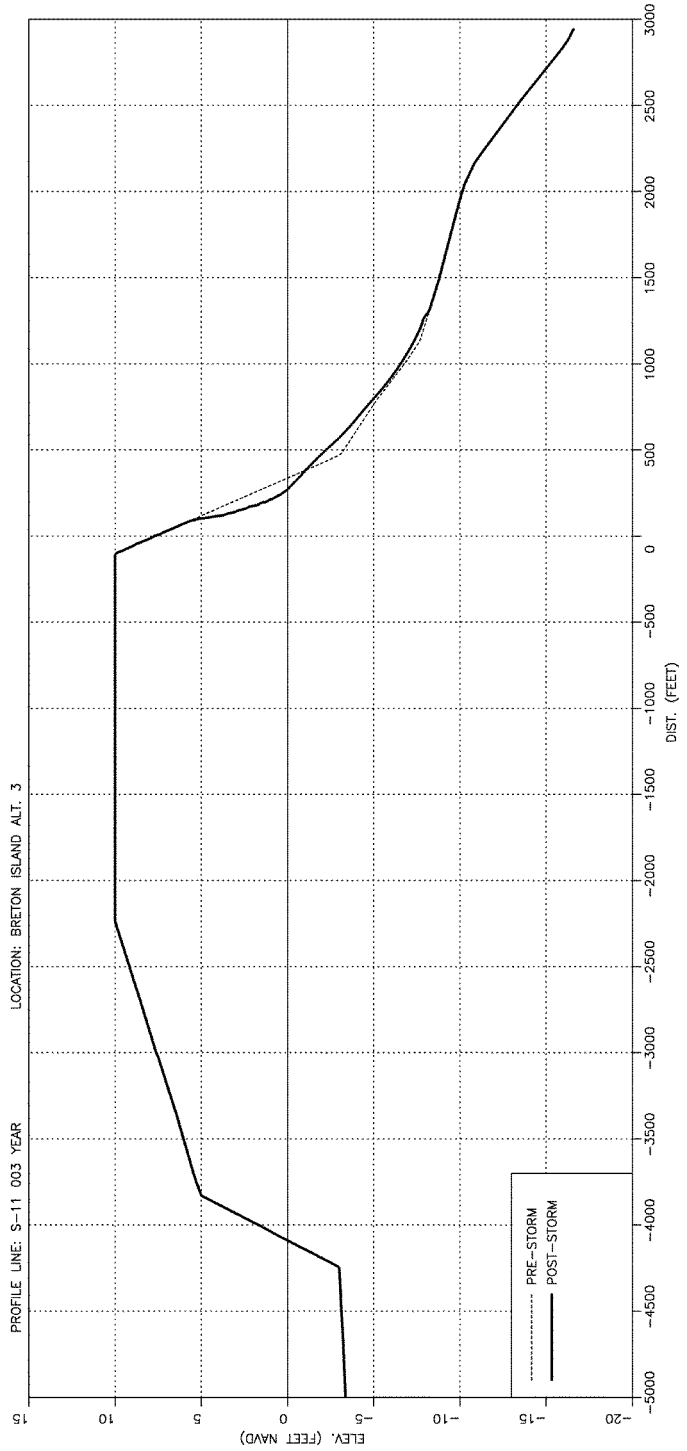

PROFILE LINE: S-11 100 YEAR
LOCATION: BRETON IS. YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
POST Med RSL
POST High RSL
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

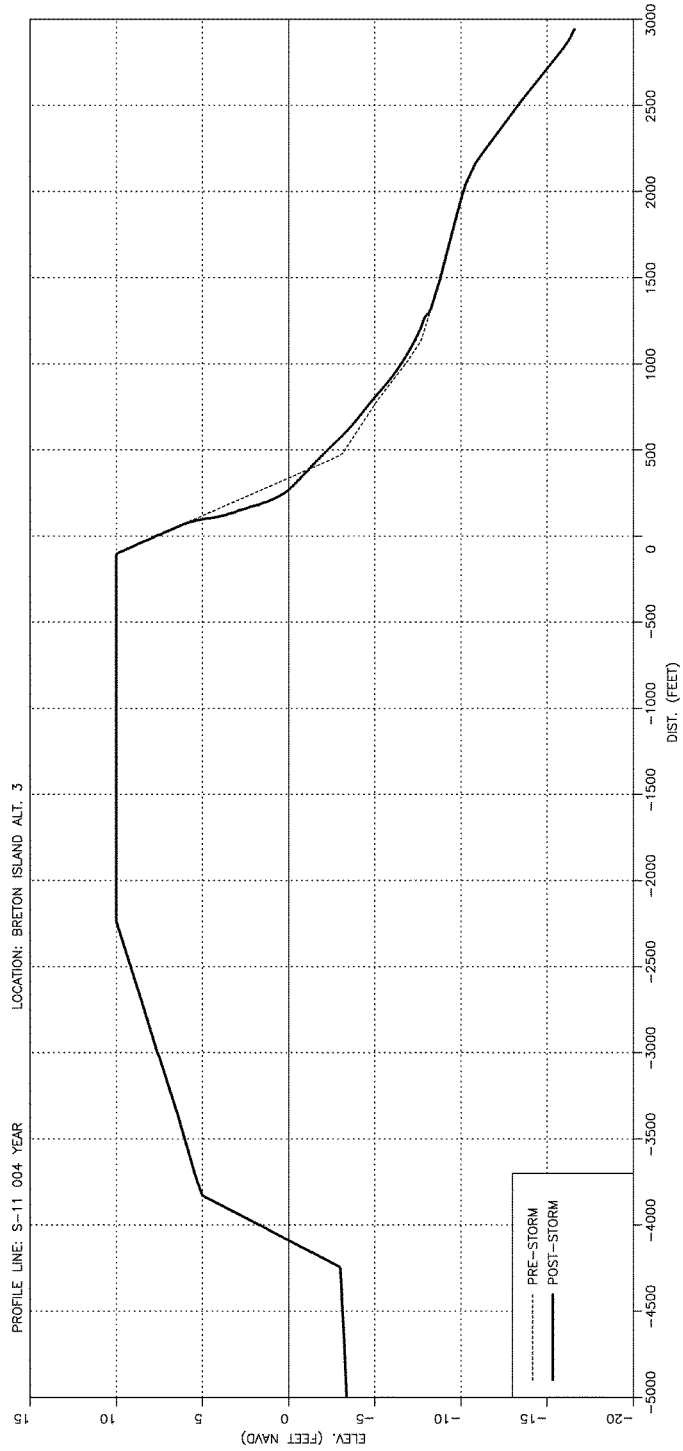
Breton Island Profile S-11

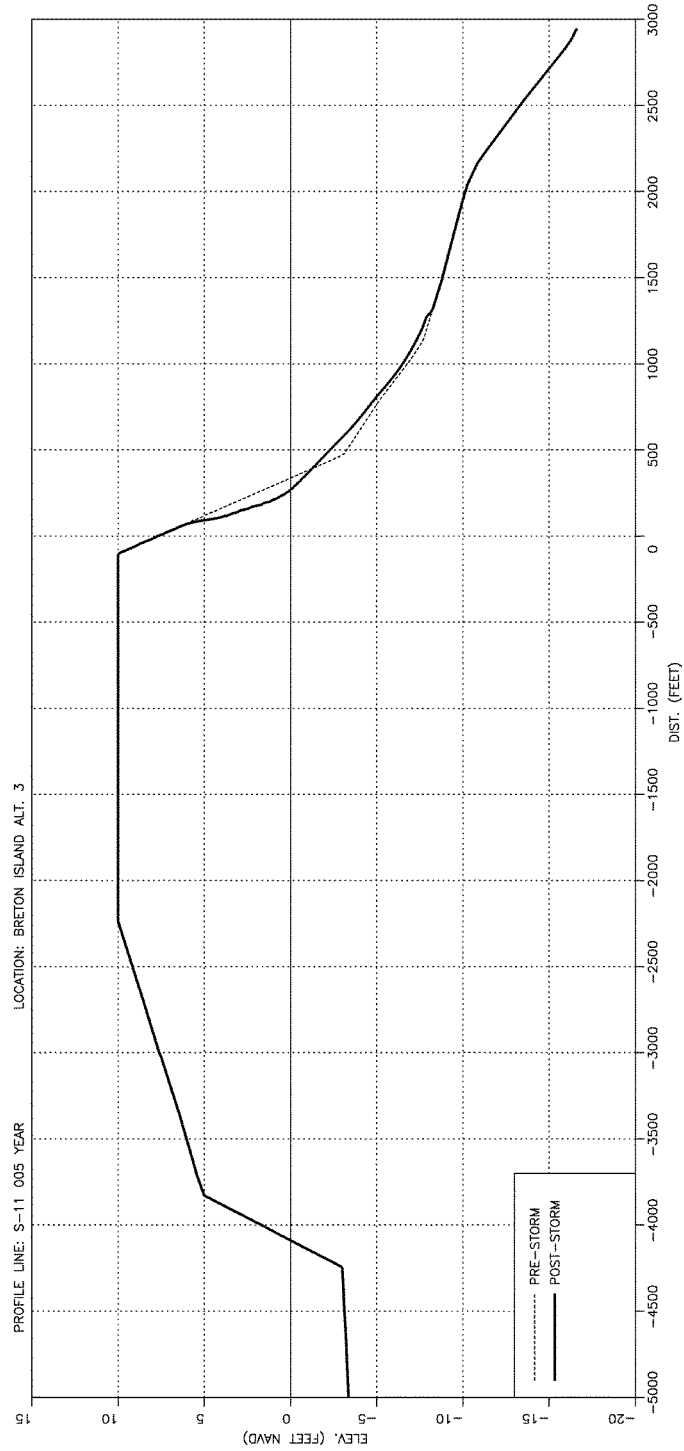
Alternative 3

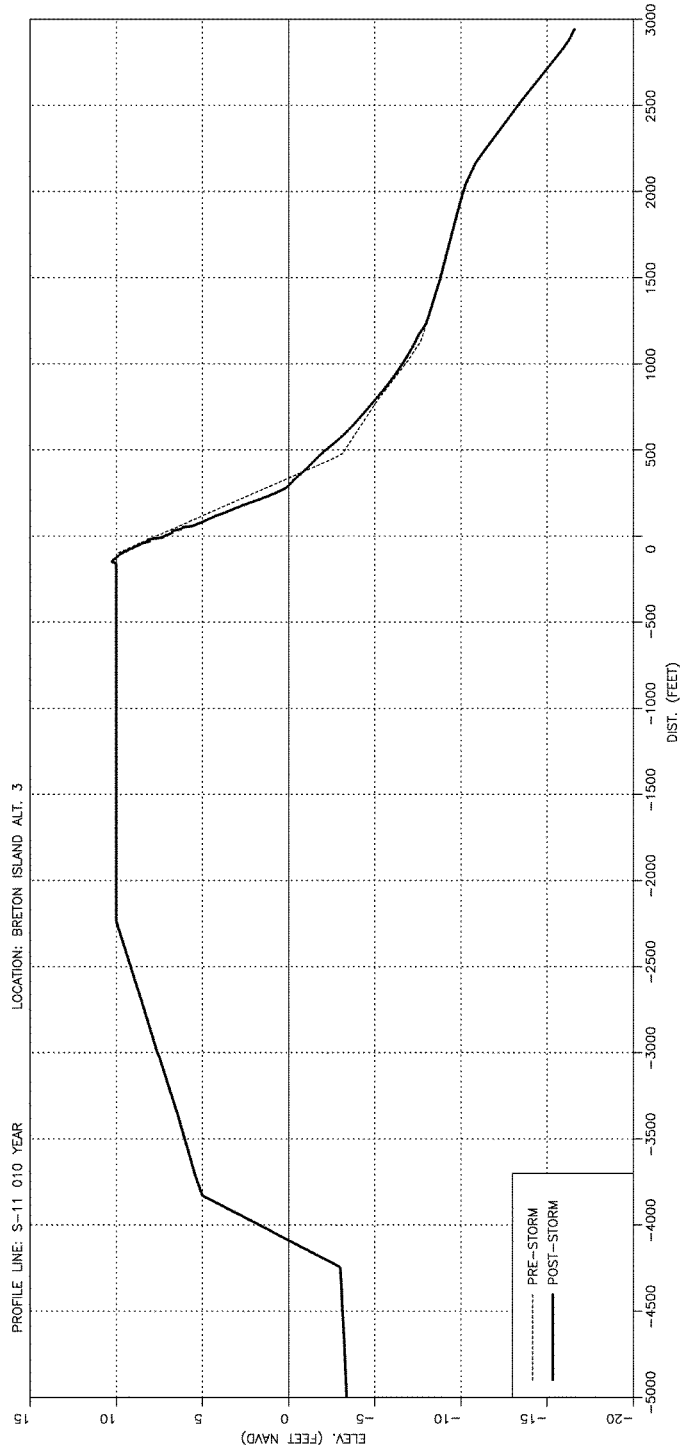

PROFILE LINE: S-11 001 YEAR
LOCATION: BRETON ISLAND ALT. 3
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
15
10
5
0
-5
-10
-15
-20
-5000
-4500
-4000
-3500
-3000
-2500
-2000
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

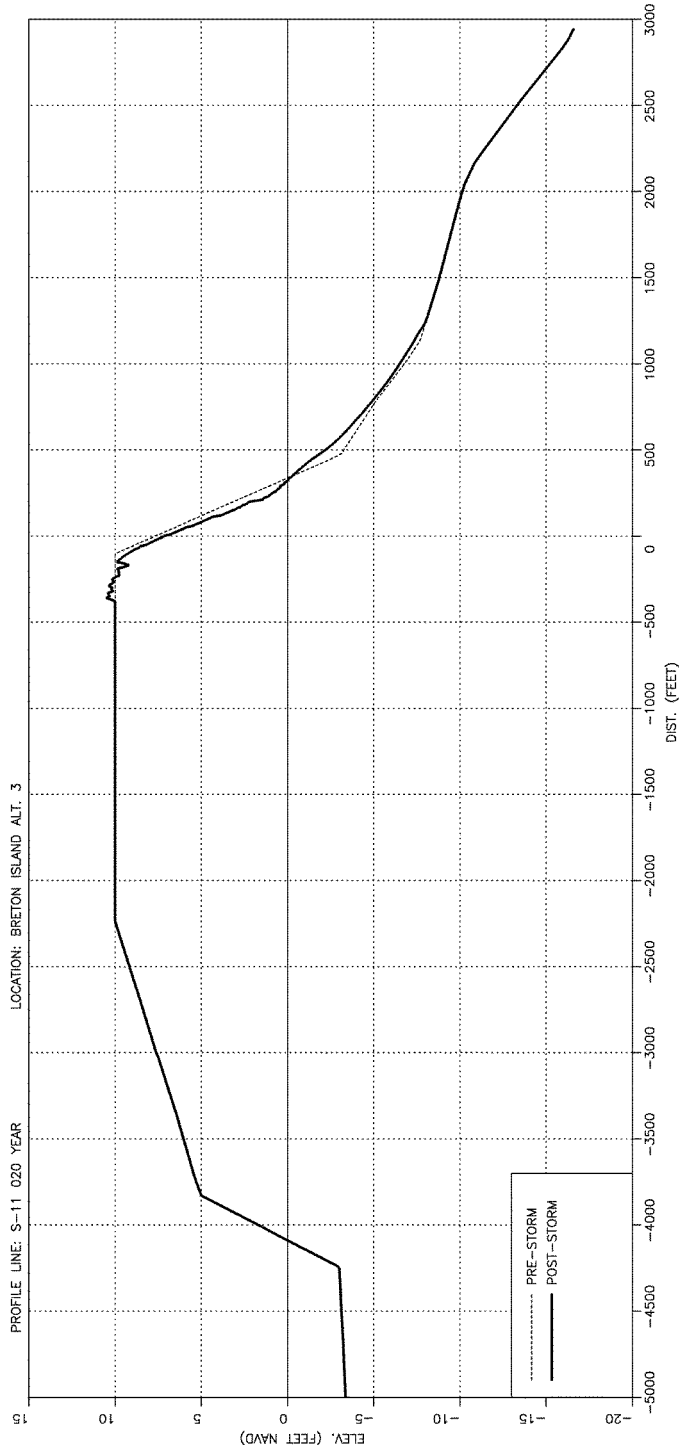

PROFILE LINE: S-11 002 YEAR
LOCATION: BRETON ISLAND ALT. 3
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
15
10
5
0
-5
-10
-15
-20
-5000
-4500
-4000
-3500
-3000
-2500
-2000
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

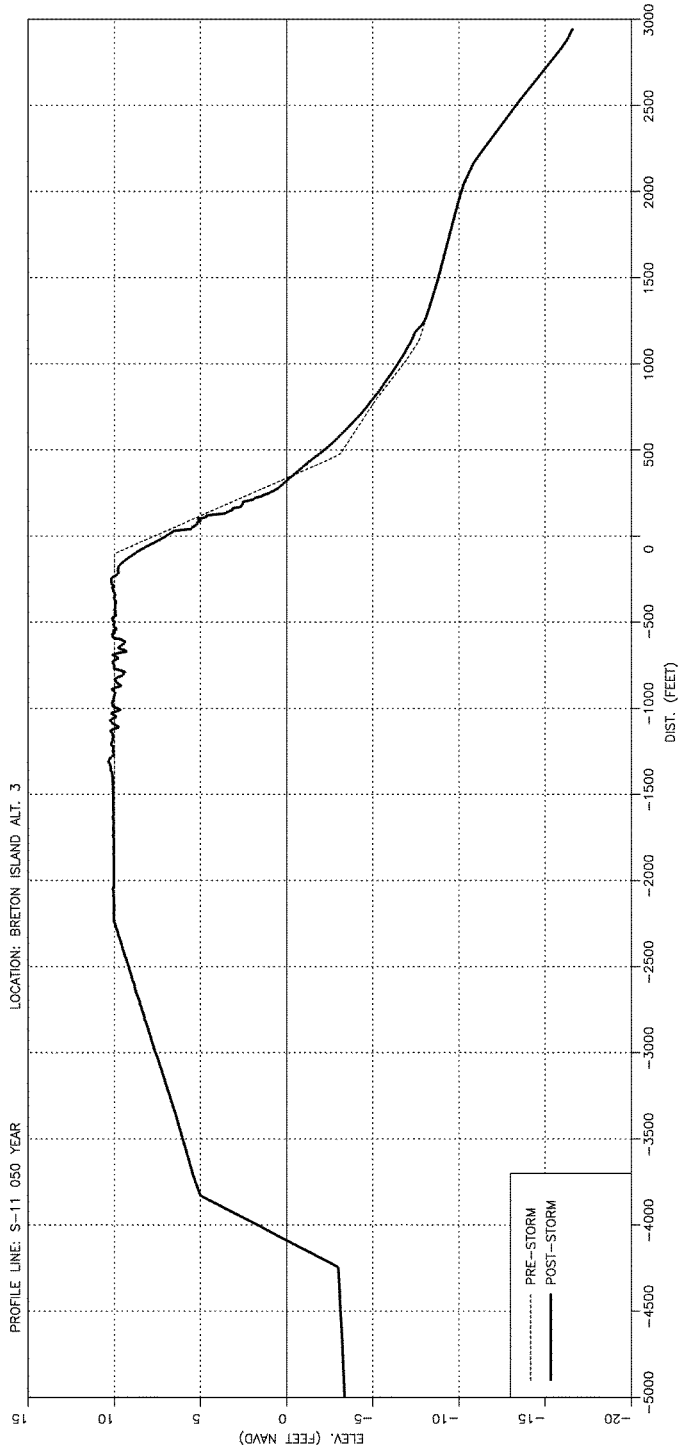

PROFILE LINE: S-11 003 YEAR
LOCATION: BRETON ISLAND ALT. 3
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
15
10
5
0
-5
-10
-15
-20
-5000
-4500
-4000
-3500
-3000
-2500
-2000
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

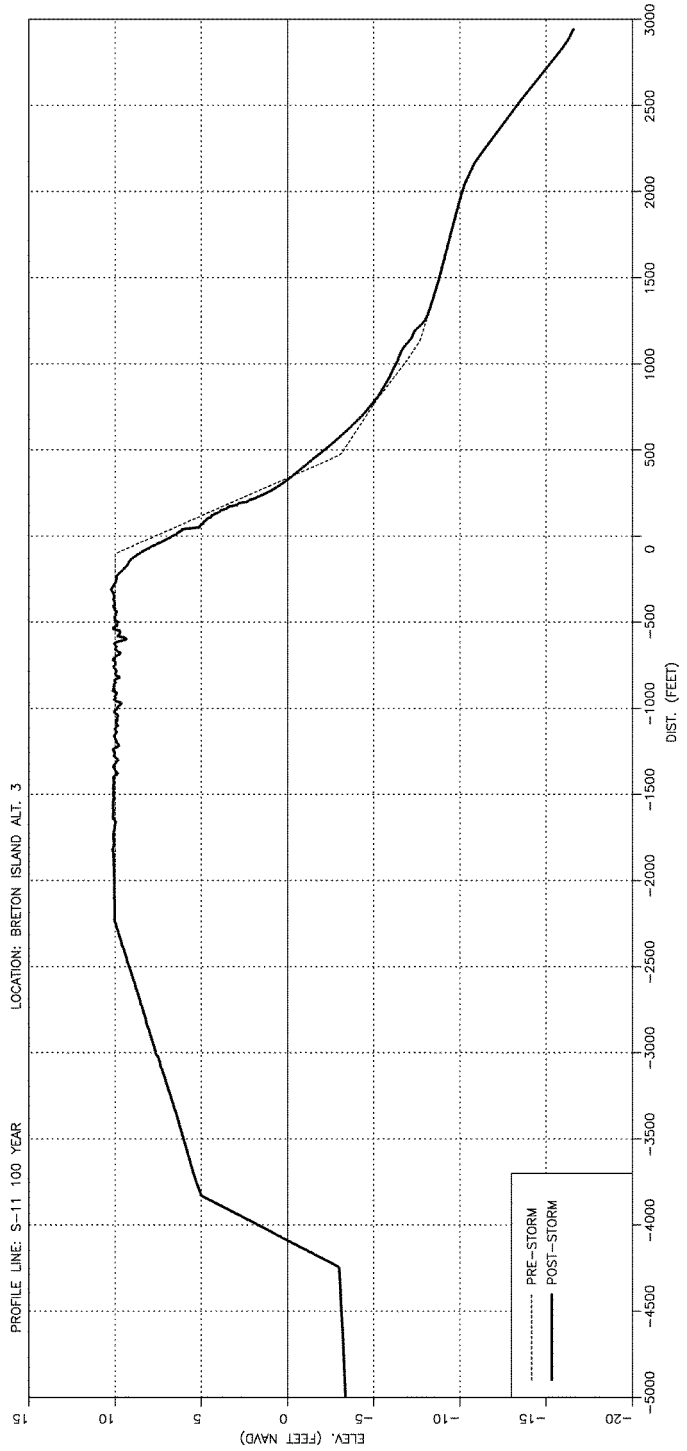

PROFILE LINE: S-11 004 YEAR
LOCATION: BRETON ISLAND ALT. 3
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
15
10
5
0
-5
-10
-15
-20
-5000
-4500
-4000
-3500
-3000
-2500
-2000
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

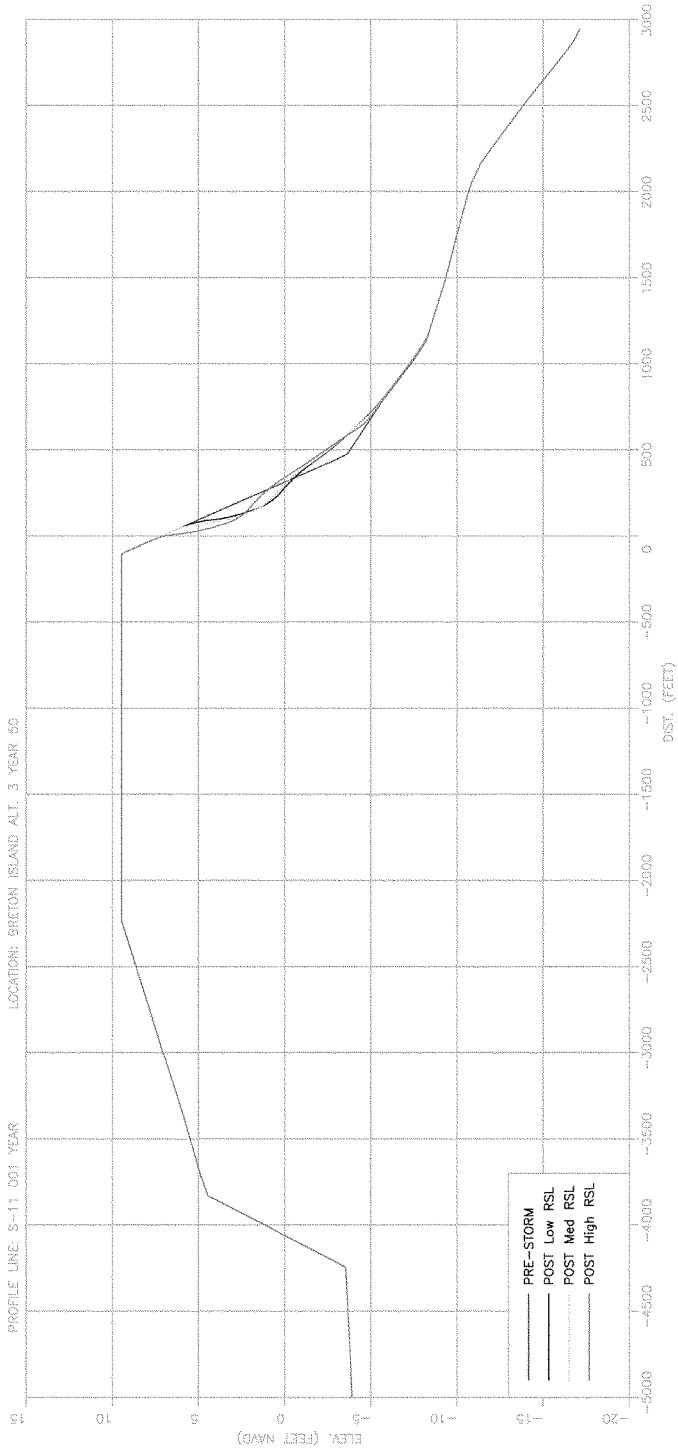

PROFILE LINE: S-11 005 YEAR
LOCATION: BRETON ISLAND ALT. 3
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
15
10
5
0
-5
-10
-15
-20
-5000
-4500
-4000
-3500
-3000
-2500
-2000
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

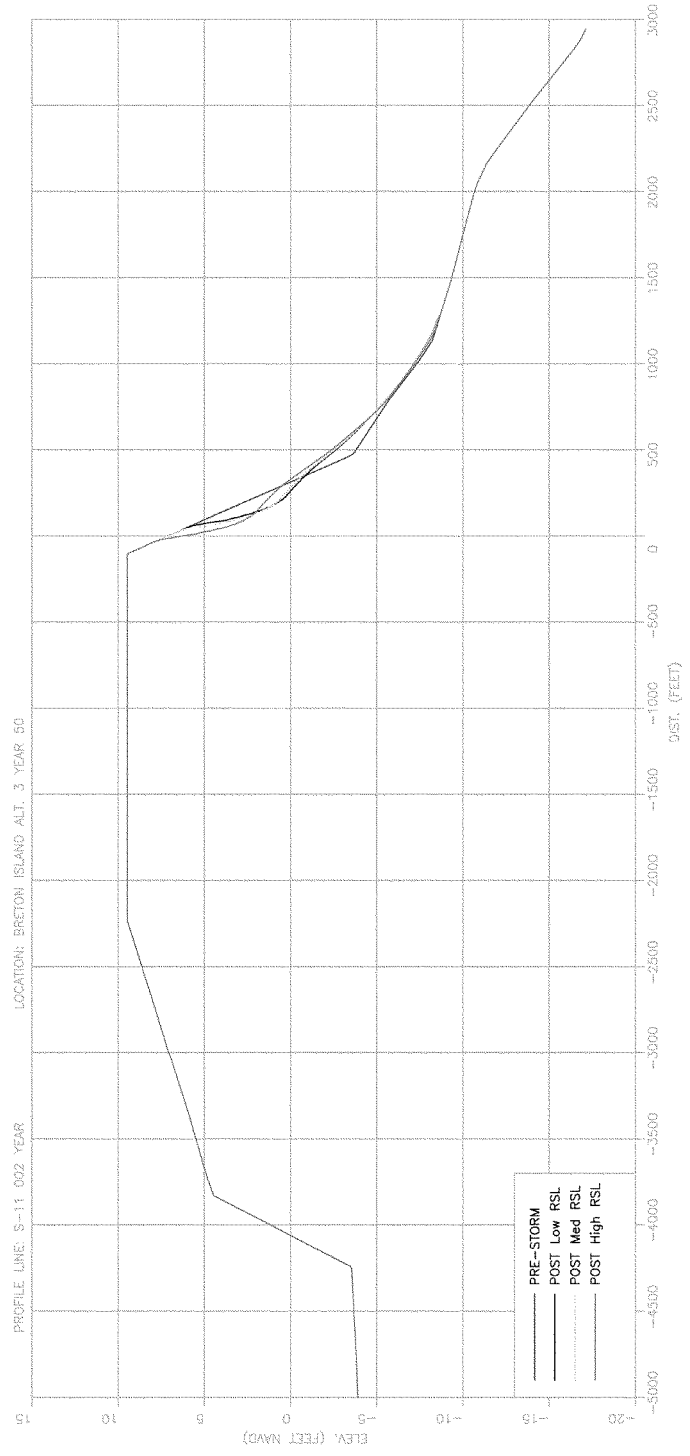

PROFILE LINE: S-11 010 YEAR
LOCATION: BRETON ISLAND ALT. 3
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
15
10
5
0
-5
-10
-15
-20
-5000
-4500
-4000
-3500
-3000
-2500
-2000
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

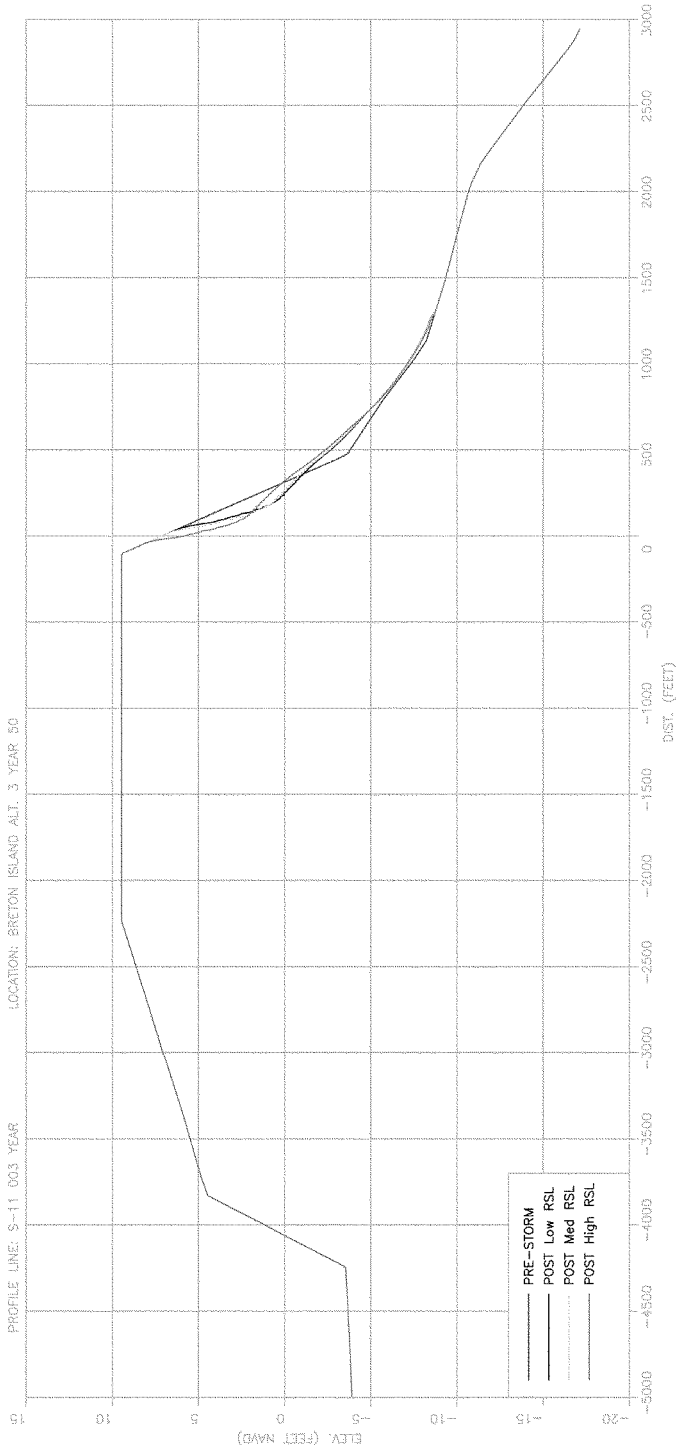

PROFILE LINE: S-11 020 YEAR
LOCATION: BRETON ISLAND ALT. 3
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
15
10
5
0
-5
-10
-15
-20
-5000
-4500
-4000
-3500
-3000
-2500
-2000
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

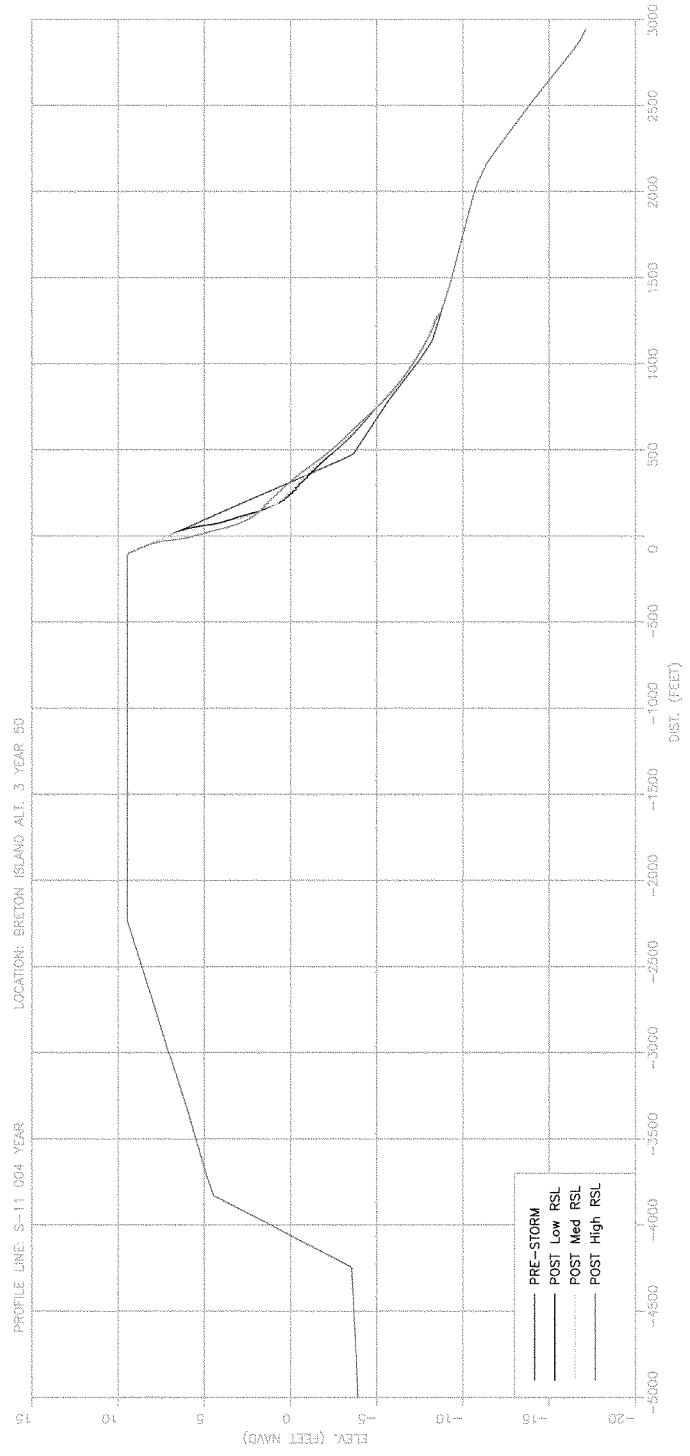

PROFILE LINE: S-11 050 YEAR
LOCATION: BRETON ISLAND ALT. 3
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
15
10
5
0
-5
-10
-15
-20
-5000
-4500
-4000
-3500
-3000
-2500
-2000
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

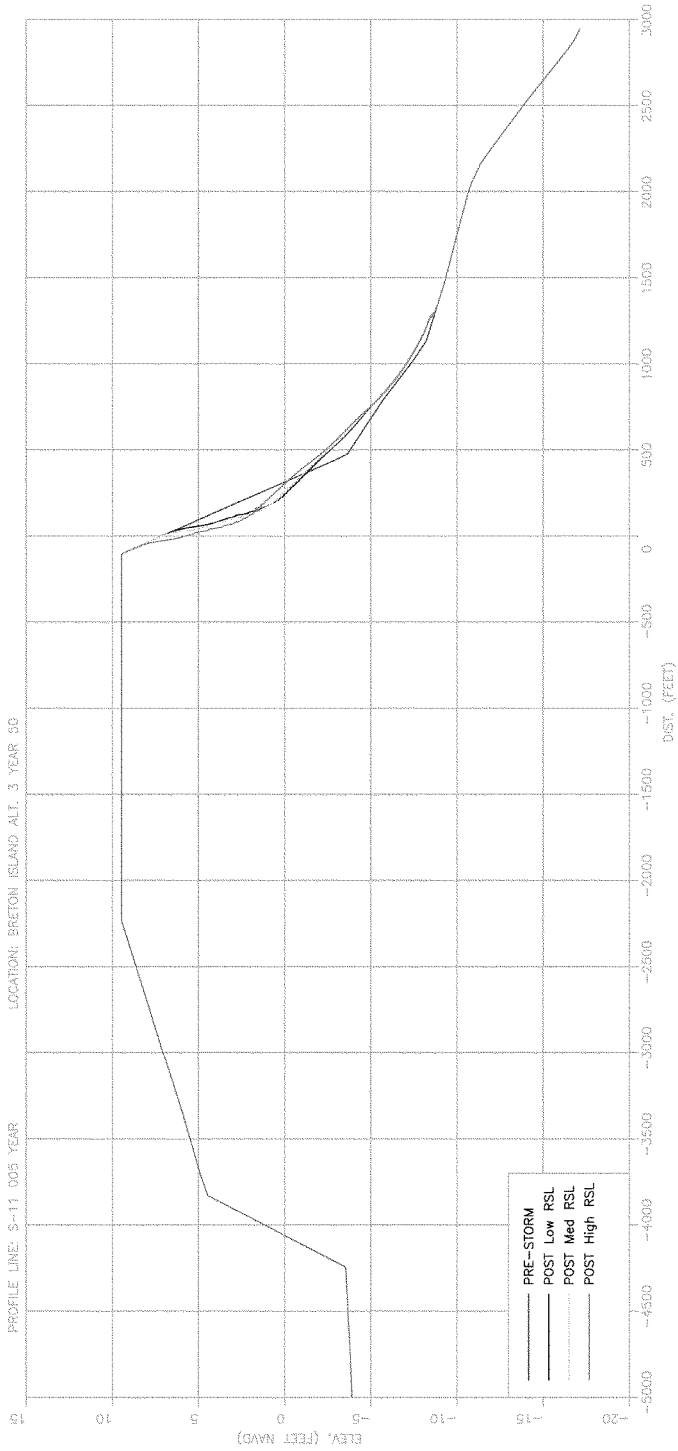

PROFILE LINE: S-11 100 YEAR
LOCATION: BRETON ISLAND ALT. 3
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
15
10
5
0
-5
-10
-15
-20
-5000
-4500
-4000
-3500
-3000
-2500
-2000
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

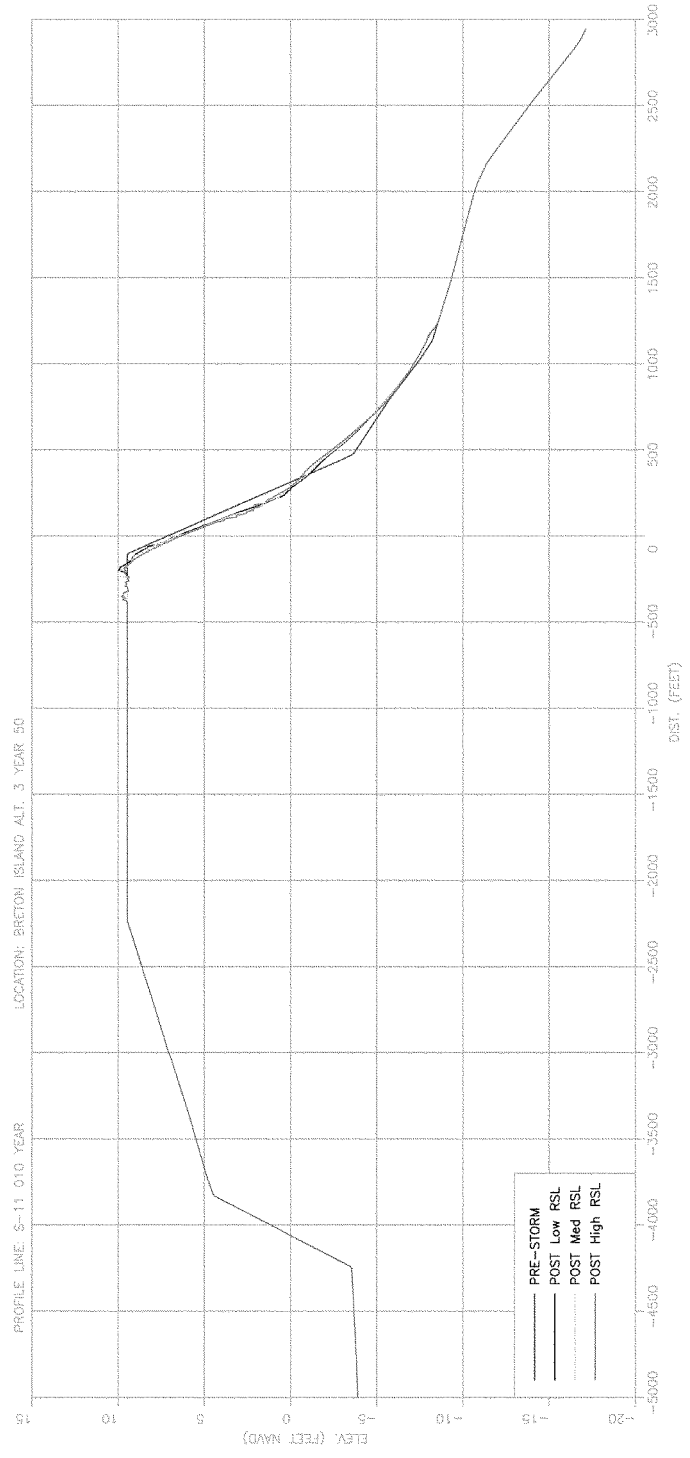

PROFILE LINE: S-11 001 YEAR
LOCATION: BRETON ISLAND ALT. 3 YEAR 60
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
POST Med RSL
POST High RSL

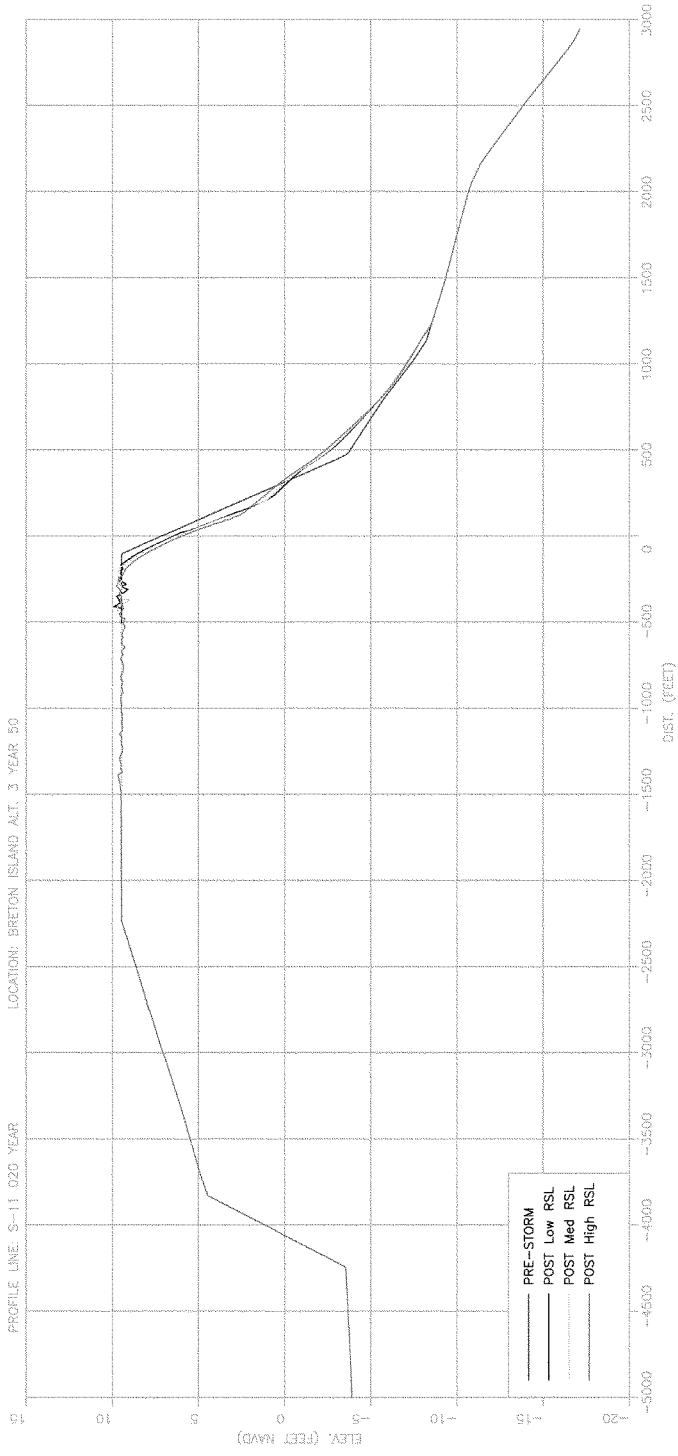

PROFILE LINE: S-11 002 YEAR
LOCATION: BRETON ISLAND ALT. 3 YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
POST Med RSL
POST High RSL
15
10
5
0
-5
-10
-15
-20
-5000
-4500
-4000
-3500
-3000
-2500
-2000
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

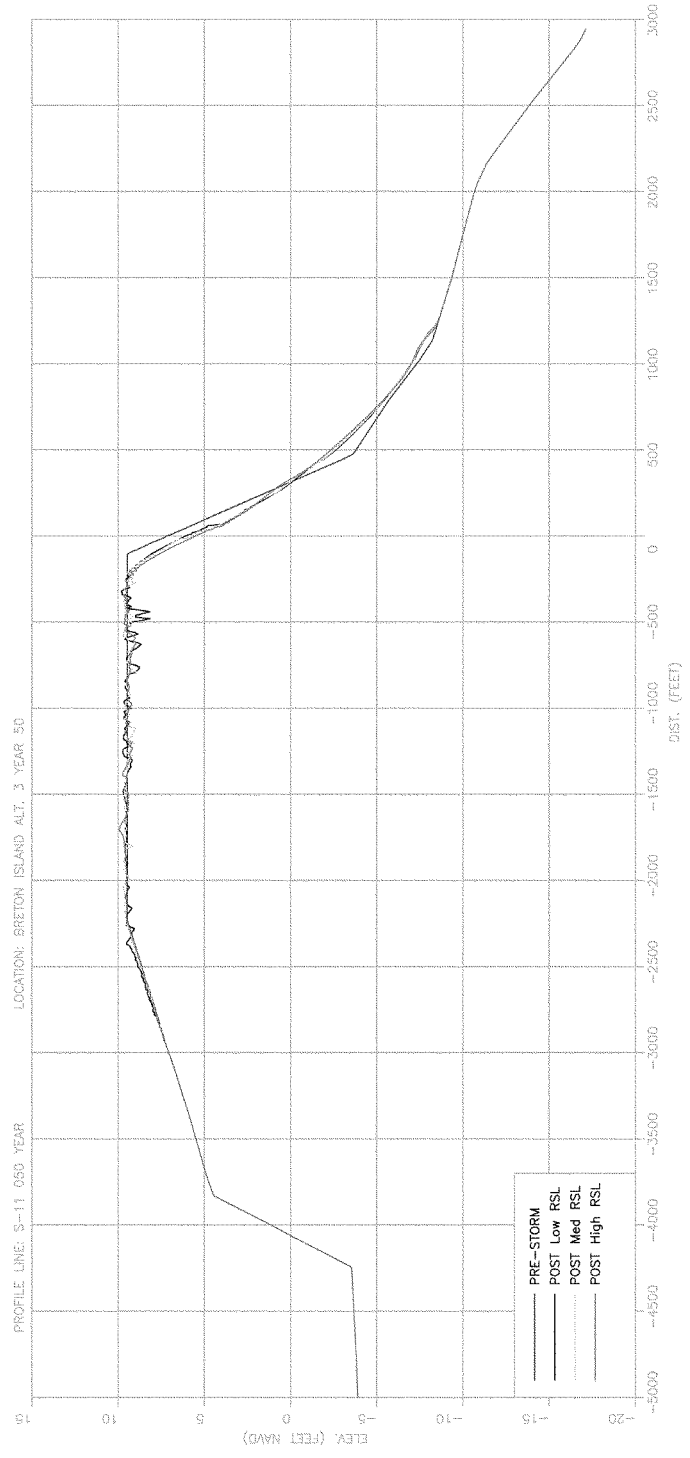

PROFILE LINE: S-11 003 YEAR
LOCATION: BRETON ISLAND ALT. 3 YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
POST Med RSL
POST High RSL
15
10
5
0
-5
-10
-15
-20
-5000
-4500
-4000
-3500
-3000
-2500
-2000
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

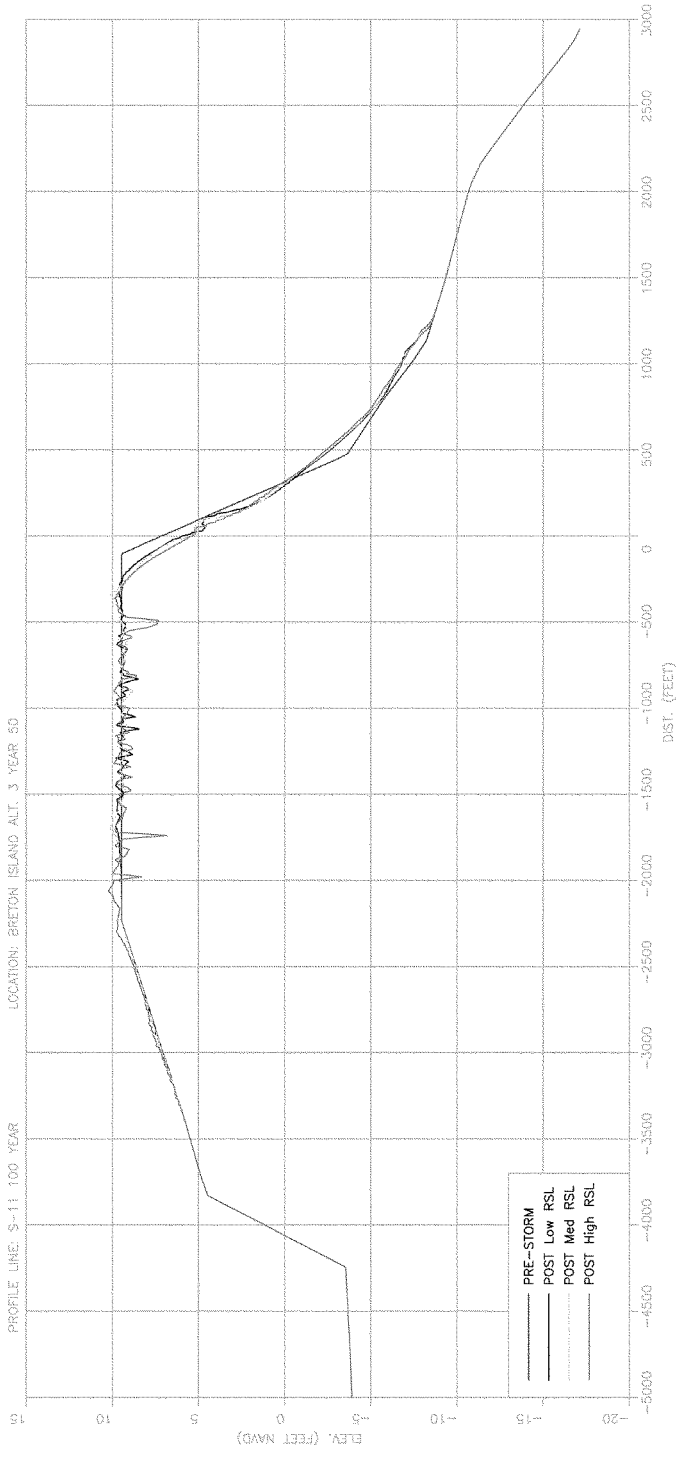

PROFILE LINE: S-11 004 YEAR
LOCATION: BRETON ISLAND ALT. 3 YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
POST Med RSL
POST High RSL
15
10
5
0
-5
-10
-15
-20
-5000
-4500
-4000
-3500
-3000
-2500
-2000
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000


PROFILE LINE: S-11 005 YEAR
LOCATION: BRETON ISLAND ALT. 3 YEAR 50
PRE-STORM
POST Low RSL
POST Med RSL
POST High RSL
ELEV. (FEET NAVD)
DIST. (FEET)
15
10
5
0
-5
-10
-15
-20
-5000
-4500
-4000
-3500
-3000
-2500
-2000
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000


PROFILE LINE S-11 010 YEAR
LOCATION: BRETON ISLAND ALT. 3 YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
POST Med RSL
POST High RSL
15
10
5
0
-5
-10
-15
-20
-5000
-4500
-4000
-3500
-3000
-2500
-2000
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

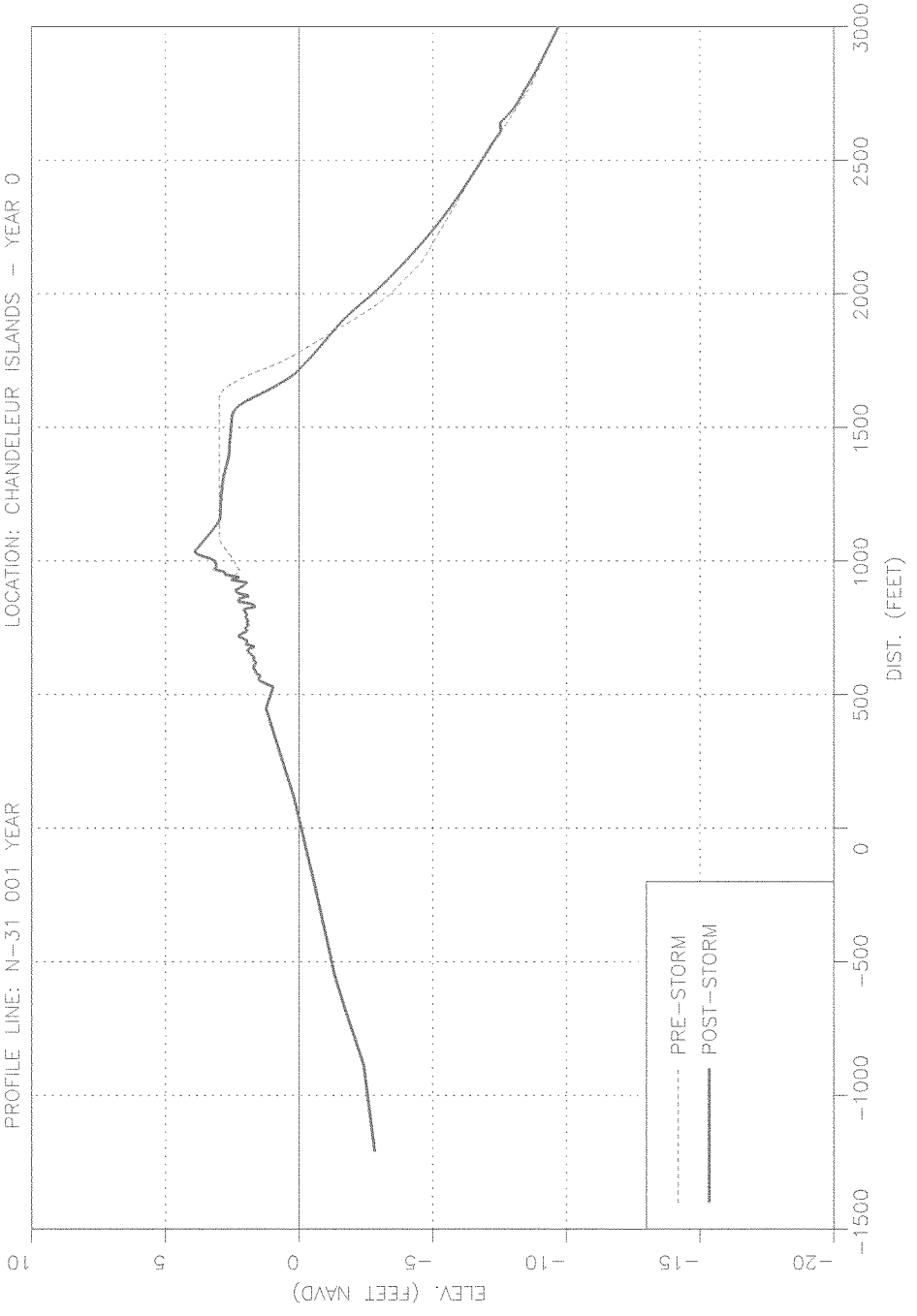

PROFILE LINE: S-11 020 YEAR
LOCATION: BRETON ISLAND ALT. 3 YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
POST Med RSL
POST High RSL
15
10
5
0
-5
-10
-15
-20
-5000
-4500
-4000
-3500
-3000
-2500
-2000
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

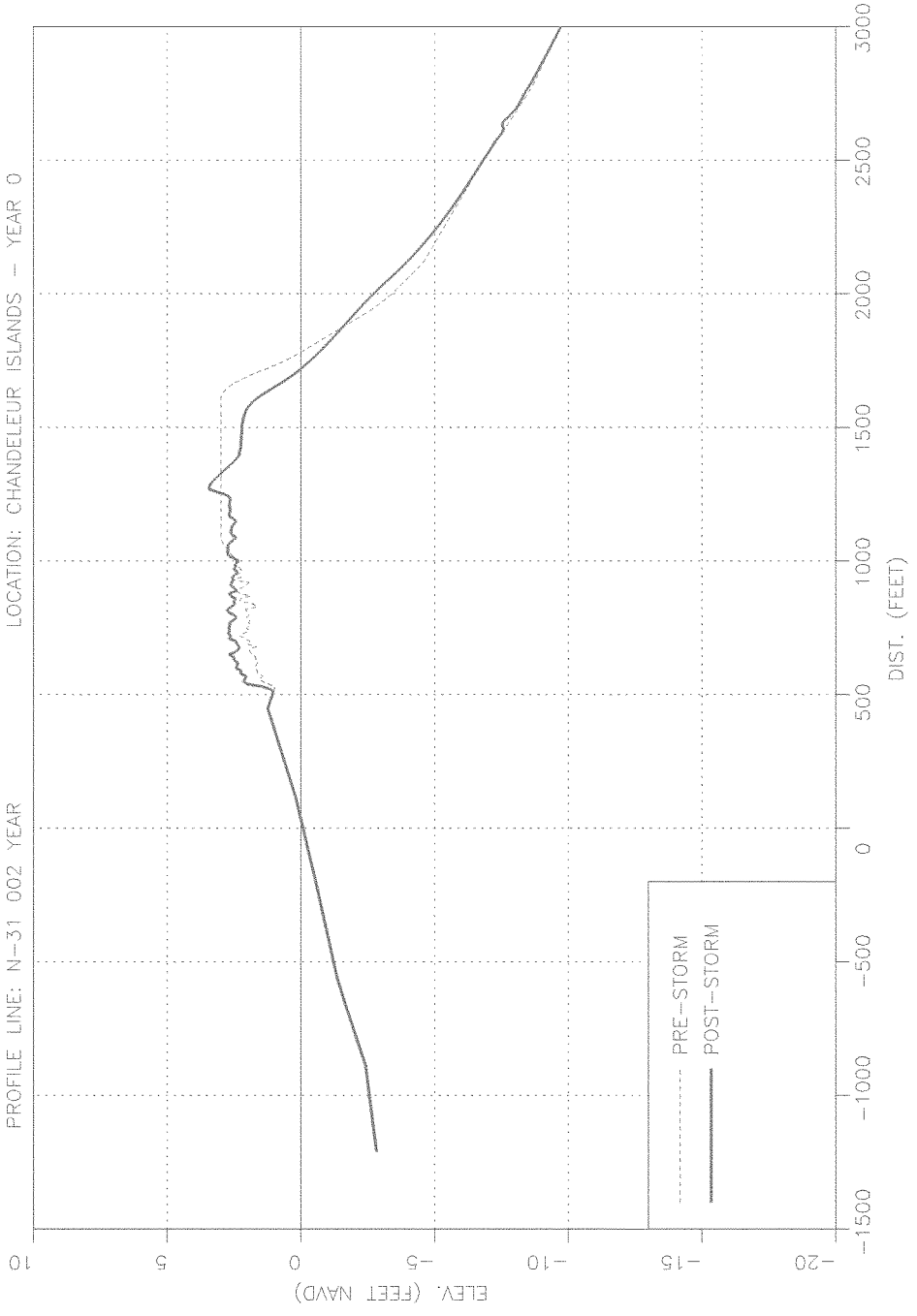

PROFILE LINE: S-11 650 YEAR
LOCATION: BRETON ISLAND ALT. 3 YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
POST Med RSL
POST High RSL

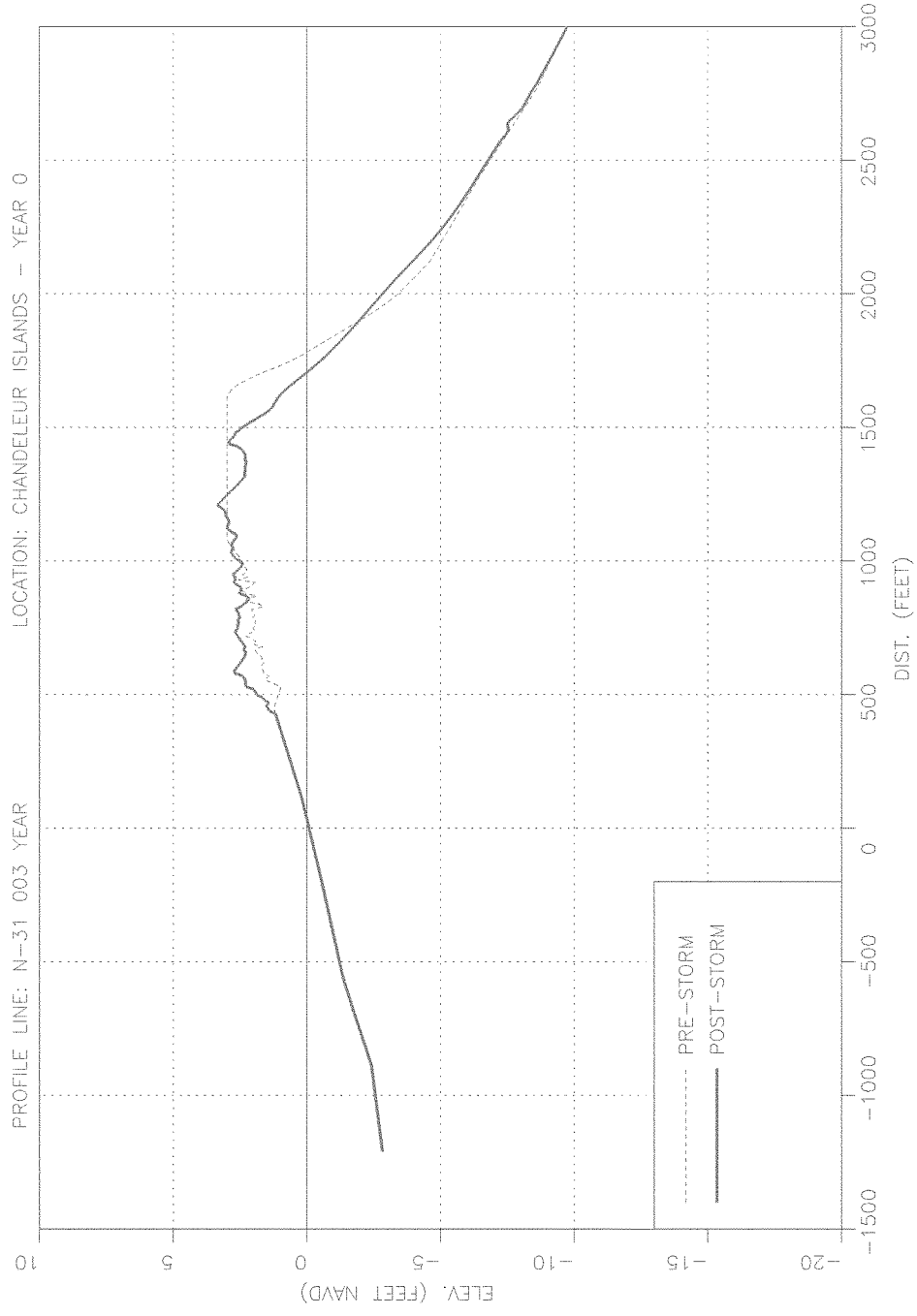

PROFILE LINE: S-11 100 YEAR
LOCATION: BRETON ISLAND ALT. 3 YEAR SD
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
POST Med RSL
POST High RSL
15
10
5
0
-5
-10
-15
-20
-5000
-4500
-4000
-3500
-3000
-2500
-2000
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

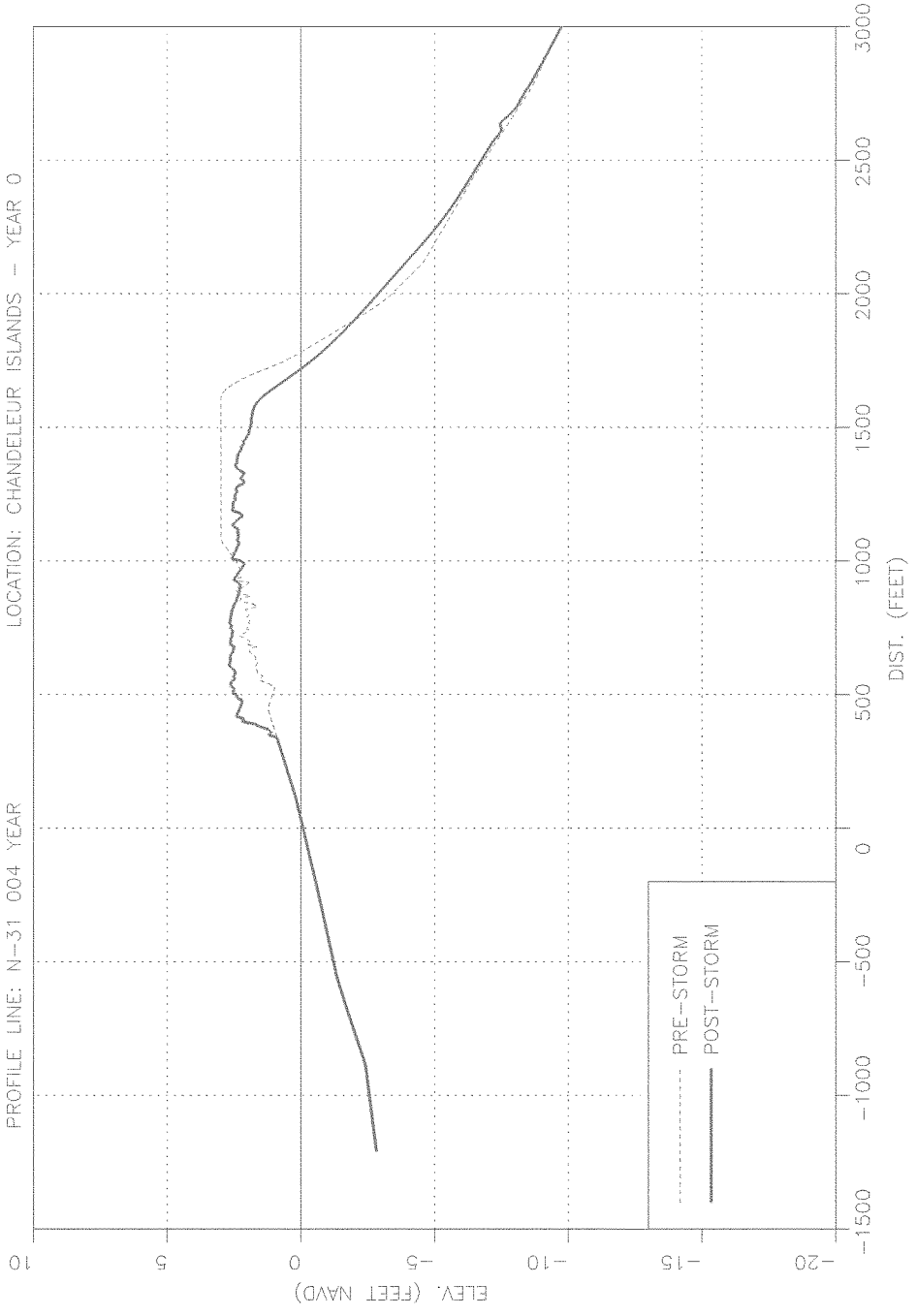
Chandeleur Islands

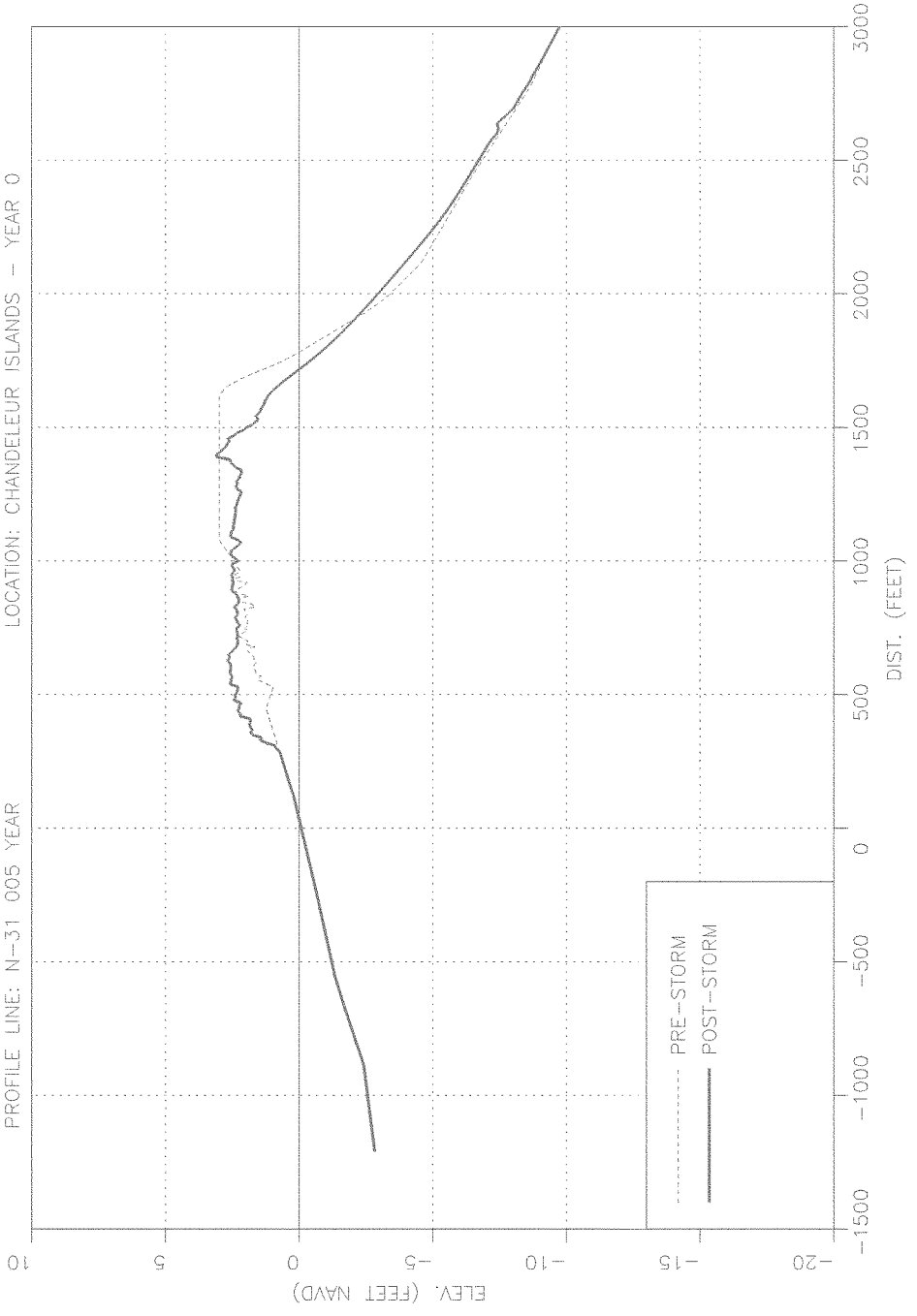
Alternative 1

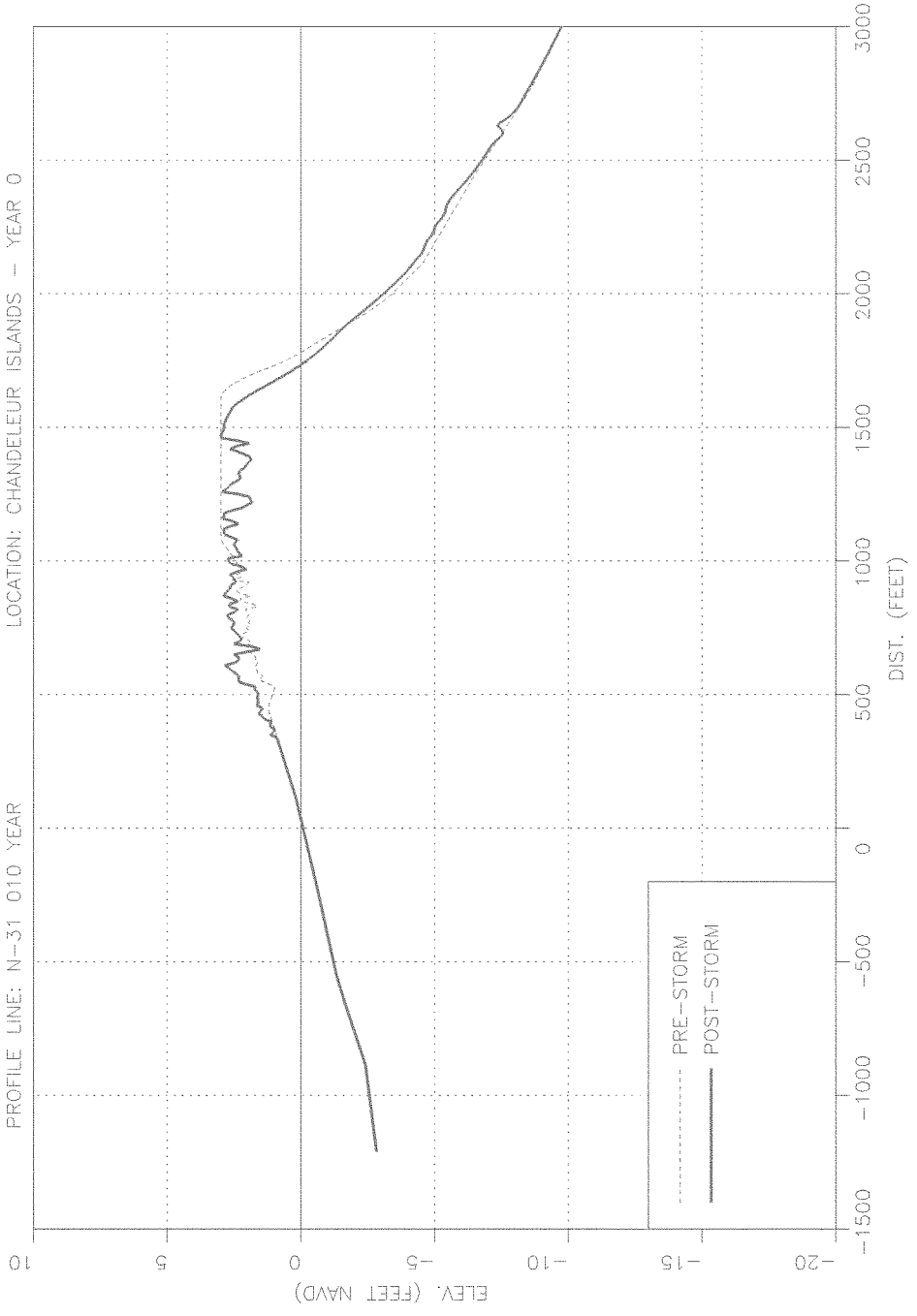

PROFILE LINE: N-31 001 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 0
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

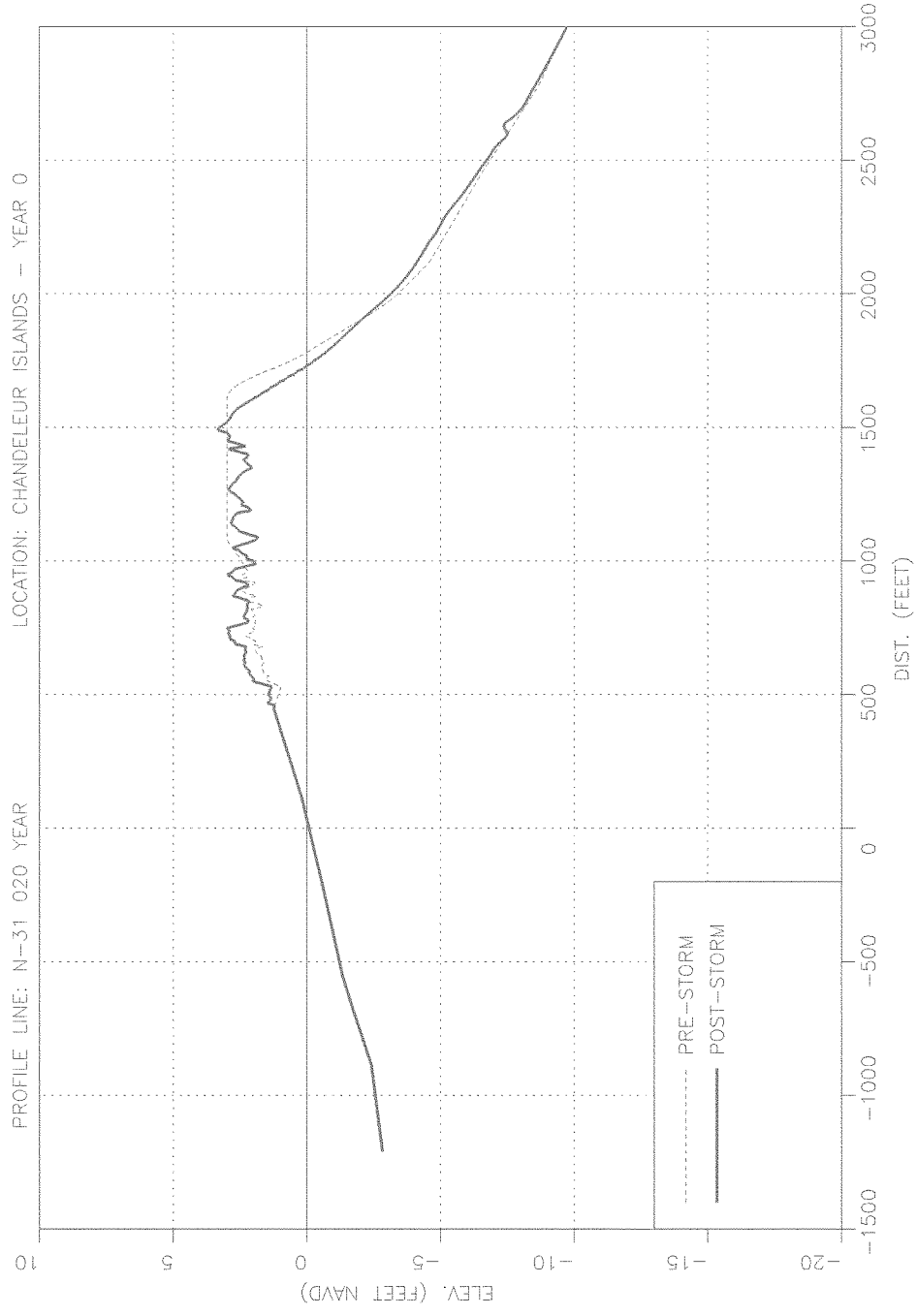

PROFILE LINE: N-31 002 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 0
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

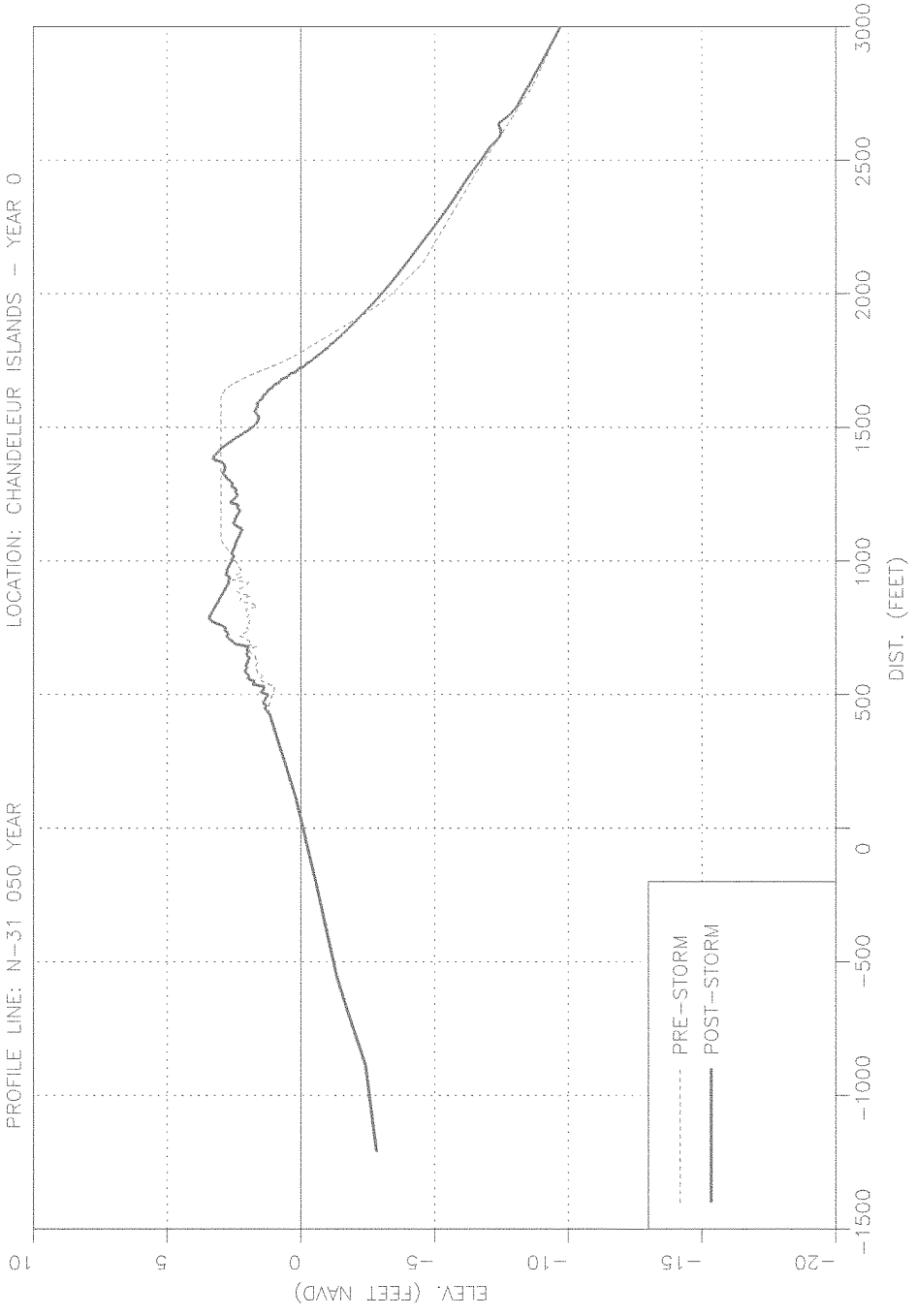

PROFILE LINE: N-31 003 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 0
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

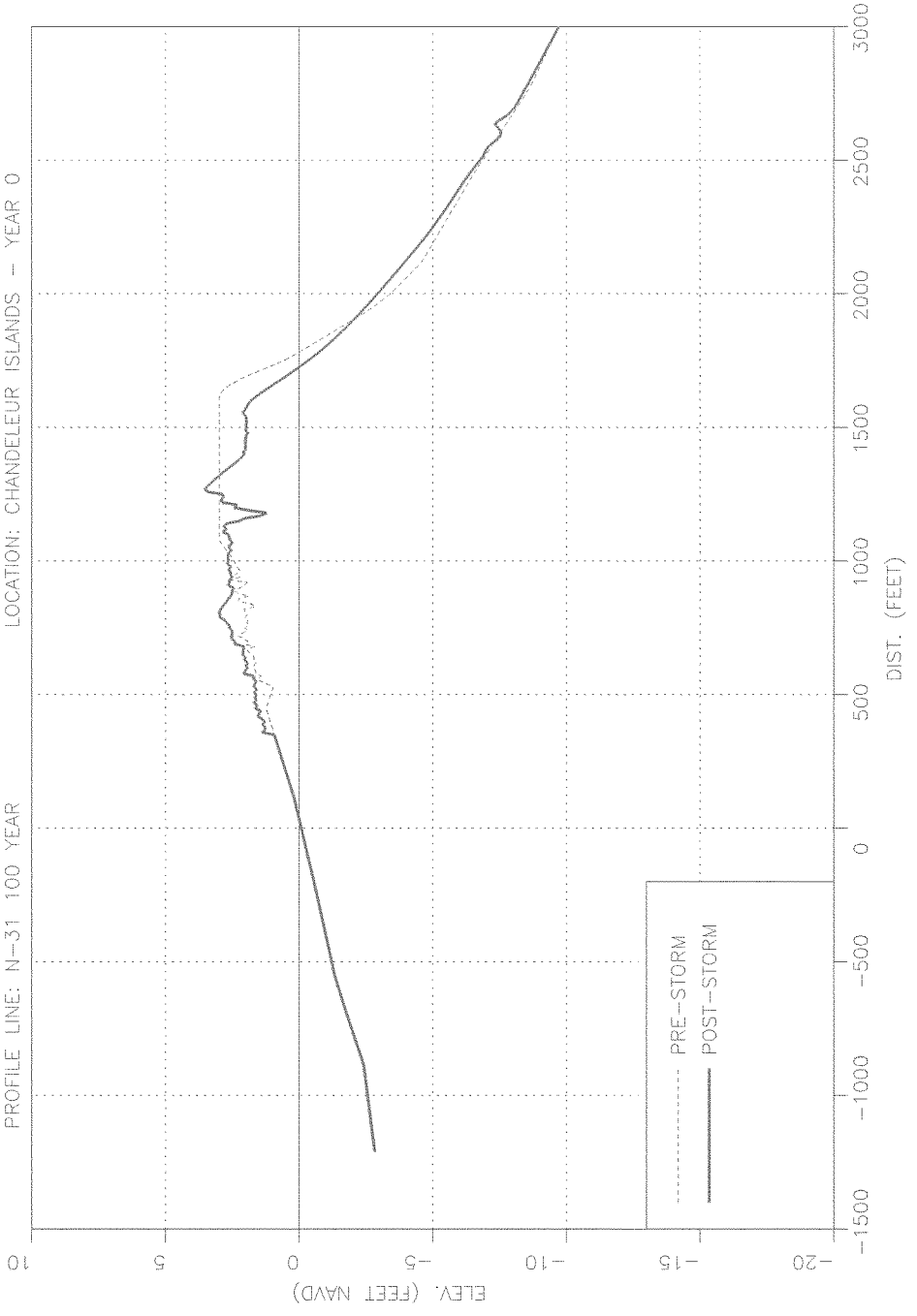

PROFILE LINE: N-31 004 YEAR
LOCATION: CHANDELEUR ISLANDS -- YEAR 0
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

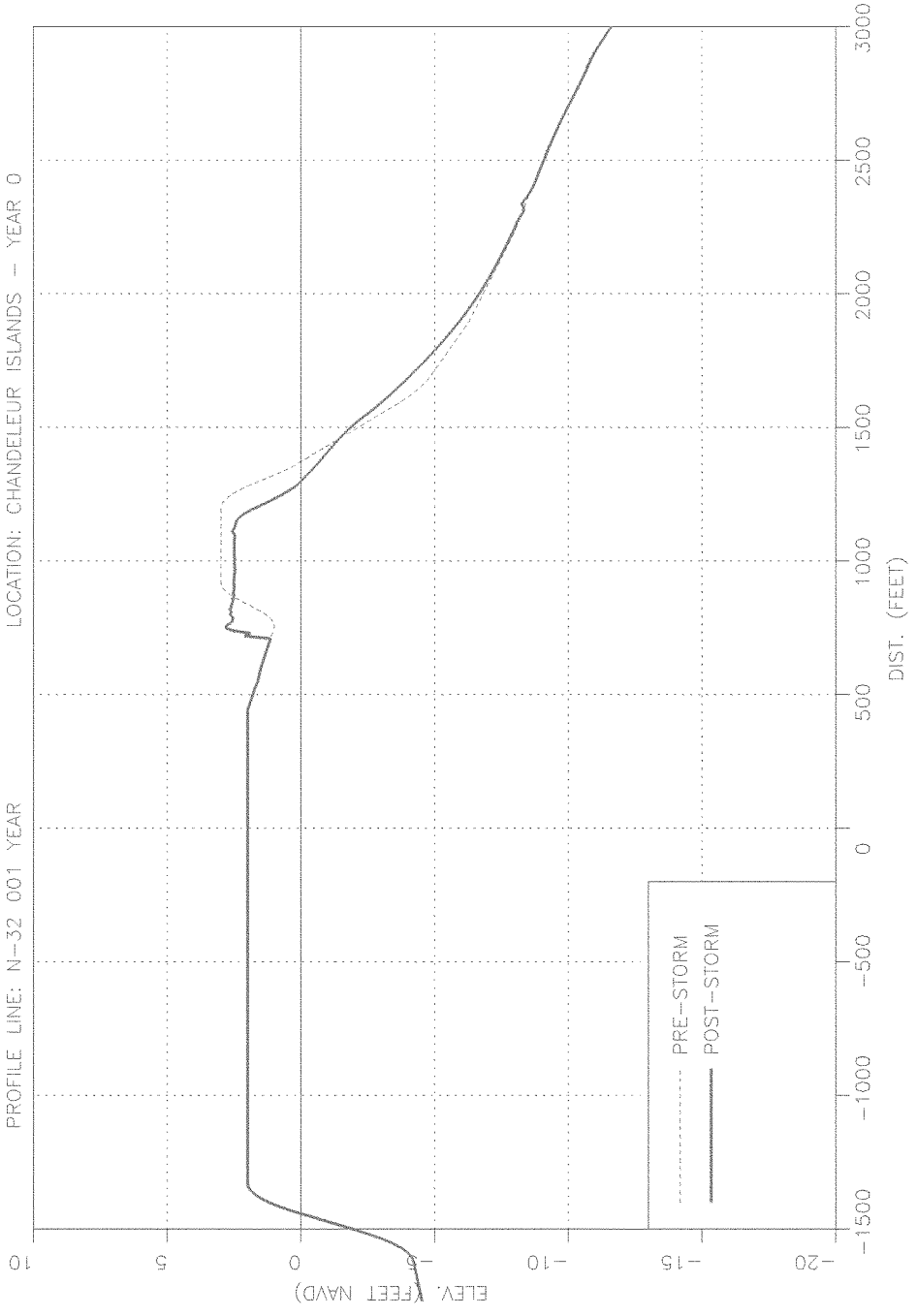

PROFILE LINE: N-31 005 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 0
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

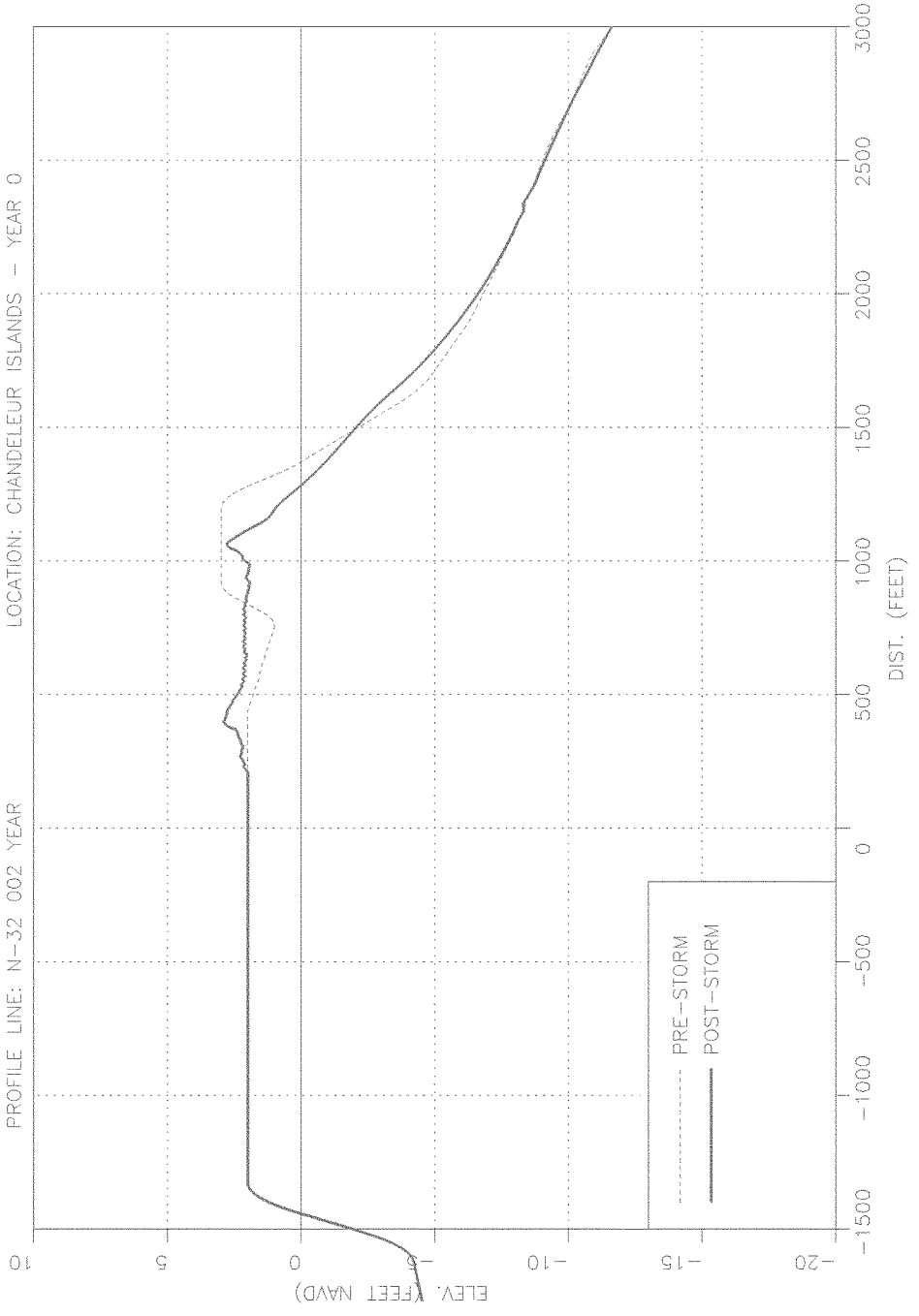

PROFILE LINE: N-31 010 YEAR
LOCATION: CHANDELEUR ISLANDS -- YEAR 0
PRE-STORM
POST-STORM
ELEV. (FEET NAVD)
DIST. (FEET)
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

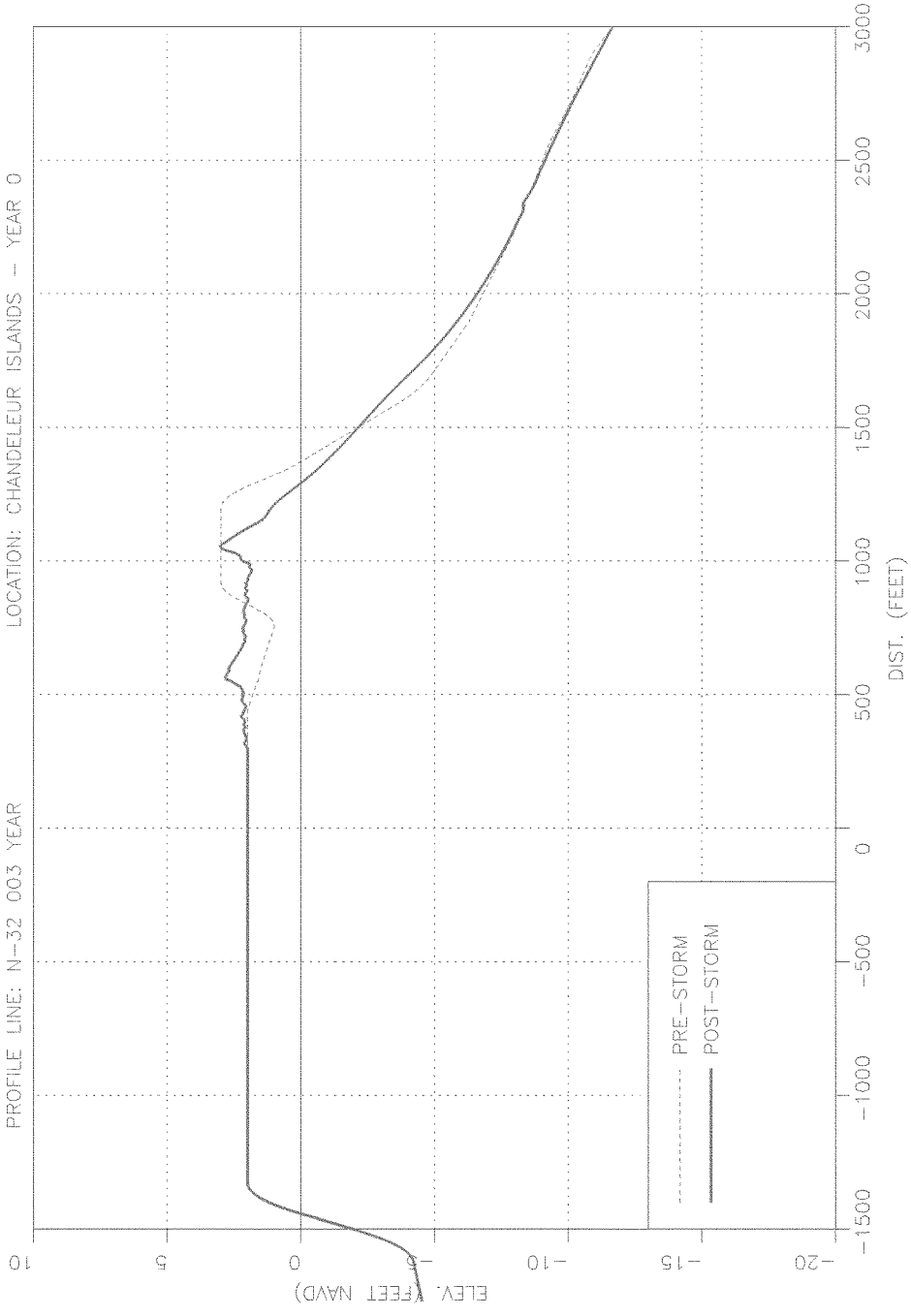

PROFILE LINE: N-31 020 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 0
PRE-STORM
POST-STORM
ELEV. (FEET NAVD)
DIST. (FEET)
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

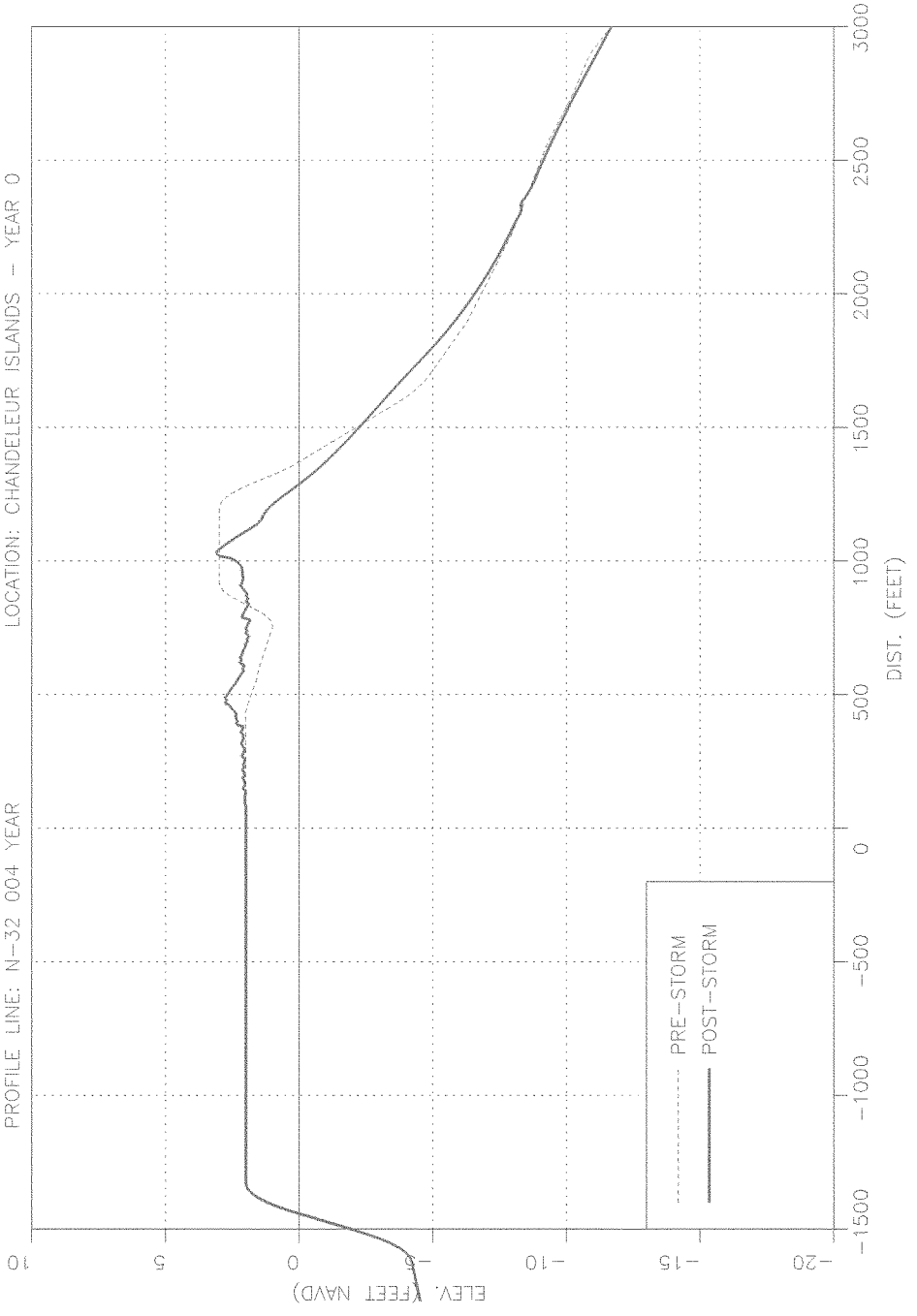

PROFILE LINE: N-31 050 YEAR
LOCATION: CHANDELEUR ISLANDS -- YEAR 0
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

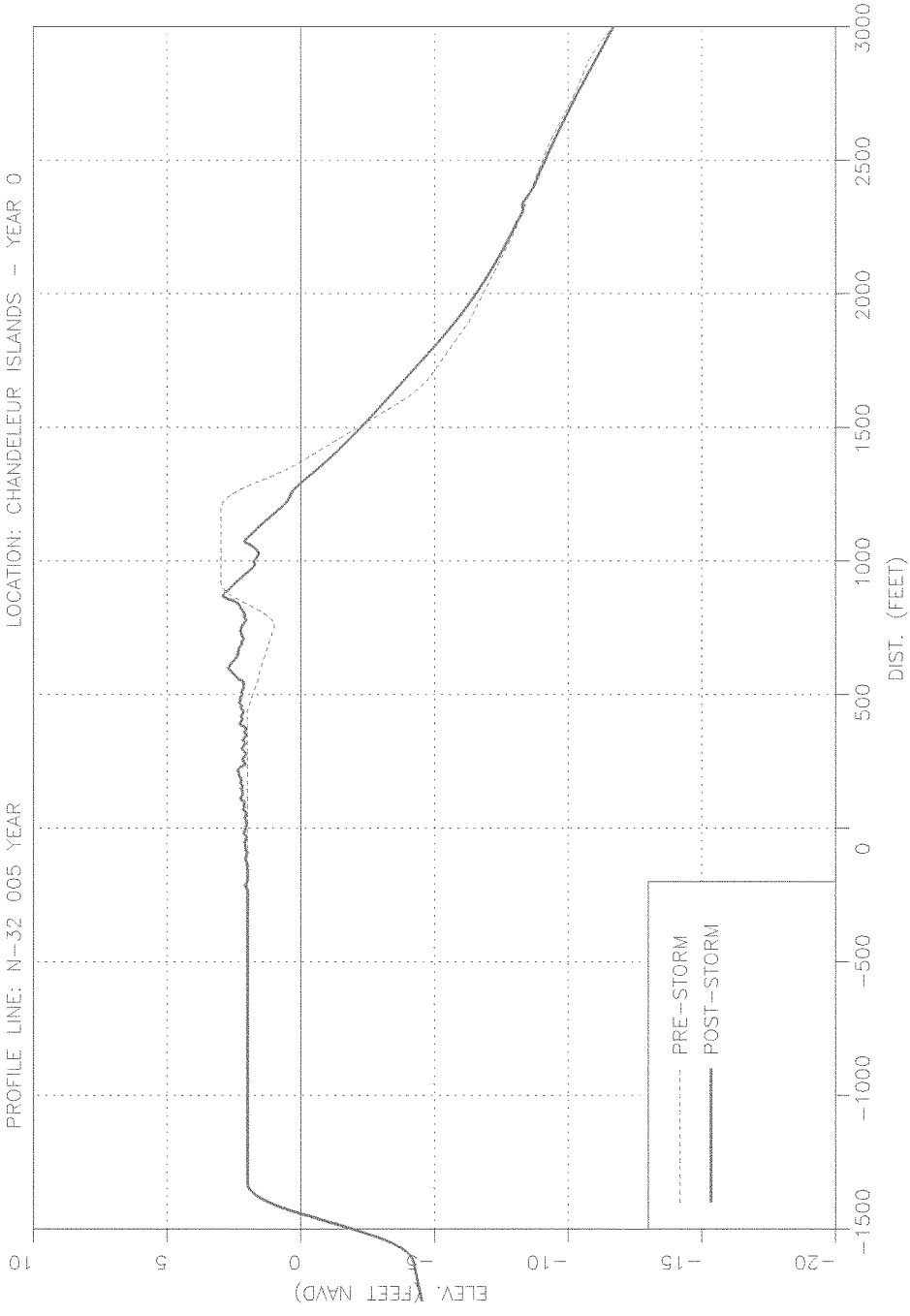

PROFILE LINE: N-31 100 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 0
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

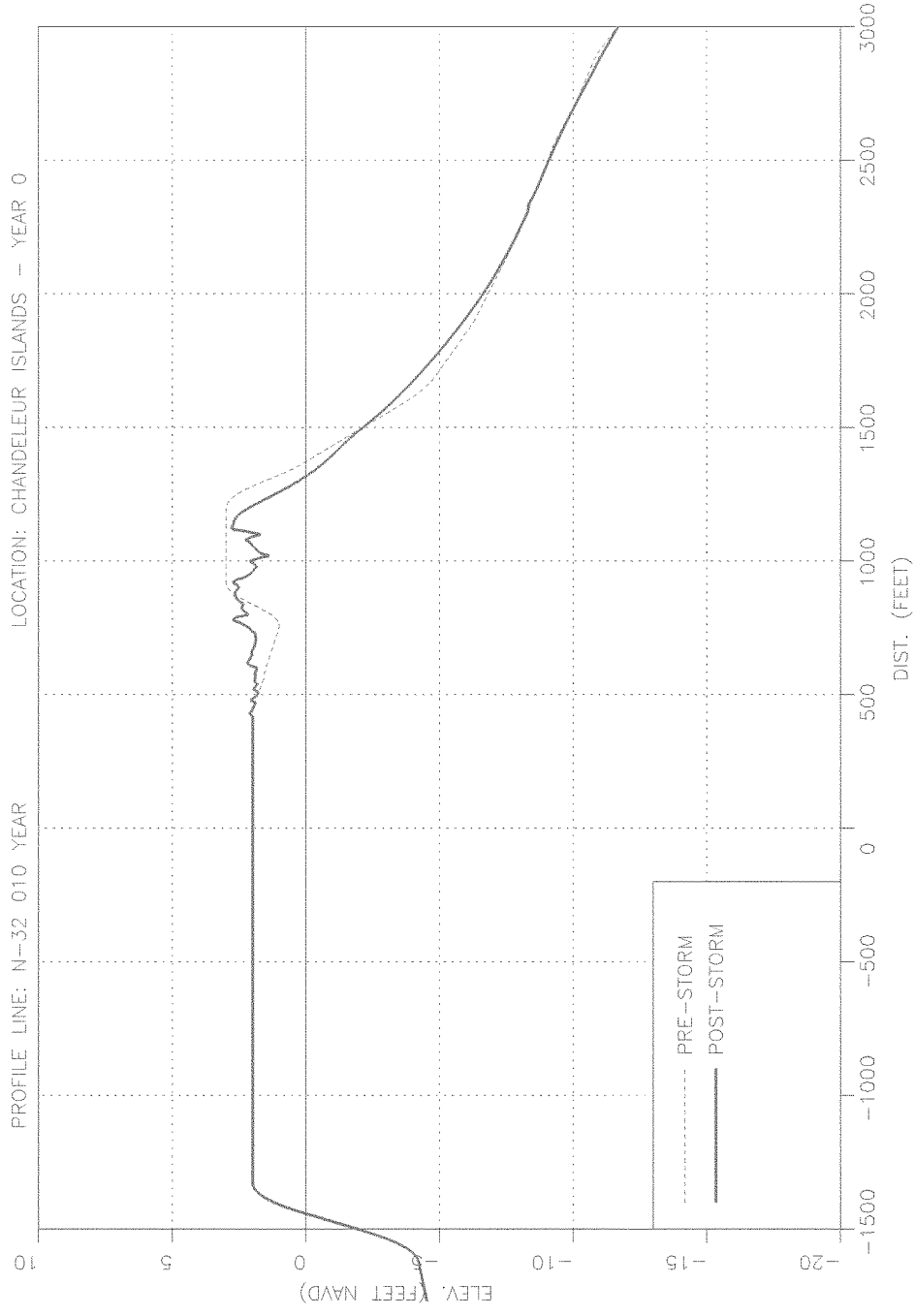

PROFILE LINE: N-32 001 YEAR
LOCATION: CHANDELEUR ISLANDS -- YEAR 0
PRE-STORM
POST-STORM
ELEV. (FEET NAVD)
DIST. (FEET)
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

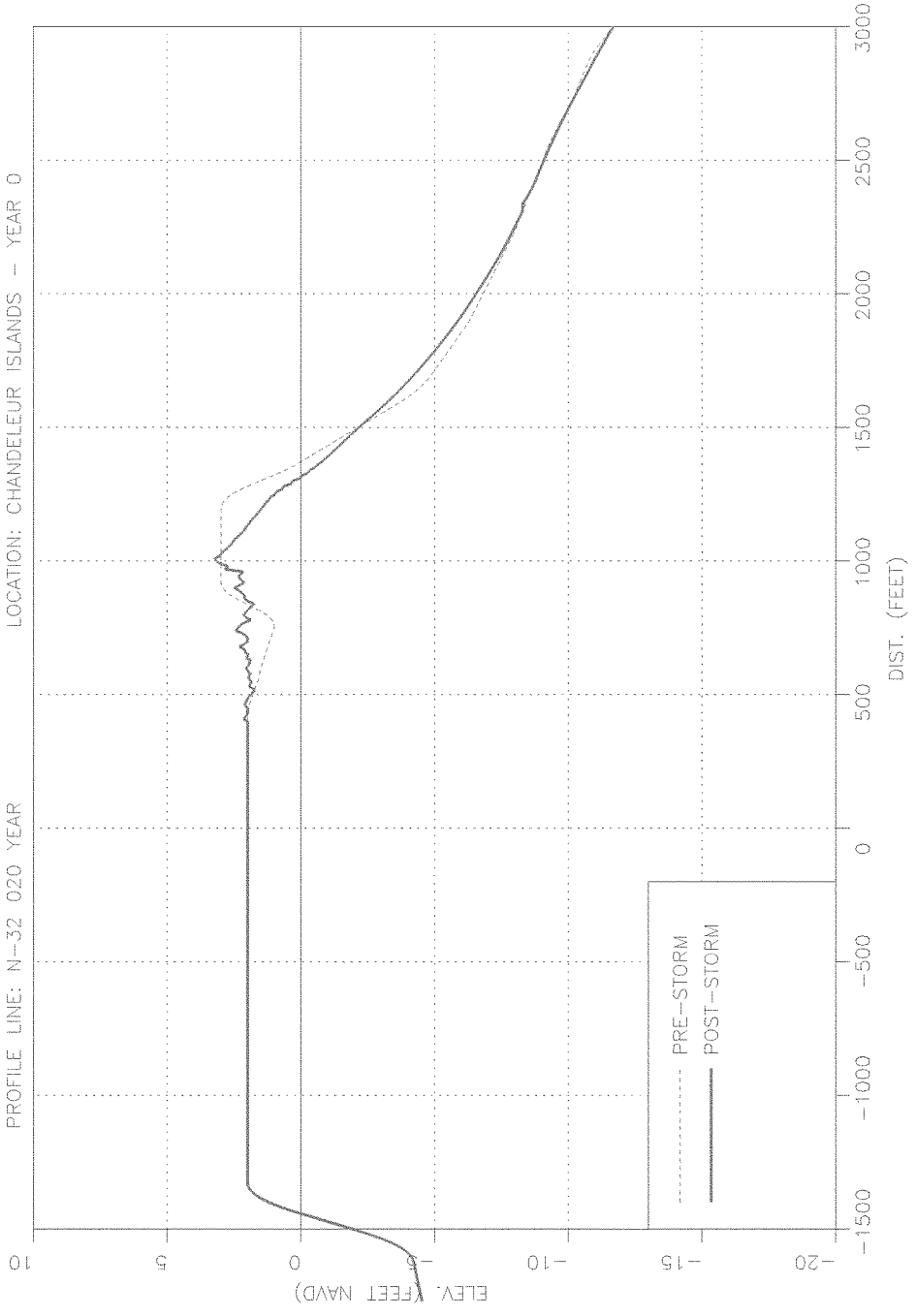

PROFILE LINE: N-32 002 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 0
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

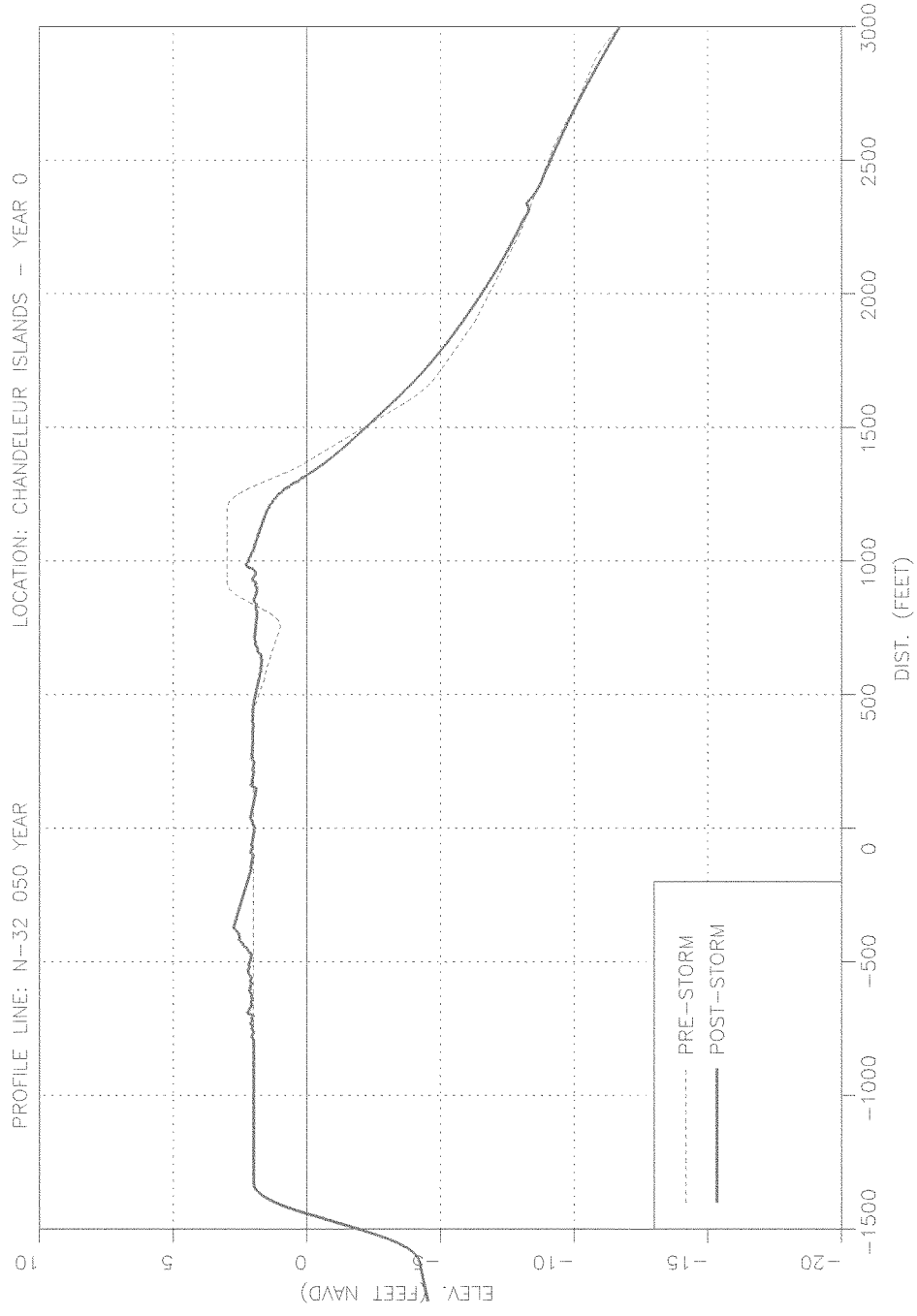

PROFILE LINE: N-32 003 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 0
ELEV. (FEET NAVD)
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000
DIST. (FEET)
PRE-STORM
POST-STORM

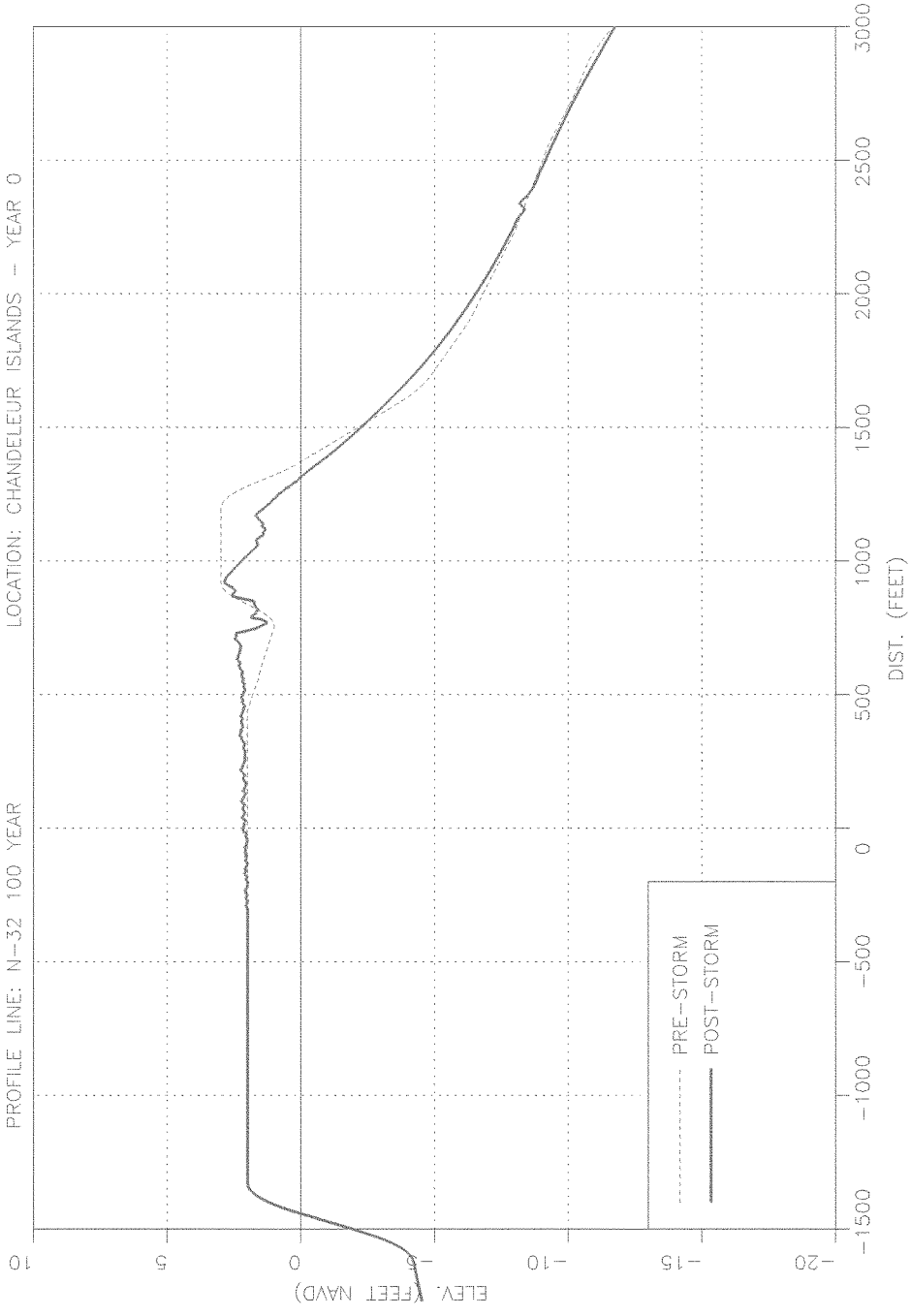

PROFILE LINE: N-32 004 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 0
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

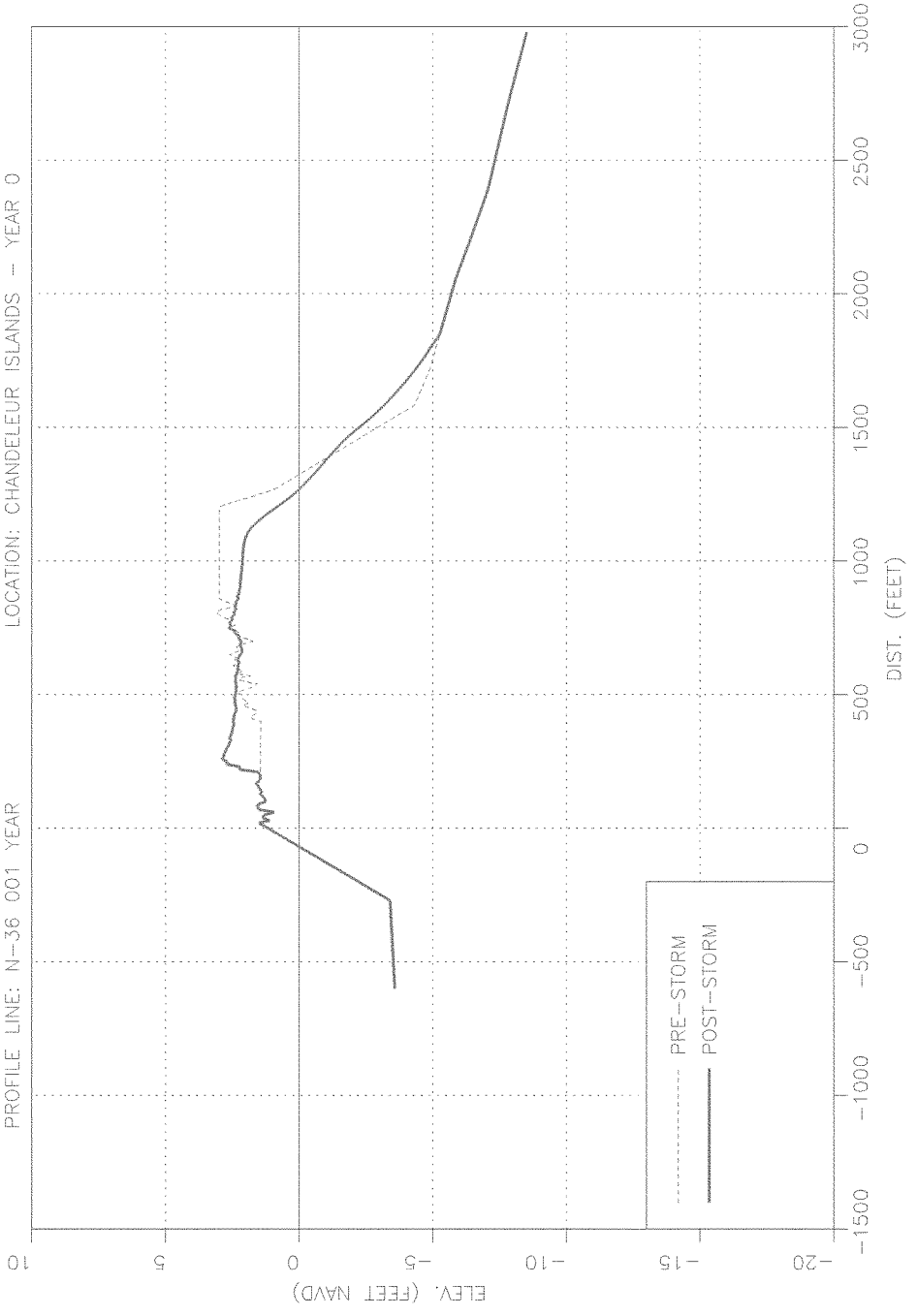

PROFILE LINE: N-32 005 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 0
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

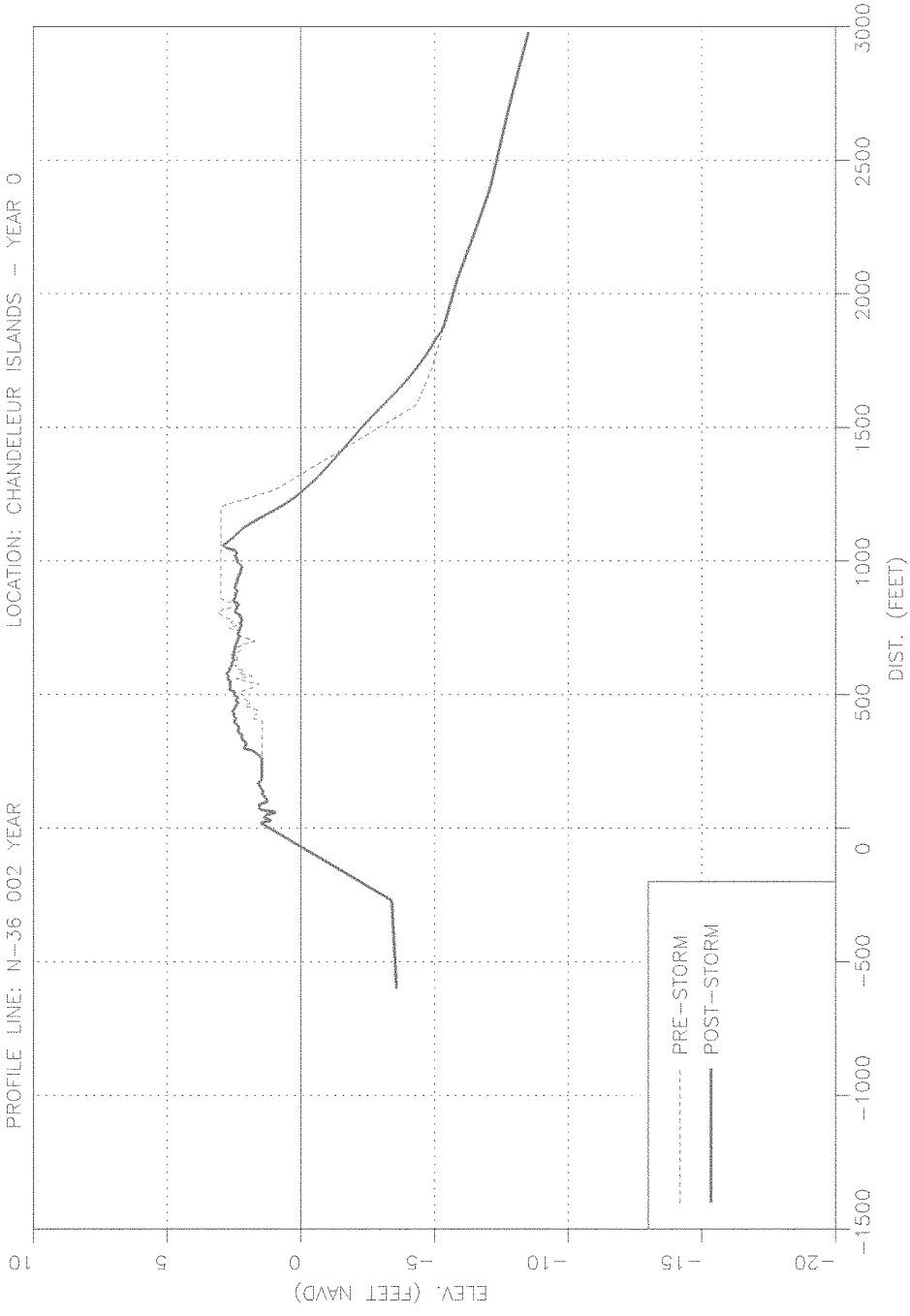

PROFILE LINE: N-32 010 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 0
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

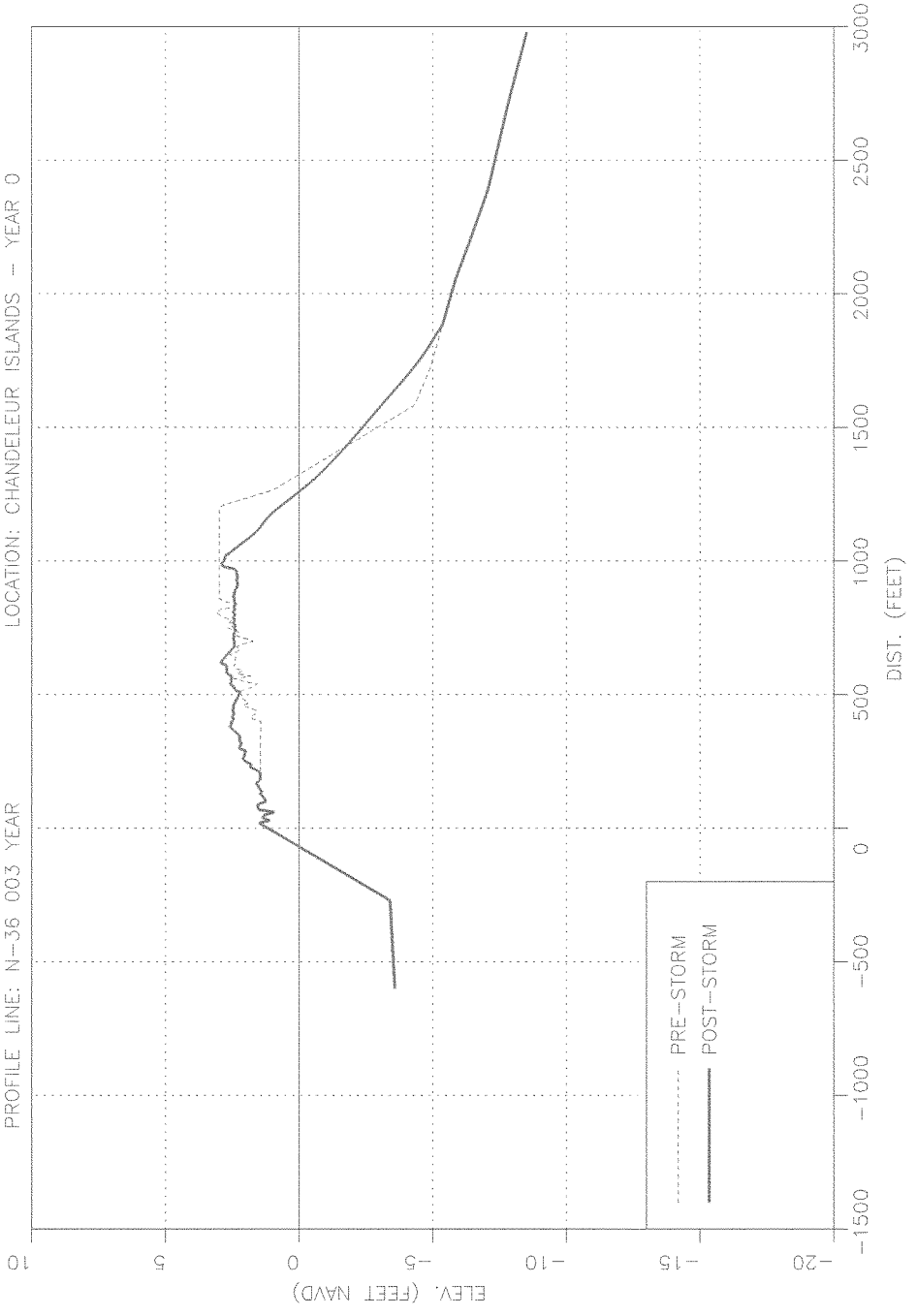

PROFILE LINE: N-32 020 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 0
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

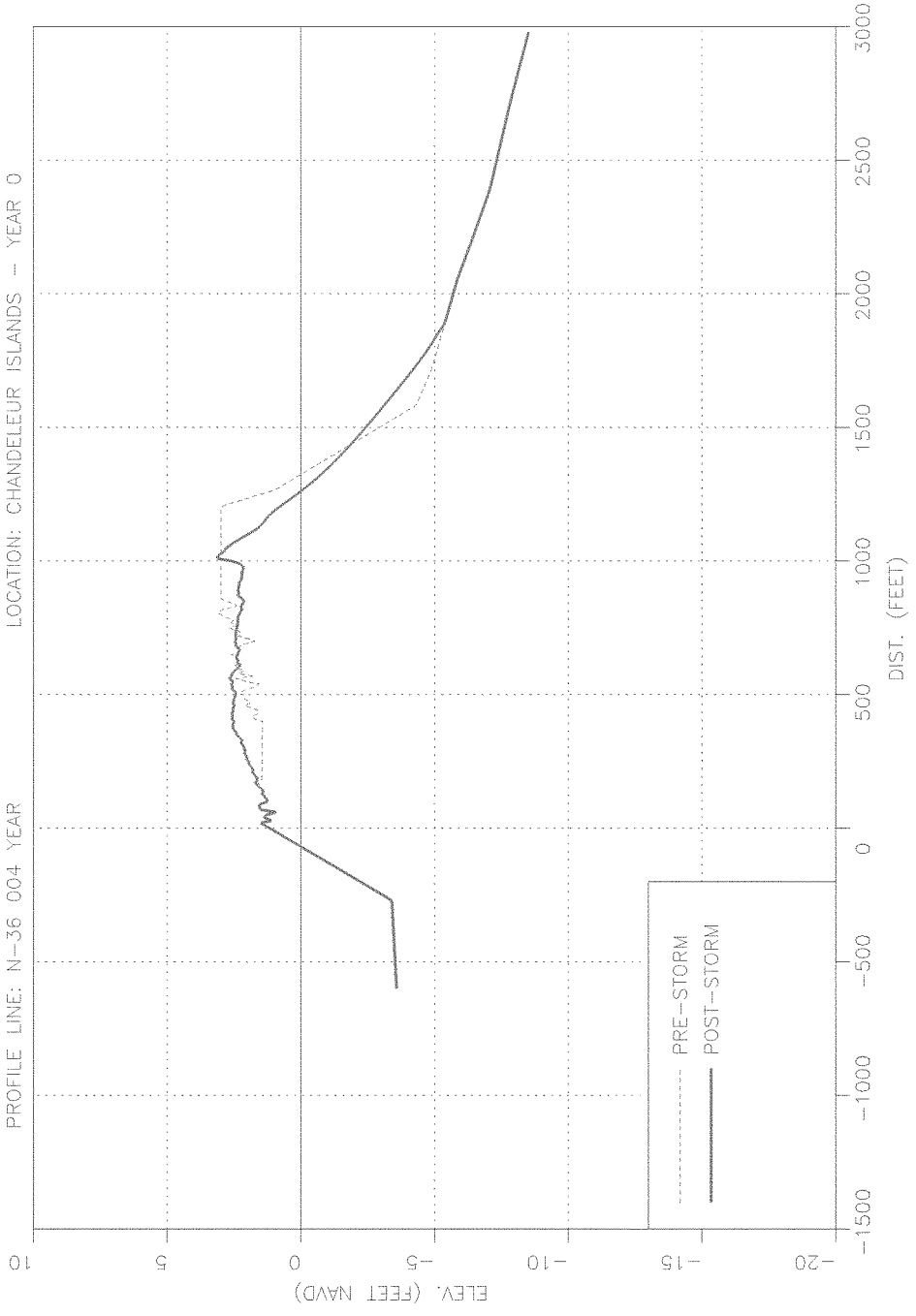

PROFILE LINE: N-32 050 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 0
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

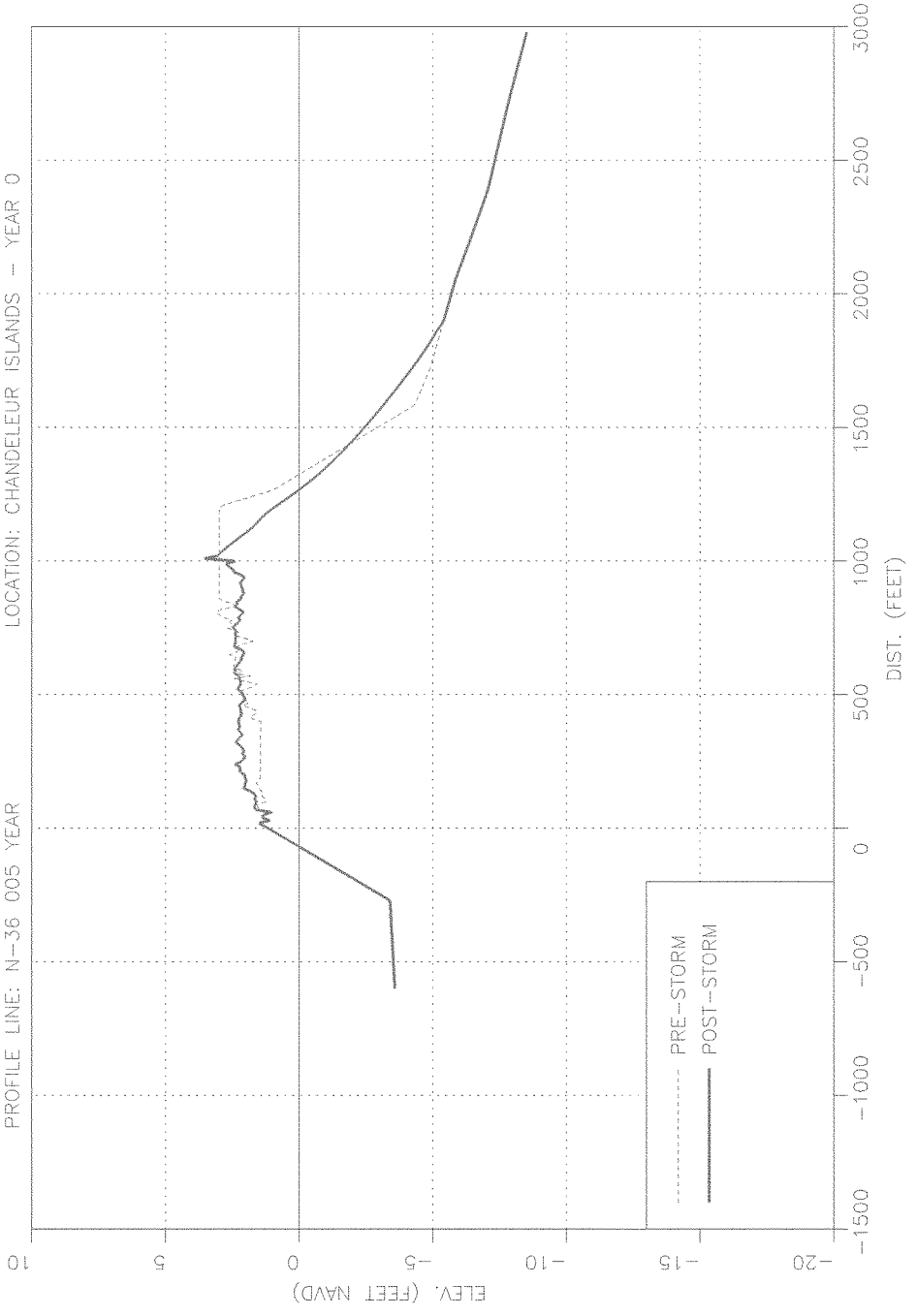

PROFILE LINE: N-32 100 YEAR
LOCATION: CHANDELEUR ISLANDS -- YEAR 0
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

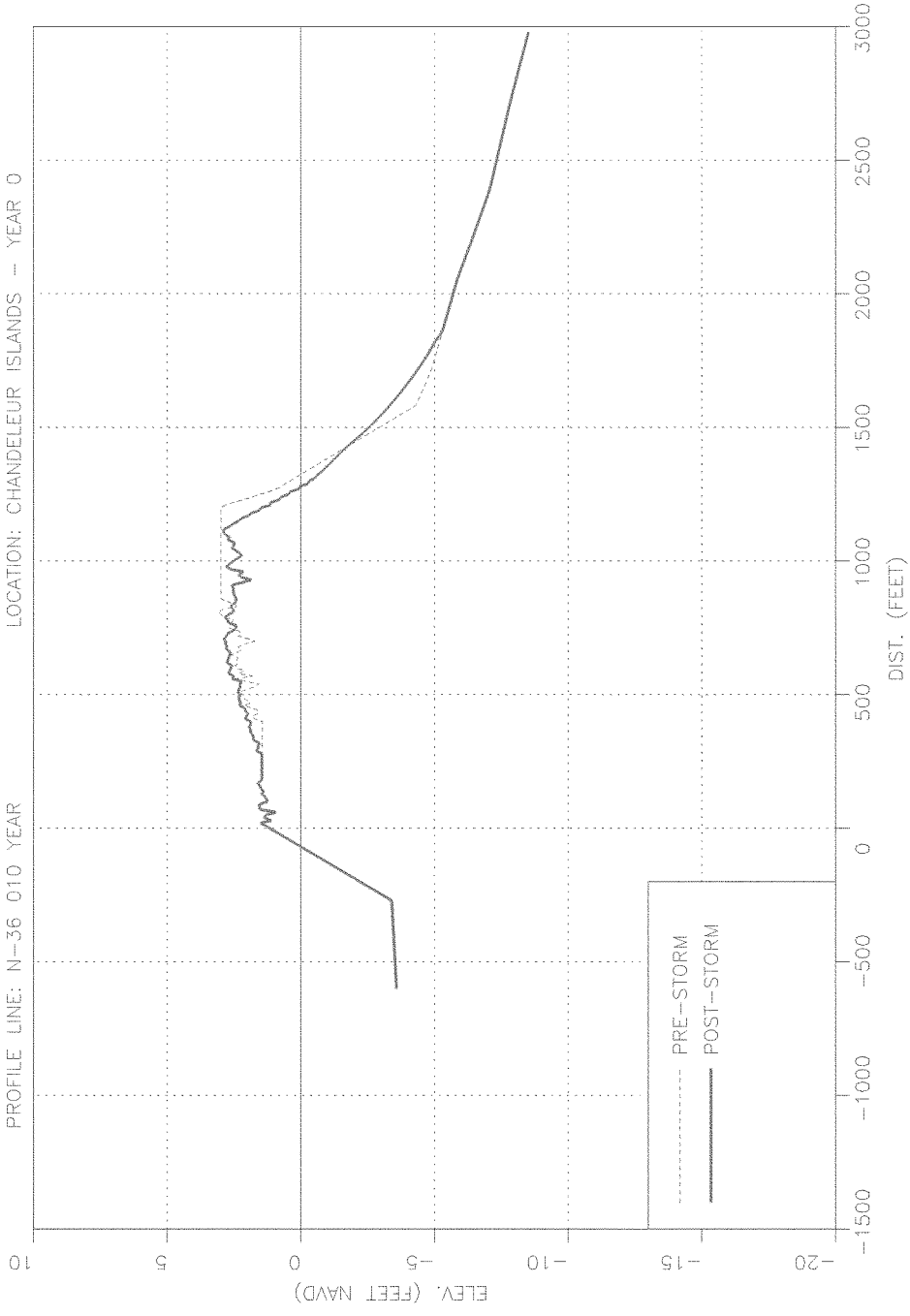

PROFILE LINE: N-36 001 YEAR
LOCATION: CHANDELEUR ISLANDS -- YEAR 0
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

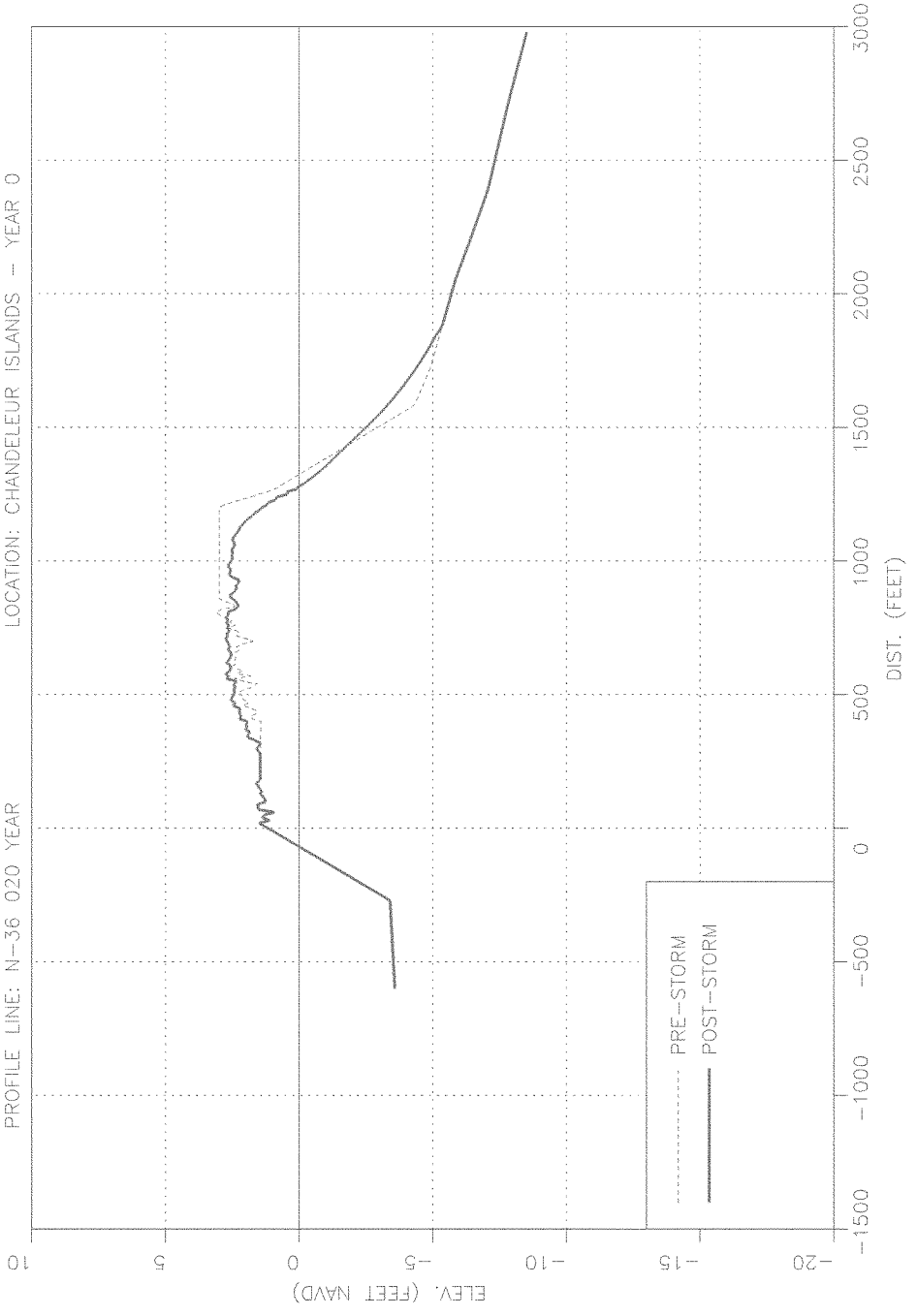

PROFILE LINE: N-36 002 YEAR
LOCATION: CHANDELEUR ISLANDS -- YEAR 0
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

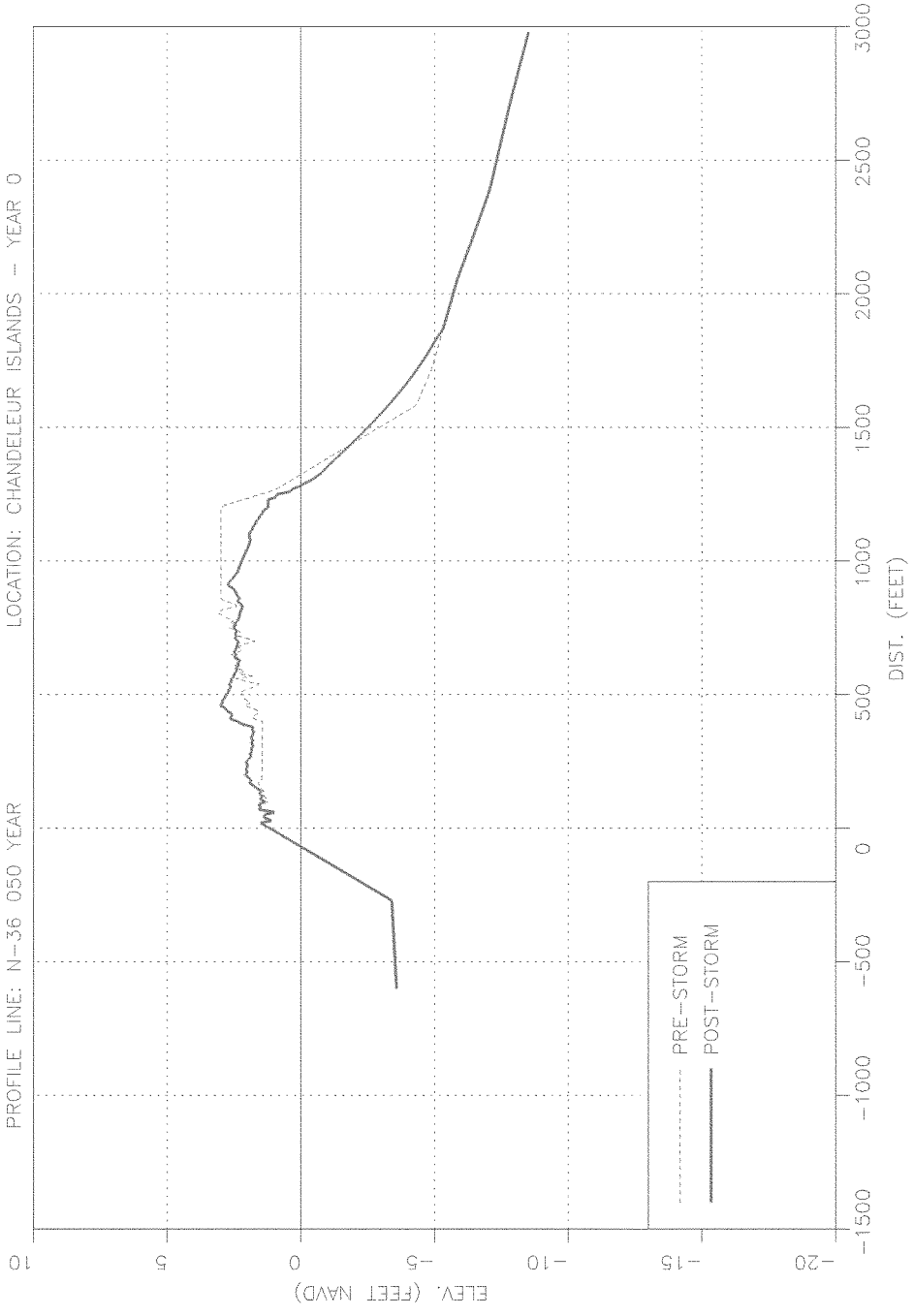

PROFILE LINE: N-36 003 YEAR
LOCATION: CHANDELEUR ISLANDS -- YEAR 0
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

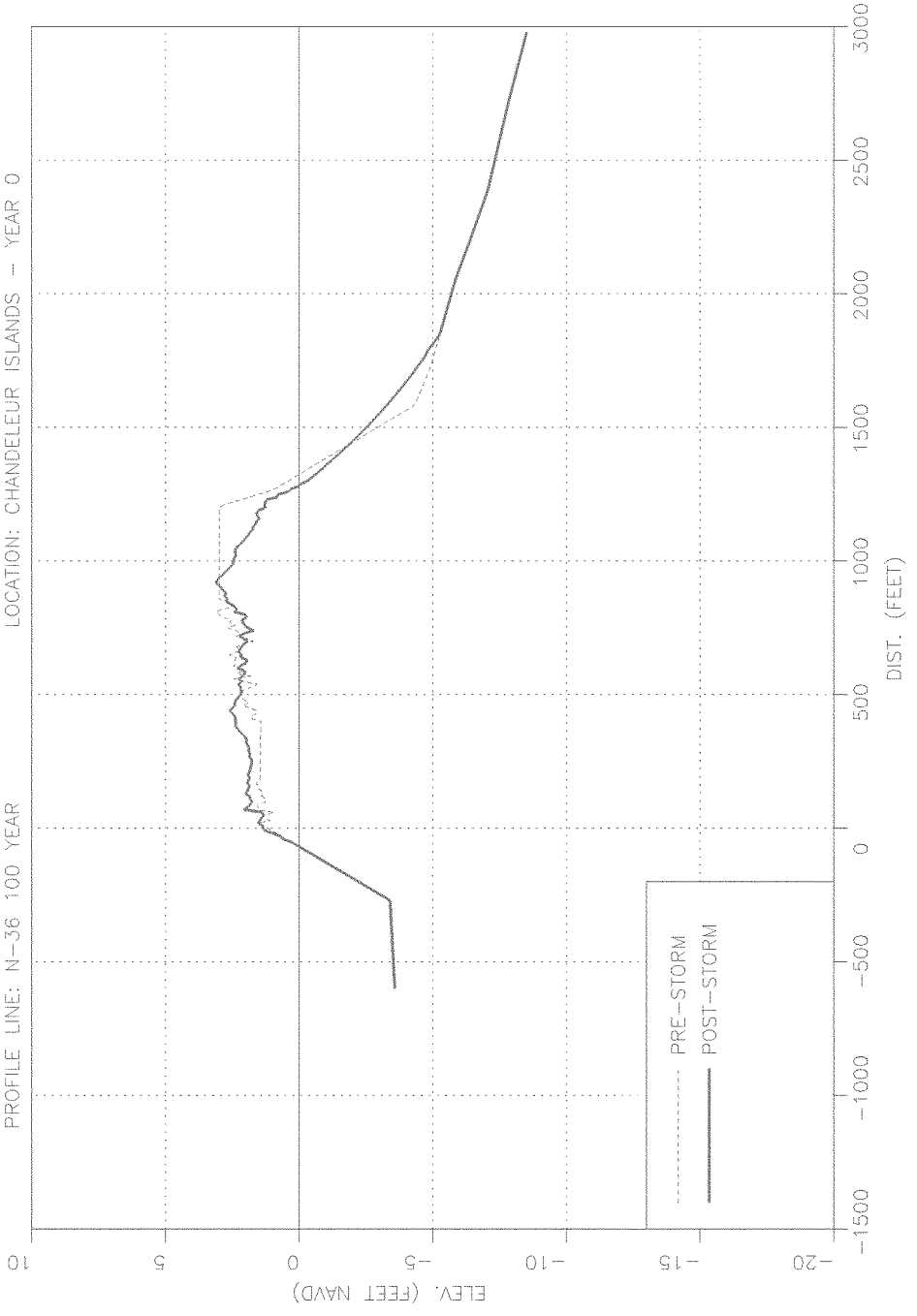

PROFILE LINE: N-36 004 YEAR
LOCATION: CHANDELEUR ISLANDS -- YEAR 0
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

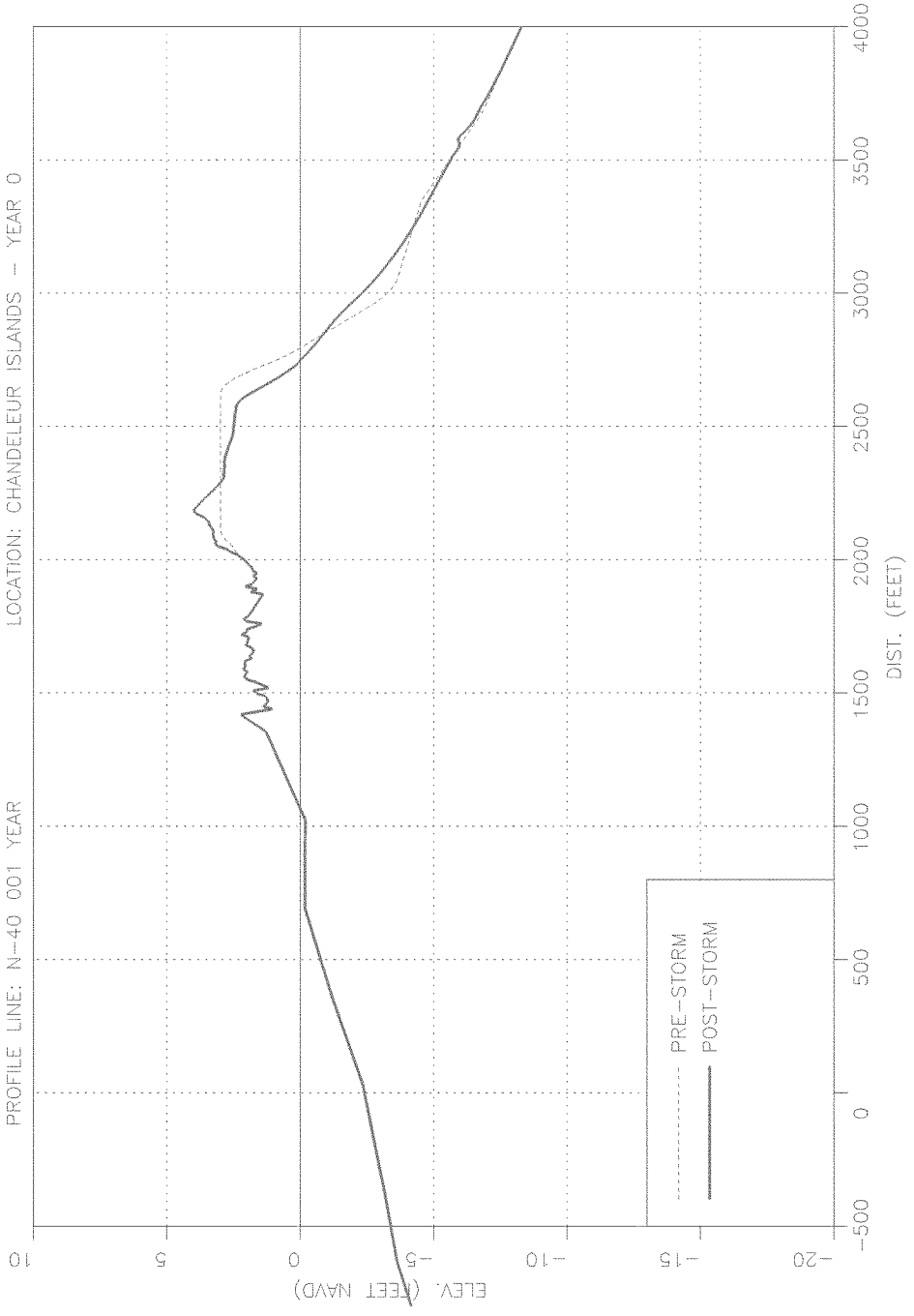

PROFILE LINE: N-36 005 YEAR
LOCATION: CHANDELEUR ISLANDS -- YEAR 0
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

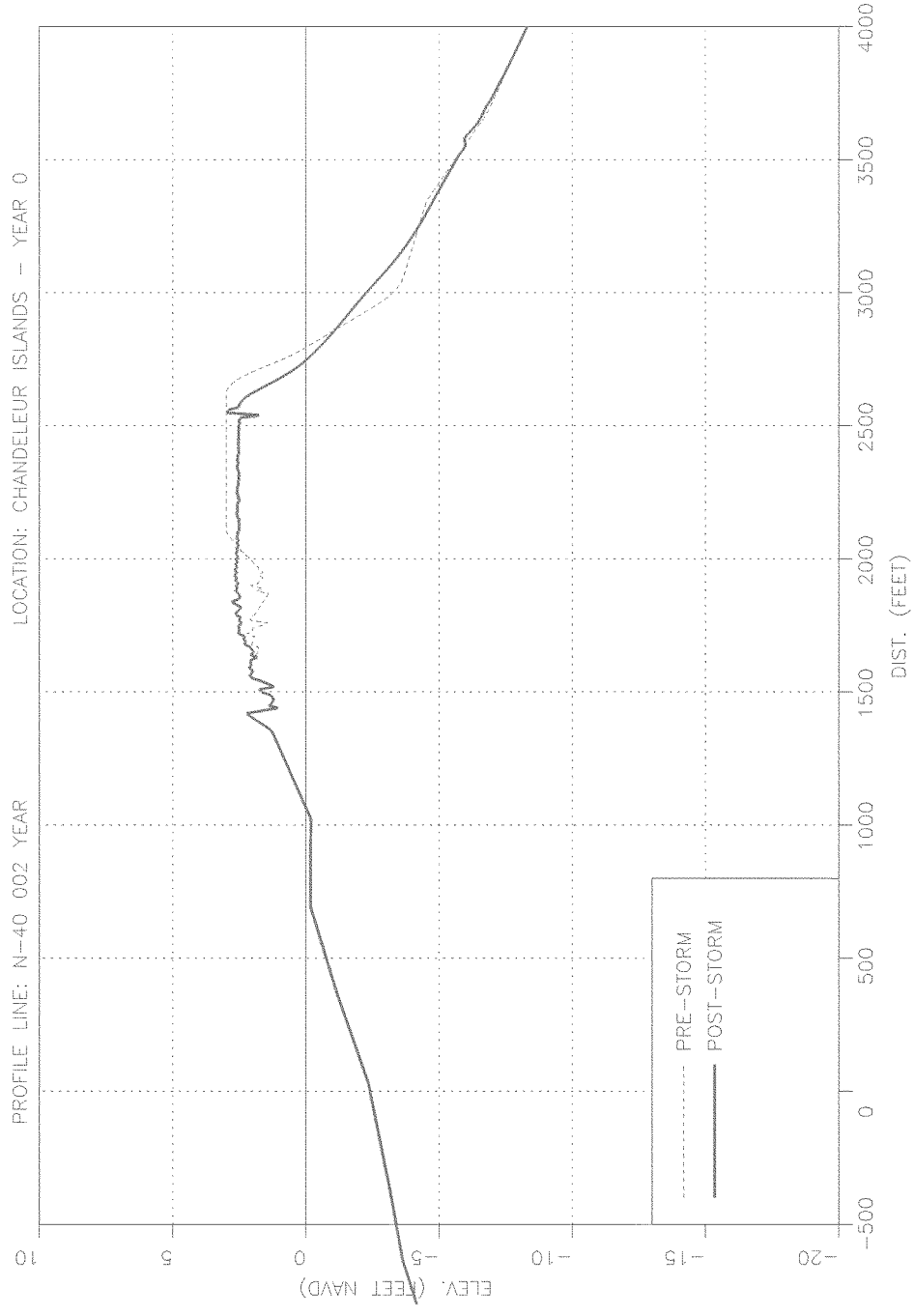

PROFILE LINE: N-36 010 YEAR
LOCATION: CHANDELEUR ISLANDS -- YEAR 0
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

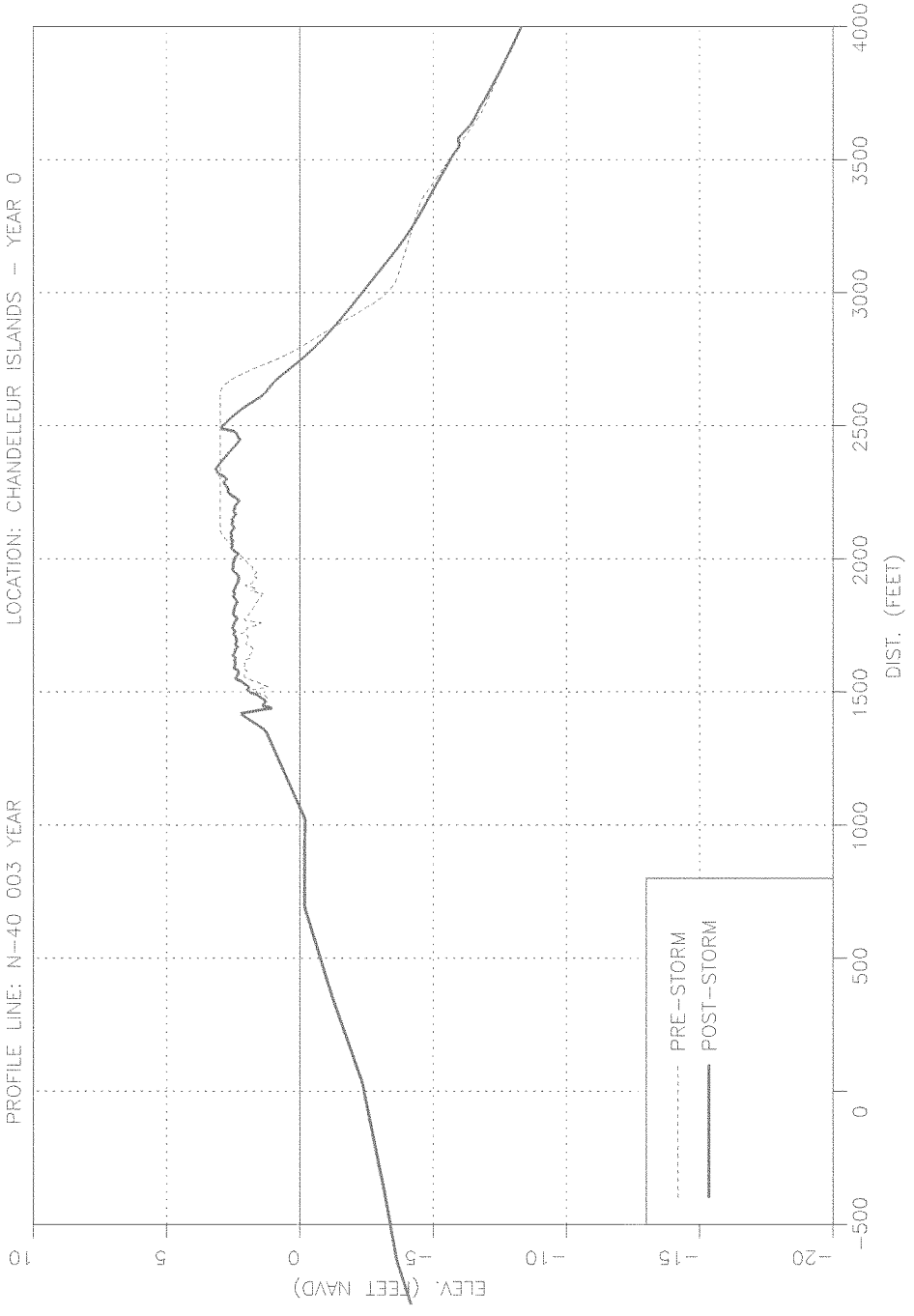

PROFILE LINE: N-36 020 YEAR
LOCATION: CHANDELEUR ISLANDS -- YEAR 0
PRE-STORM
POST-STORM
ELEV. (FEET NAVD)
DIST. (FEET)
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

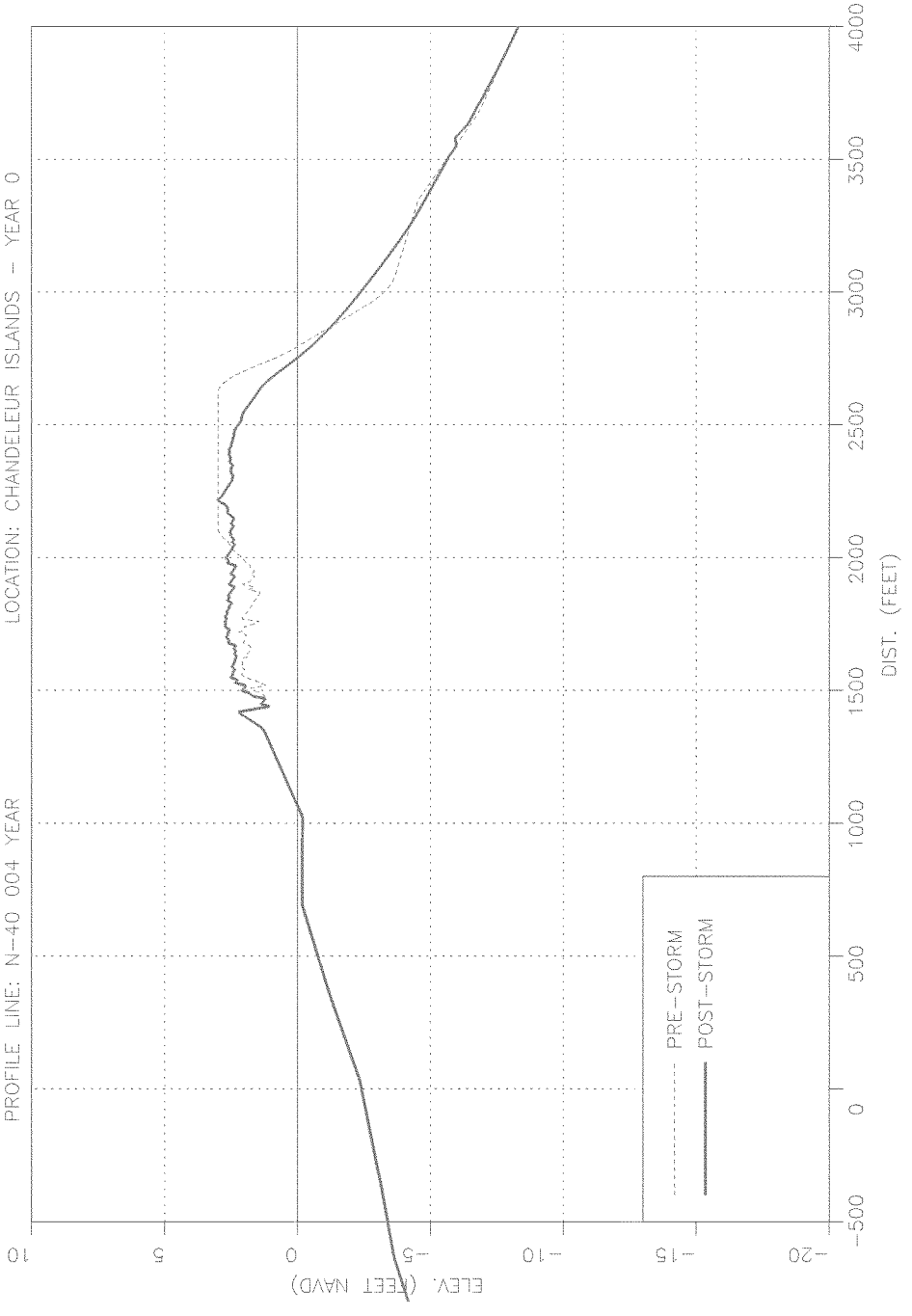

PROFILE LINE: N-36 050 YEAR
LOCATION: CHANDELEUR ISLANDS -- YEAR 0
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

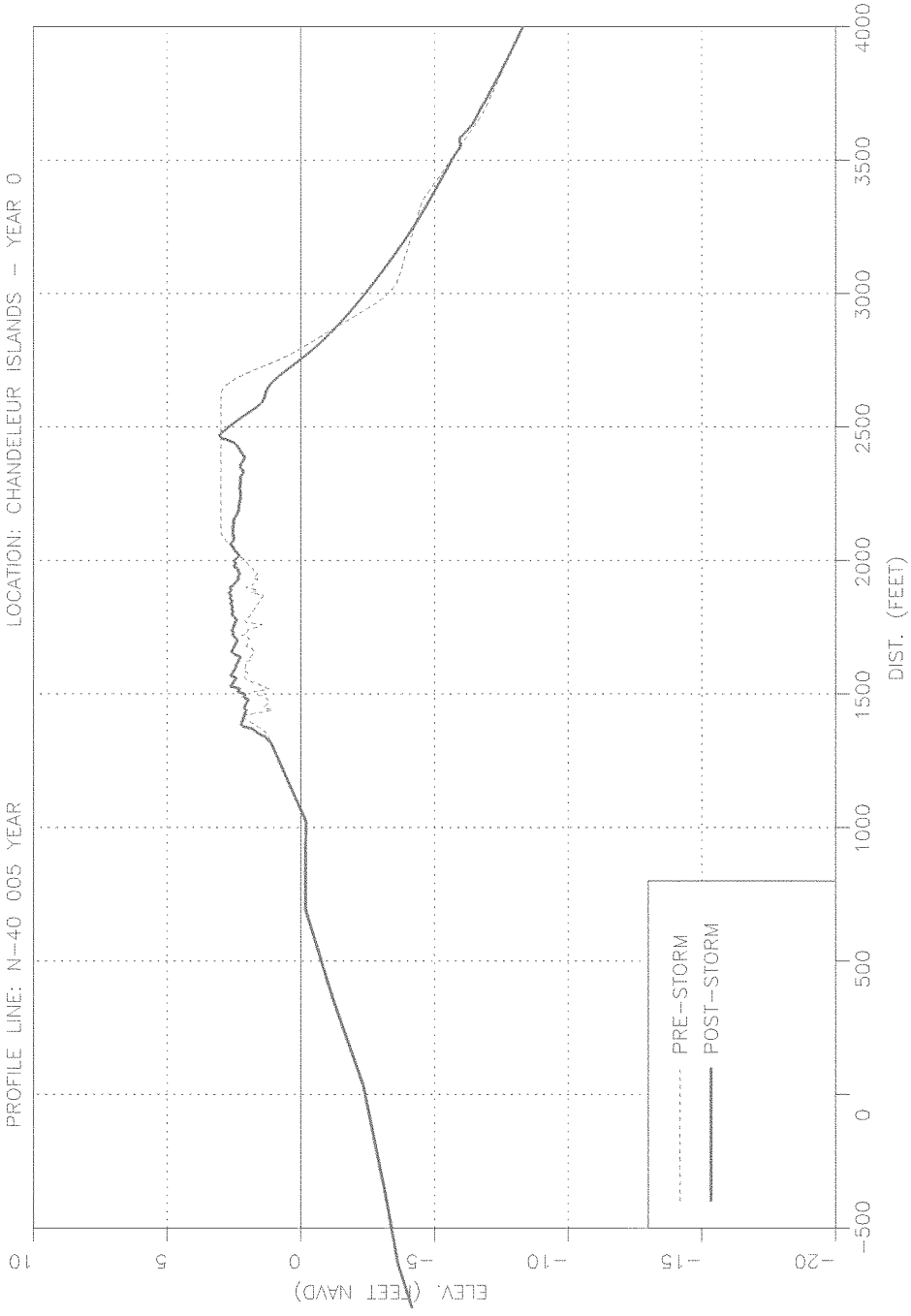

PROFILE LINE: N-36 100 YEAR
LOCATION: CHANDELEUR ISLANDS -- YEAR 0
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

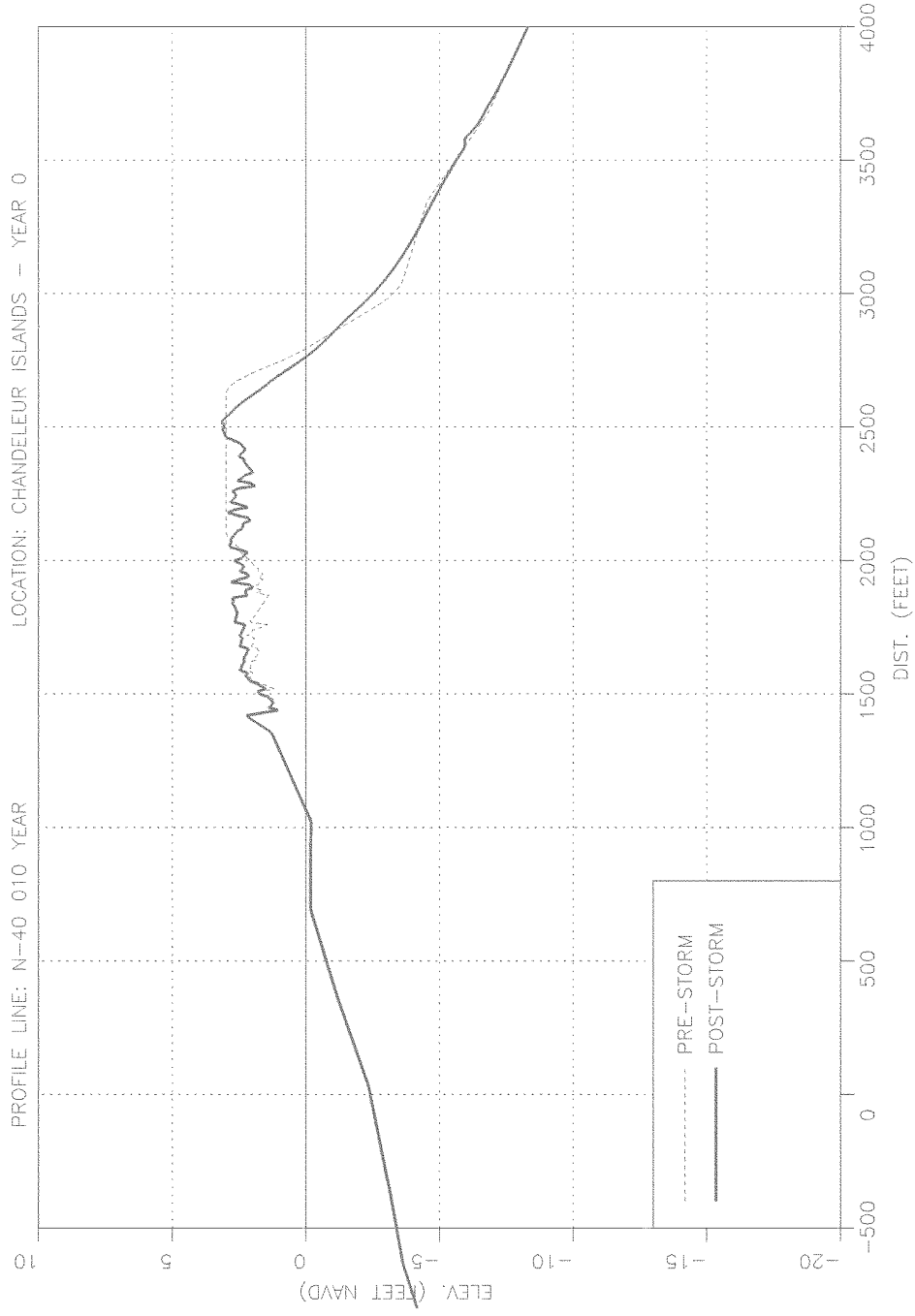

PROFILE LINE: N-40 001 YEAR
LOCATION: CHANDELEUR ISLANDS -- YEAR 0
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

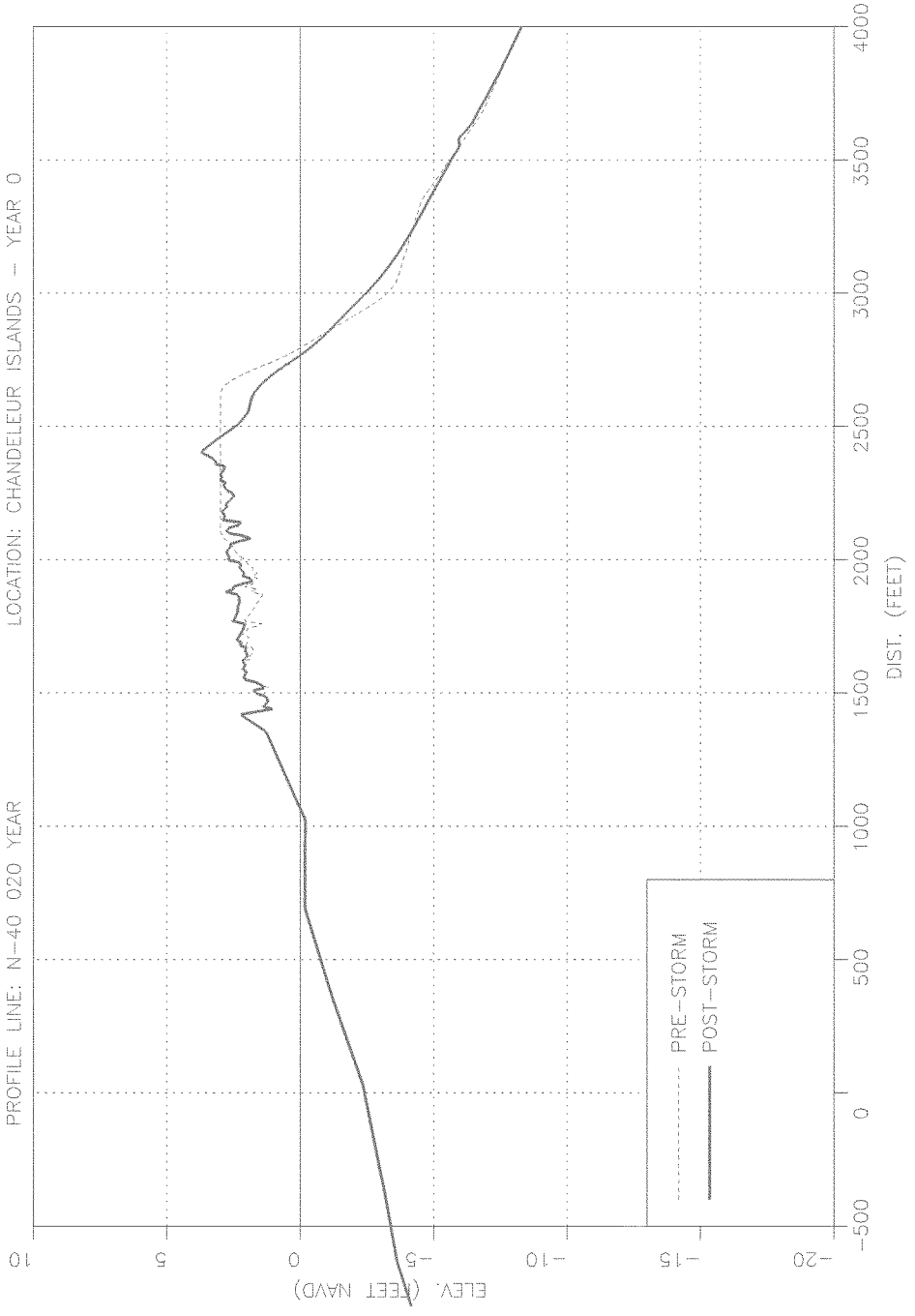

PROFILE LINE: N-40 002 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 0
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

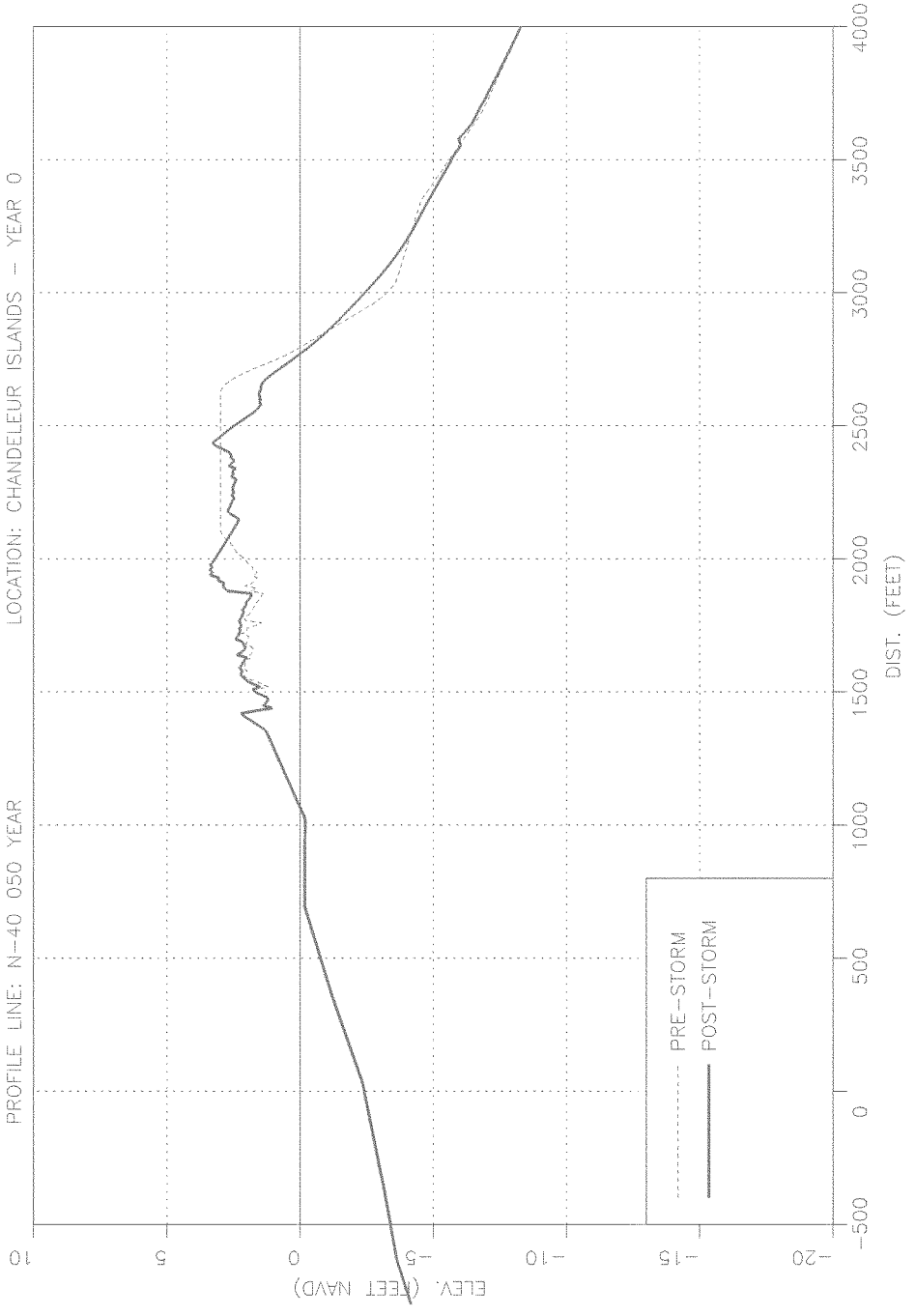

PROFILE LINE: N-40 003 YEAR
LOCATION: CHANDELEUR ISLANDS -- YEAR 0
PRE-STORM
POST-STORM
ELEV. (FEET NAVD)
DIST. (FEET)
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

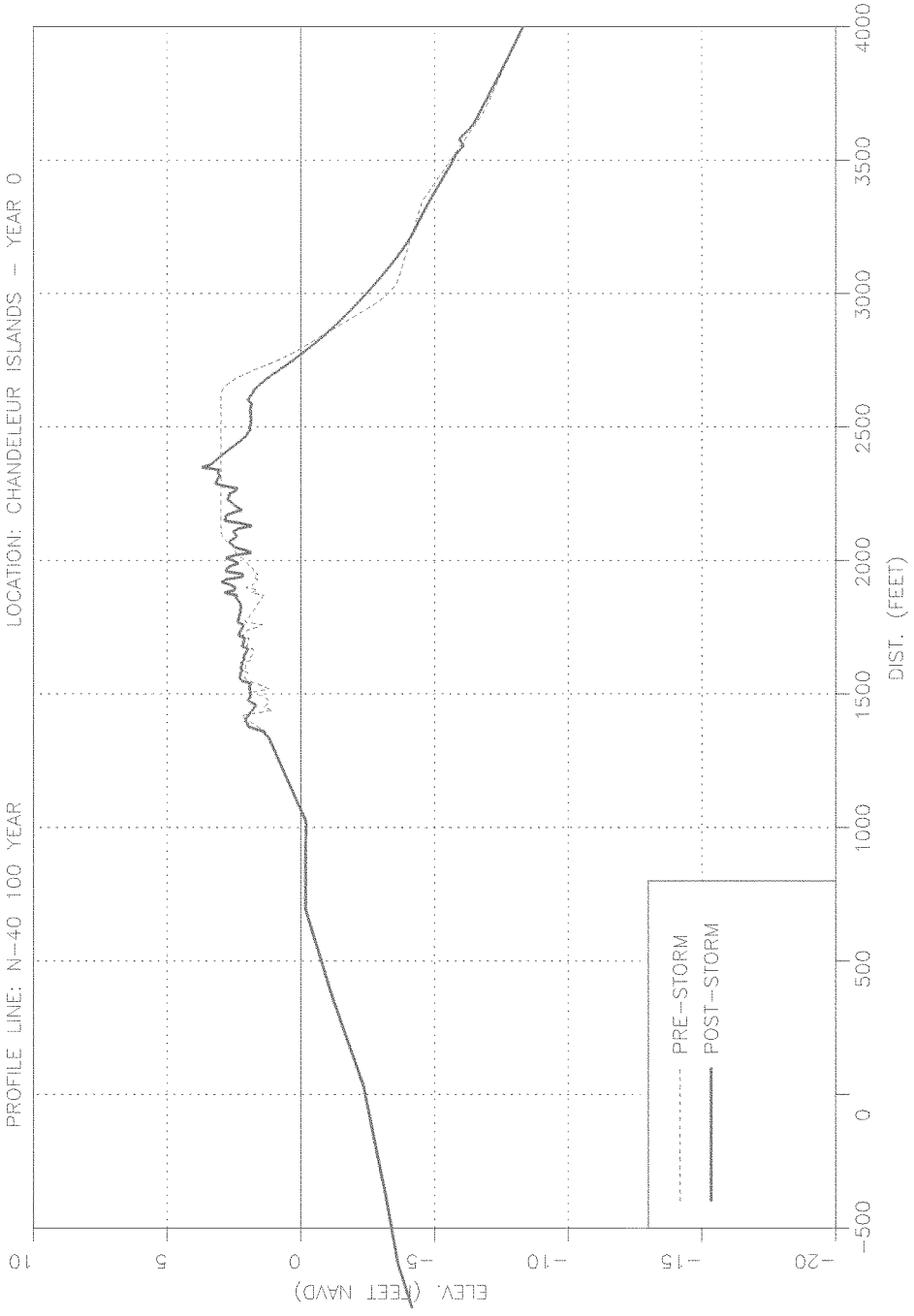

PROFILE LINE: N-40 004 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 0
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

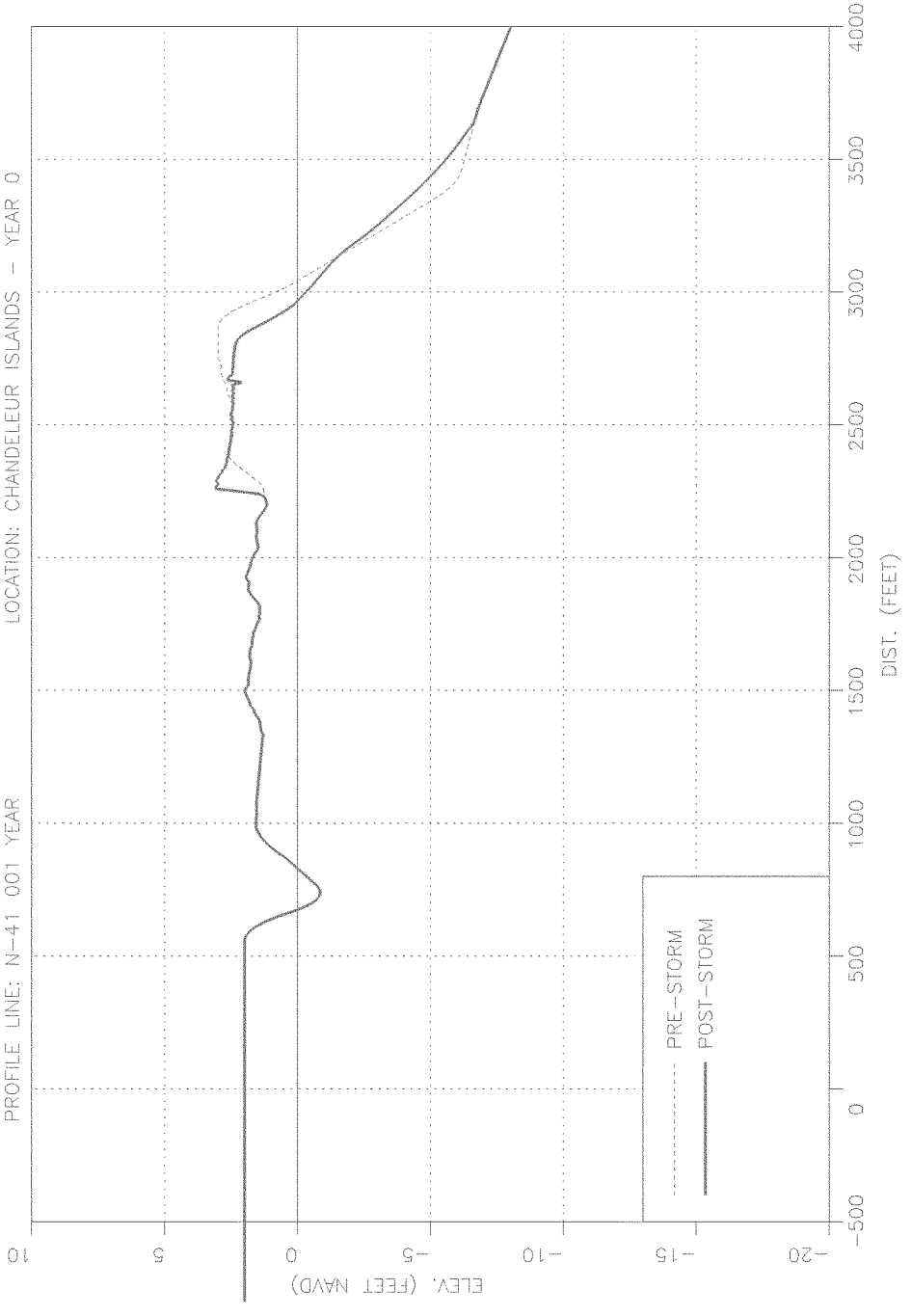

PROFILE LINE: N-40 005 YEAR
LOCATION: CHANDELEUR ISLANDS -- YEAR 0
PRE-STORM
POST-STORM
ELEV. (FEET NAVD)
DIST. (FEET)
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

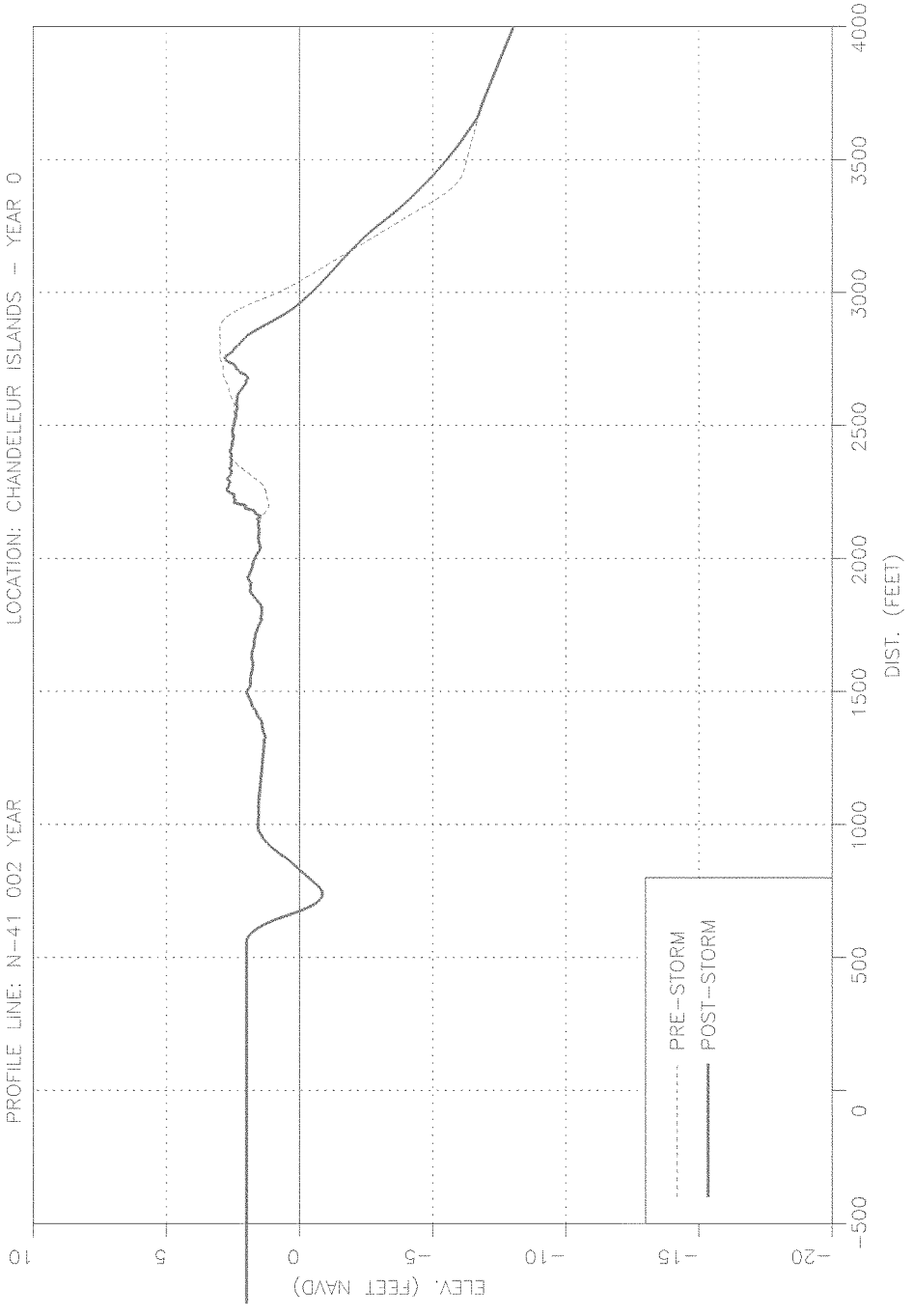

PROFILE LINE: N-40 010 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 0
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

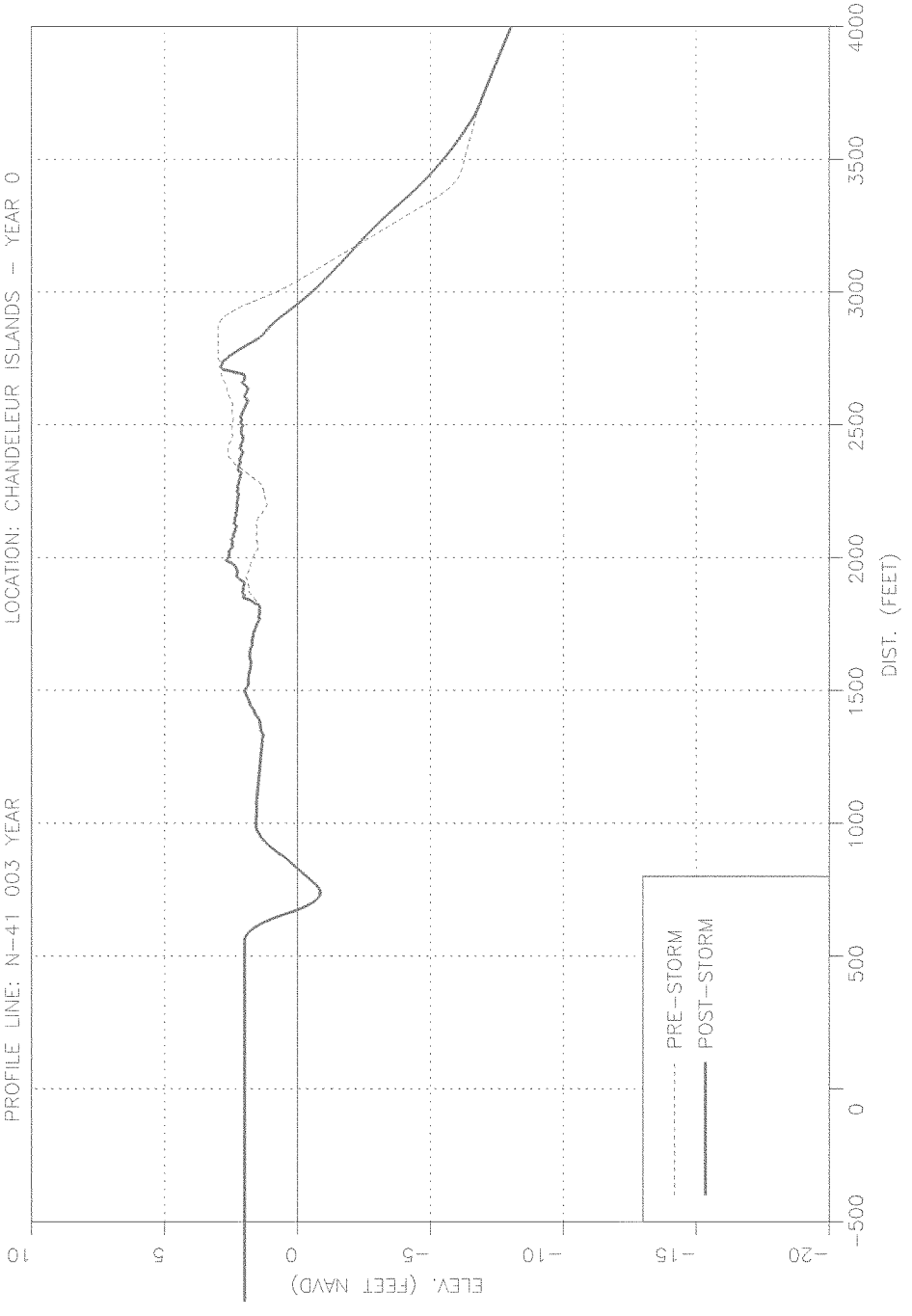

PROFILE LINE: N-40 020 YEAR
LOCATION: CHANDELEUR ISLANDS -- YEAR 0
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

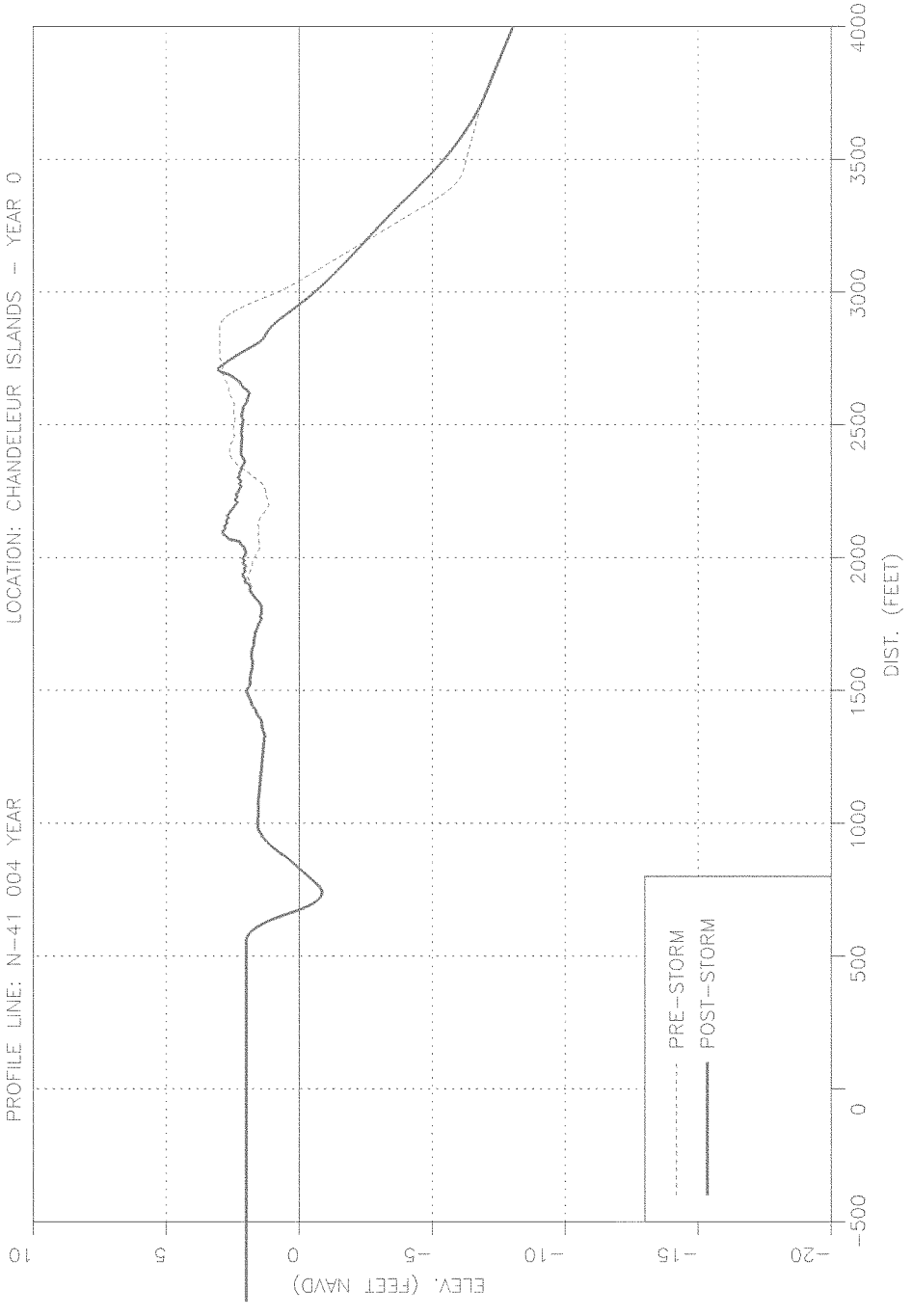

PROFILE LINE: N-40 050 YEAR
LOCATION: CHANDELEUR ISLANDS -- YEAR 0
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

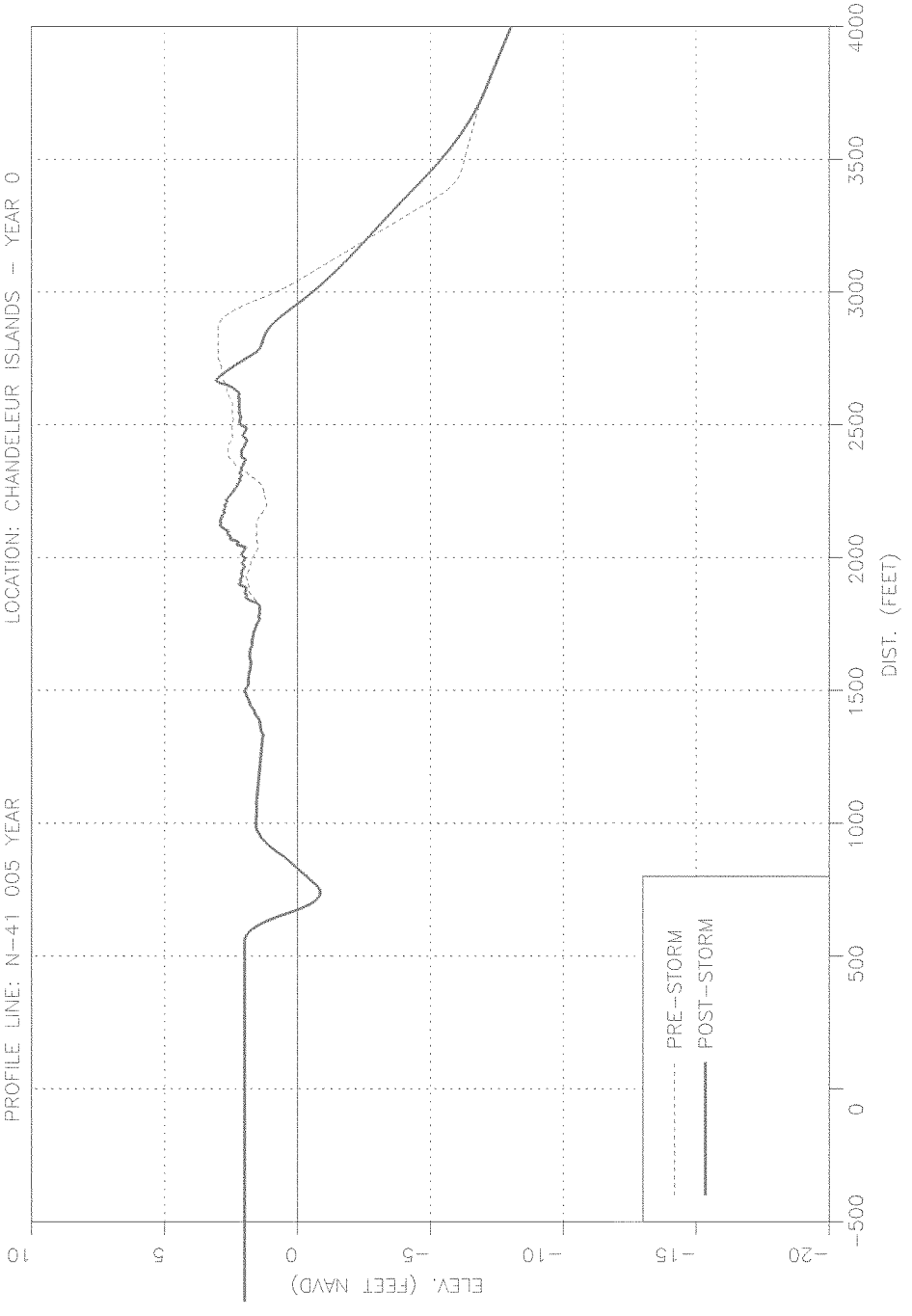

PROFILE LINE: N-40 100 YEAR
LOCATION: CHANDELEUR ISLANDS -- YEAR 0
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

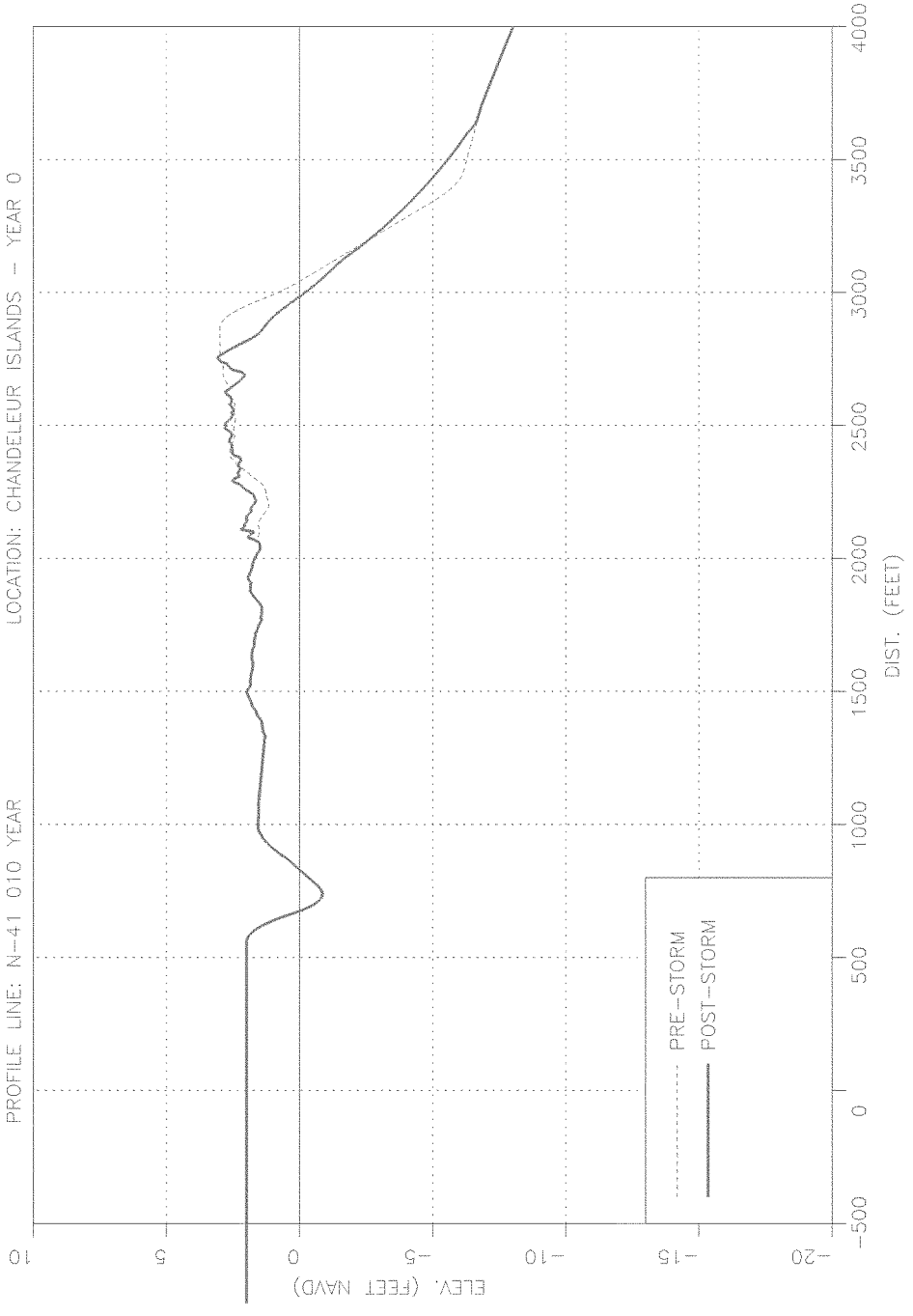

PROFILE LINE: N-41 001 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 0
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

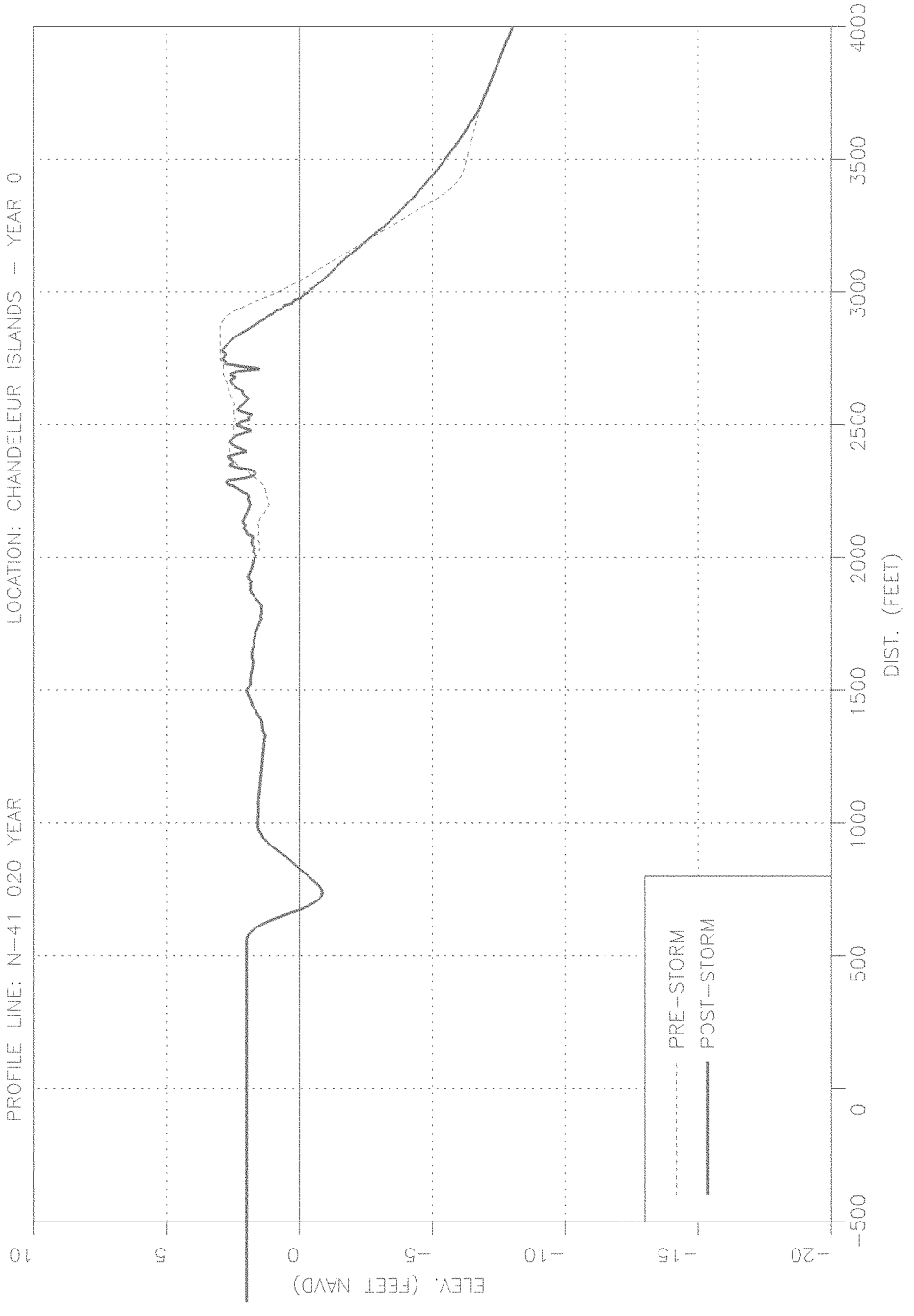

PROFILE LINE: N-41 002 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 0
PRE-STORM
POST-STORM
ELEV. (FEET NAVD)
DIST. (FEET)
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

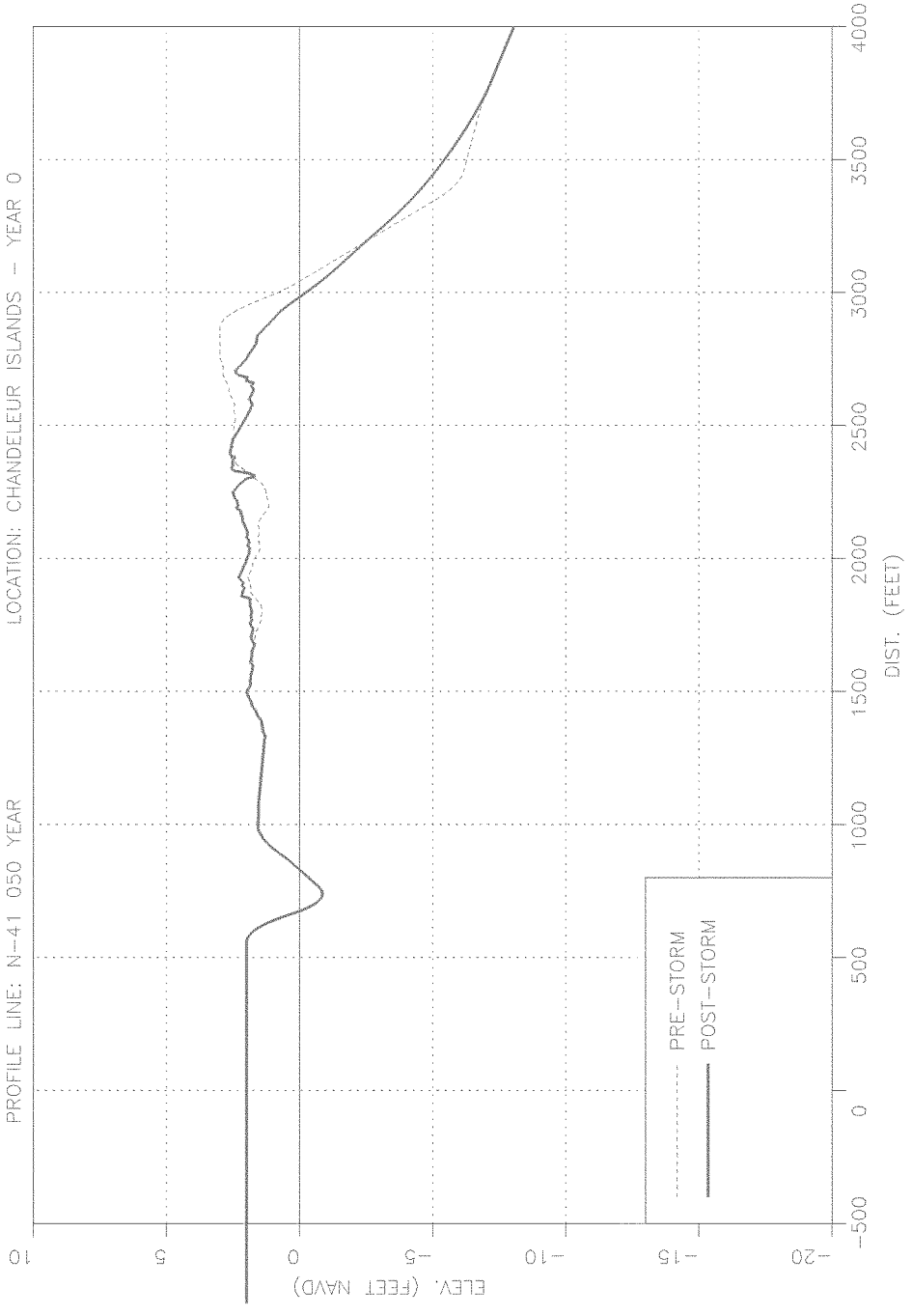

PROFILE LINE: N-41 003 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 0
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

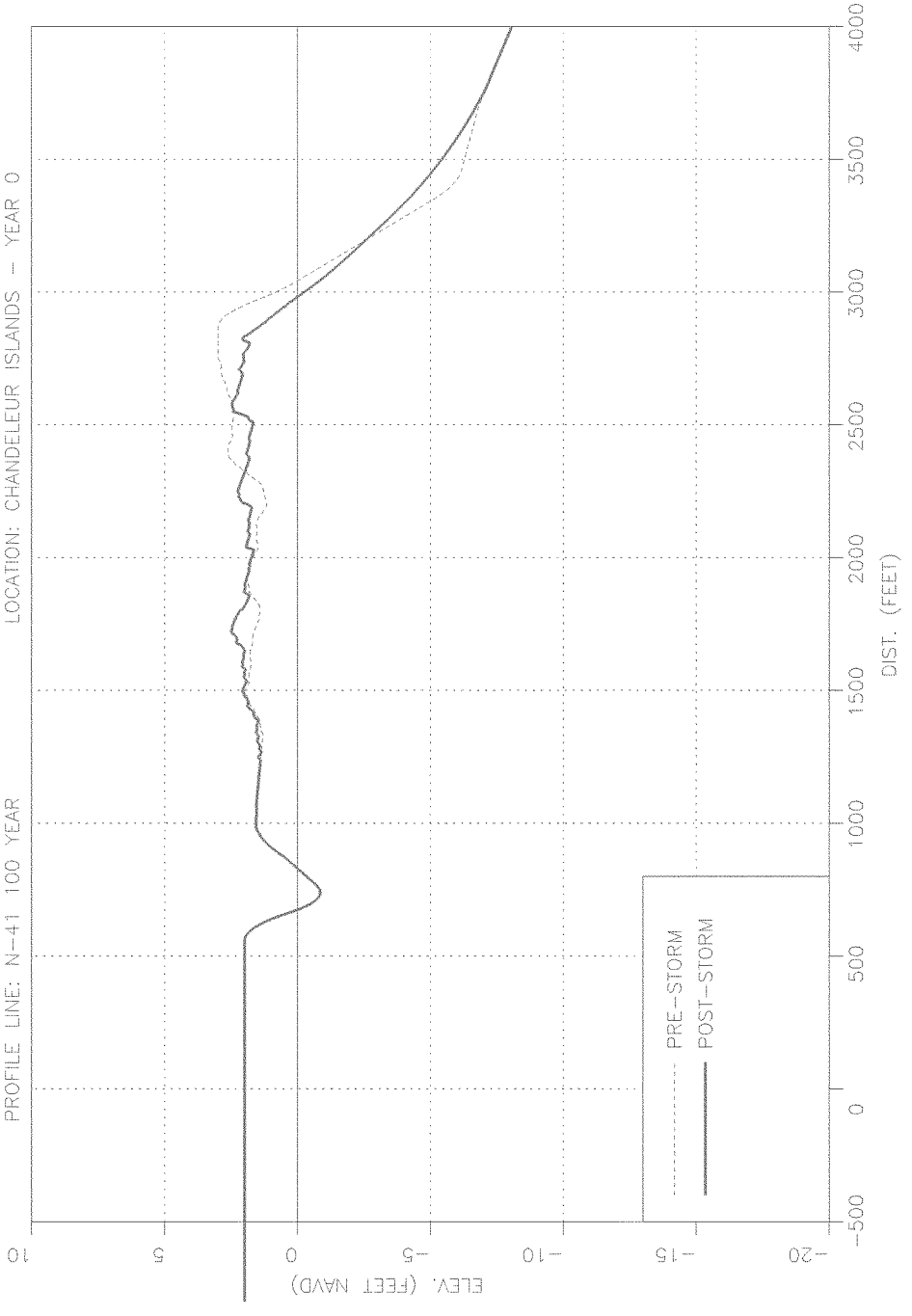

PROFILE LINE: N-41 004 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 0
PRE-STORM
POST-STORM
ELEV. (FEET NAVD)
DIST. (FEET)
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

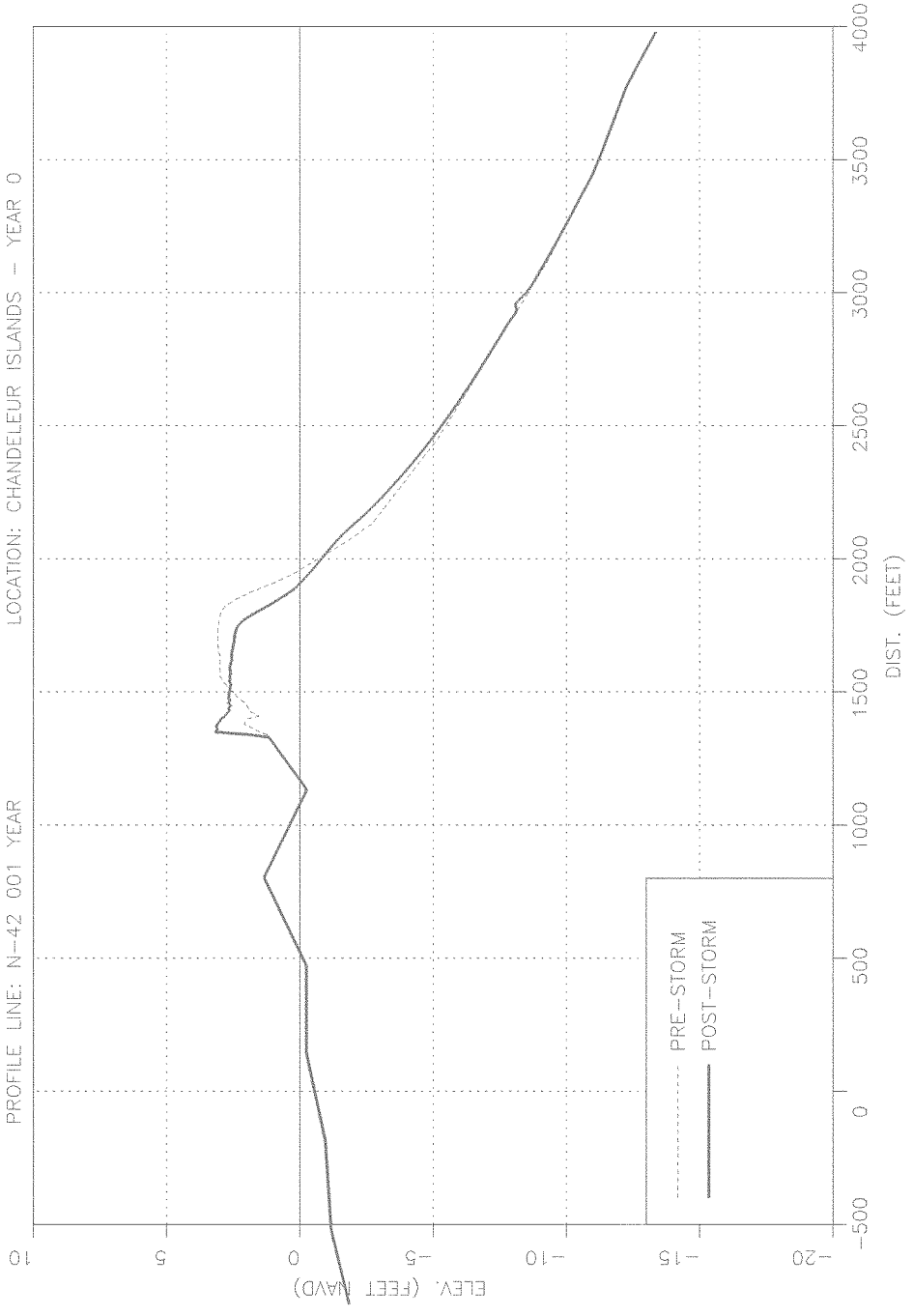

PROFILE LINE: N-41 005 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 0
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

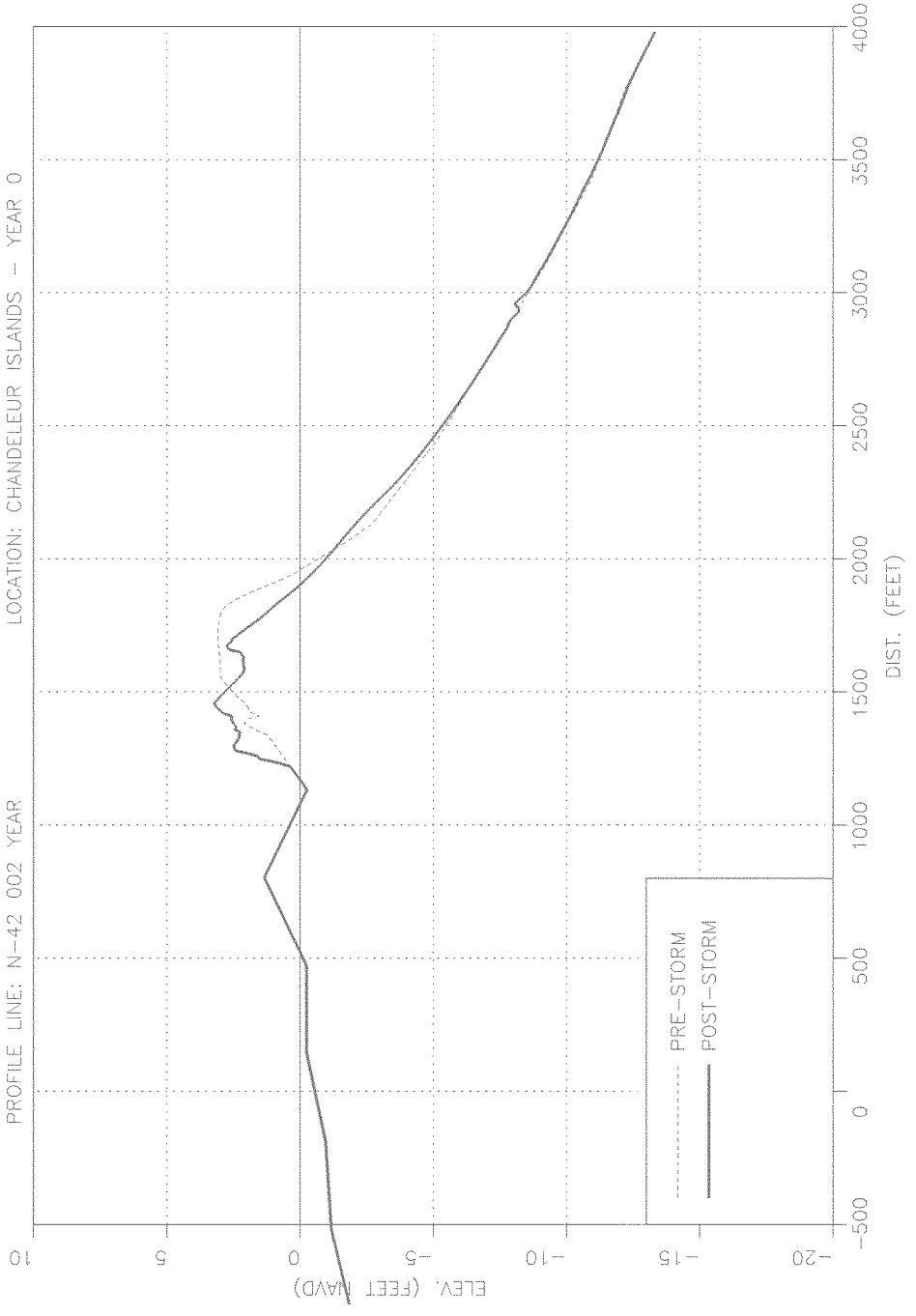

PROFILE LINE: N-41 010 YEAR
LOCATION: CHANDELEUR ISLANDS -- YEAR 0
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

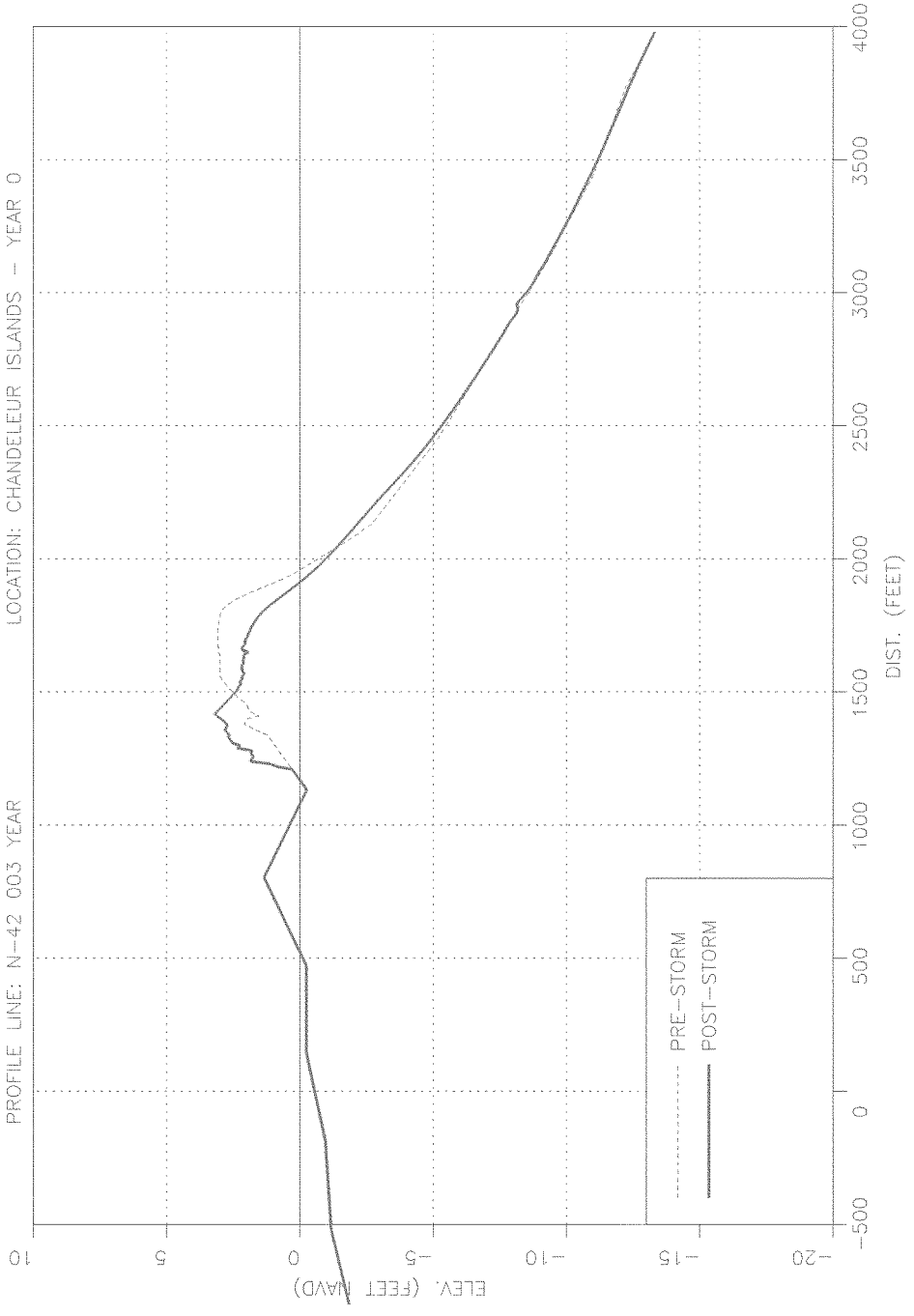

PROFILE LINE: N-41 020 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 0
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

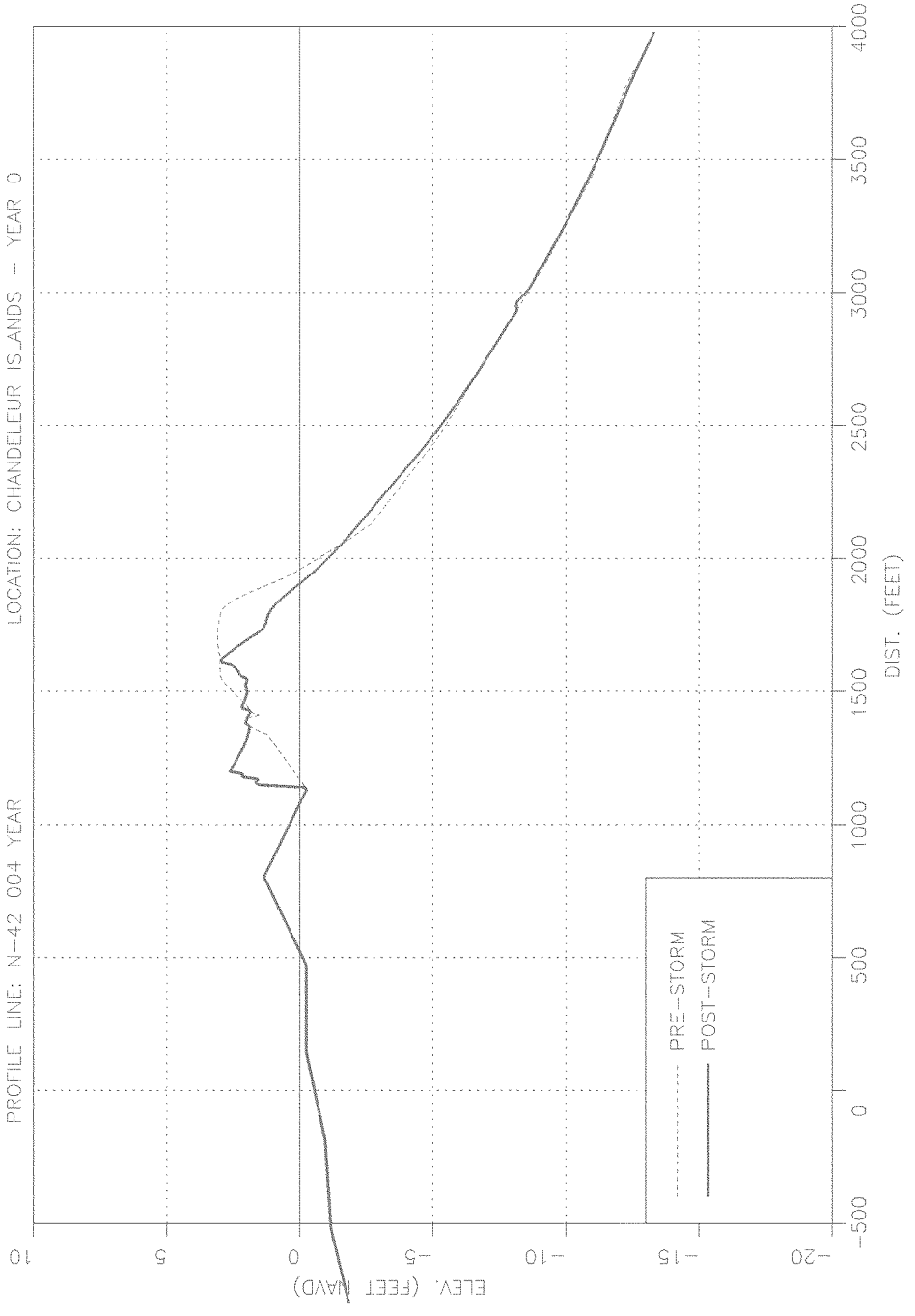

PROFILE LINE: N-41 050 YEAR
LOCATION: CHANDELEUR ISLANDS -- YEAR 0
PRE-STORM
POST-STORM
ELEV. (FEET NAVD)
DIST. (FEET)
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

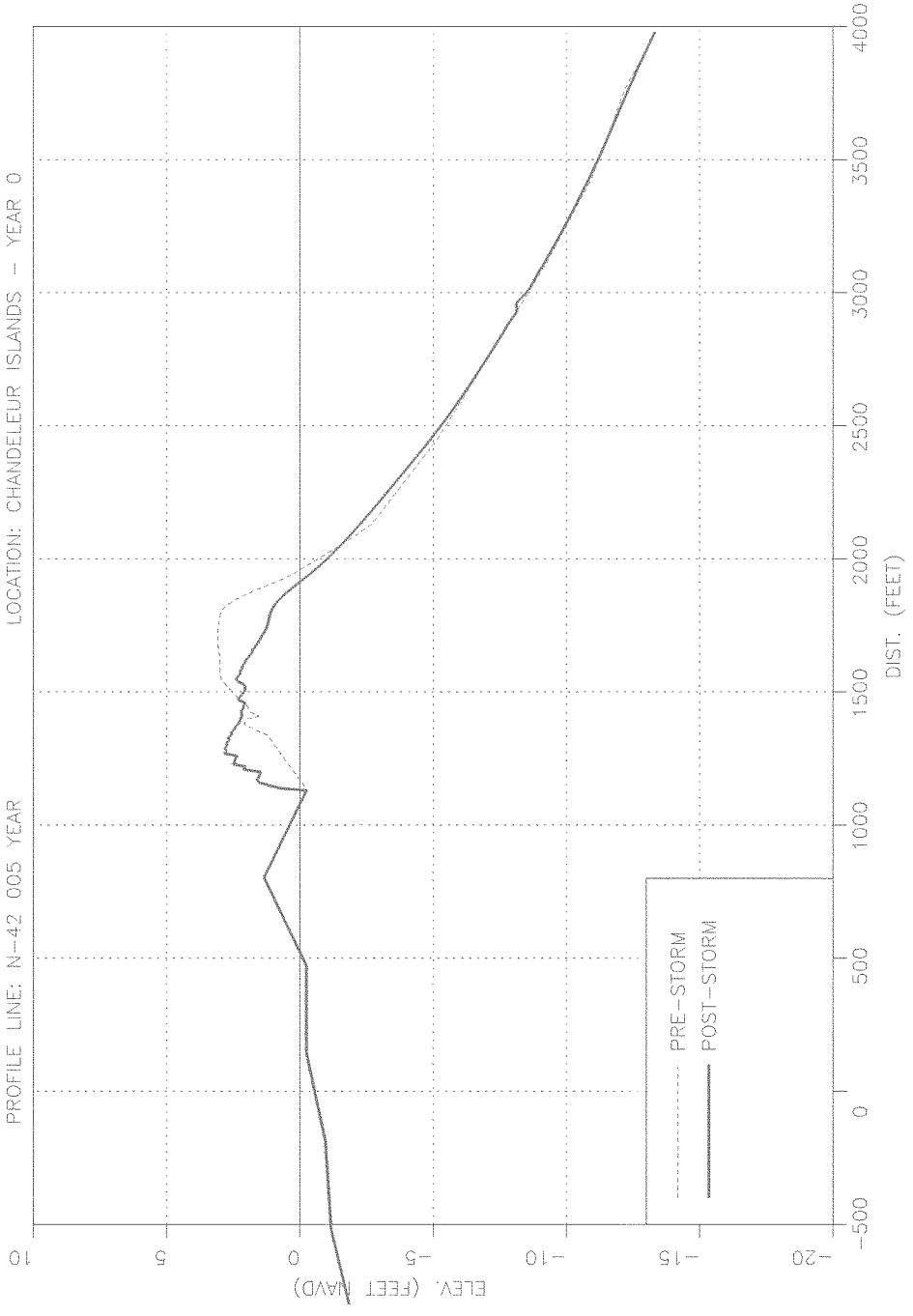

PROFILE LINE: N-41 100 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 0
ELEV. (FEET NAVD)
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000
DIST. (FEET)
PRE-STORM
POST-STORM

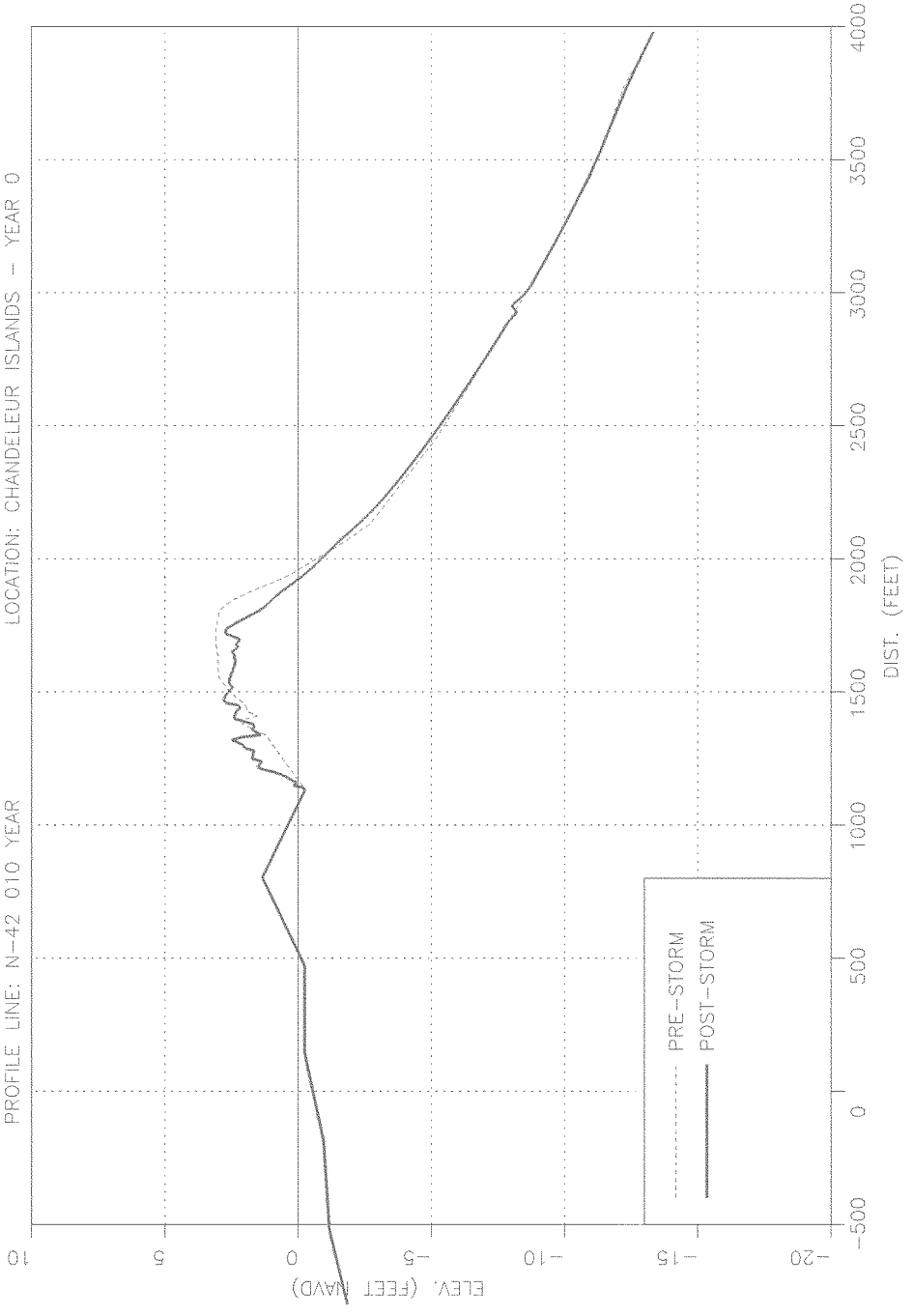

PROFILE LINE: N-42 001 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 0
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

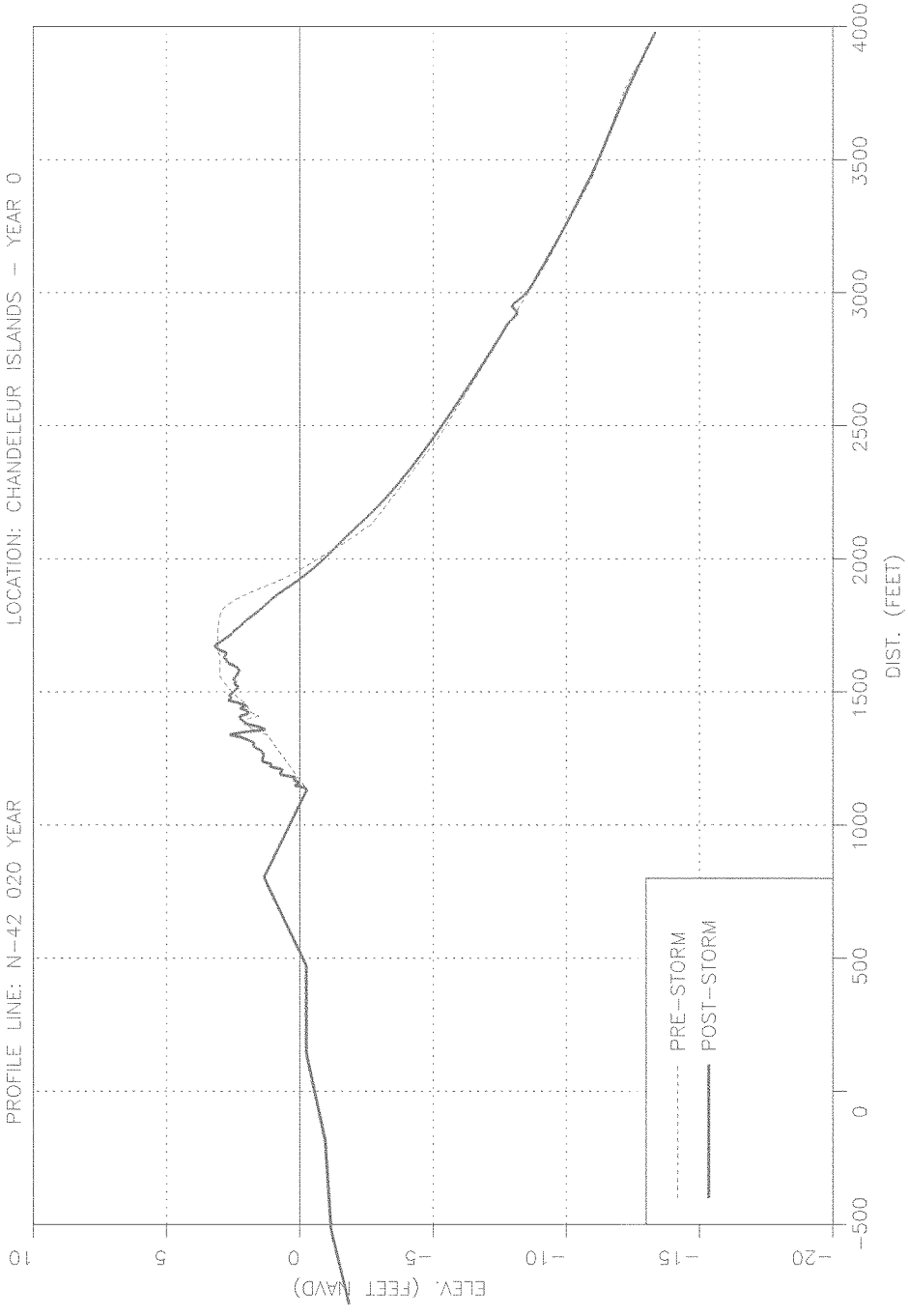

PROFILE LINE: N-42 002 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 0
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

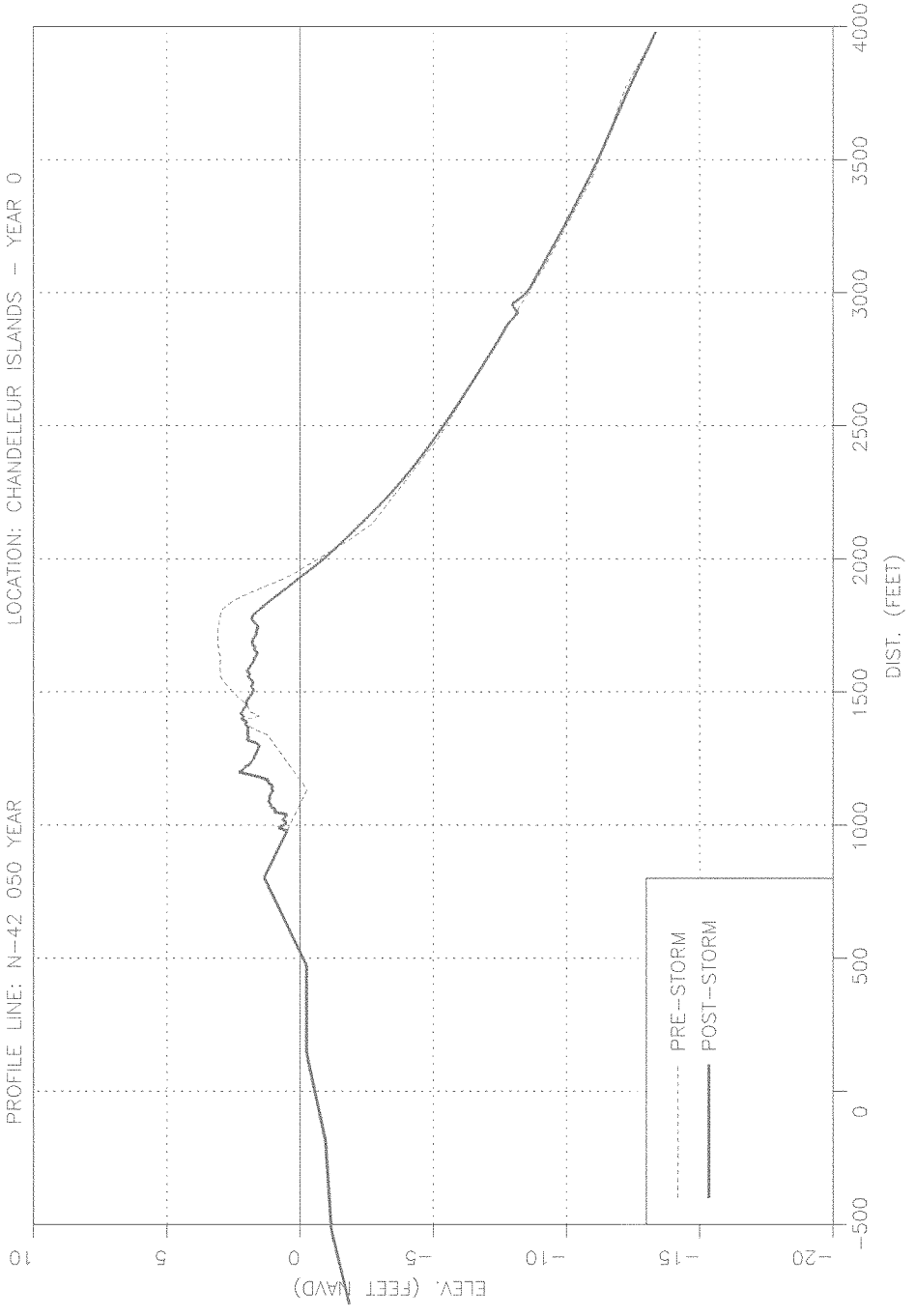

PROFILE LINE: N-42 003 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 0
PRE-STORM
POST-STORM
ELEV. (FEET NAVD)
DIST. (FEET)
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

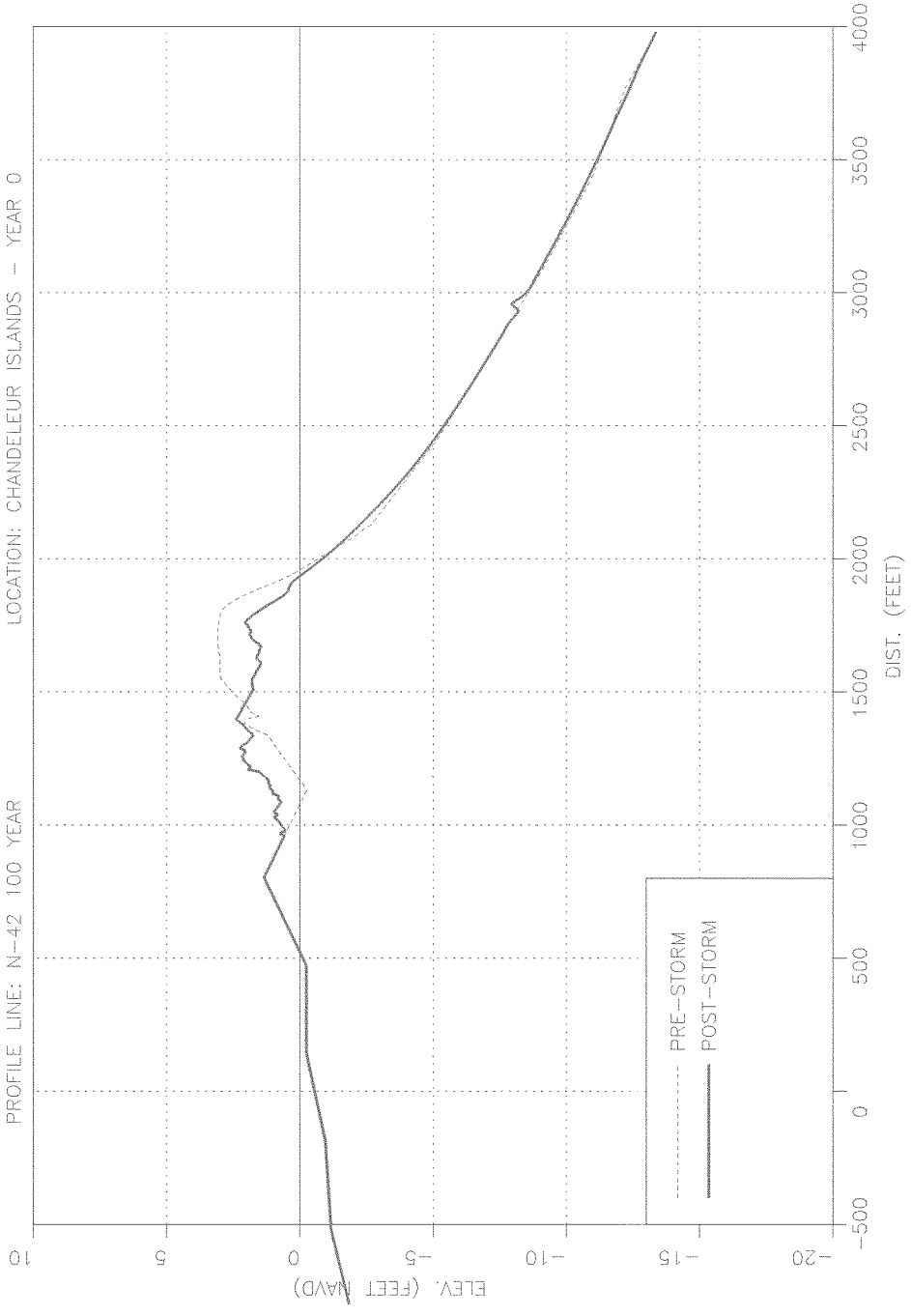

PROFILE LINE: N-42 004 YEAR
LOCATION: CHANDELEUR ISLANDS -- YEAR 0
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

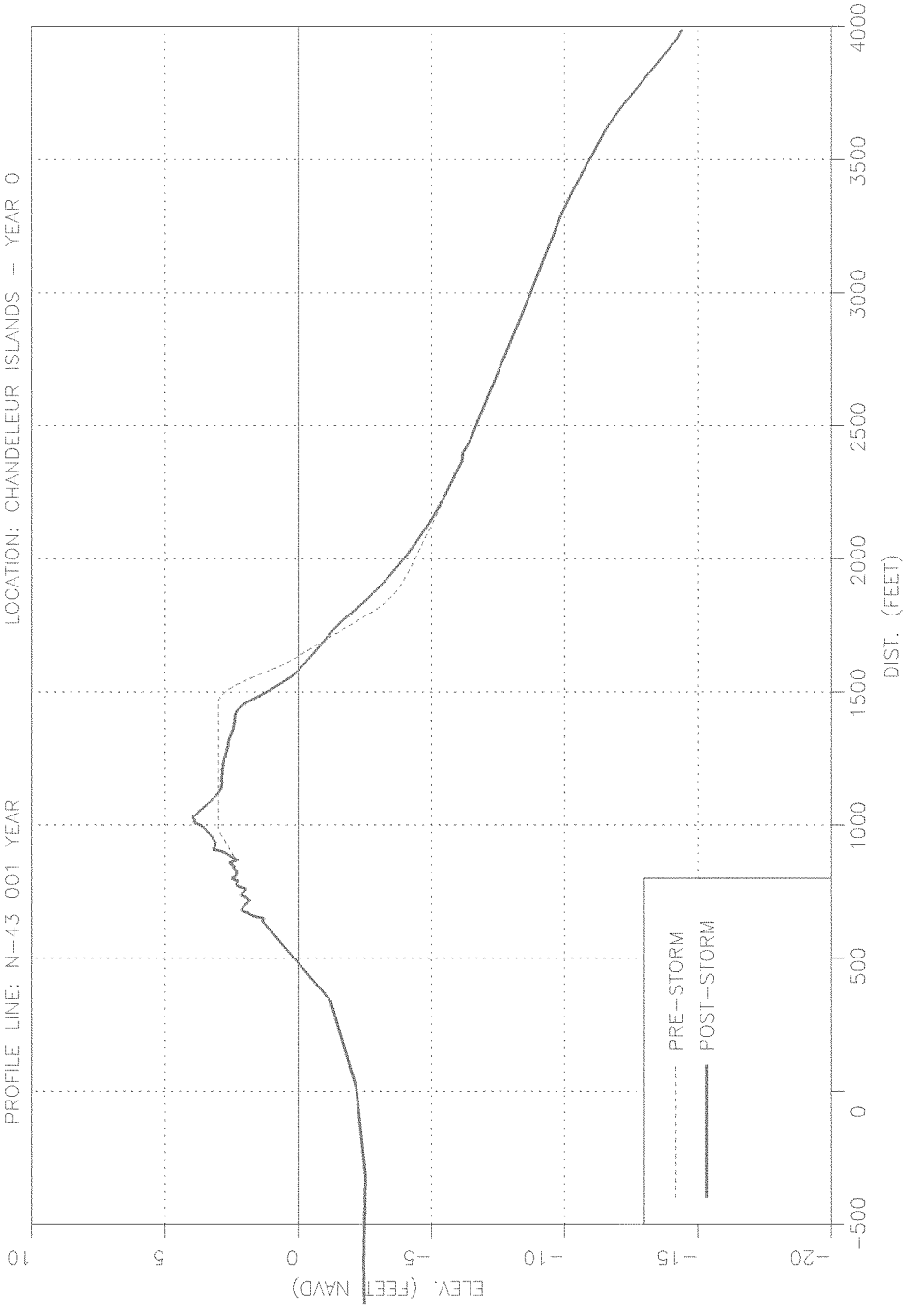

PROFILE LINE: N-42 005 YEAR
LOCATION: CHANDELEUR ISLANDS -- YEAR 0
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

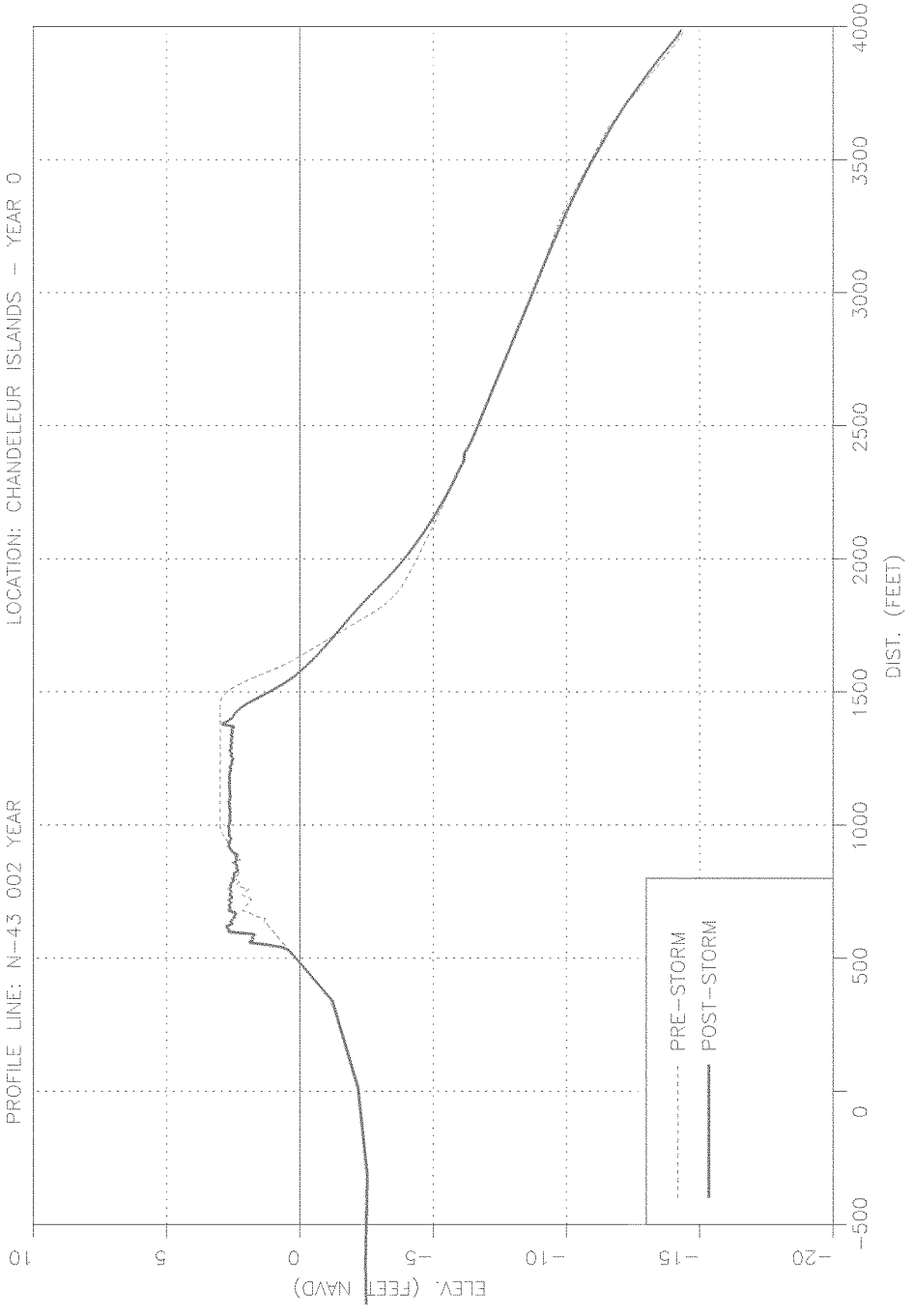

PROFILE LINE: N-42 010 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 0
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

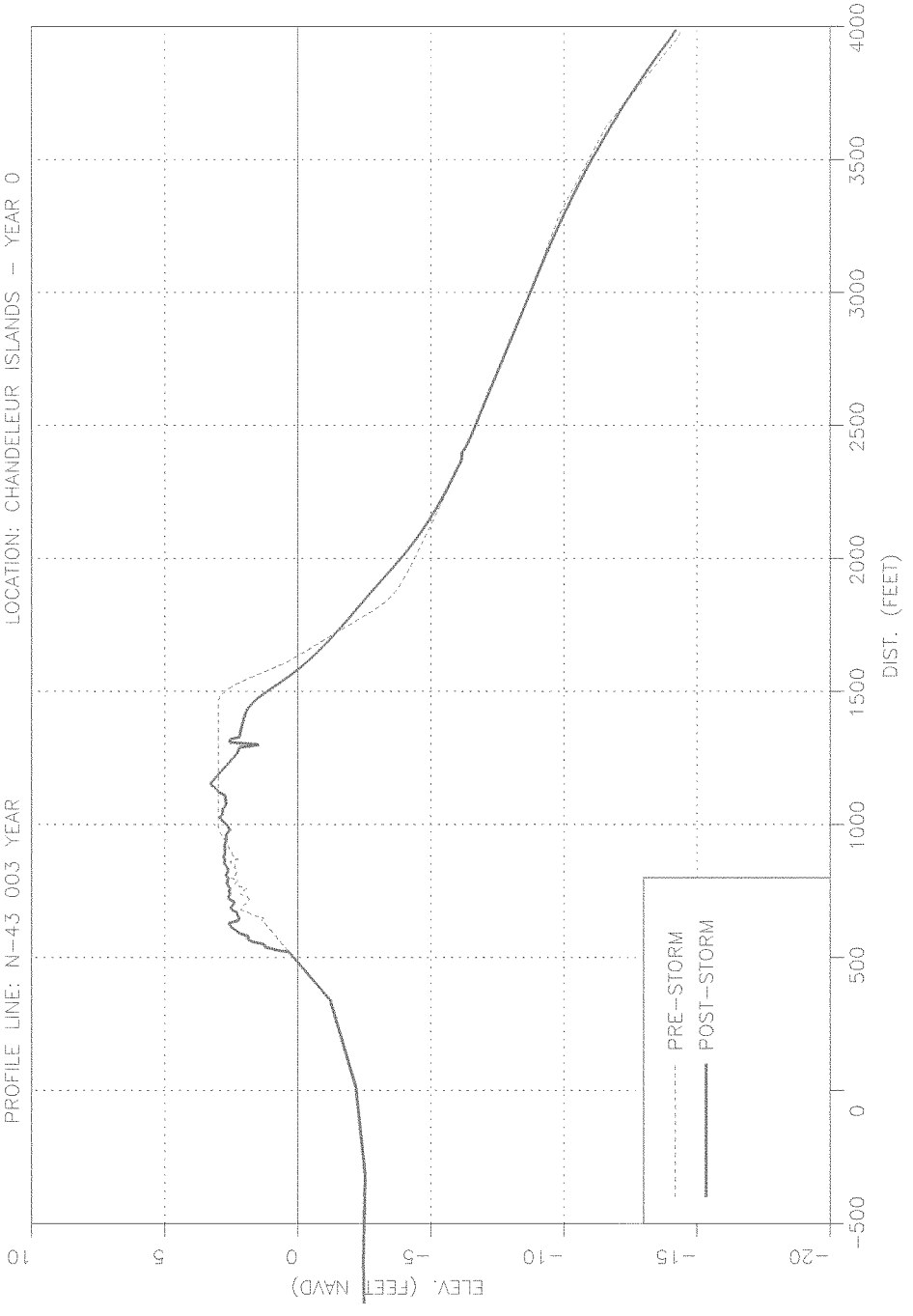

PROFILE LINE: N-42 020 YEAR
LOCATION: CHANDELEUR ISLANDS -- YEAR 0
PRE-STORM
POST-STORM
ELEV. (FEET NAVD)
DIST. (FEET)
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

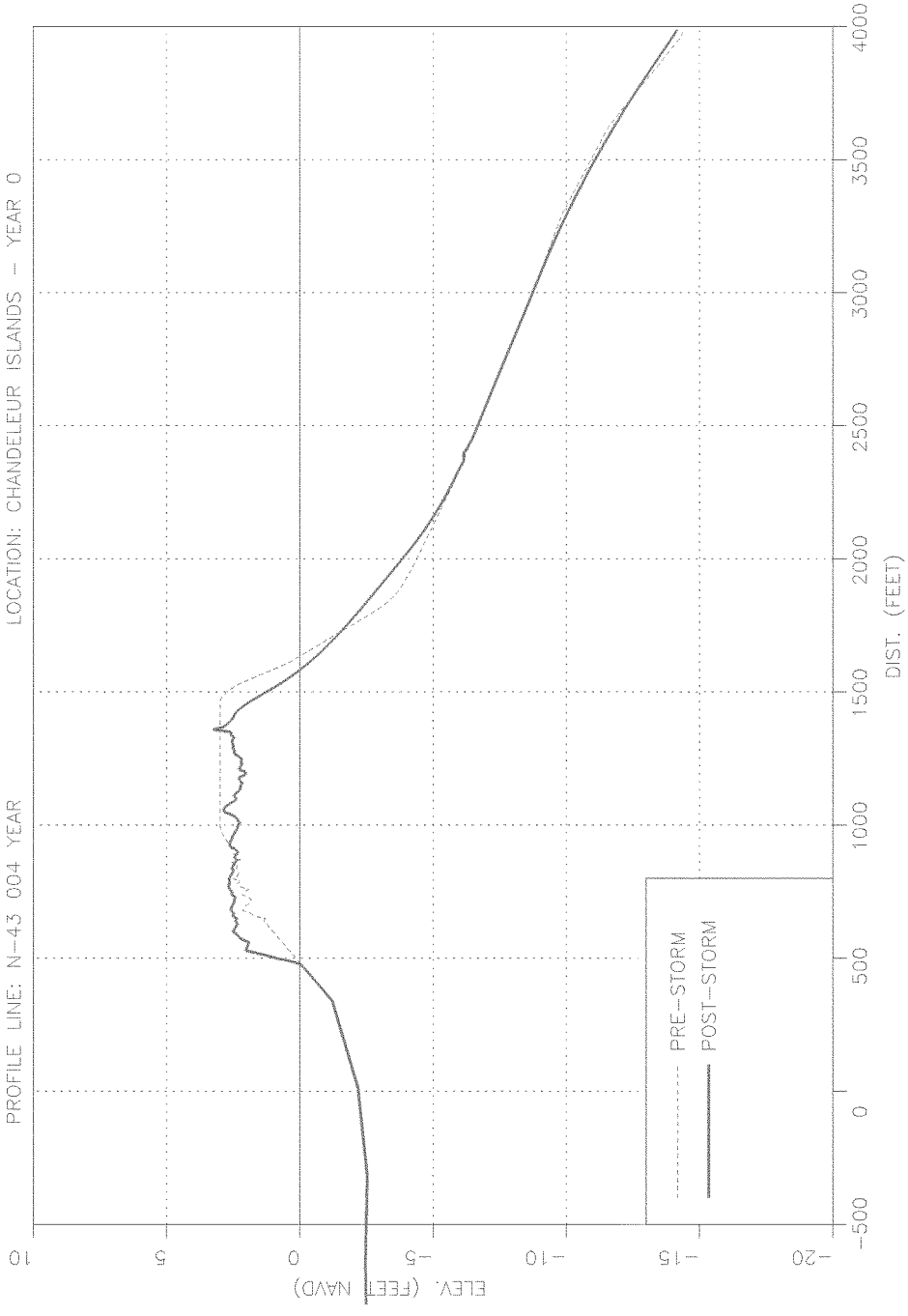

PROFILE LINE: N-42 050 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 0
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000


PROFILE LINE: N-42 100 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 0
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

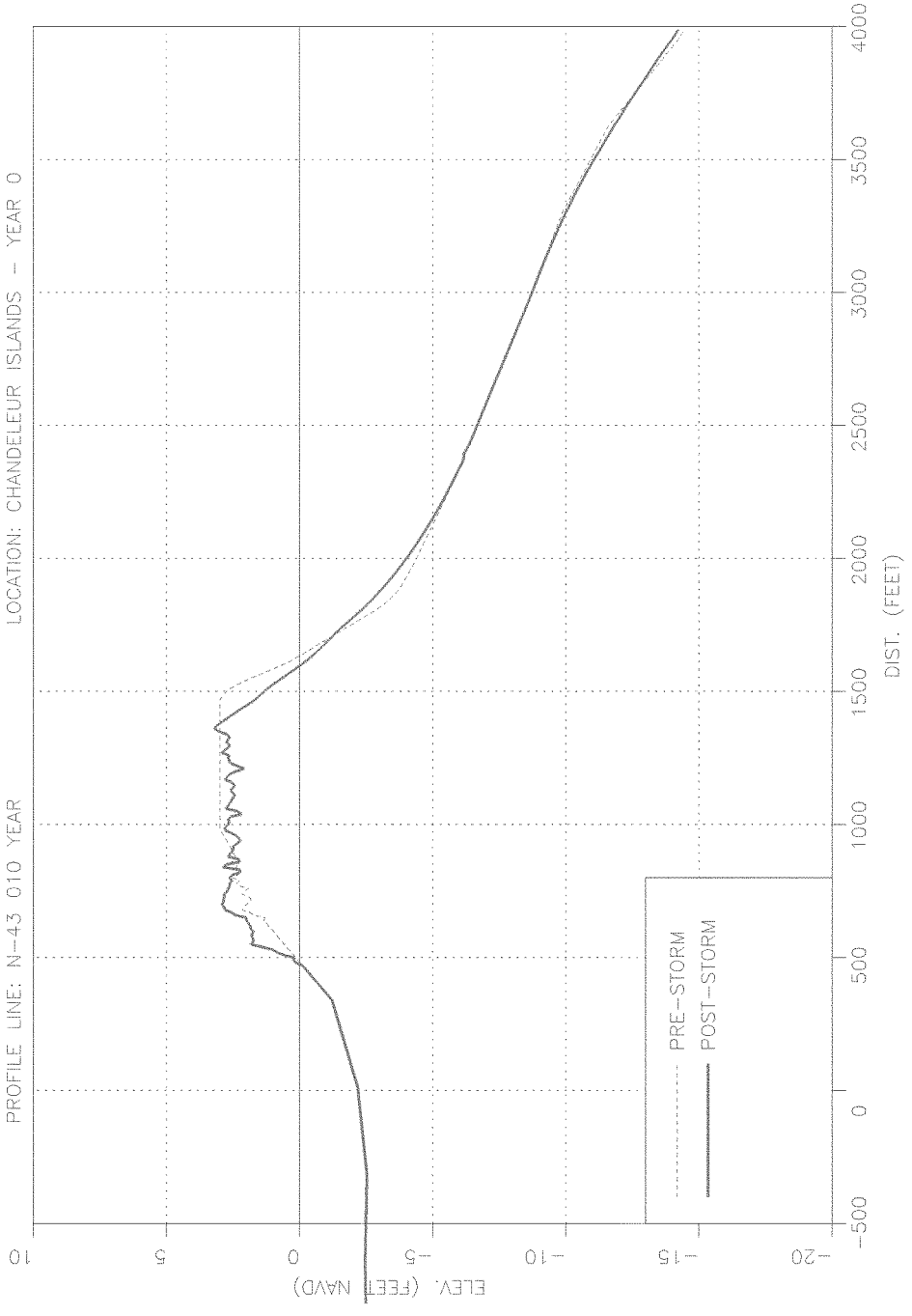

PROFILE LINE: N-43 001 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 0
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

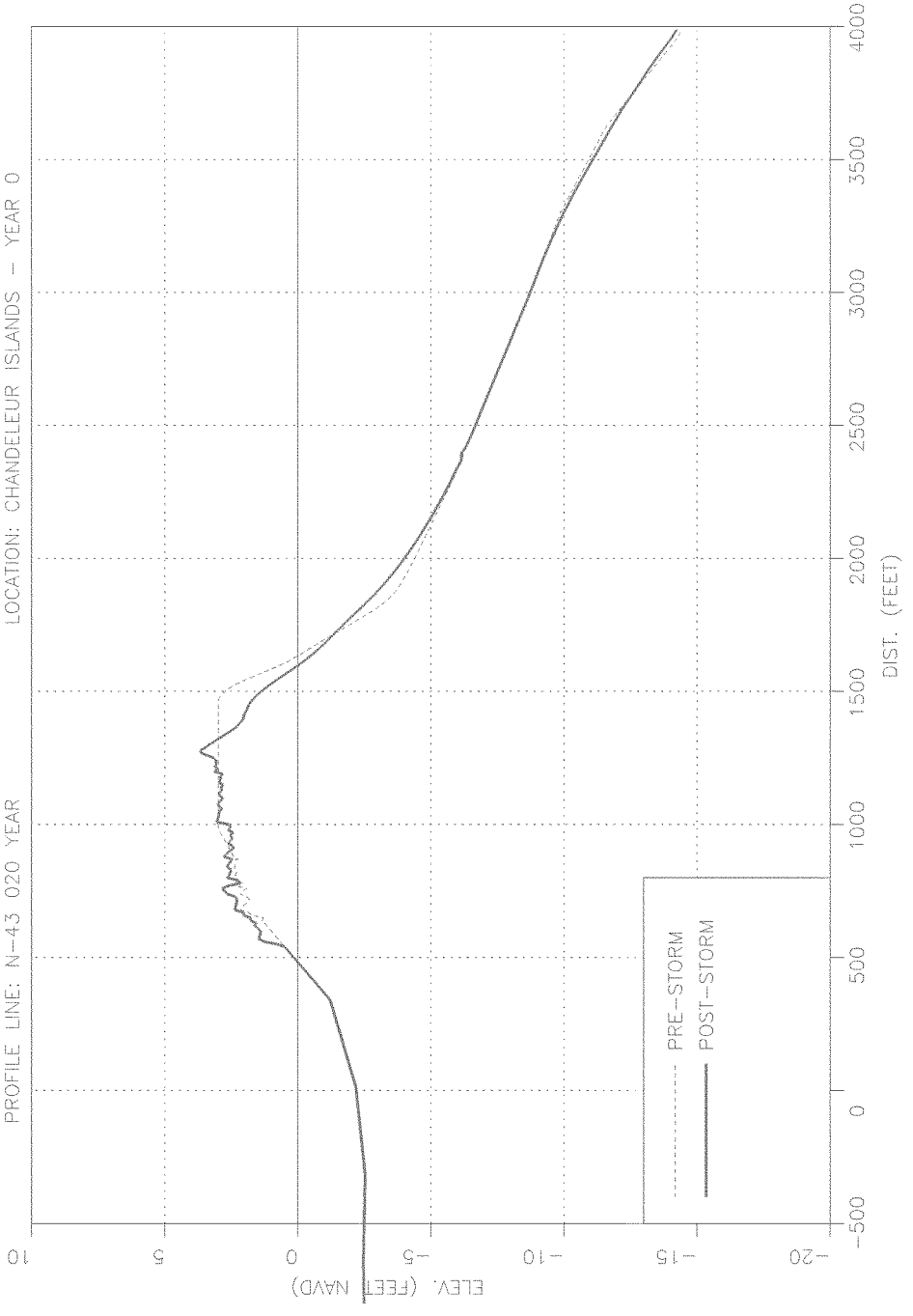

PROFILE LINE: N-43 002 YEAR
LOCATION: CHANDELEUR ISLANDS -- YEAR 0
PRE-STORM
POST-STORM
ELEV. (FEET NAVD)
DIST. (FEET)
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

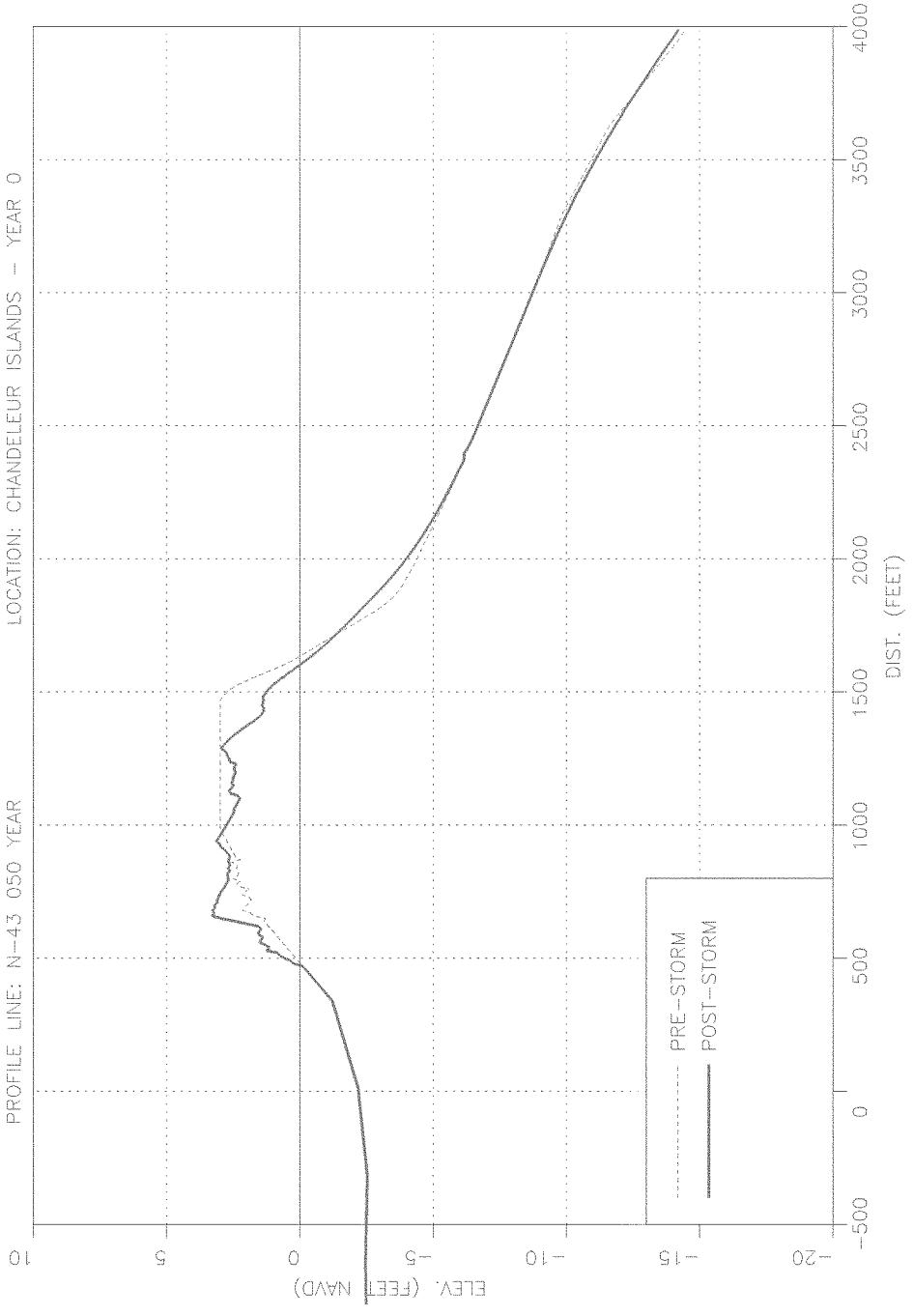

PROFILE LINE: N-43 003 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 0
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

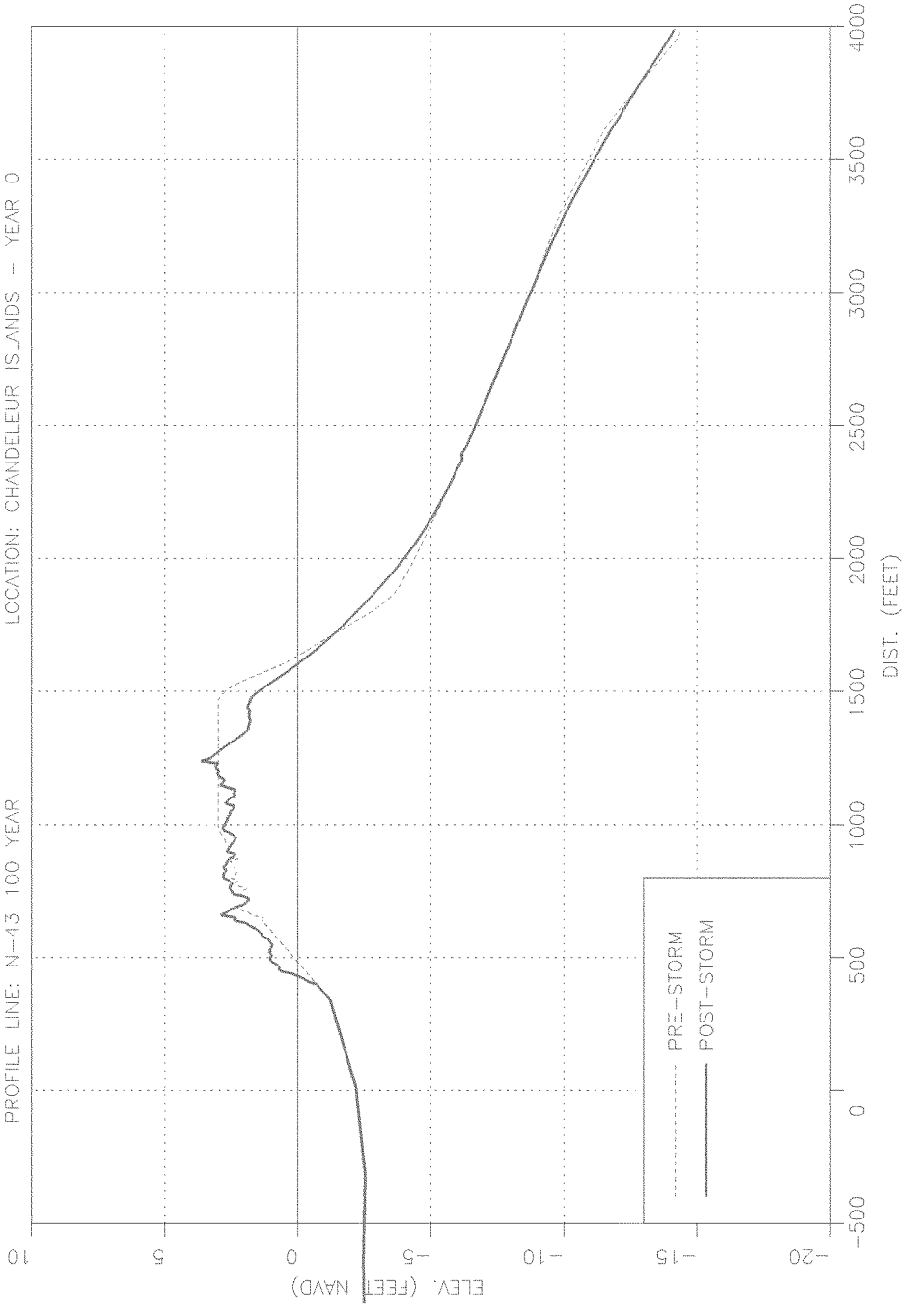

PROFILE LINE: N-43 004 YEAR
LOCATION: CHANDELEUR ISLANDS -- YEAR 0
PRE-STORM
POST-STORM
ELEV. (FEET NAVD)
DIST. (FEET)
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

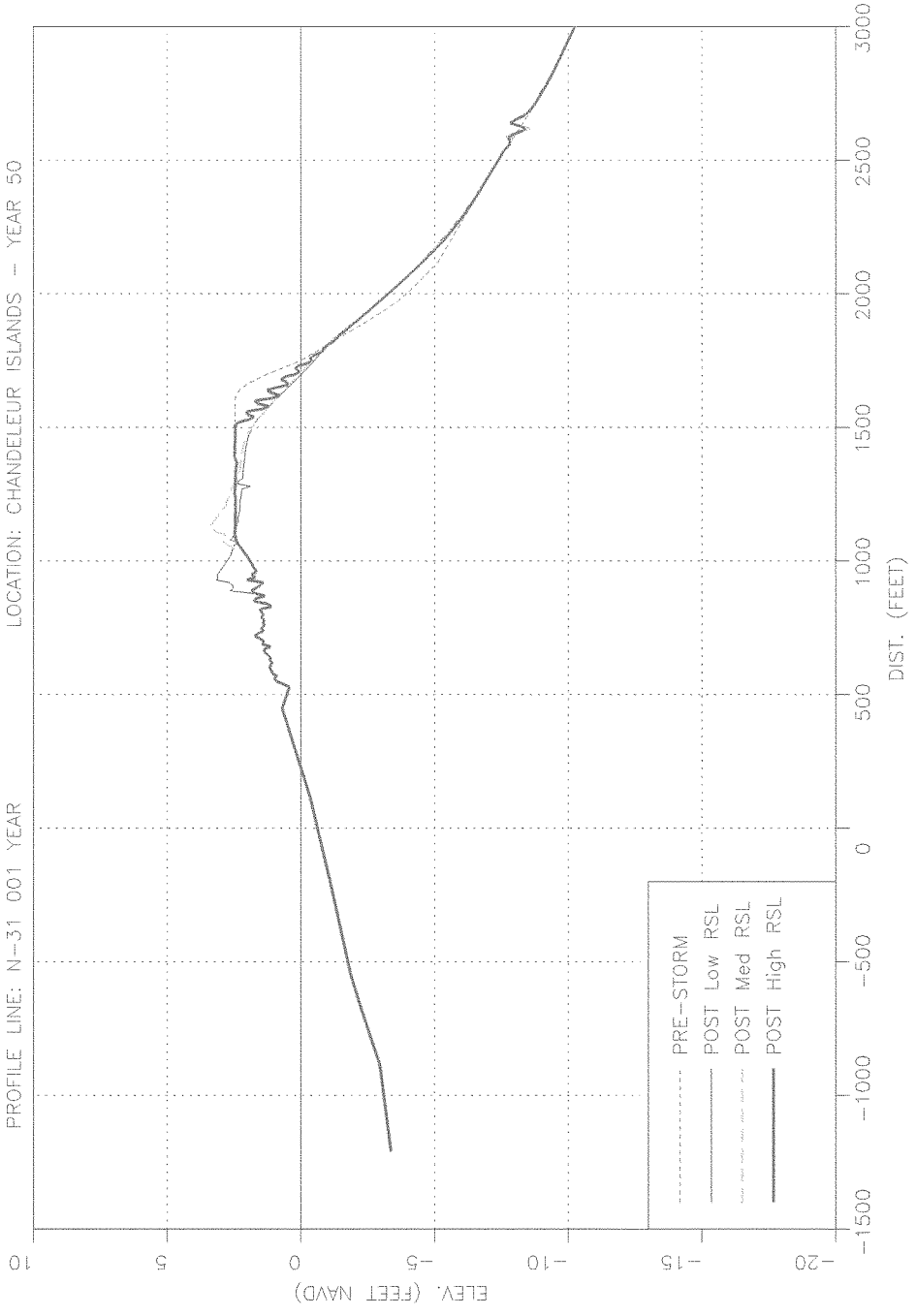

PROFILE LINE: N-43 005 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 0
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

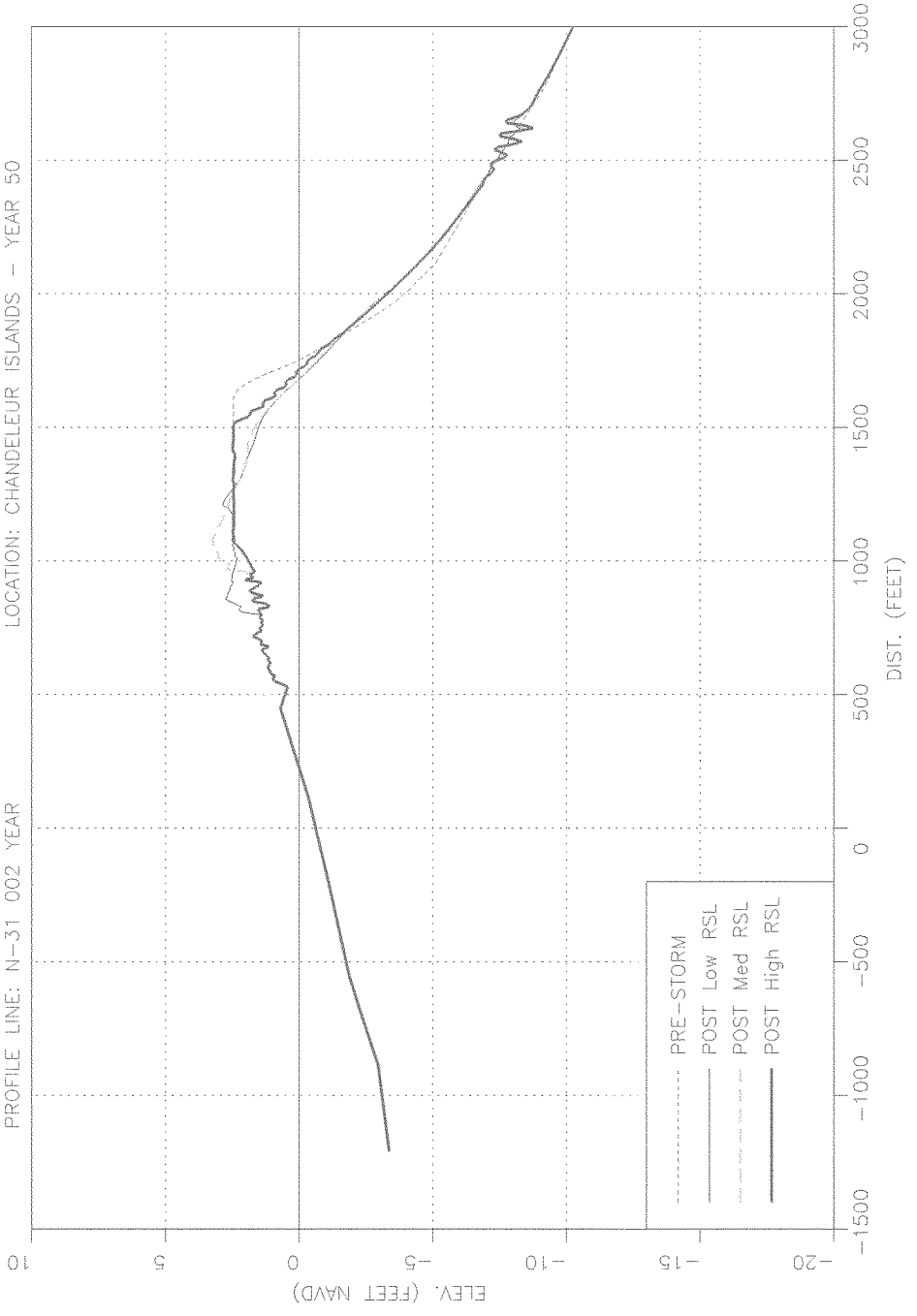

PROFILE LINE: N-43 010 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 0
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

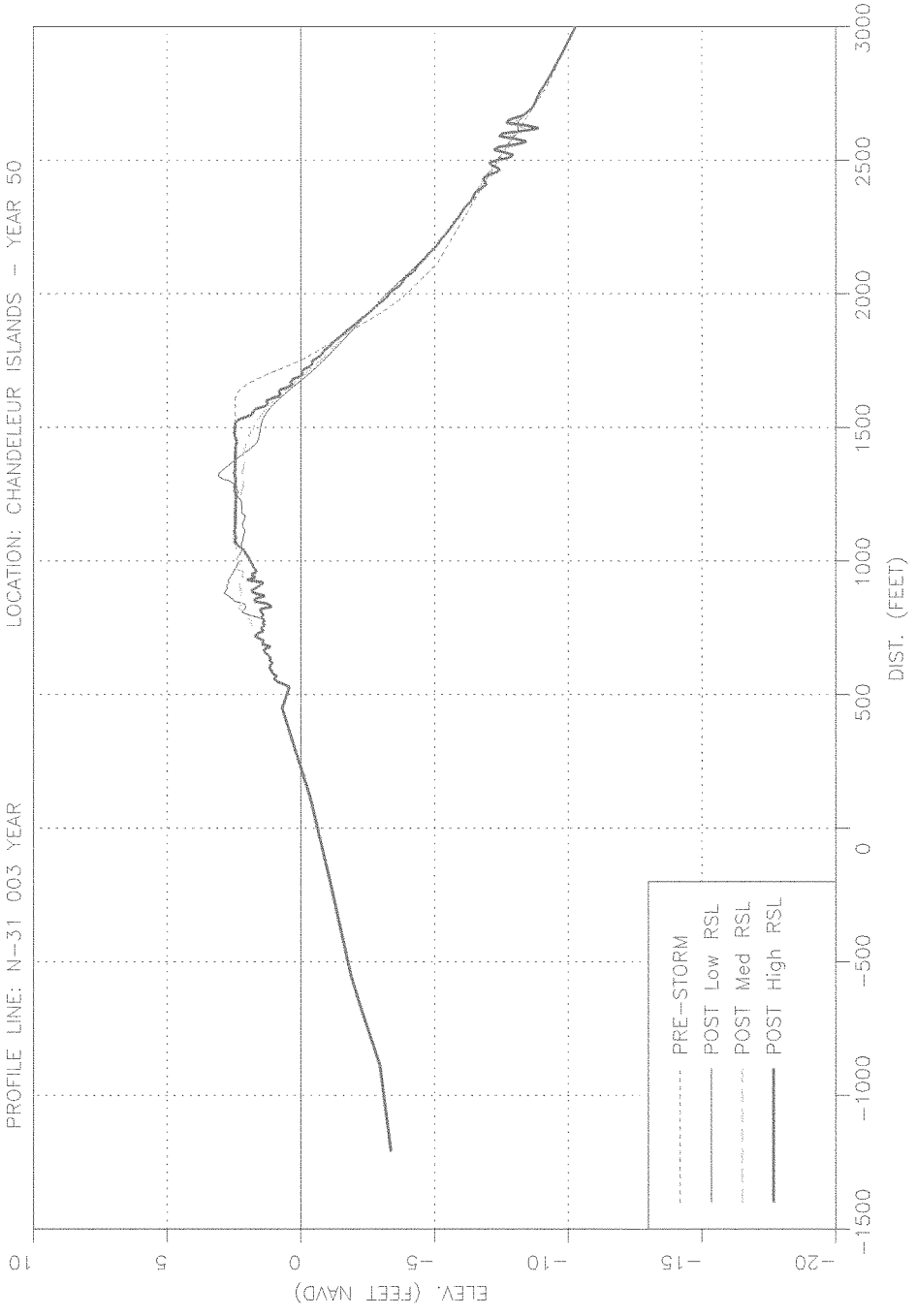

PROFILE LINE: N-43 020 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 0
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

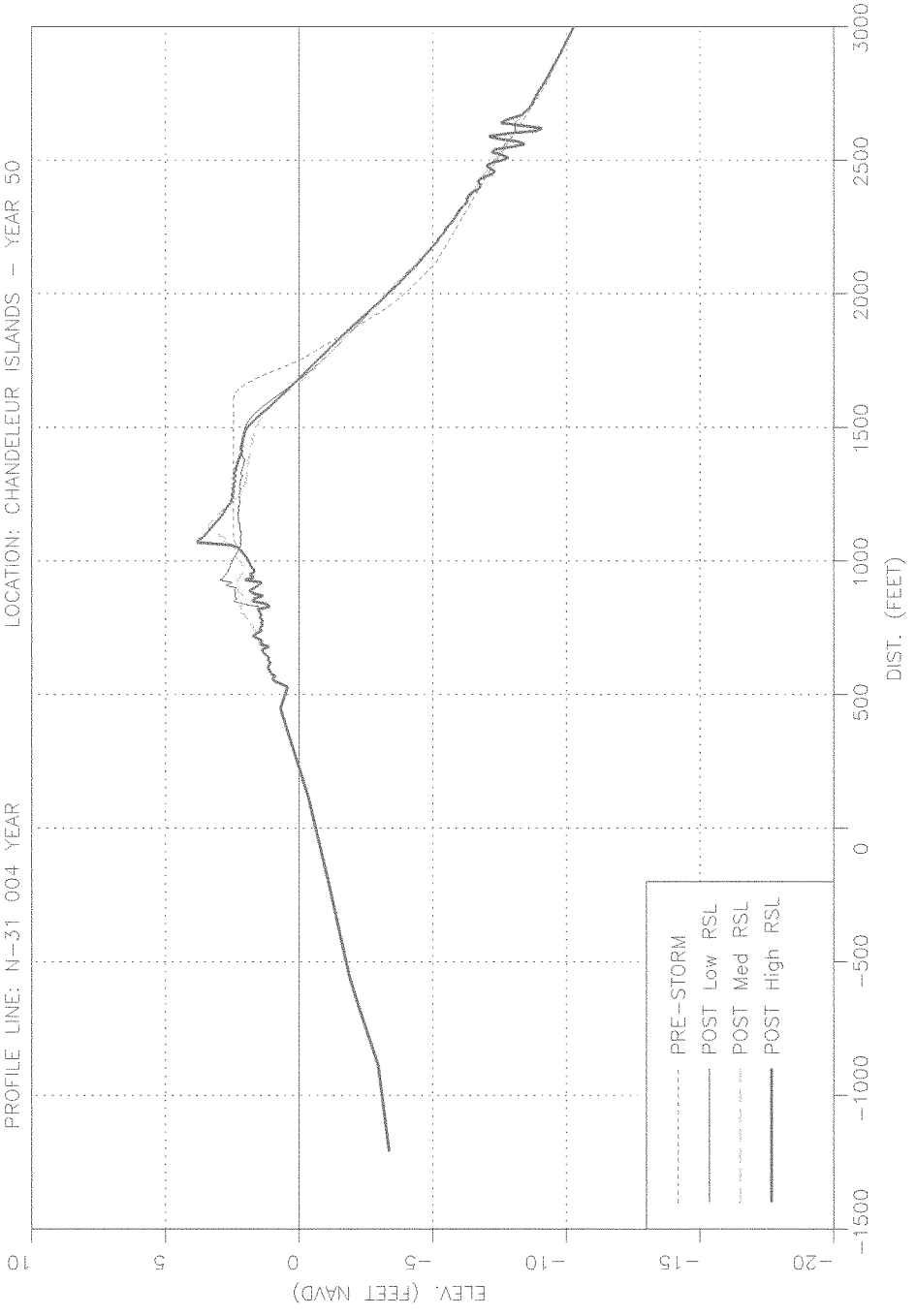

PROFILE LINE: N-43 050 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 0
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

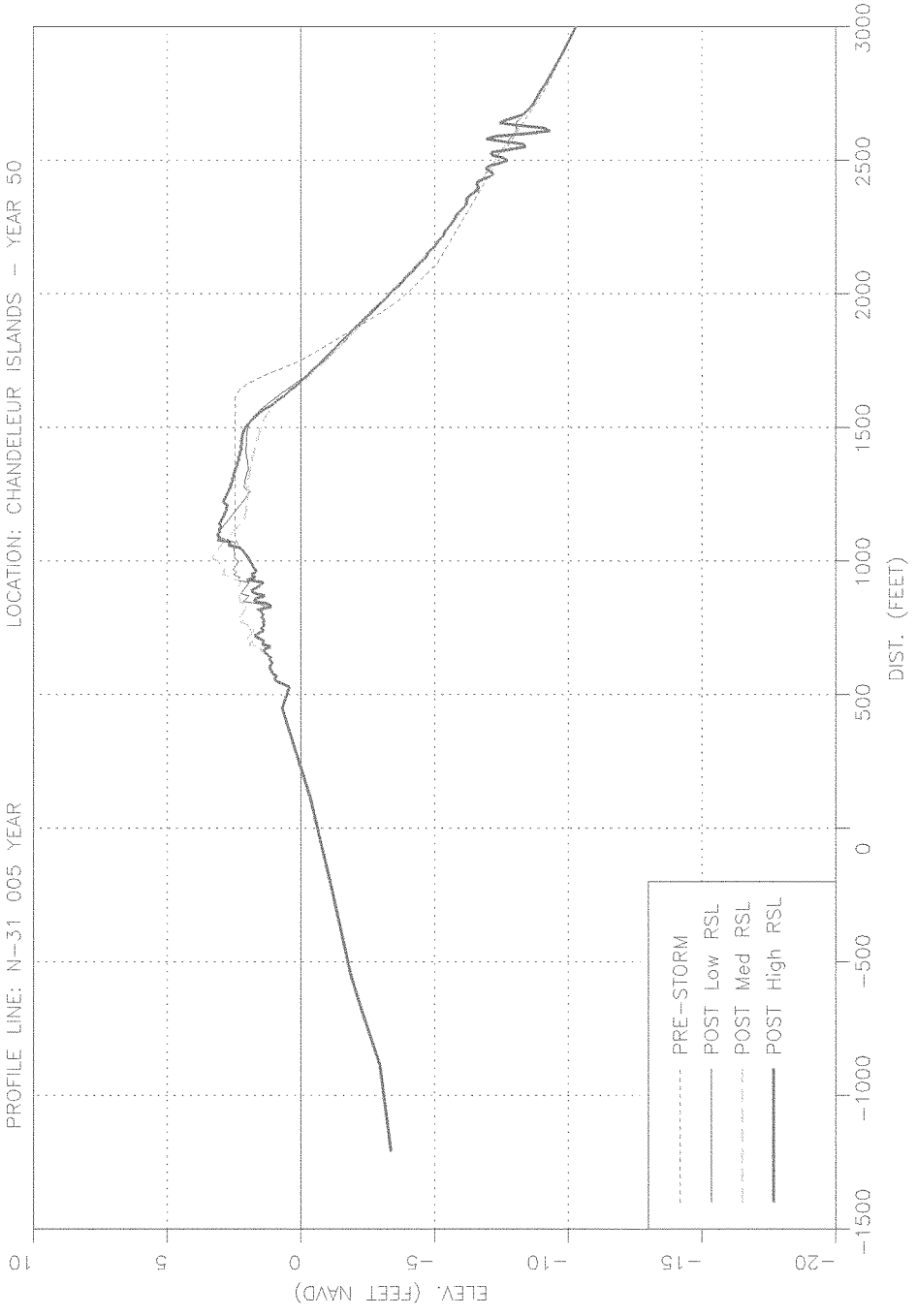

PROFILE LINE: N-43 100 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 0
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

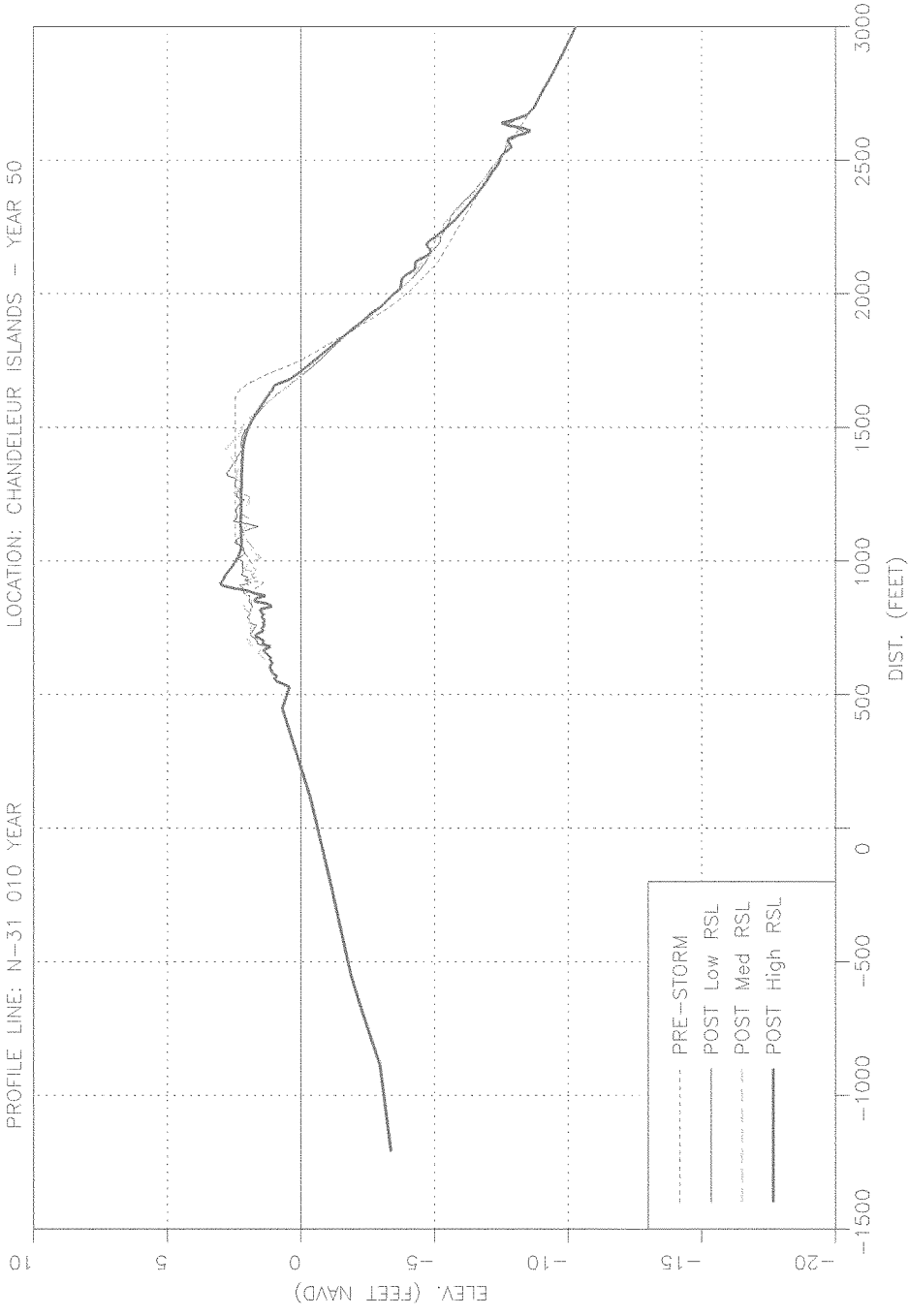

PROFILE LINE: N-31 001 YEAR
LOCATION: CHANDELEUR ISLANDS -- YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
POST Med RSL
POST High RSL
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

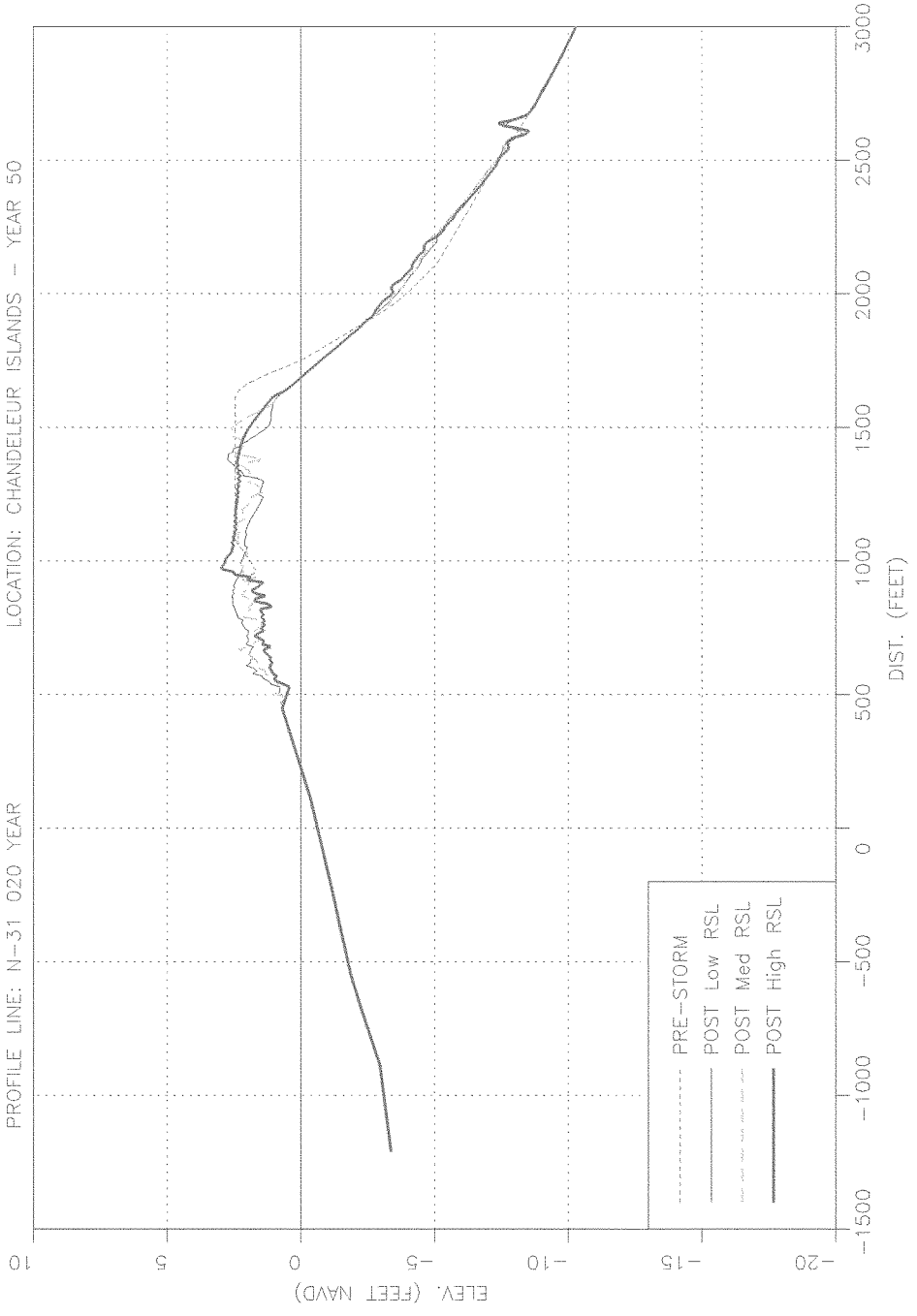

PROFILE LINE: N-31 002 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
POST Med RSL
POST High RSL
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

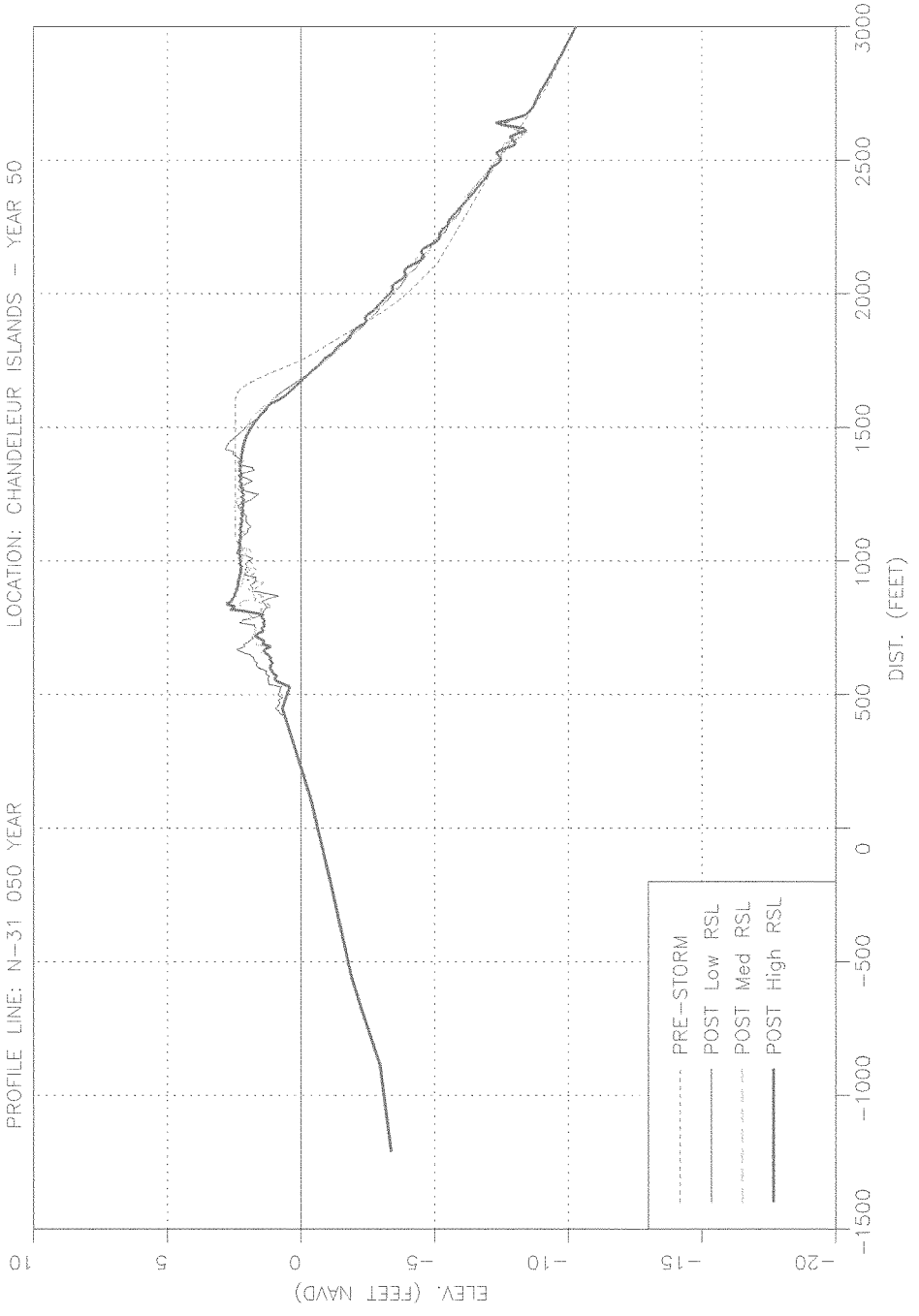

PROFILE LINE: N-31 003 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
POST Med RSL
POST High RSL
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

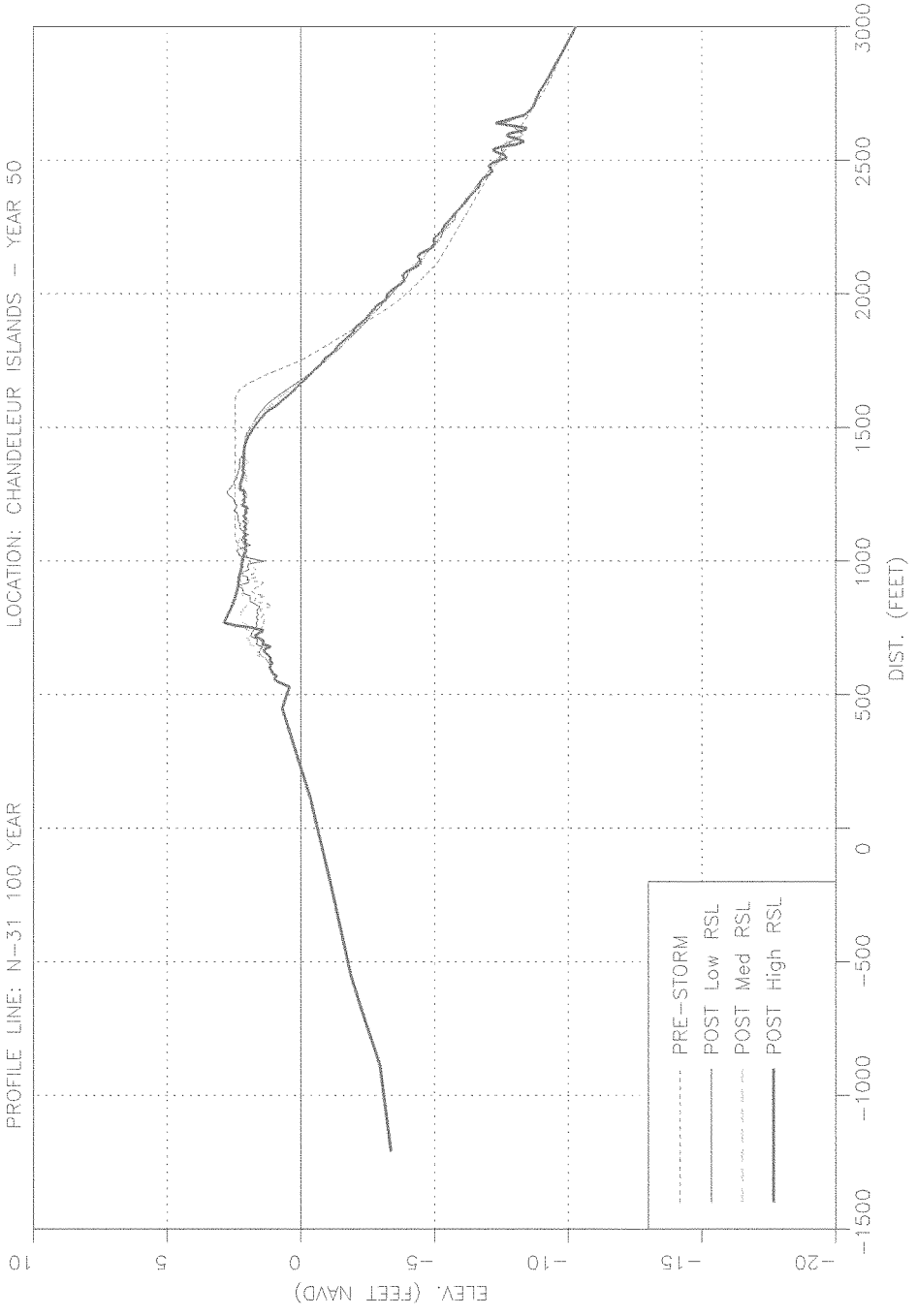

PROFILE LINE: N-31 004 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
POST Med RSL
POST High RSL
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

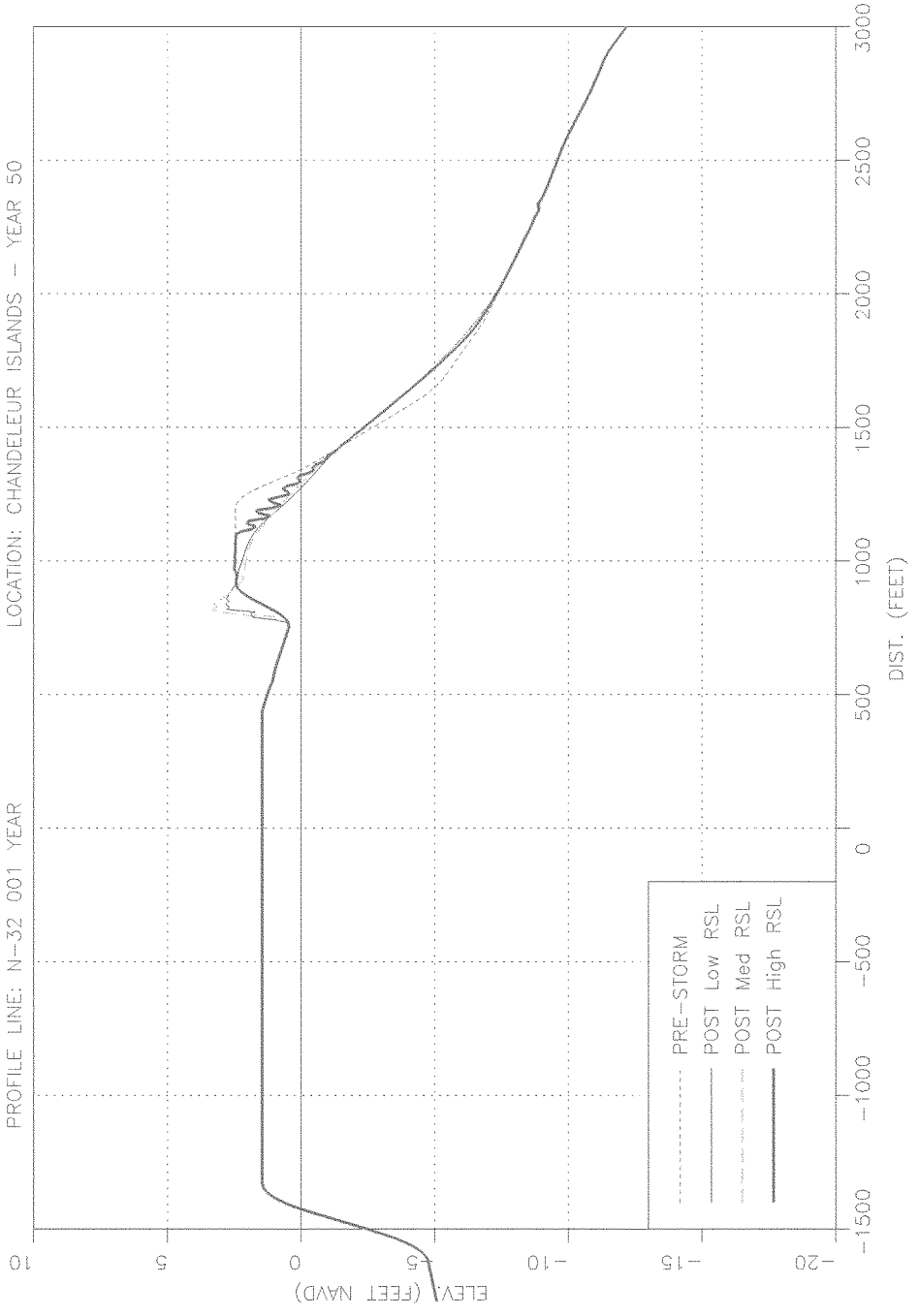

PROFILE LINE: N-31 005 YEAR
LOCATION: CHANDELEUR ISLANDS -- YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
POST Med RSL
POST High RSL
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

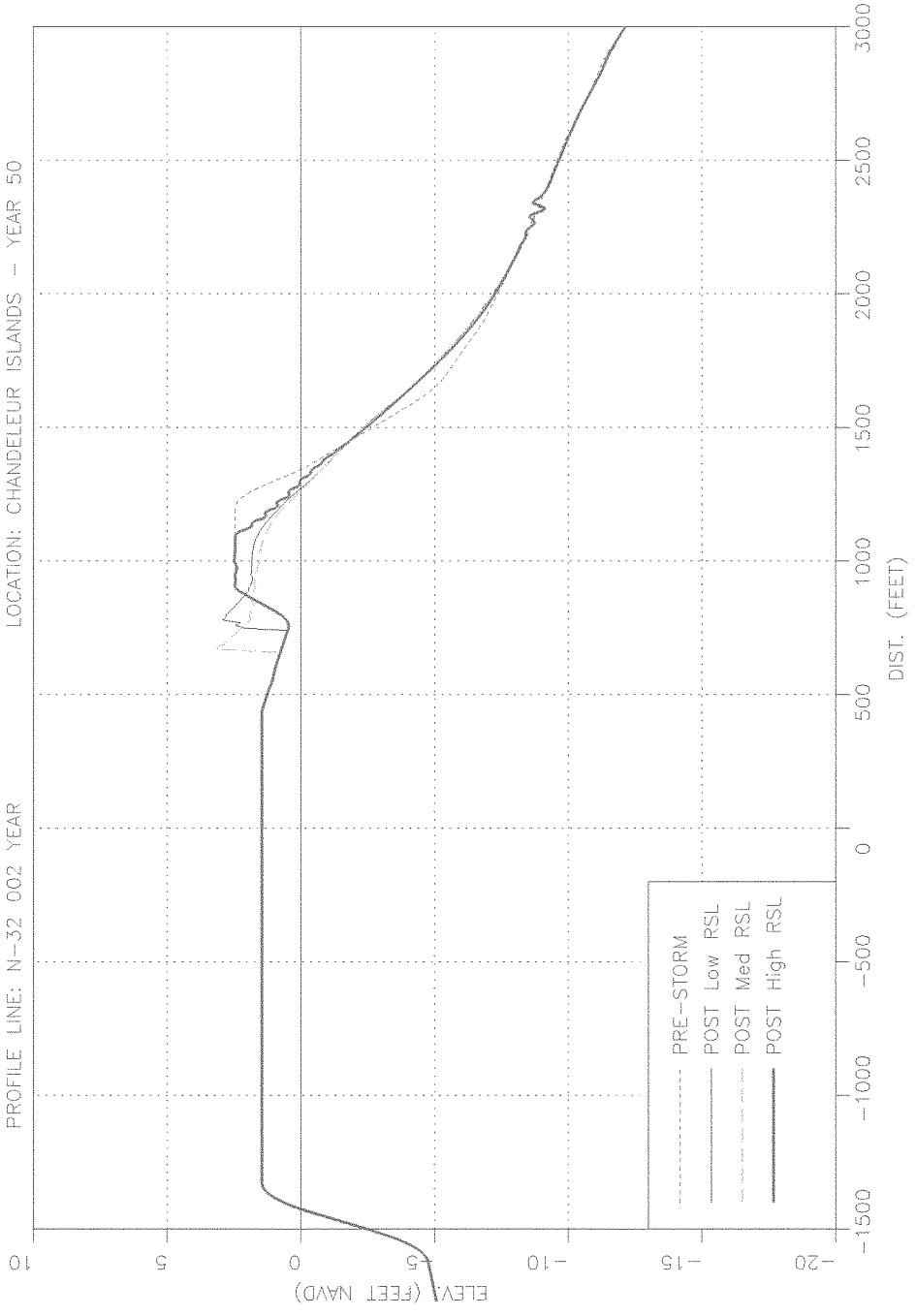

PROFILE LINE: N-31 010 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
POST Med RSL
POST High RSL
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

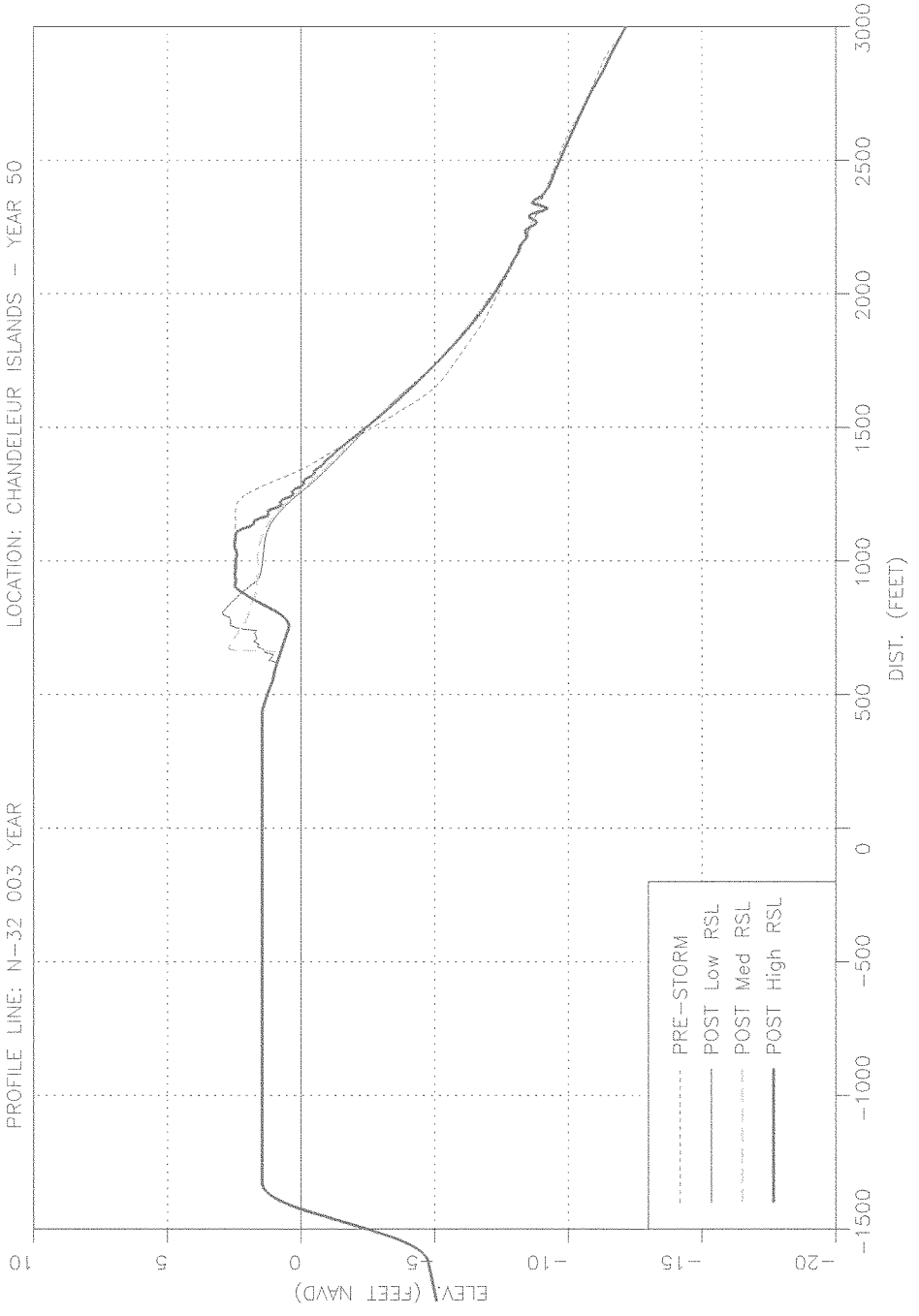

PROFILE LINE: N-31 020 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
POST Med RSL
POST High RSL
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

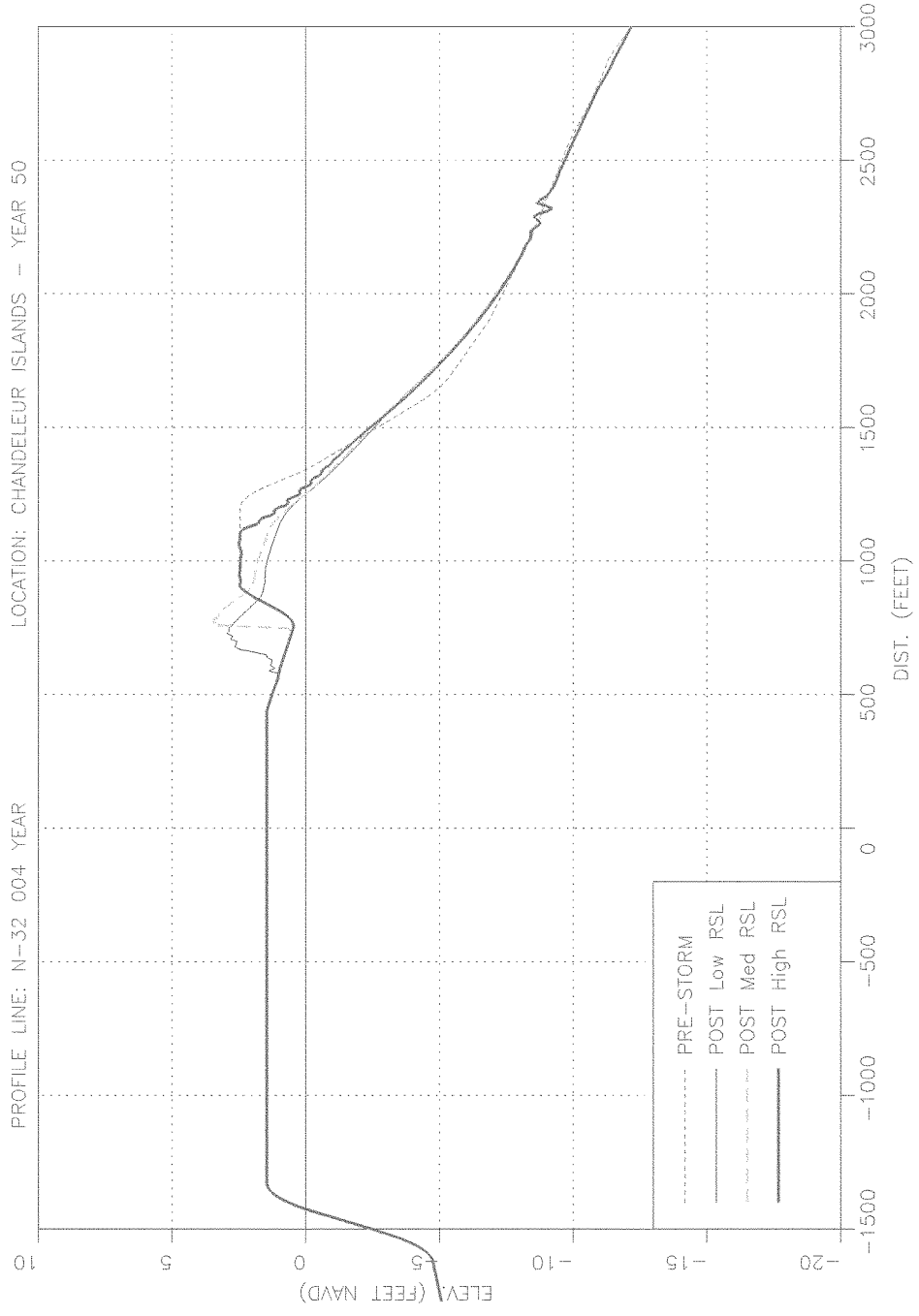

PROFILE LINE: N-31 050 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 50
PRE-STORM
POST Low RSL
POST Med RSL
POST High RSL
ELEV. (FEET NAVD)
DIST. (FEET)
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

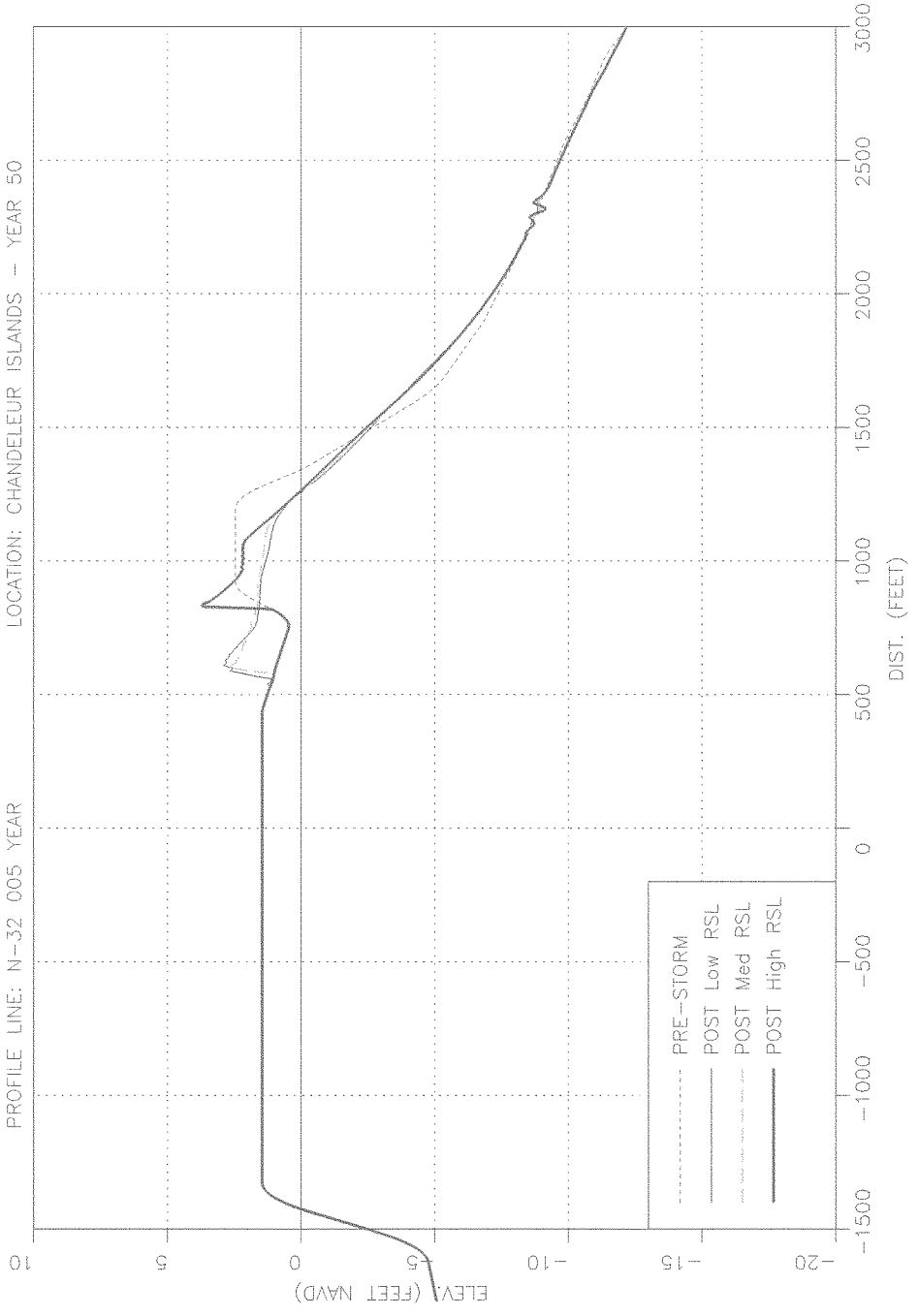

PROFILE LINE: N-31 100 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
POST Med RSL
POST High RSL
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

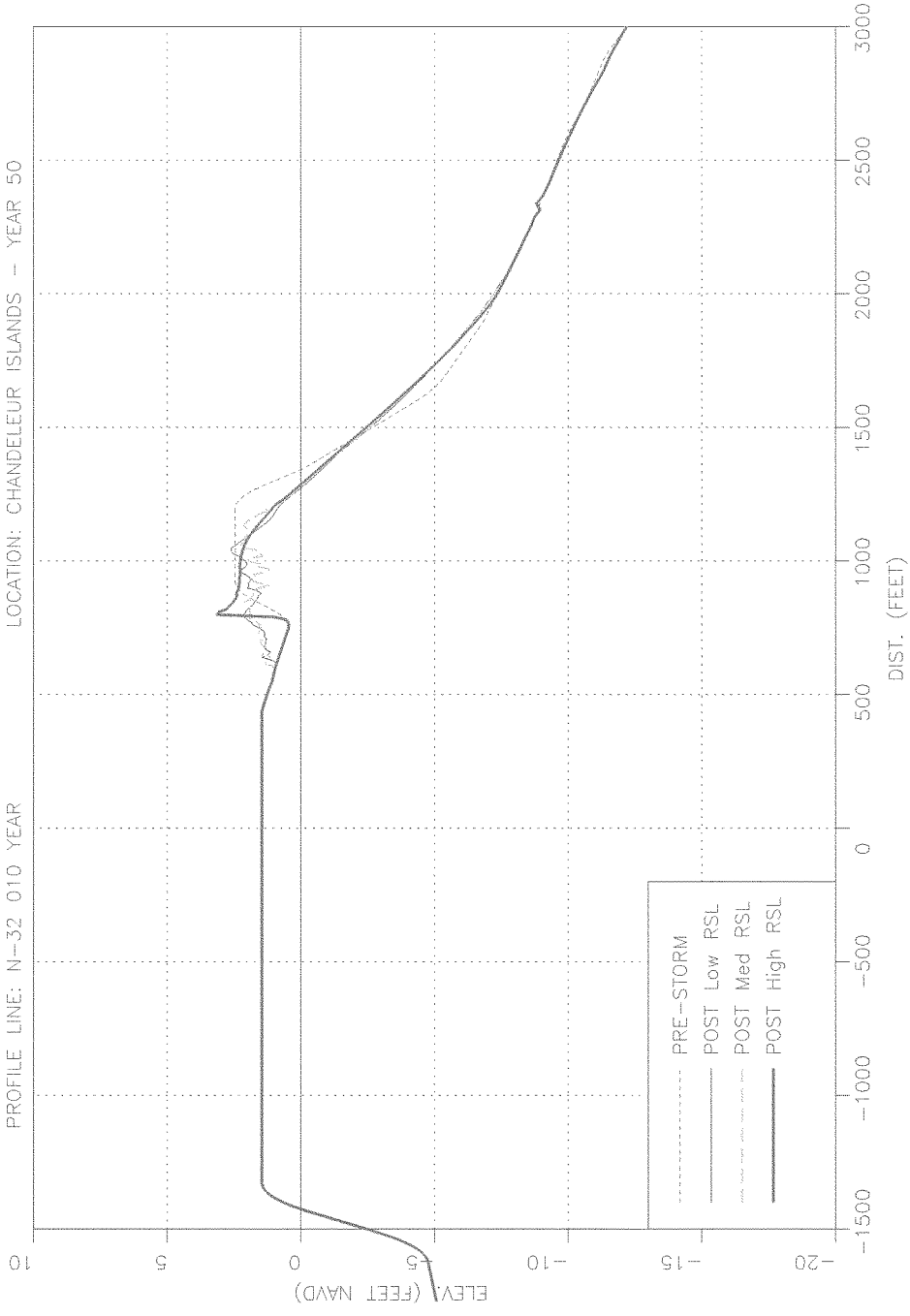

PROFILE LINE: N-32 001 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
POST Med RSL
POST High RSL
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

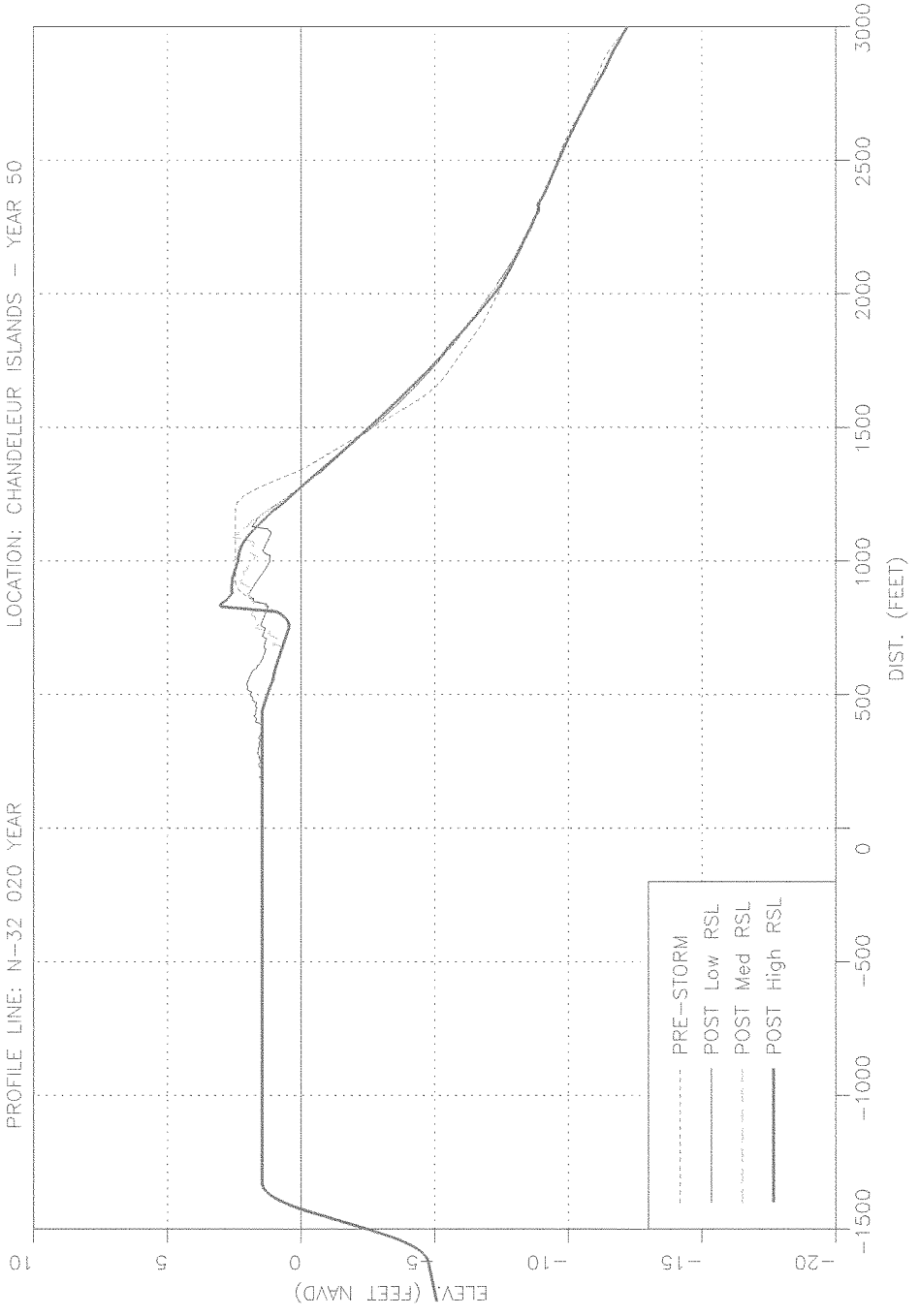

PROFILE LINE: N-32 002 YEAR
LOCATION: CHANDELEUR ISLANDS -- YEAR 50
PRE-STORM
POST Low RSL
POST Med RSL
POST High RSL
ELEV. (FEET NAVD)
DIST. (FEET)
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

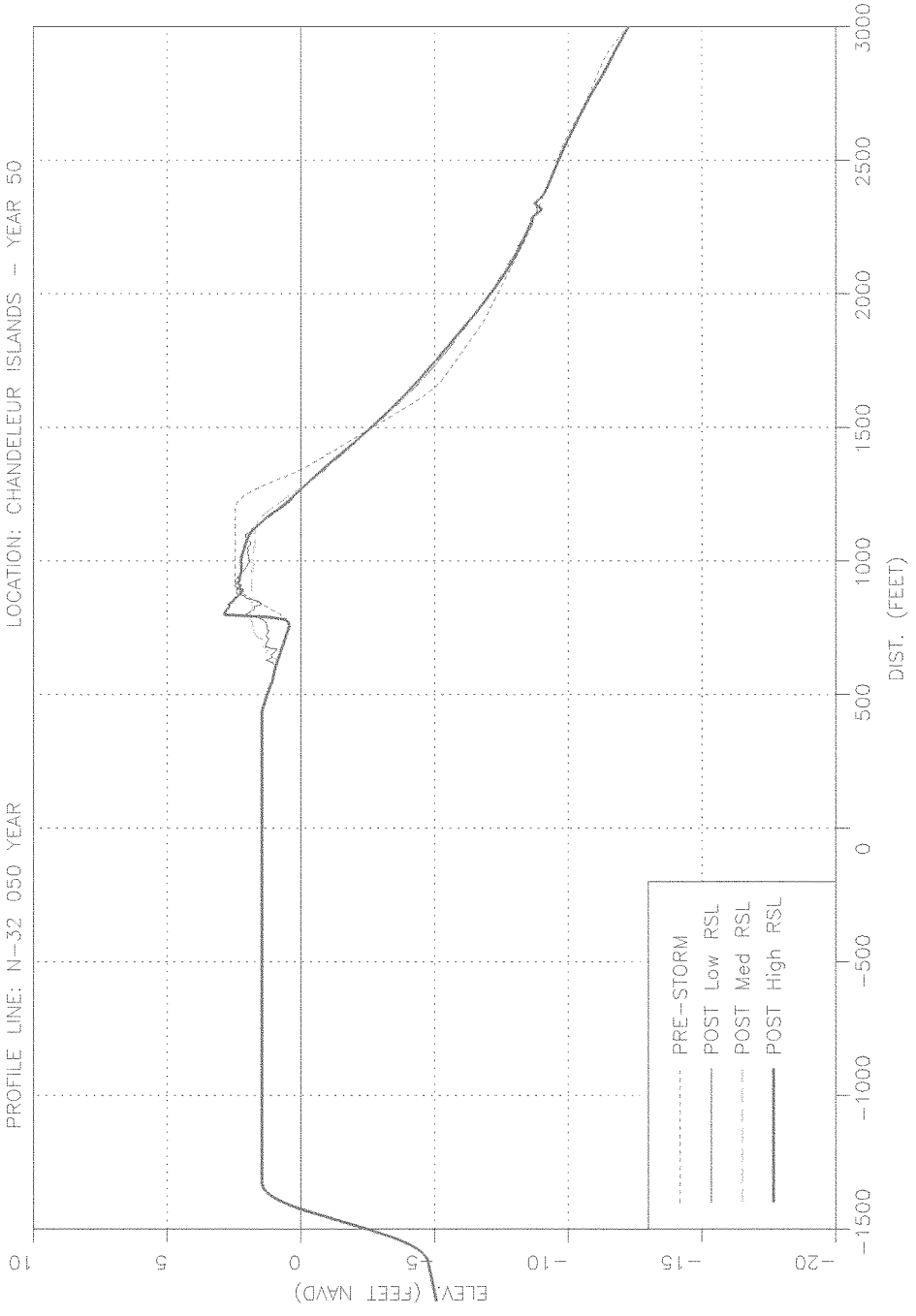

PROFILE LINE: N-32 003 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000
PRE-STORM
POST Low RSL
POST Med RSL
POST High RSL

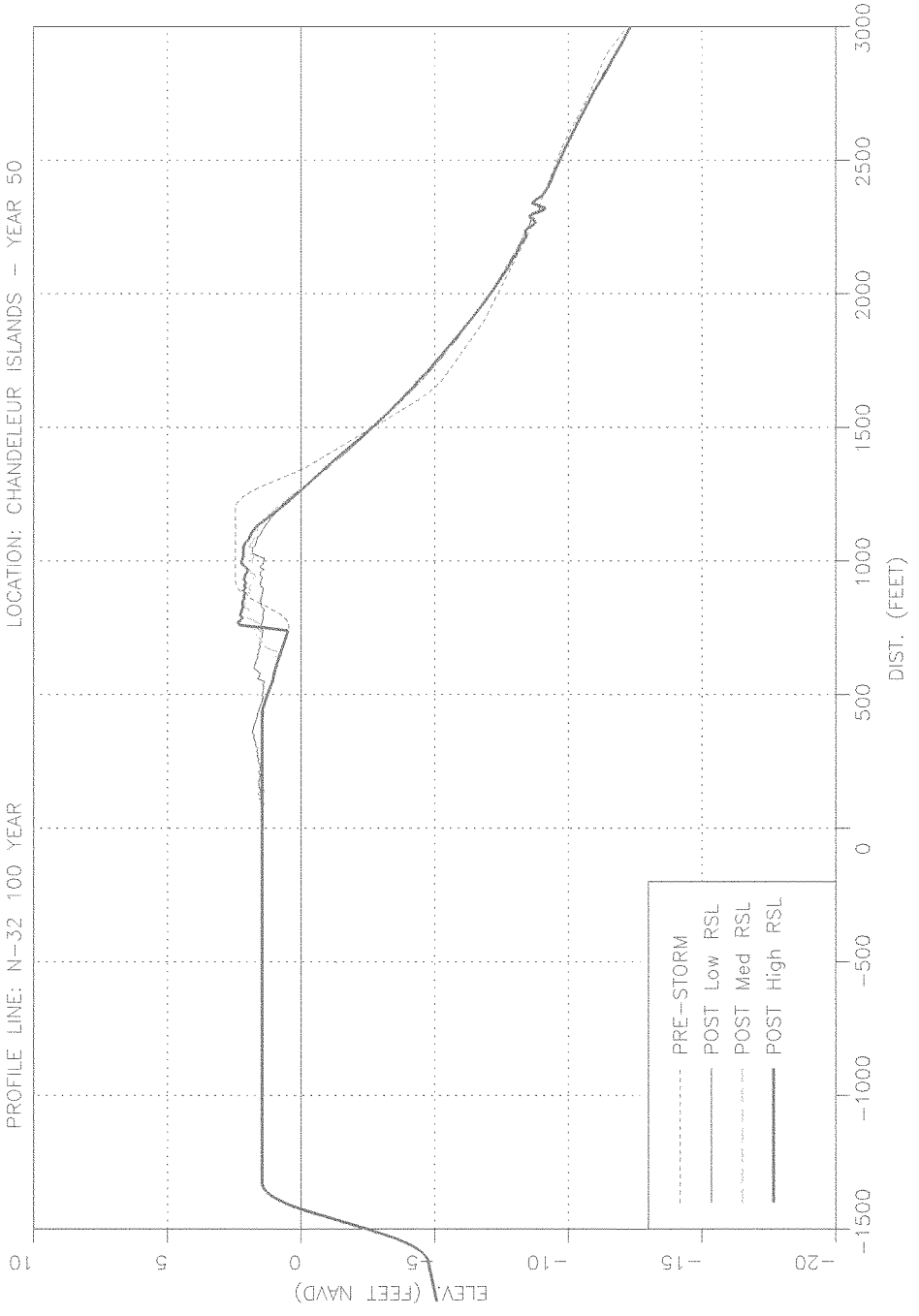

PROFILE LINE: N-32 004 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 50
PRE-STORM
POST Low RSL
POST Med RSL
POST High RSL
ELEV. (FEET NAVD)
DIST. (FEET)
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

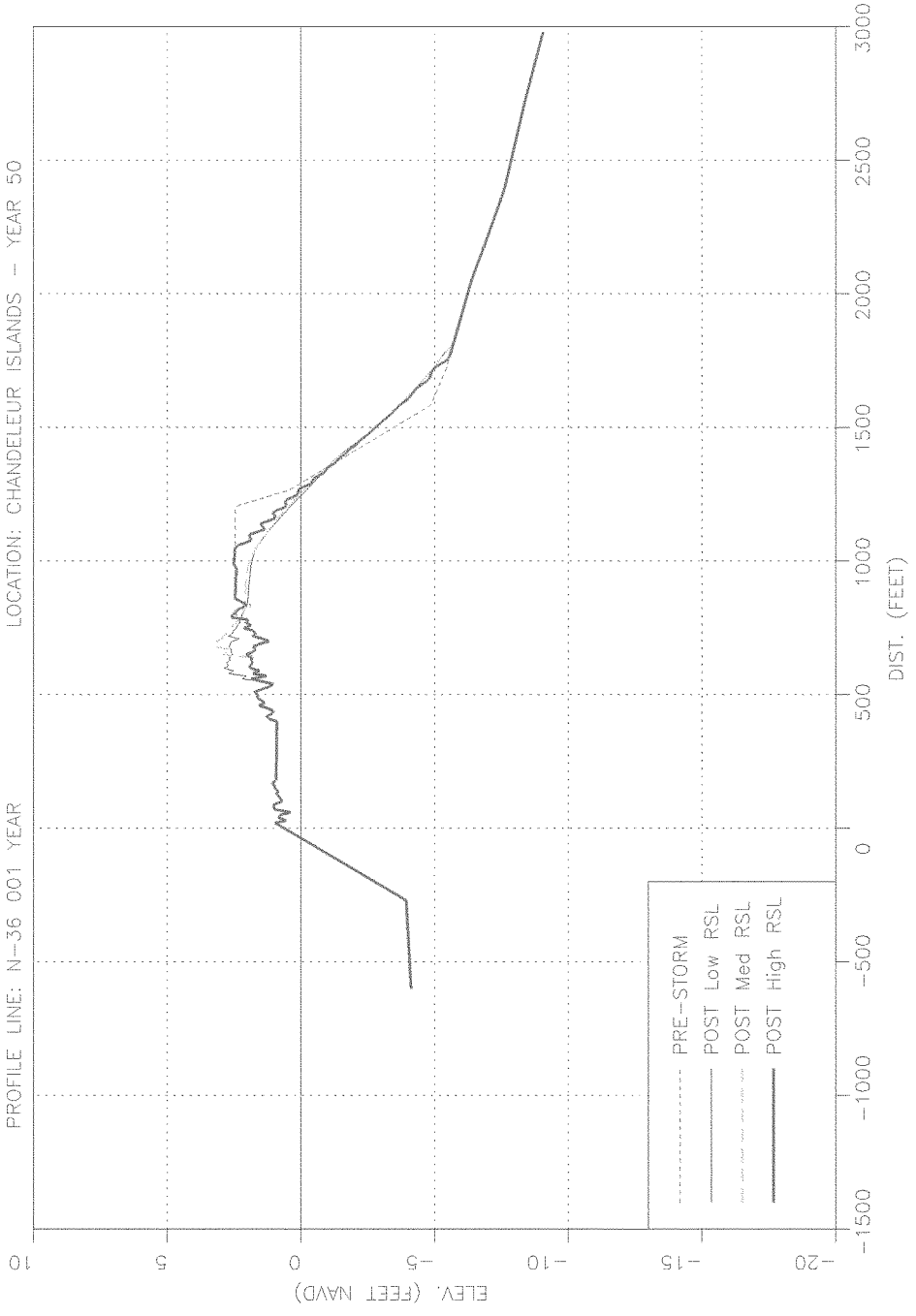

PROFILE LINE: N-32 005 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000
PRE-STORM
POST Low RSL
POST Med RSL
POST High RSL

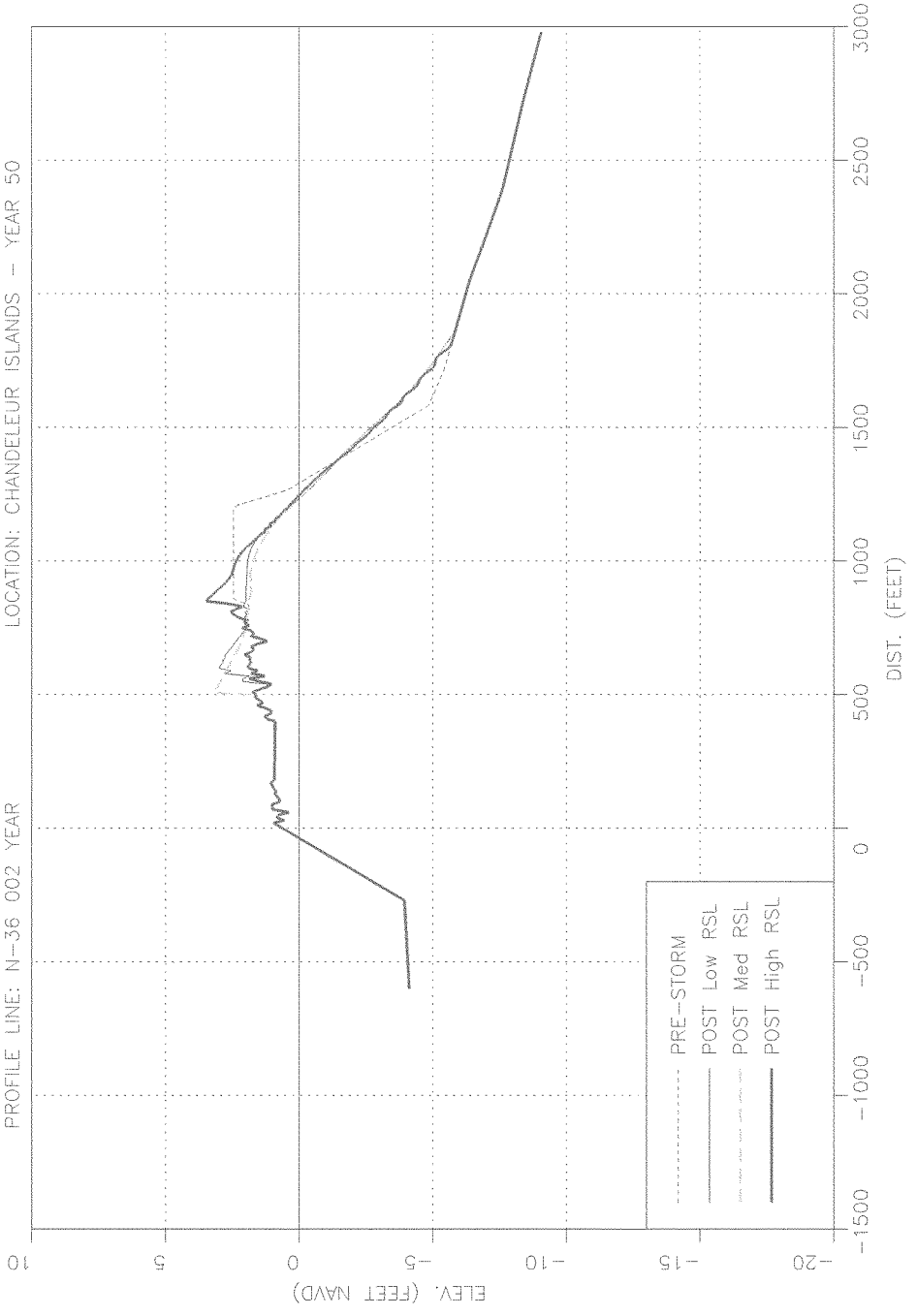

PROFILE LINE: N-32 010 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 50
PRE-STORM
POST Low RSL
POST Med RSL
POST High RSL
ELEV. (FEET NAVD)
DIST. (FEET)
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

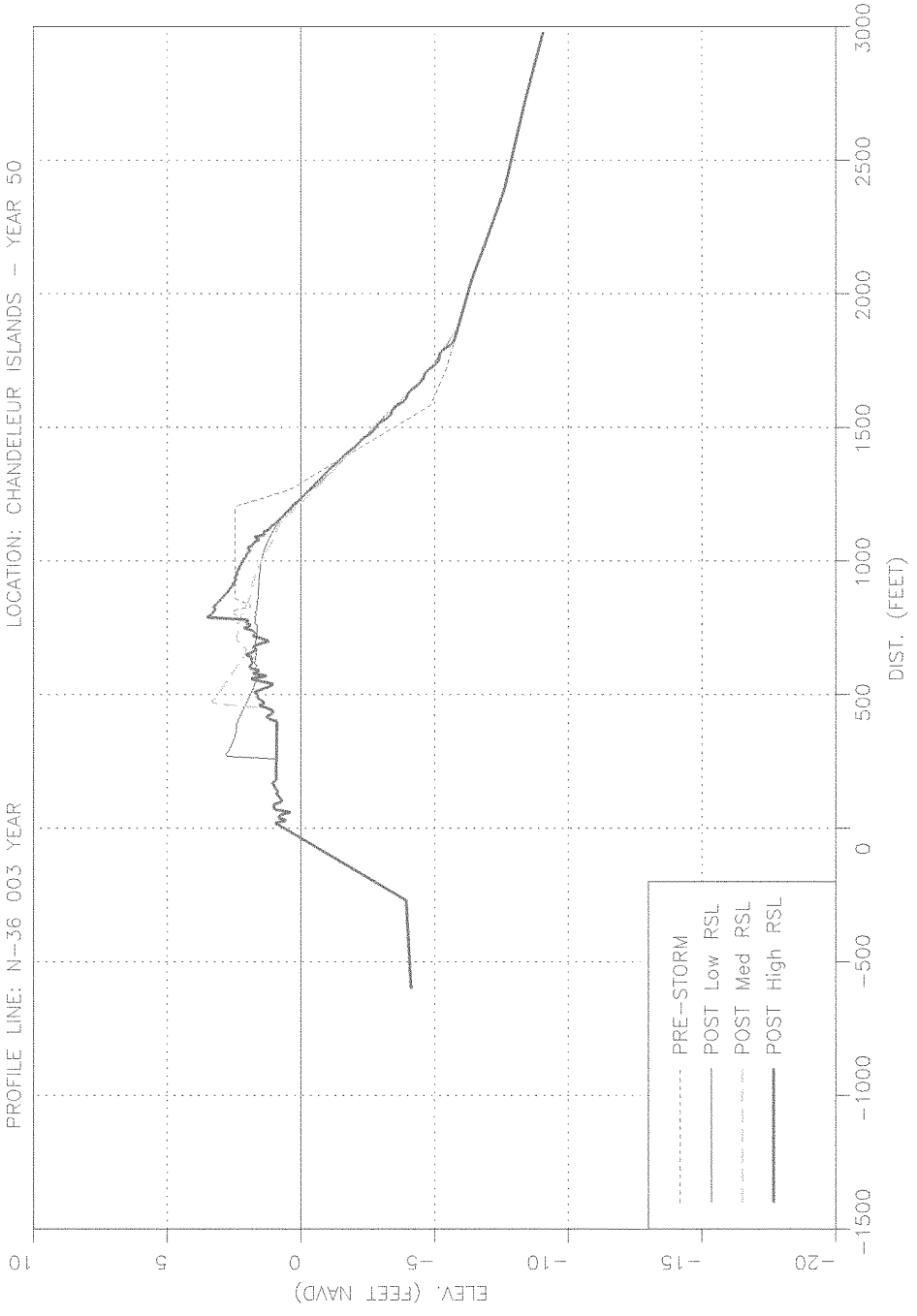

PROFILE LINE: N-32 020 YEAR
LOCATION: CHANDELEUR ISLANDS -- YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000
PRE-STORM
POST Low RSL
POST Med RSL
POST High RSL

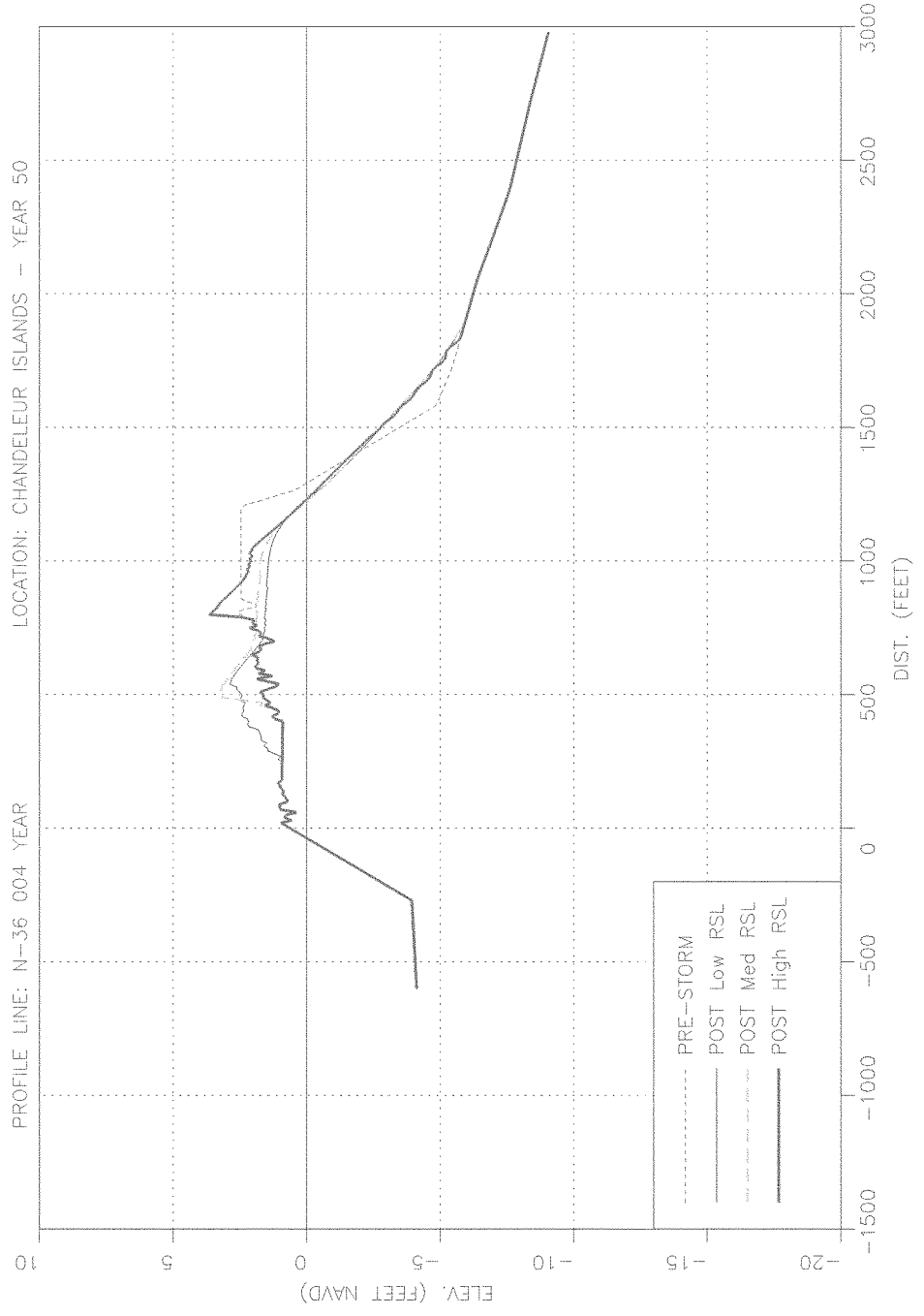

PROFILE LINE: N-32 050 YEAR
LOCATION: CHANDELEUR ISLANDS -- YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
POST Med RSL
POST High RSL
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

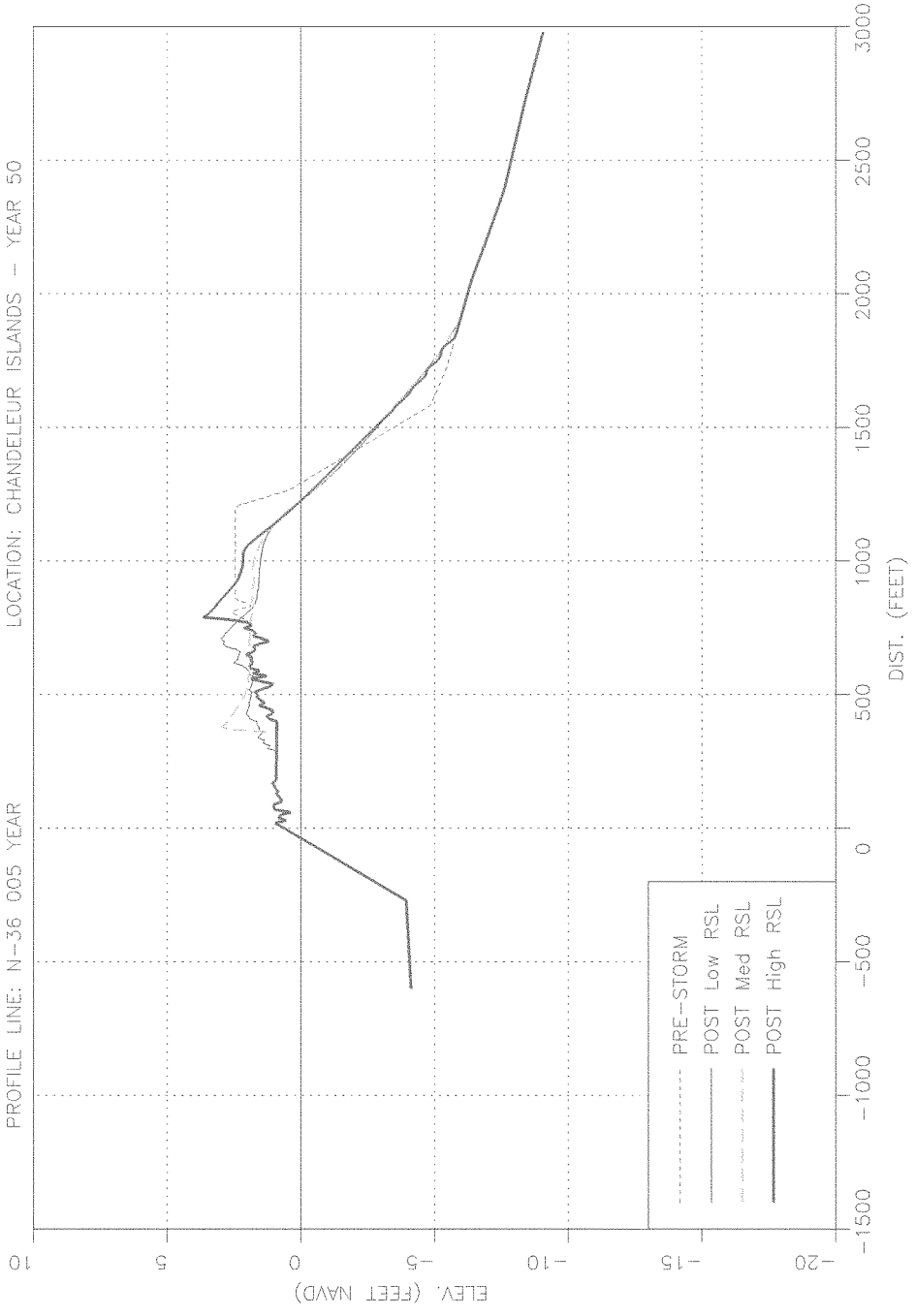

PROFILE LINE: N-32 100 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000
PRE-STORM
POST Low RSL
POST Med RSL
POST High RSL

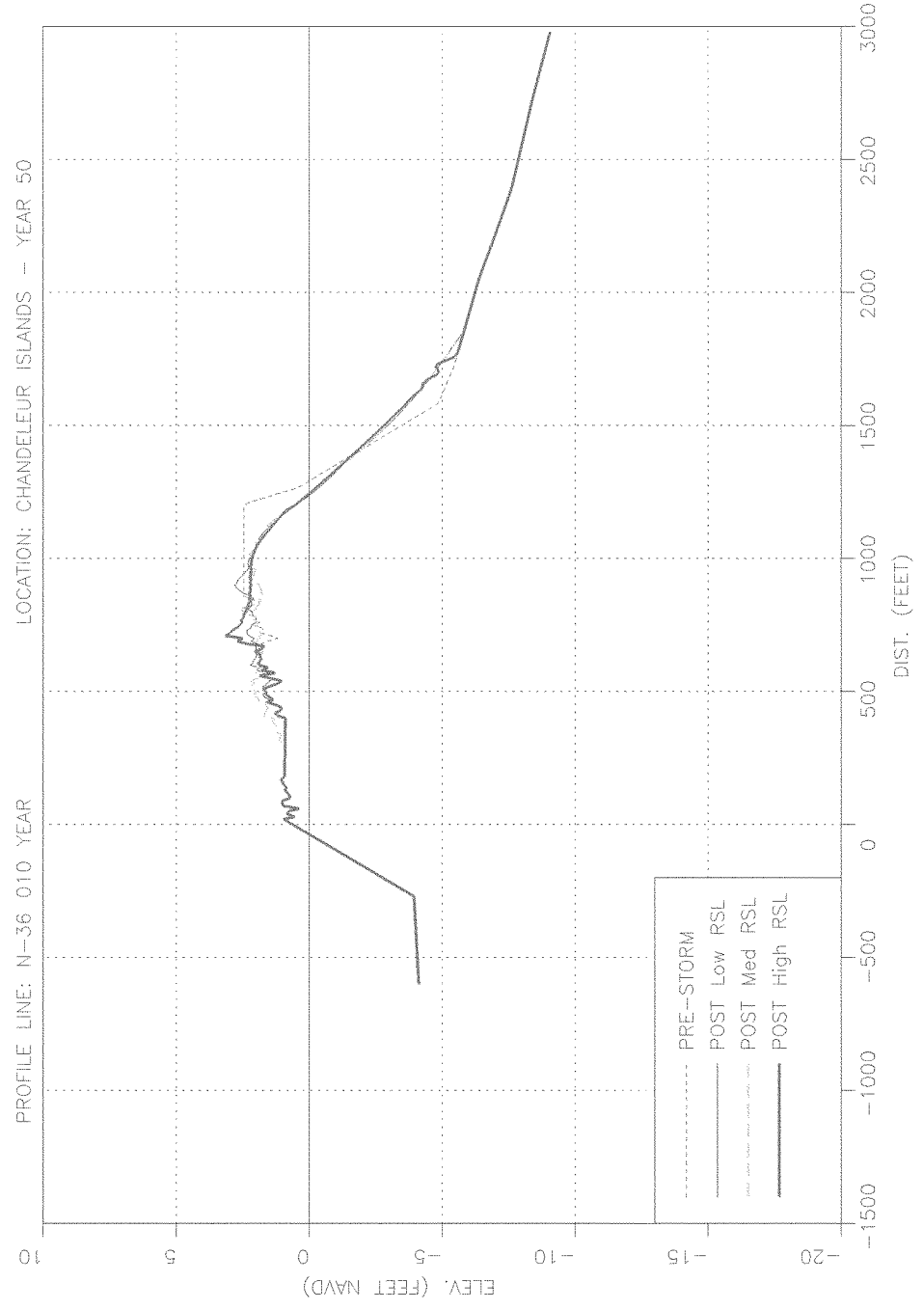

PROFILE LINE: N-36 001 YEAR
LOCATION: CHANDELEUR ISLANDS -- YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
POST Med RSL
POST High RSL
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

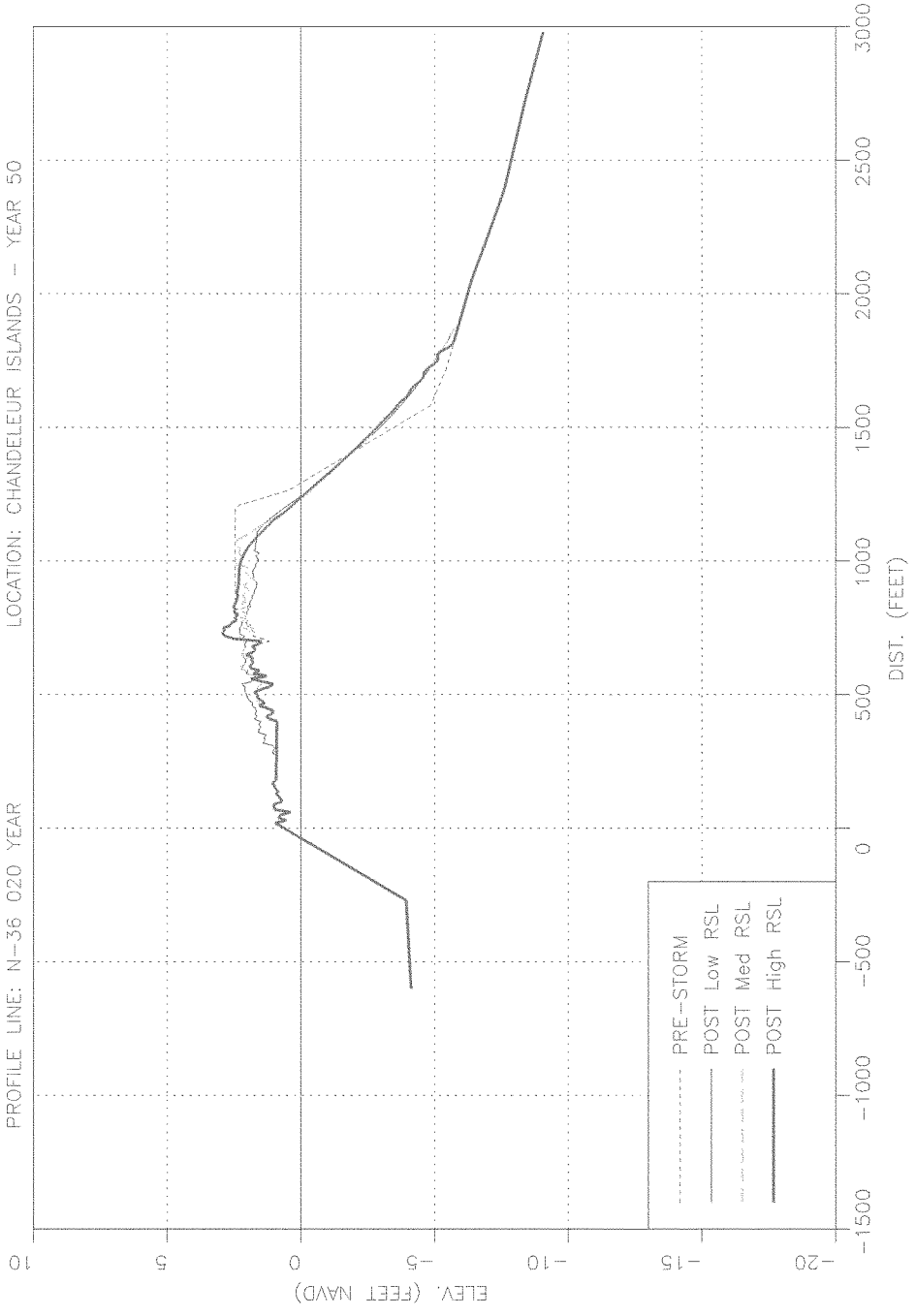

PROFILE LINE: N-36 002 YEAR
LOCATION: CHANDELEUR ISLANDS -- YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
POST Med RSL
POST High RSL
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

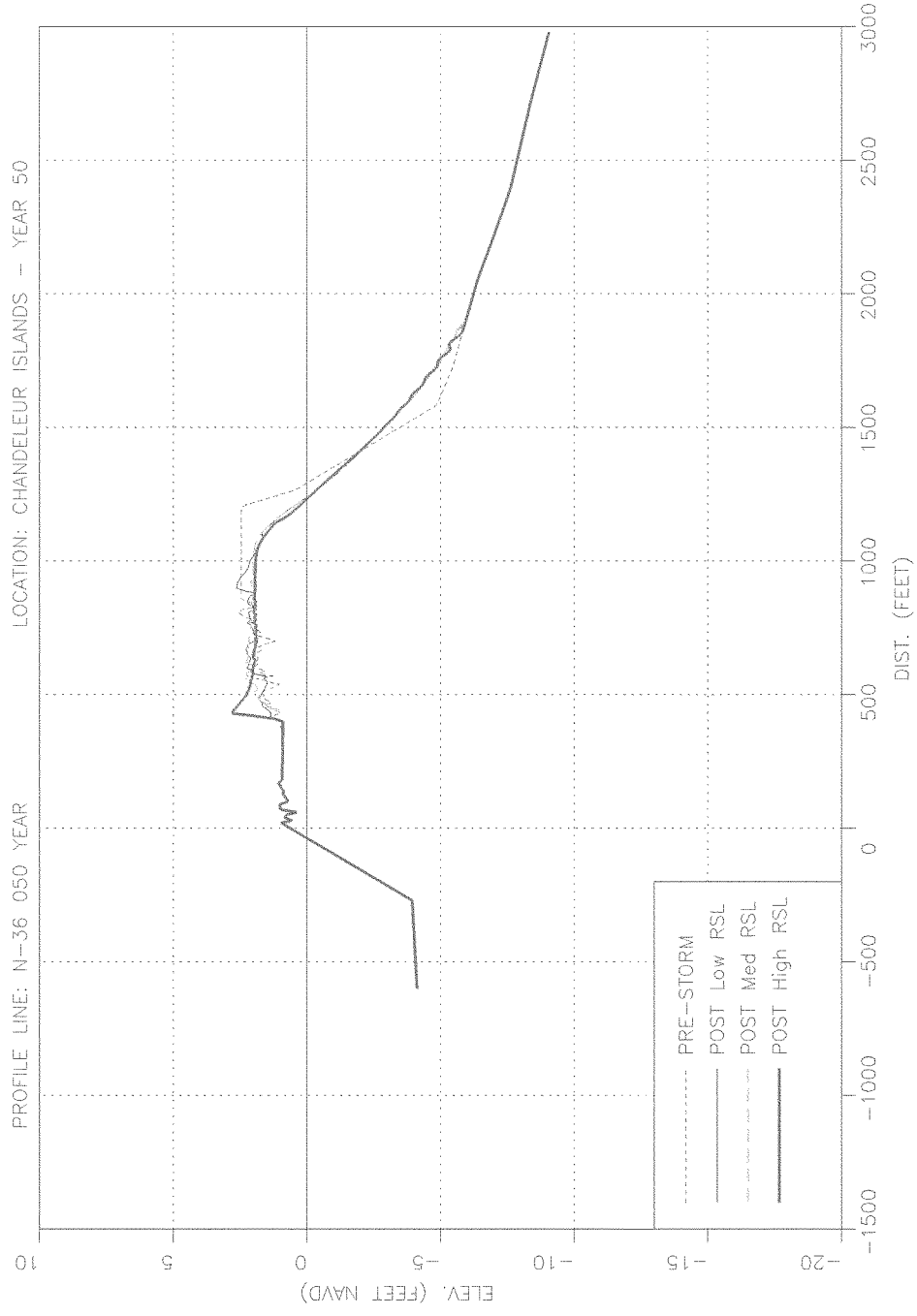

PROFILE LINE: N-36 003 YEAR
LOCATION: CHANDELEUR ISLANDS -- YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
POST Med RSL
POST High RSL
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

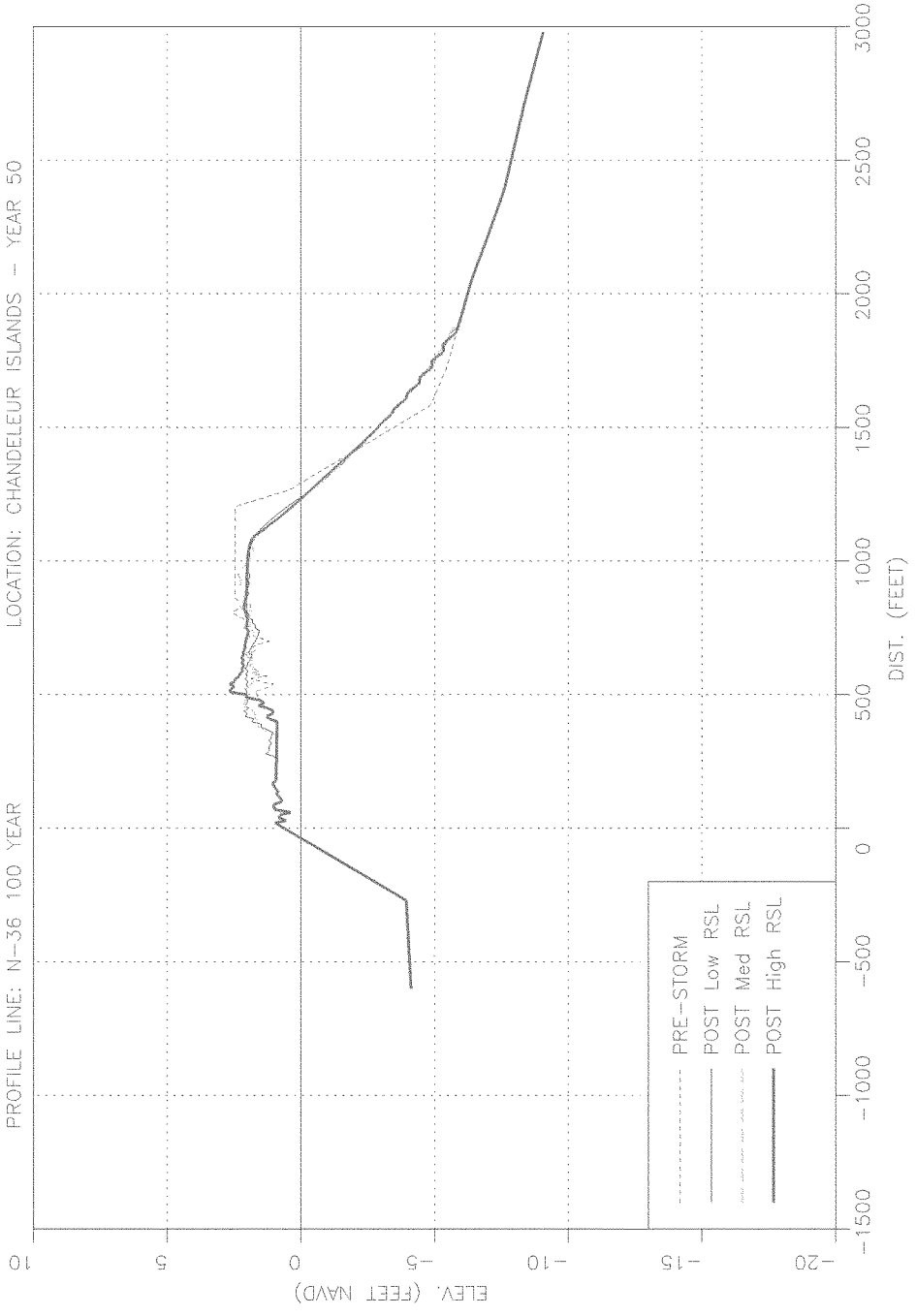

PROFILE LINE: N-36 004 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
POST Med RSL
POST High RSL
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

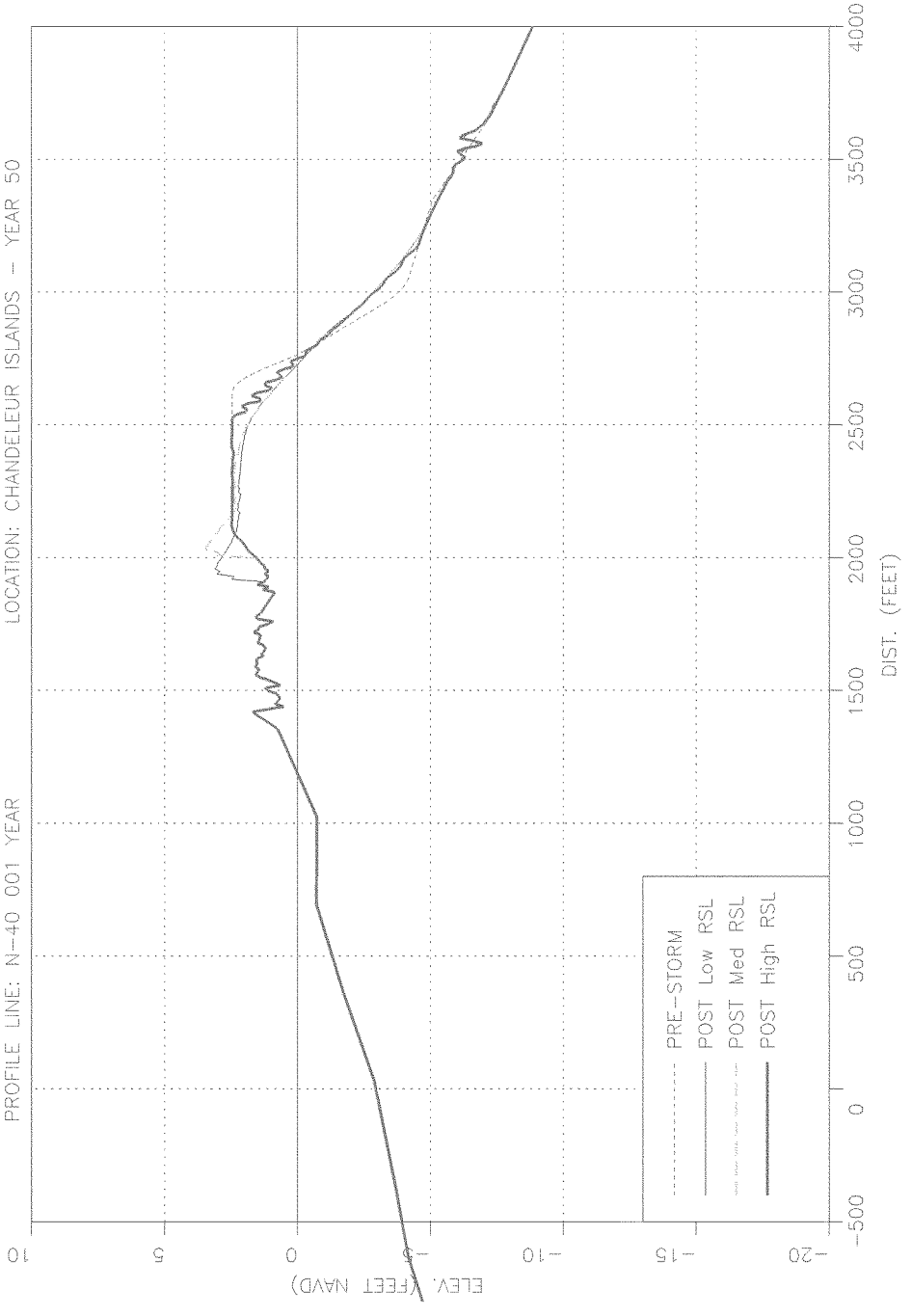

PROFILE LINE: N-36 005 YEAR
LOCATION: CHANDELEUR ISLANDS -- YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
POST Med RSL
POST High RSL
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

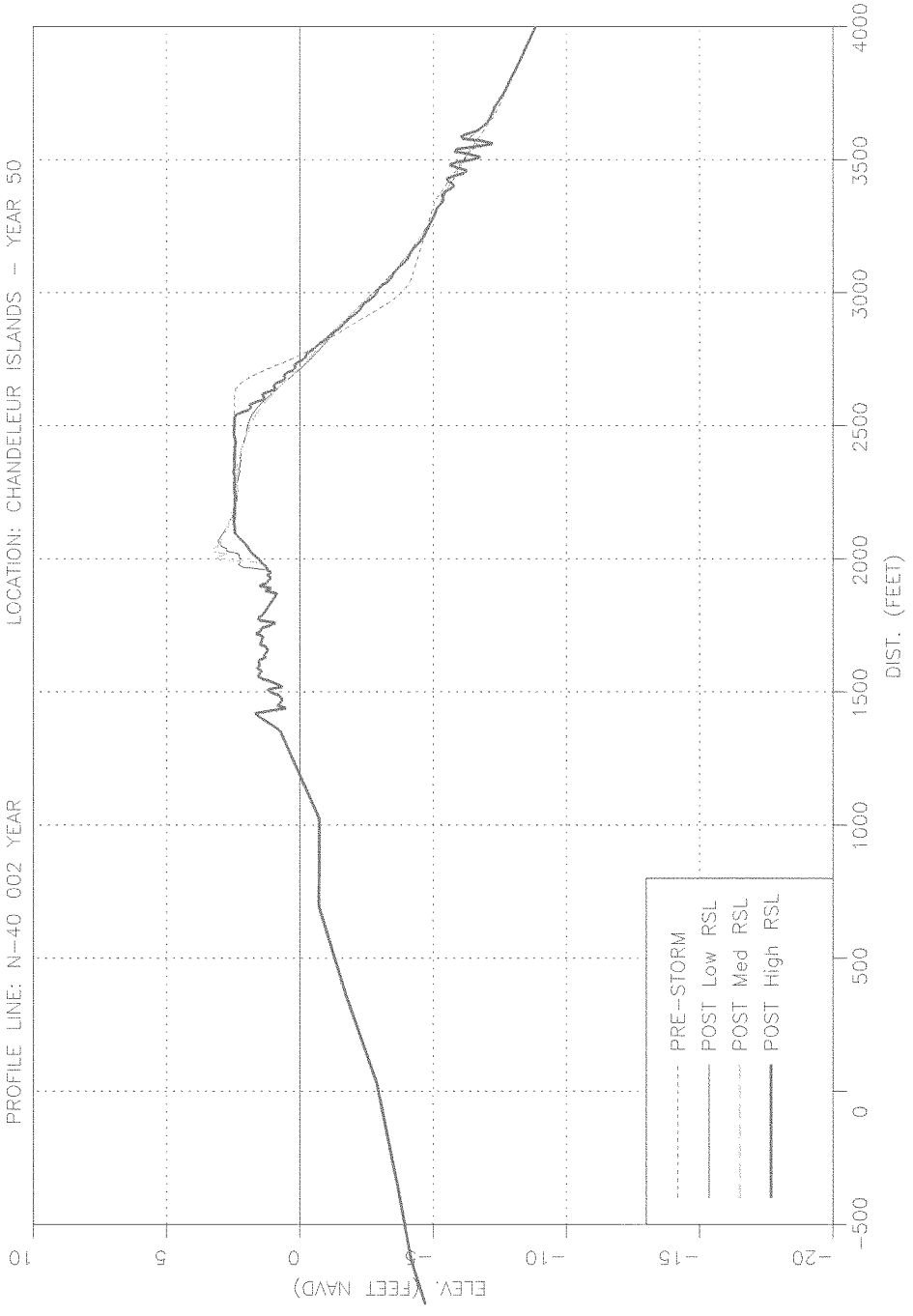

PROFILE LINE: N-36 010 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000
PRE-STORM
POST Low RSL
POST Med RSL
POST High RSL

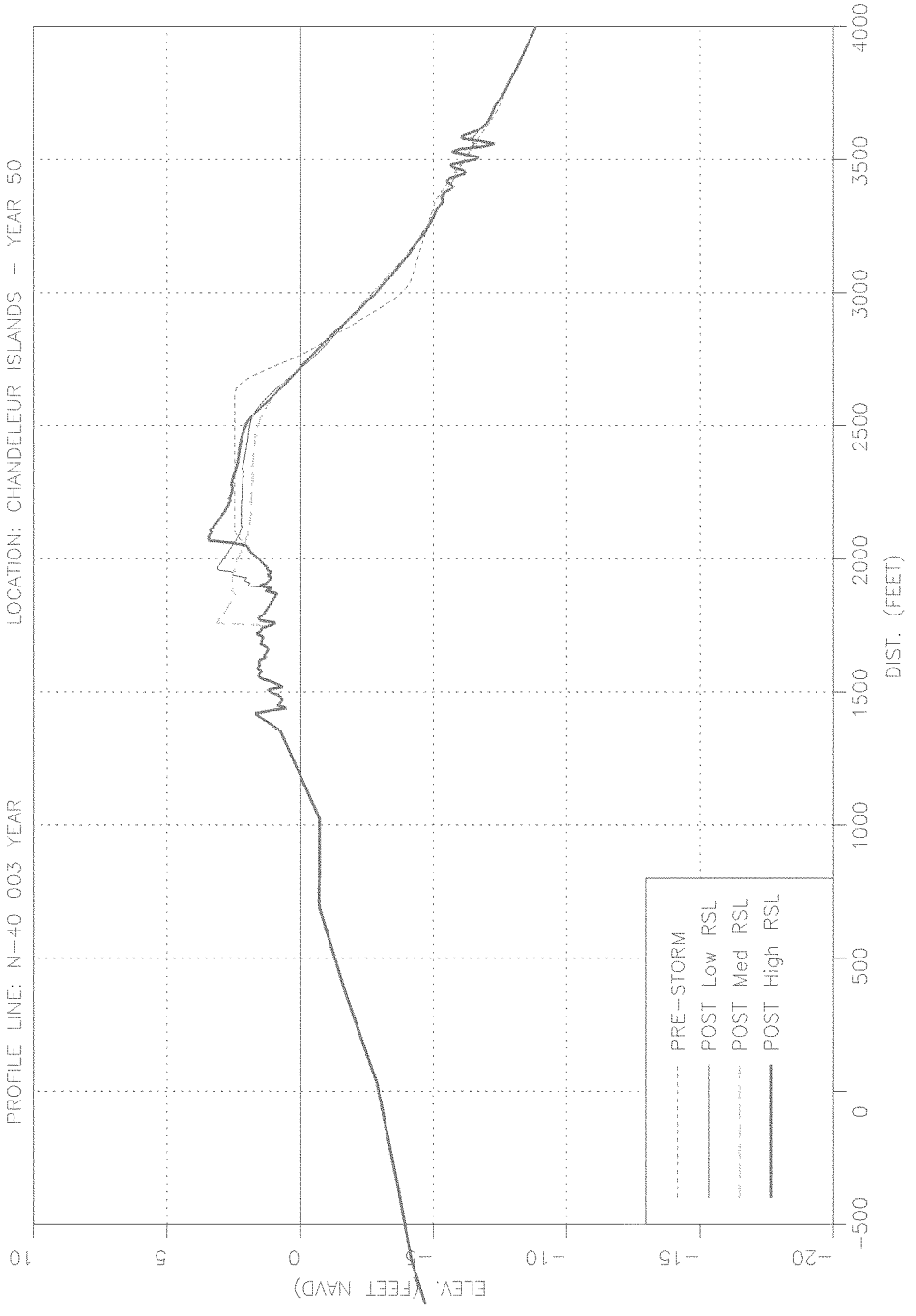

PROFILE LINE: N-36 020 YEAR
LOCATION: CHANDELEUR ISLANDS -- YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
POST Med RSL
POST High RSL
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

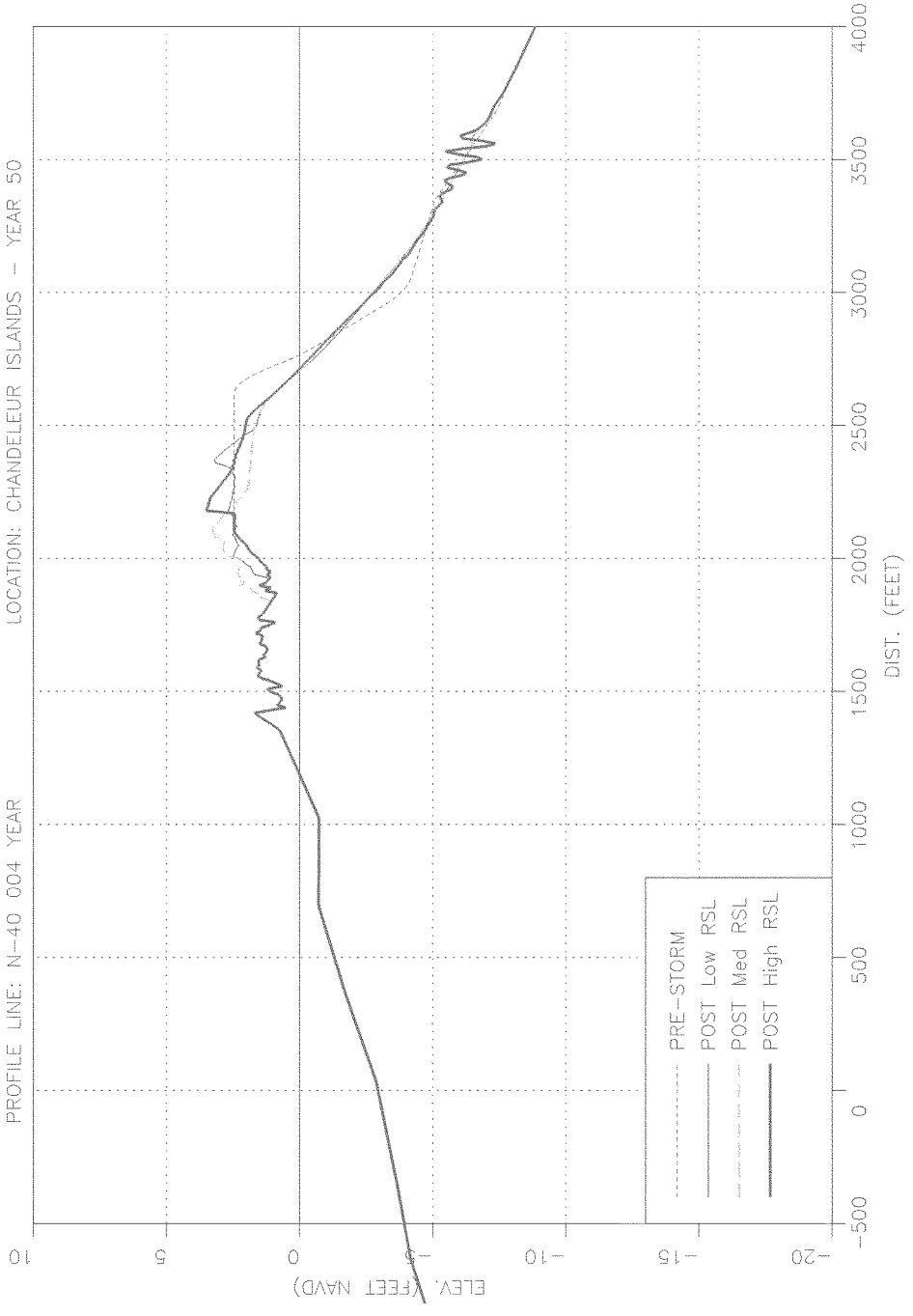

PROFILE LINE: N-36 050 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000
PRE-STORM
POST Low RSL
POST Med RSL
POST High RSL

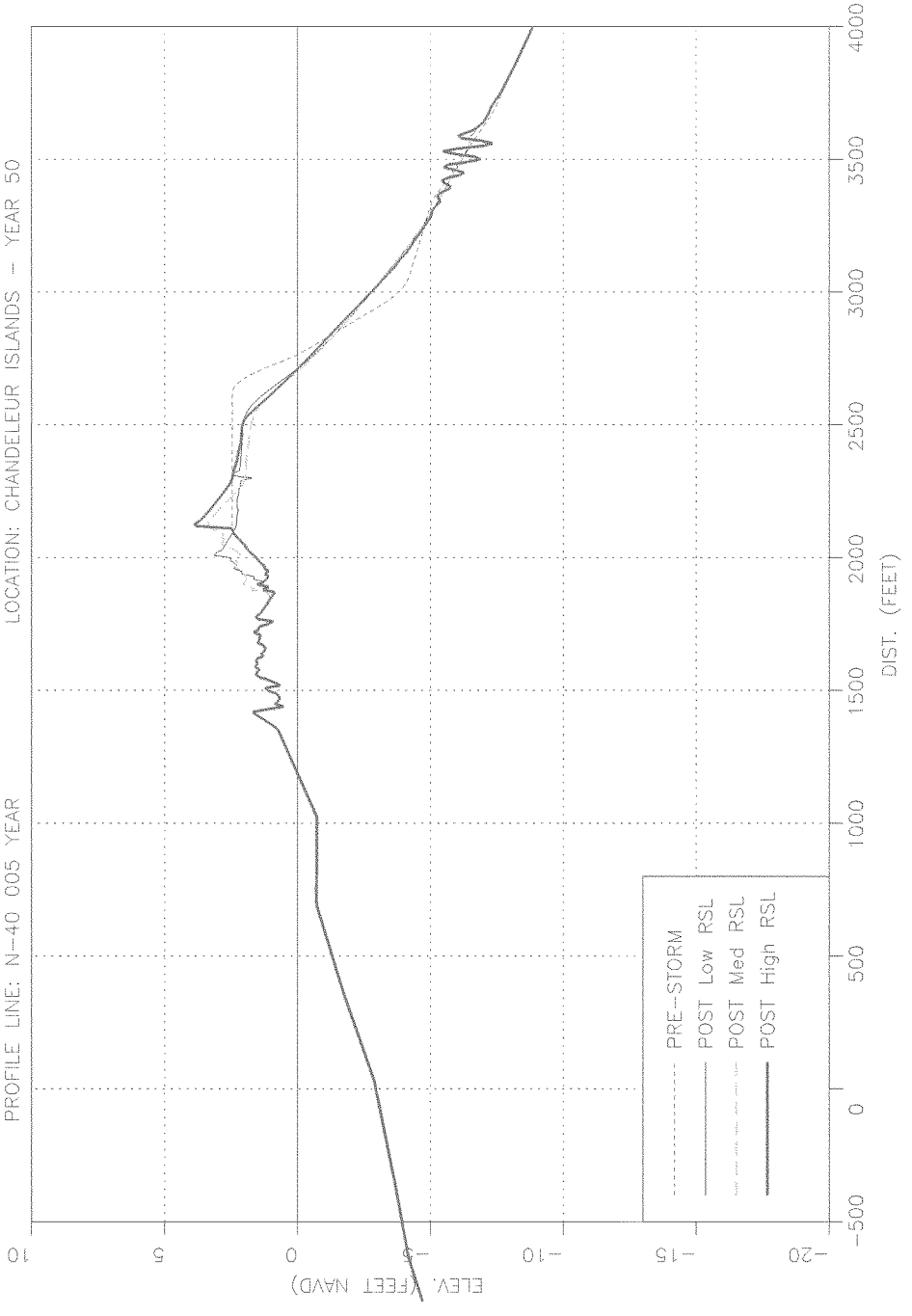

PROFILE LINE: N-36 100 YEAR
LOCATION: CHANDELEUR ISLANDS -- YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
POST Med RSL
POST High RSL
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

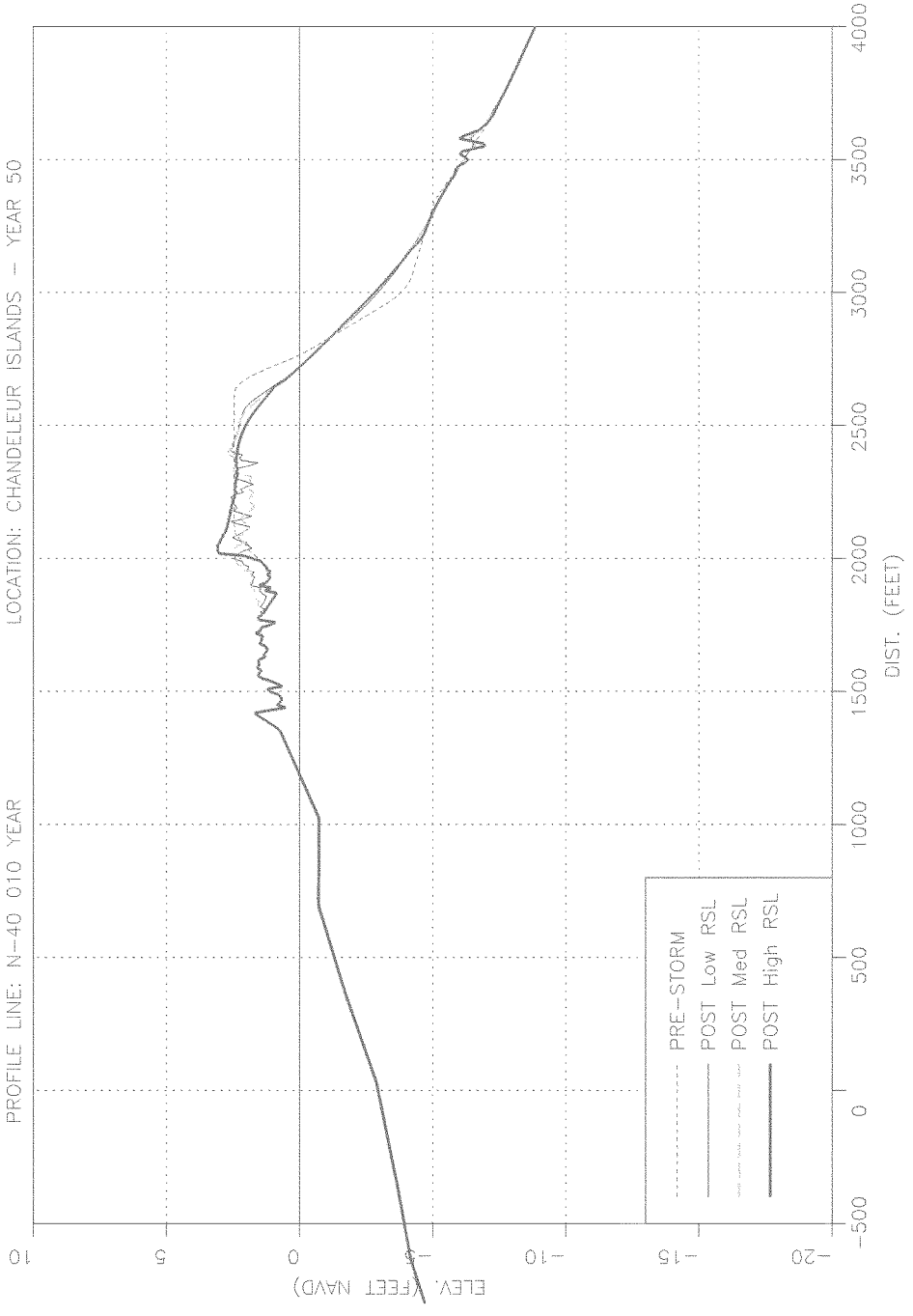

PROFILE LINE: N-40 001 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000
PRE-STORM
POST Low RSL
POST Med RSL
POST High RSL

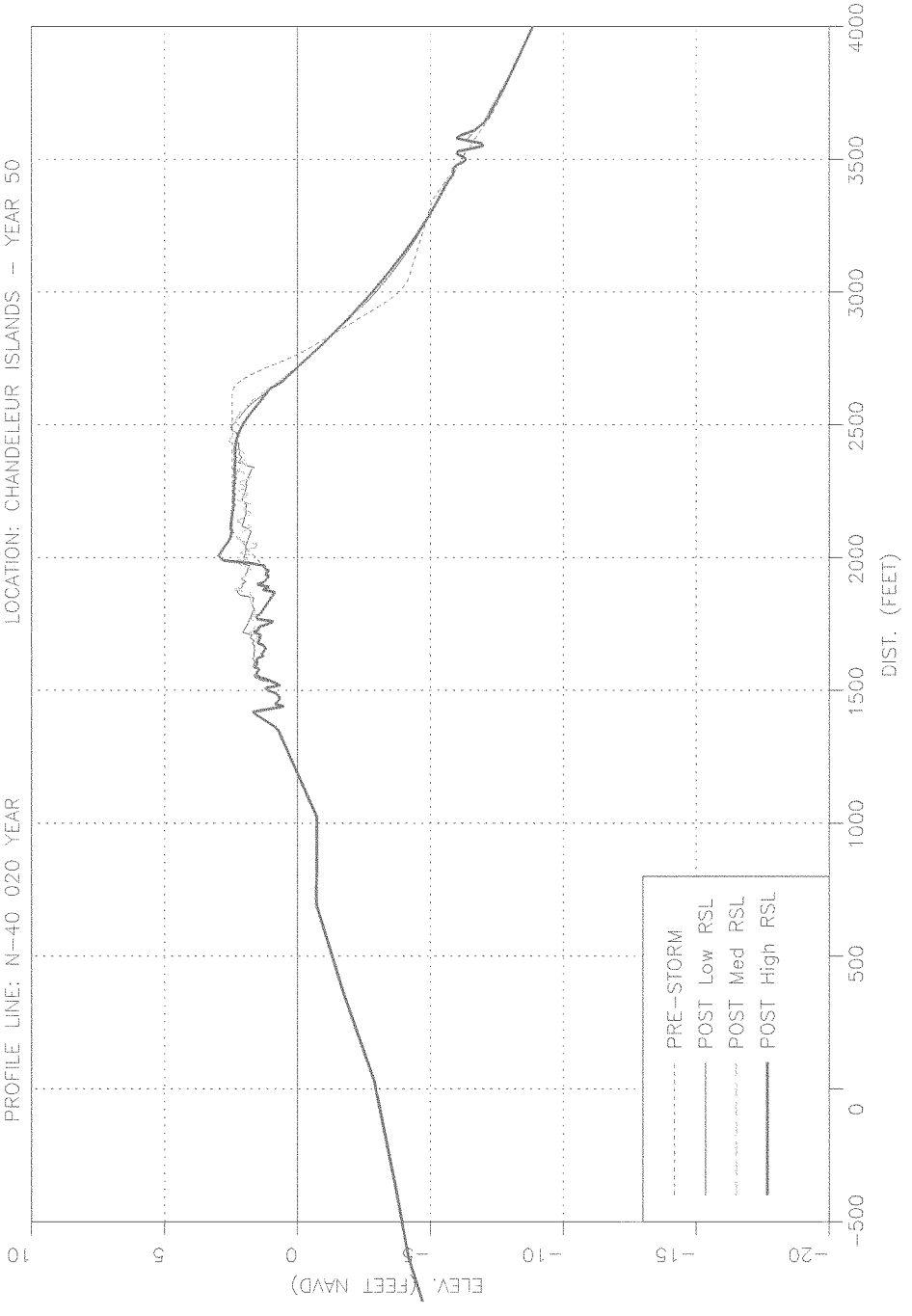

PROFILE LINE: N-40 002 YEAR
LOCATION: CHANDELEUR ISLANDS -- YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
POST Med RSL
POST High RSL
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

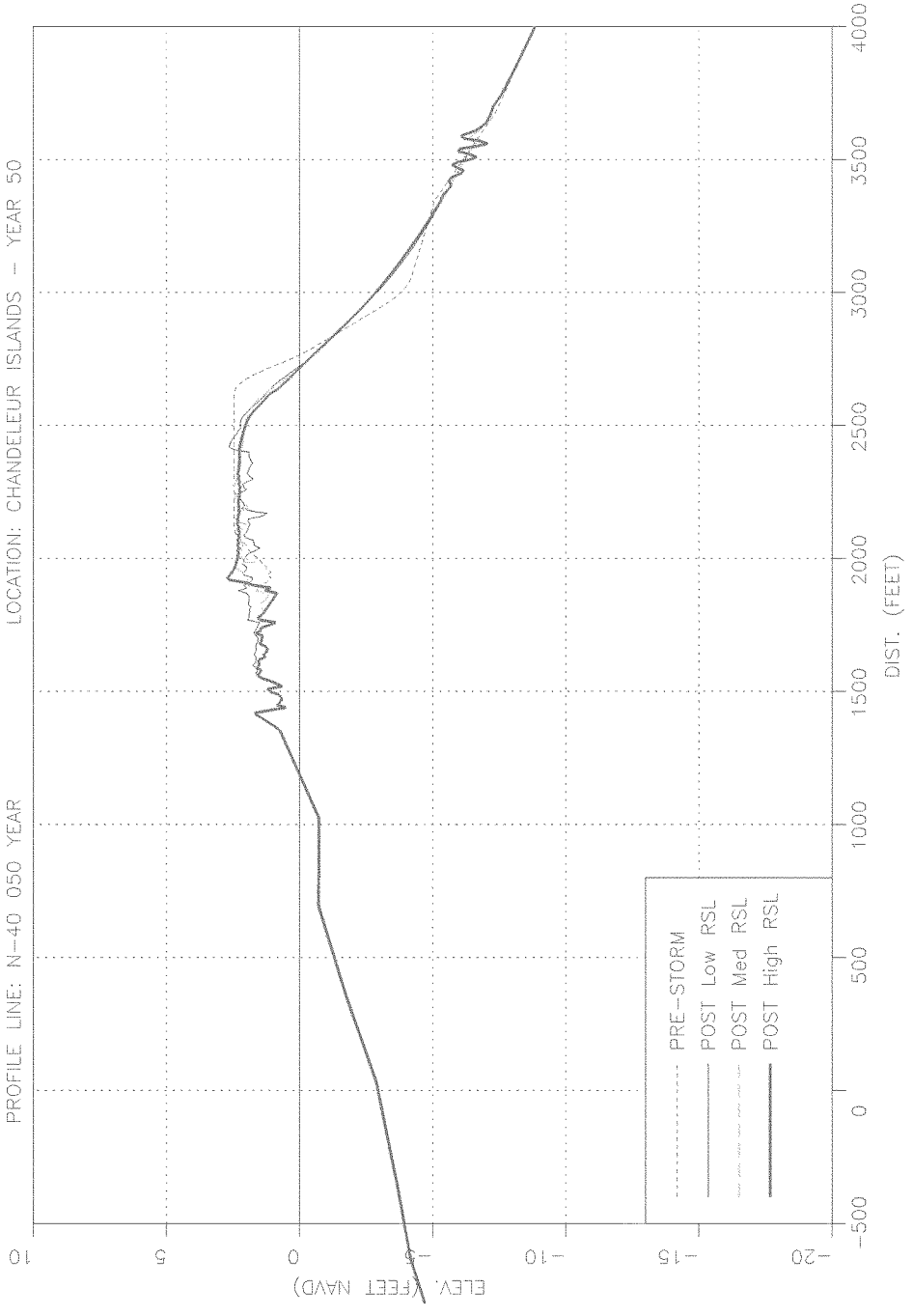

PROFILE LINE: N-40 003 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
POST Med RSL
POST High RSL
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

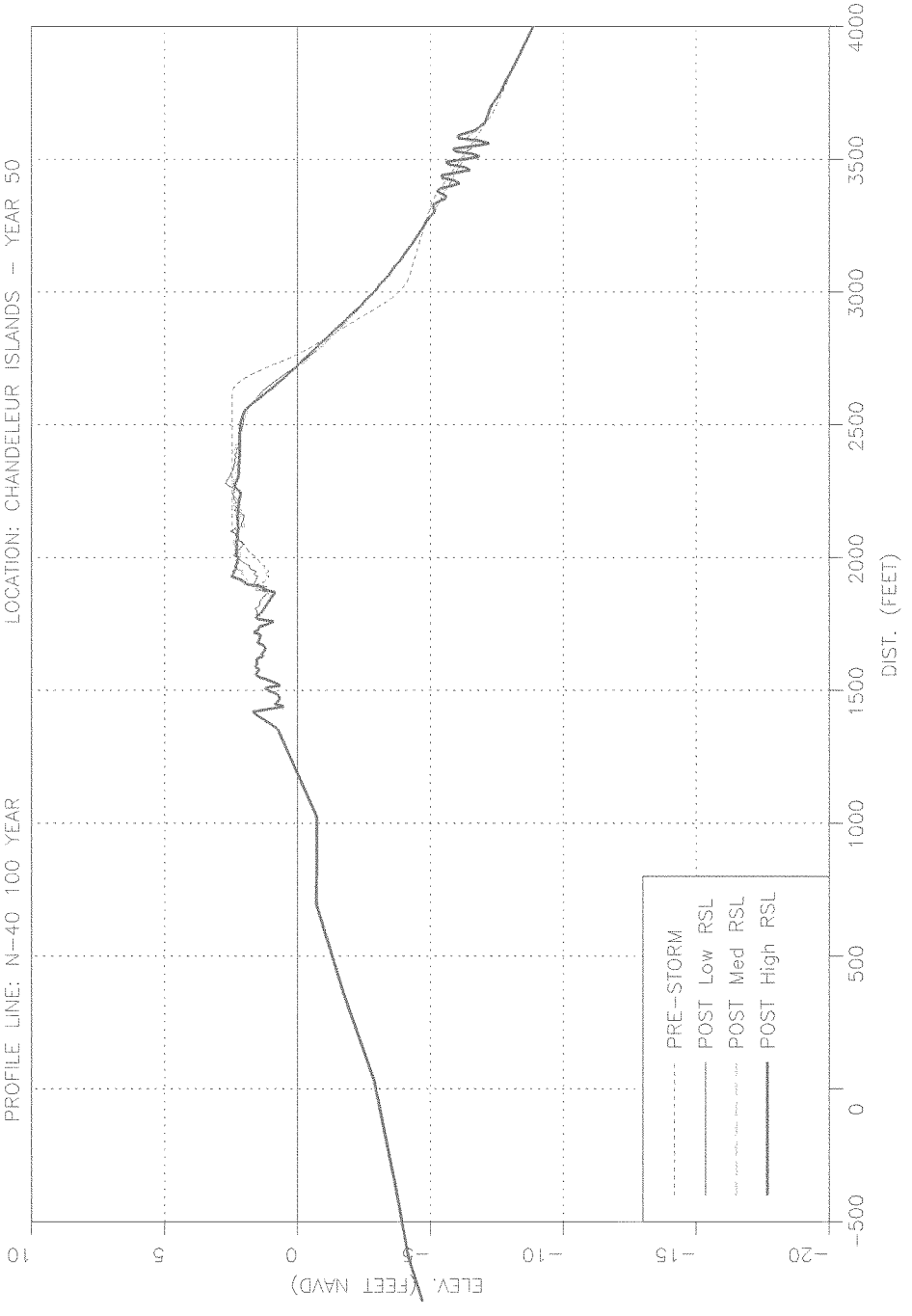

PROFILE LINE: N-40 004 YEAR
LOCATION: CHANDELEUR ISLANDS -- YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
POST Med RSL
POST High RSL
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

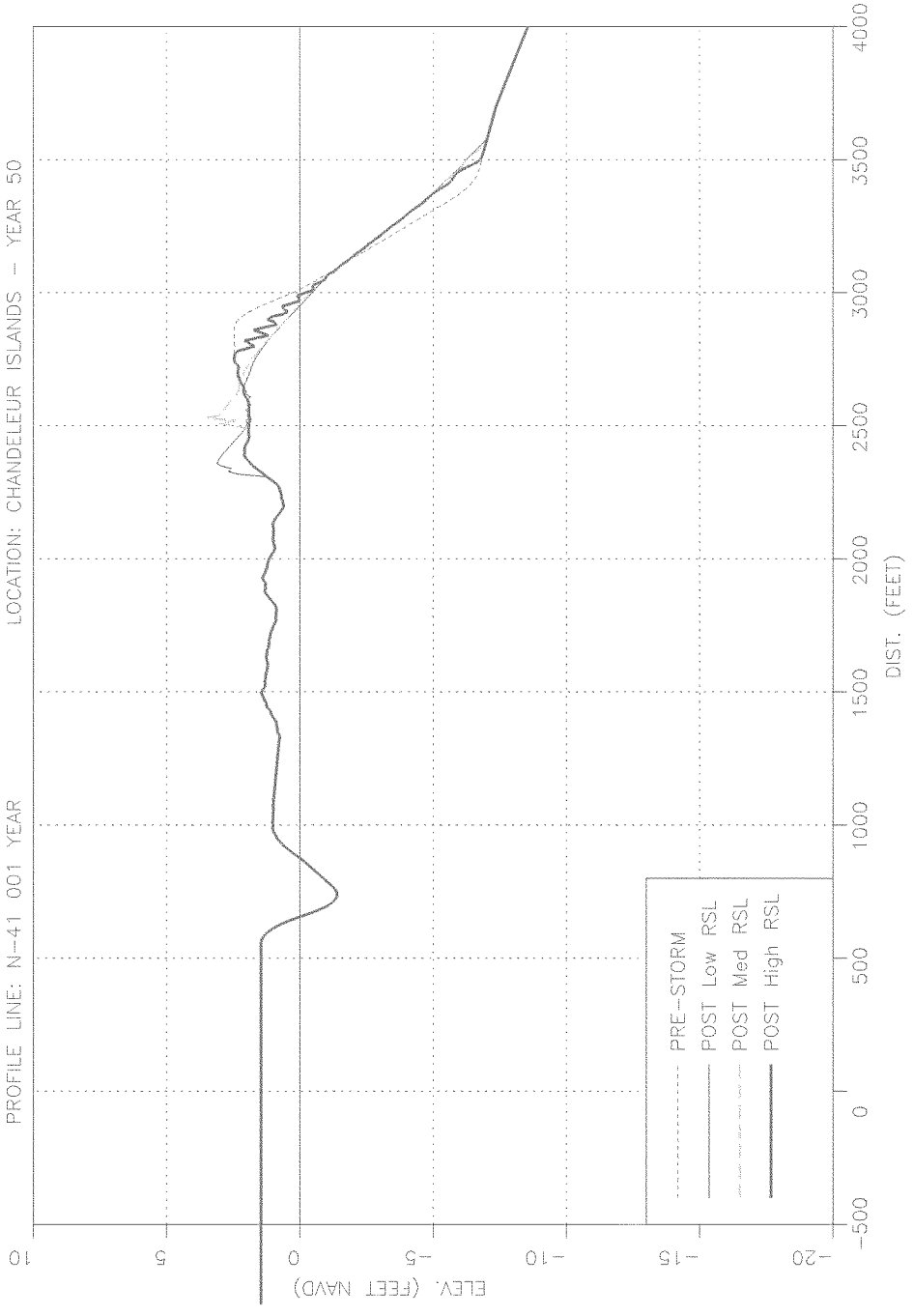

PROFILE LINE: N-40 005 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
POST Med RSL
POST High RSL
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

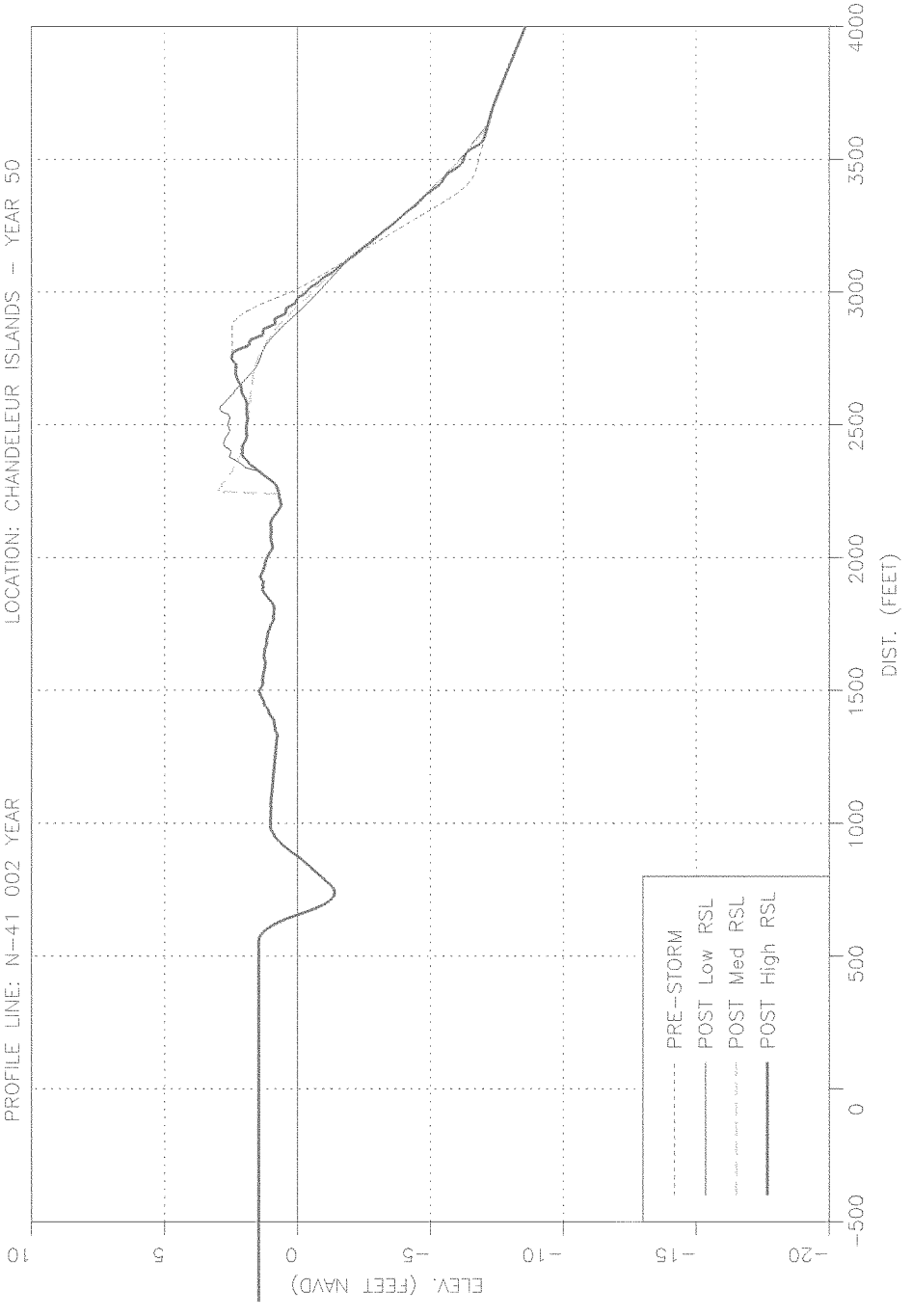

PROFILE LINE: N-40 010 YEAR
LOCATION: CHANDELEUR ISLANDS -- YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000
PRE-STORM
POST Low RSL
POST Med RSL
POST High RSL

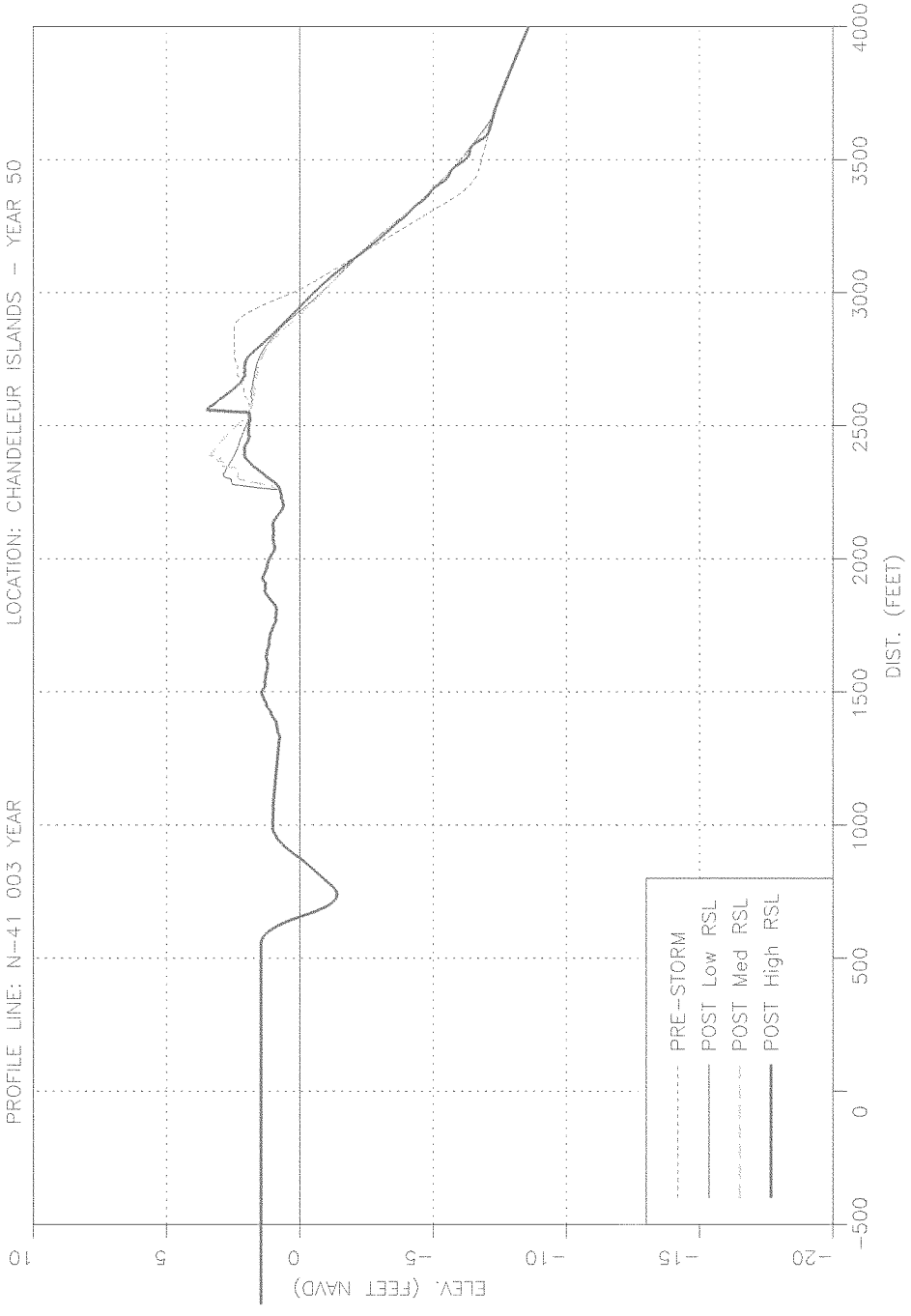

PROFILE LINE: N-40 020 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
POST Med RSL
POST High RSL
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

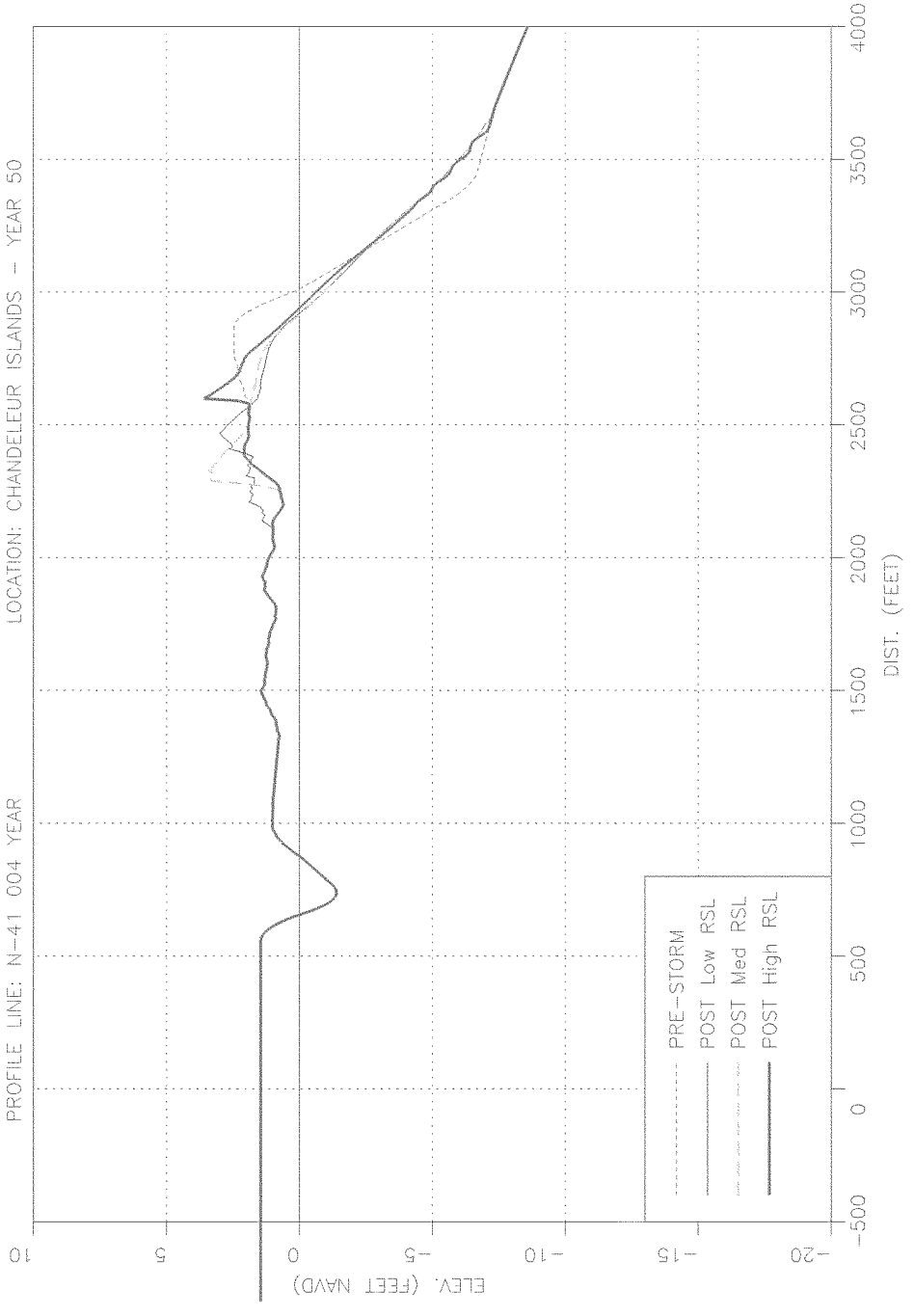

PROFILE LINE: N-40 050 YEAR
LOCATION: CHANDELEUR ISLANDS -- YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
POST Med RSL
POST High RSL
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

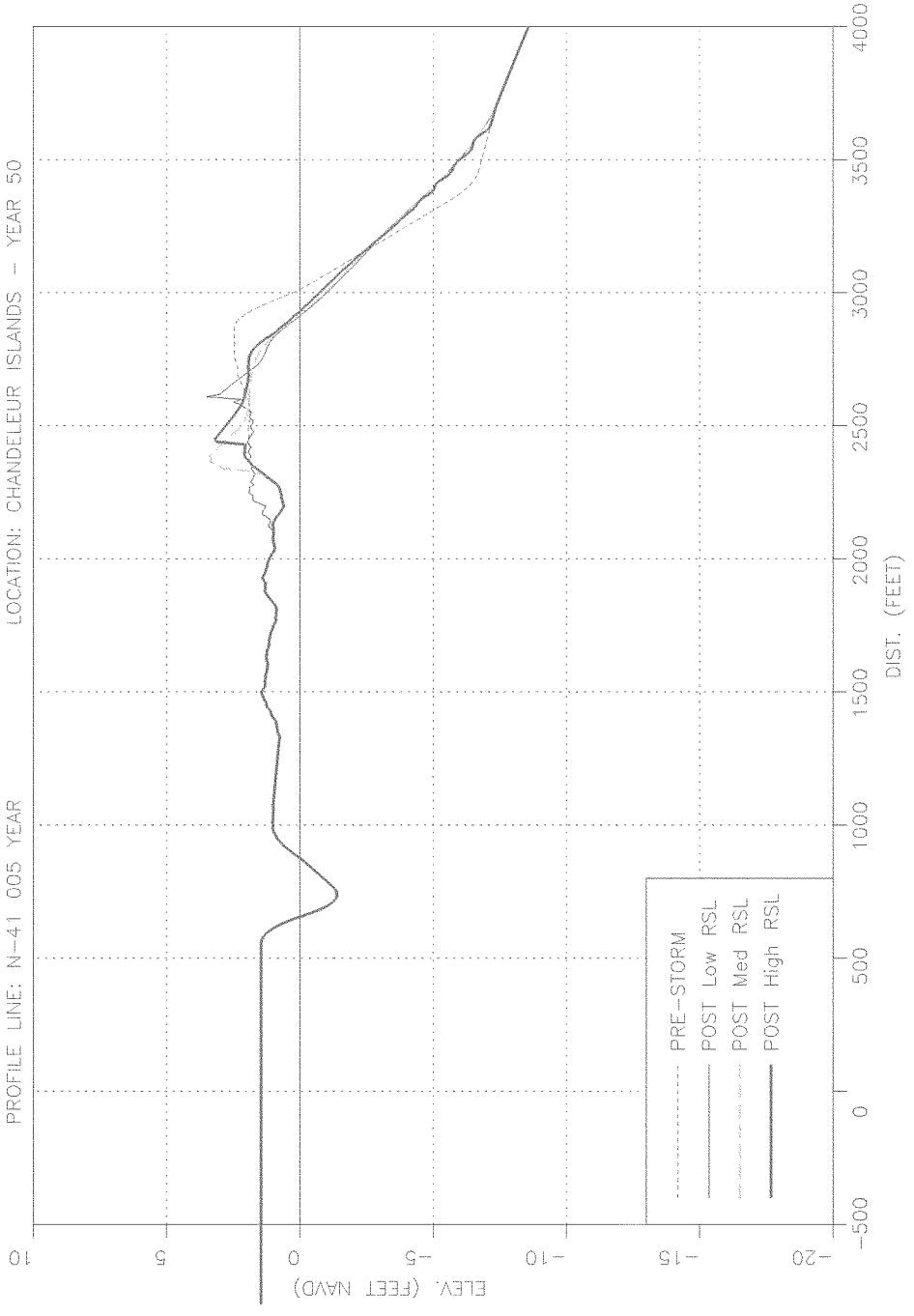

PROFILE LINE: N-40 100 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
POST Med RSL
POST High RSL
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

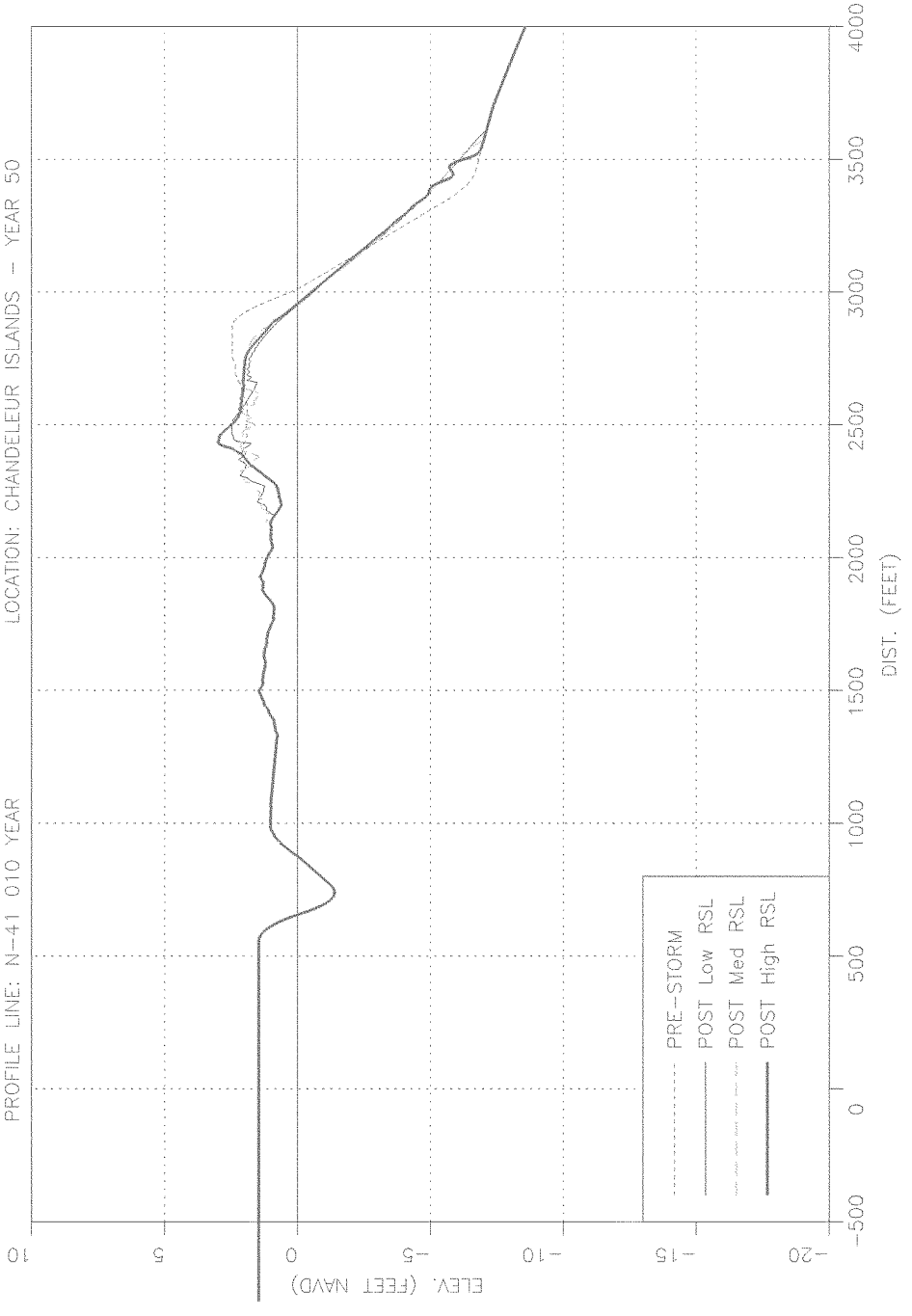

PROFILE LINE: N-41 001 YEAR
LOCATION: CHANDELEUR ISLANDS -- YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
POST Med RSL
POST High RSL
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

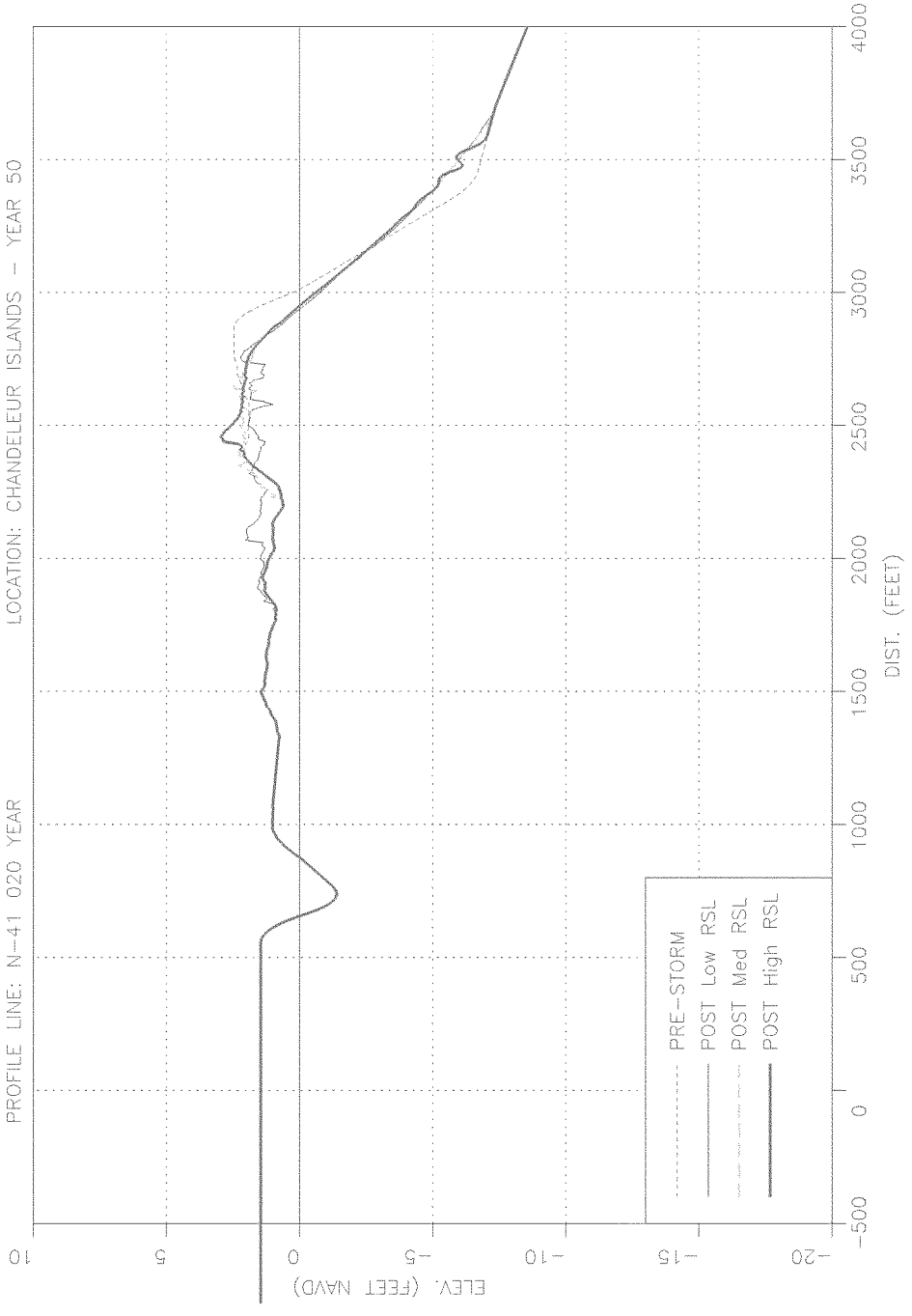

PROFILE LINE: N-41 002 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
POST Med RSL
POST High RSL
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

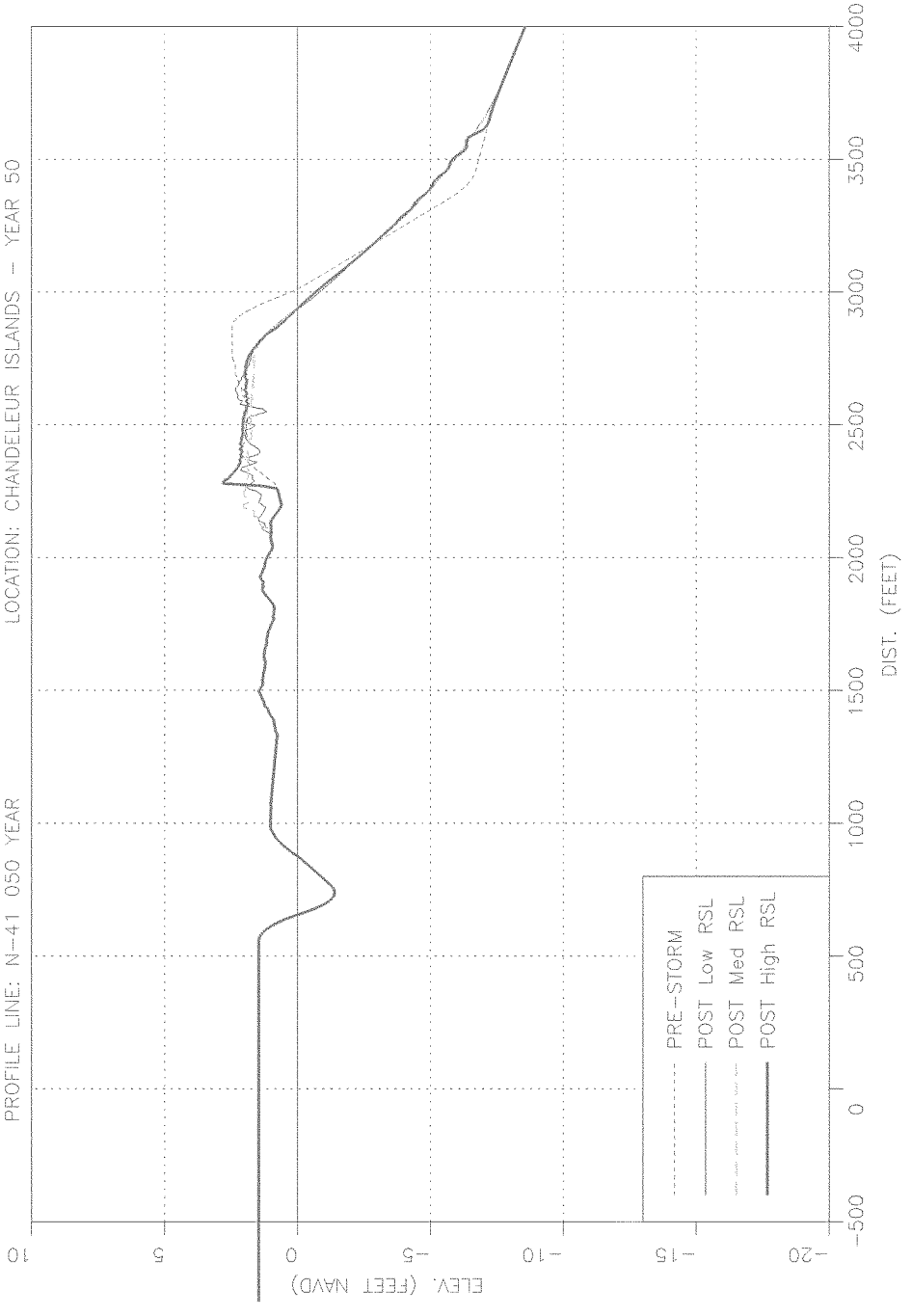

PROFILE LINE: N-41 003 YEAR
LOCATION: CHANDELEUR ISLANDS -- YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
POST Med RSL
POST High RSL
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

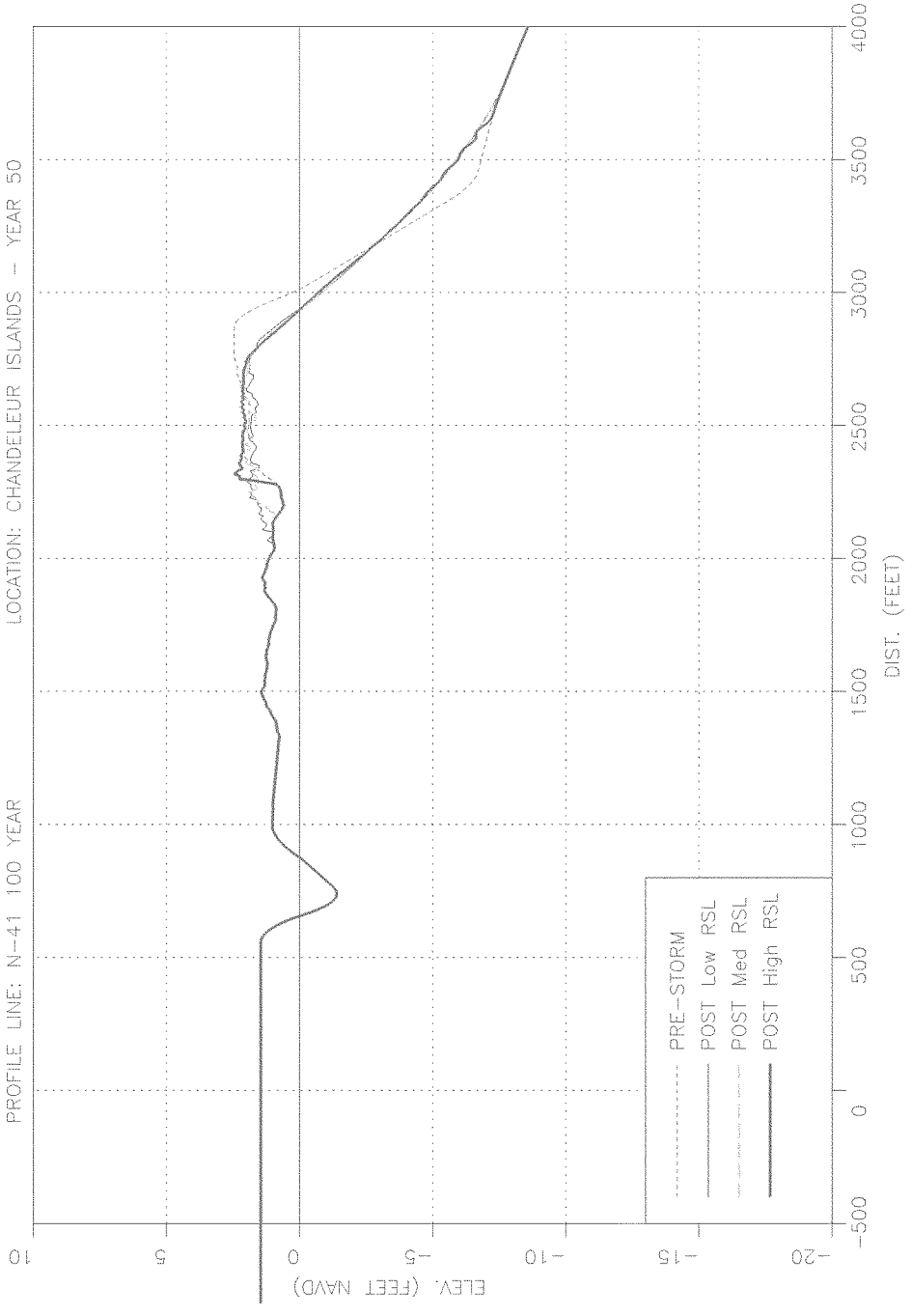

PROFILE LINE: N-41 004 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
POST Med RSL
POST High RSL
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

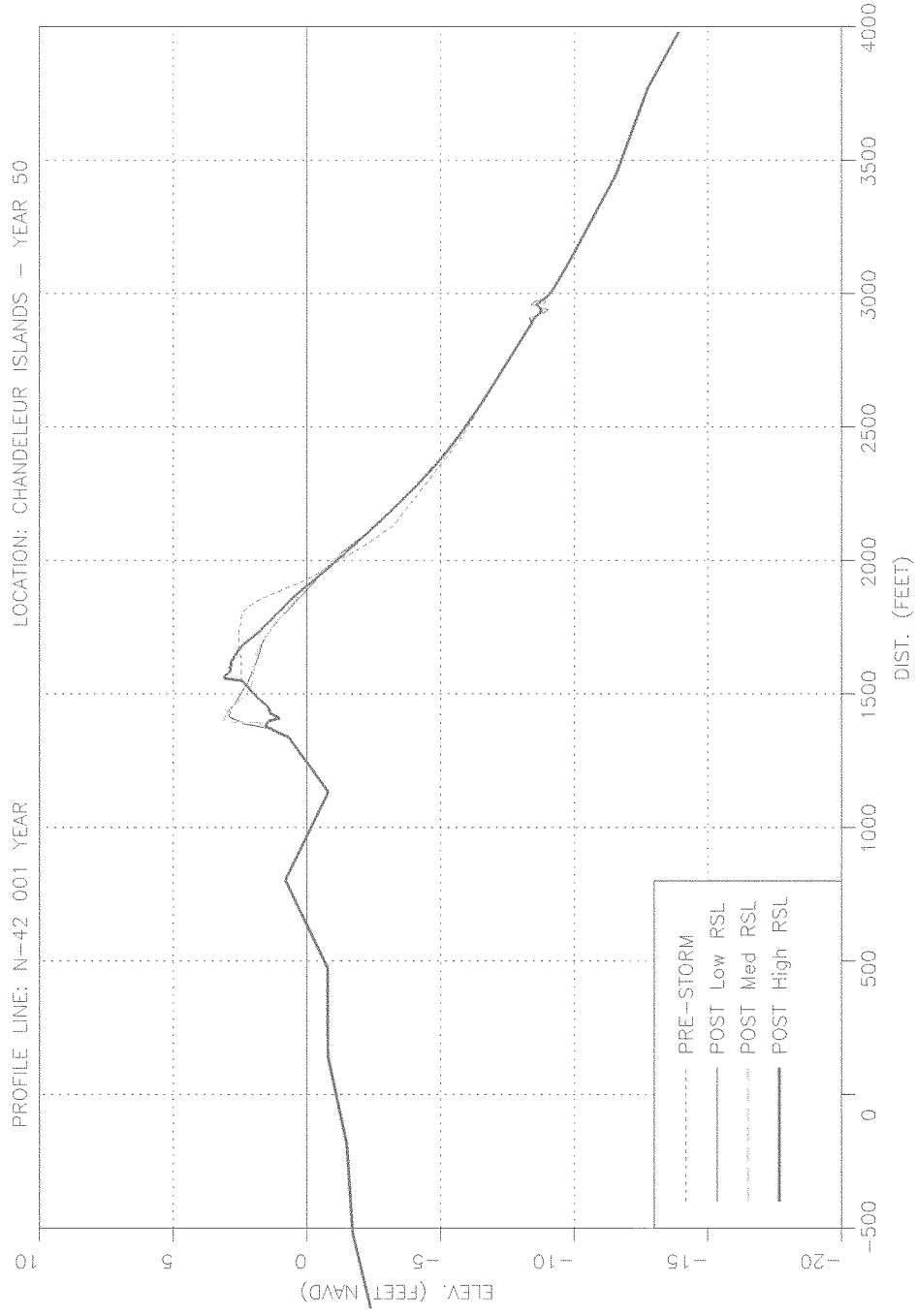

PROFILE LINE: N-41 005 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
POST Med RSL
POST High RSL
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

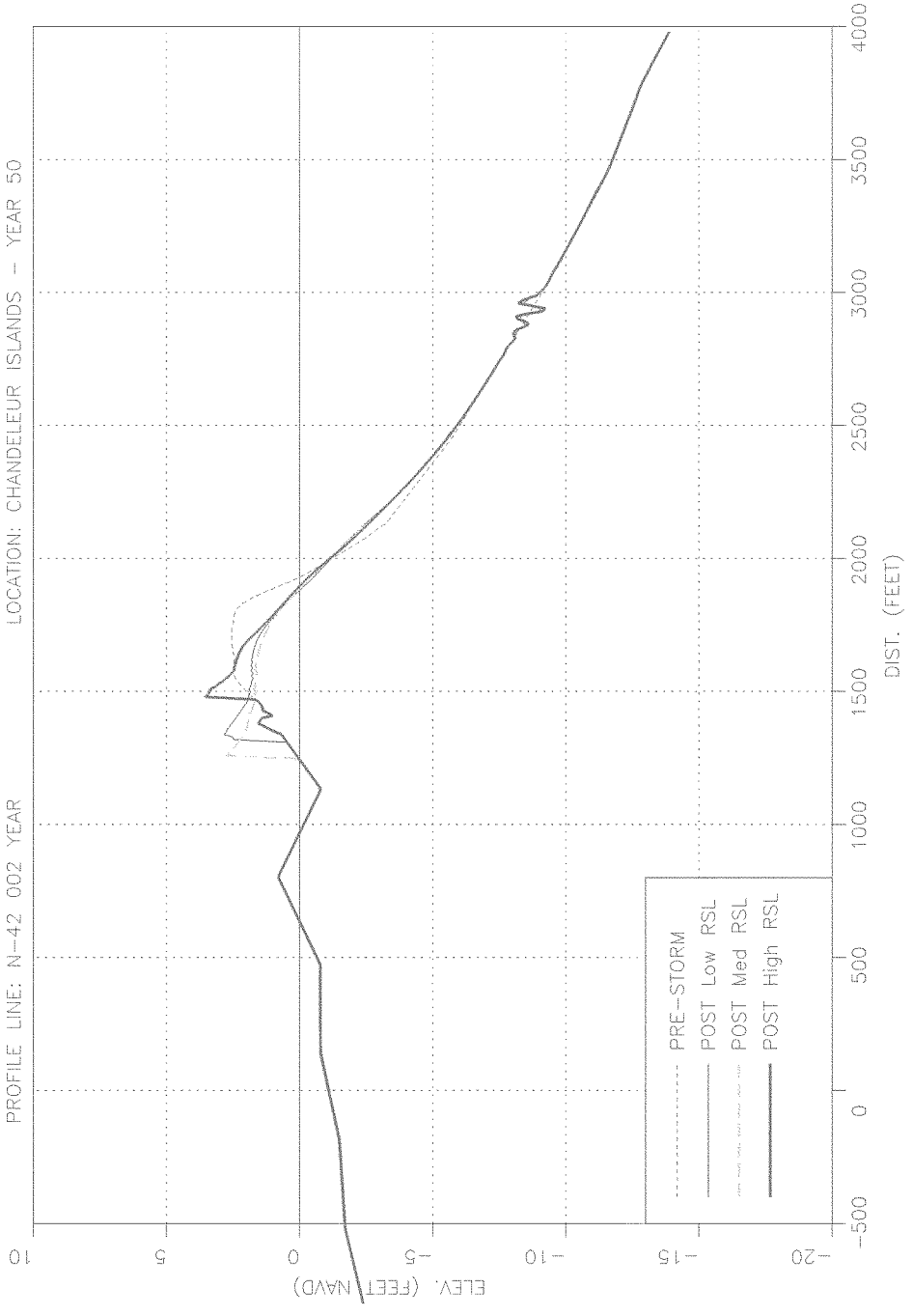

PROFILE LINE: N-41 010 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
POST Med RSL
POST High RSL
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

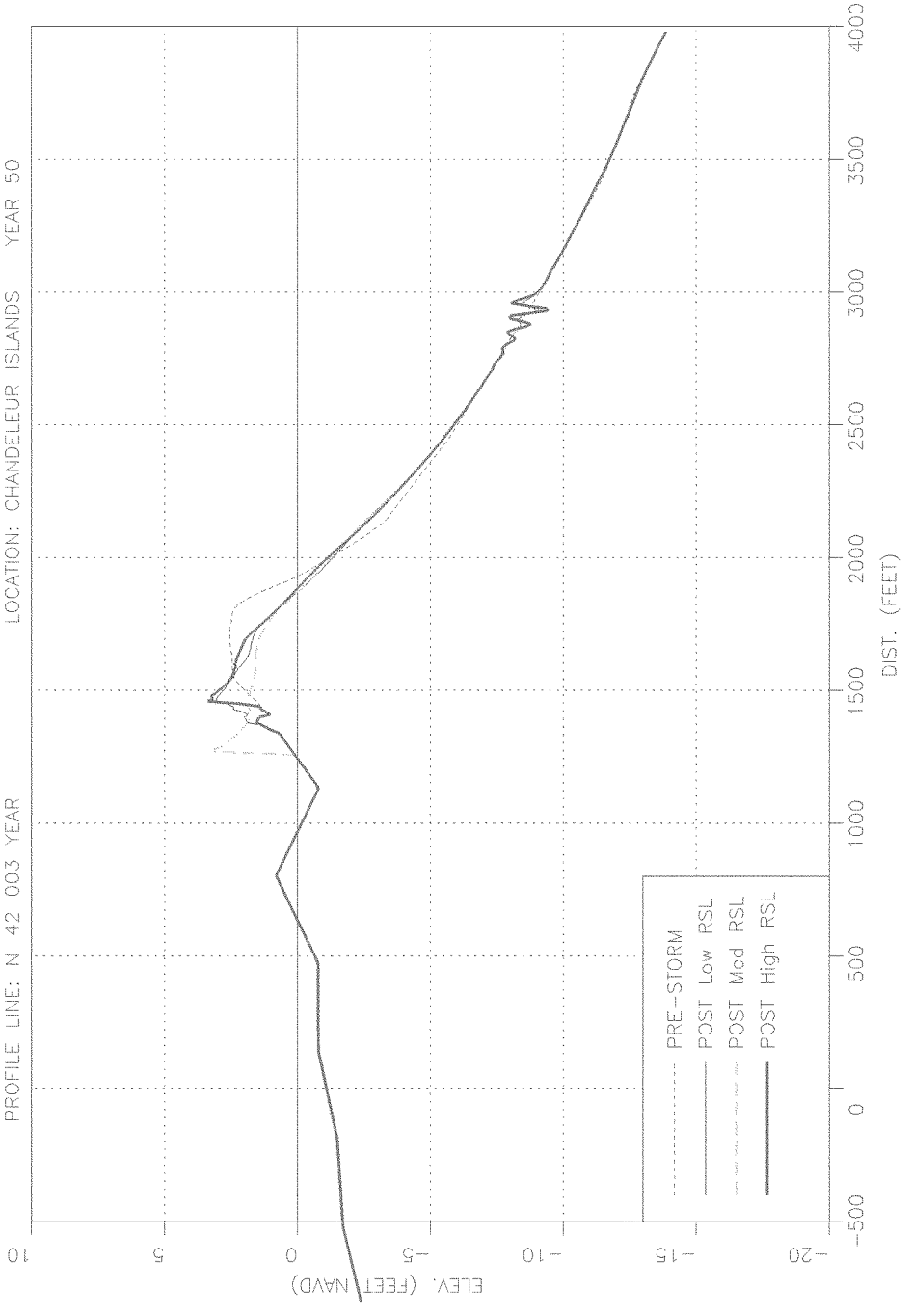

PROFILE LINE: N-41 020 YEAR
LOCATION: CHANDELEUR ISLANDS -- YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
POST Med RSL
POST High RSL
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

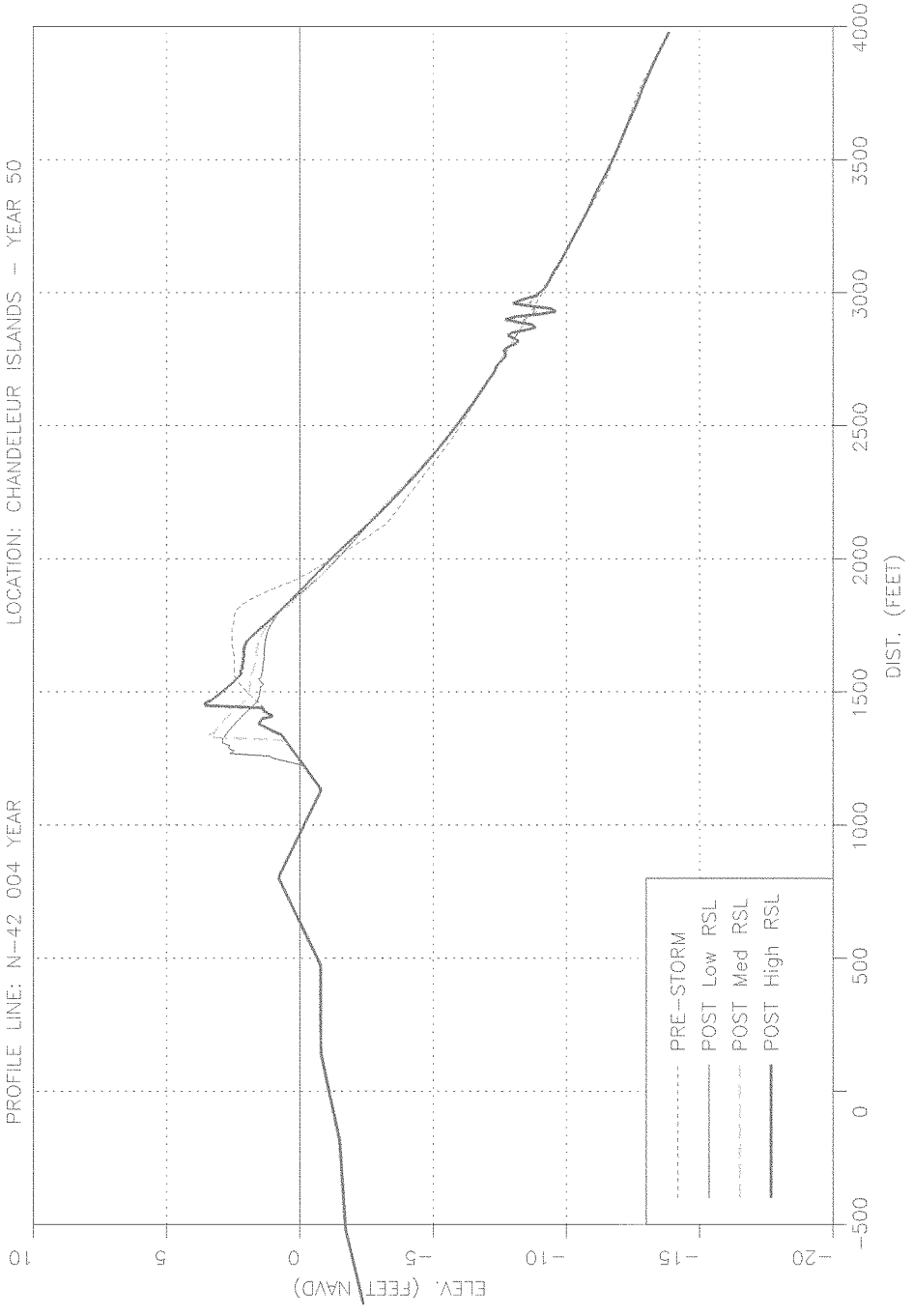

PROFILE LINE: N-41 050 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
POST Med RSL
POST High RSL
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

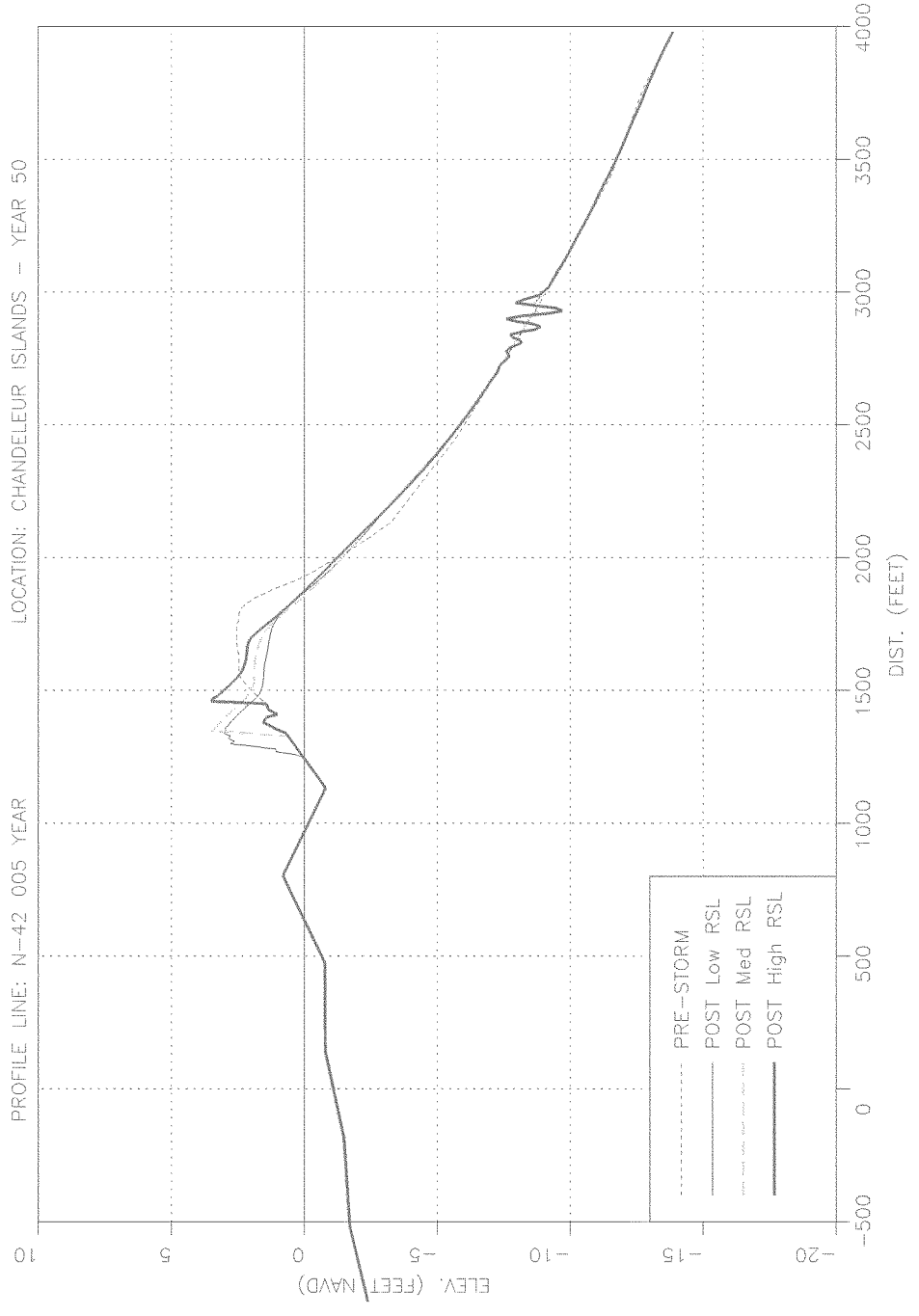

PROFILE LINE: N-41 100 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
POST Med RSL
POST High RSL
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

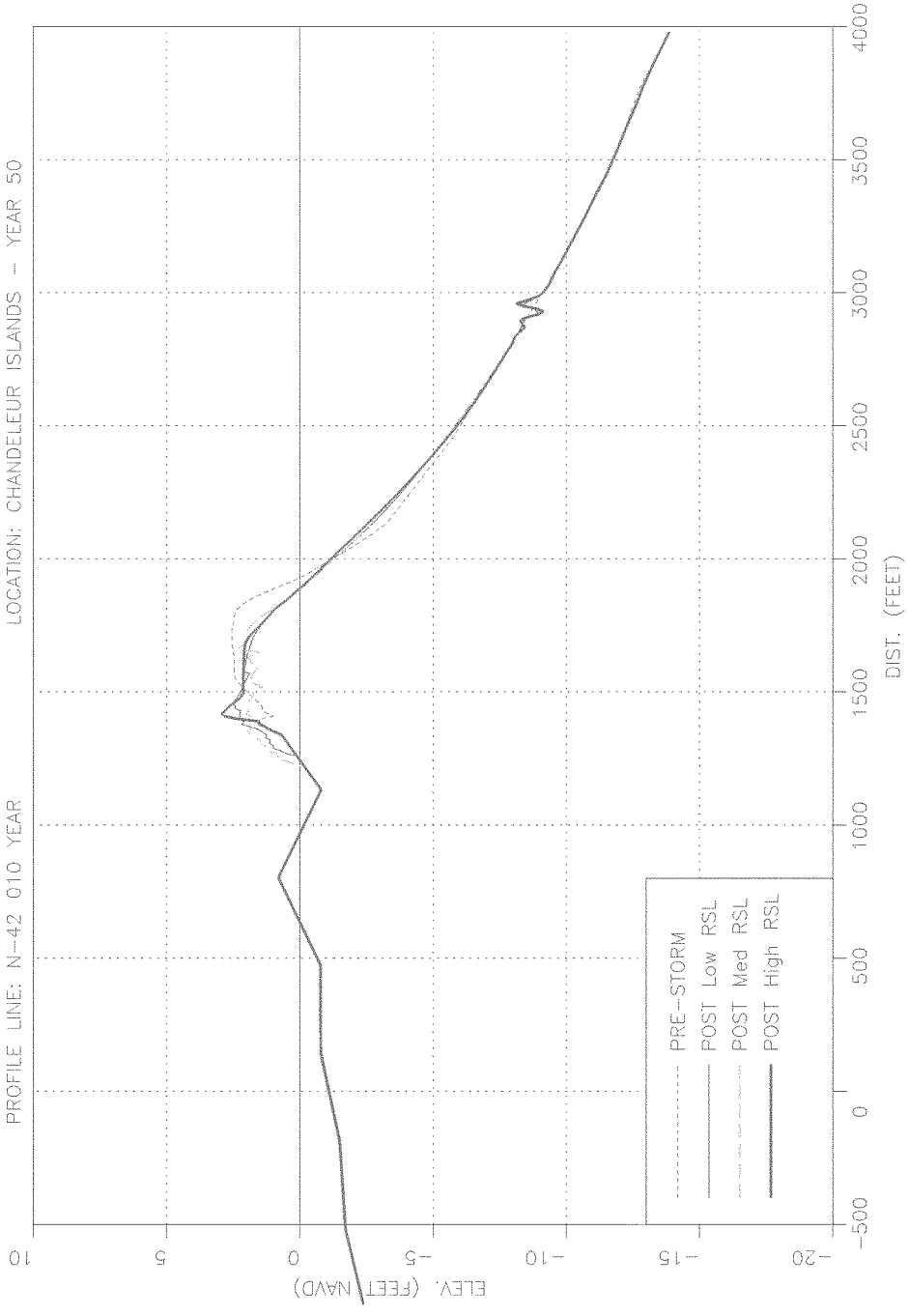

PROFILE LINE: N-42 001 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000
PRE-STORM
POST Low RSL
POST Med RSL
POST High RSL

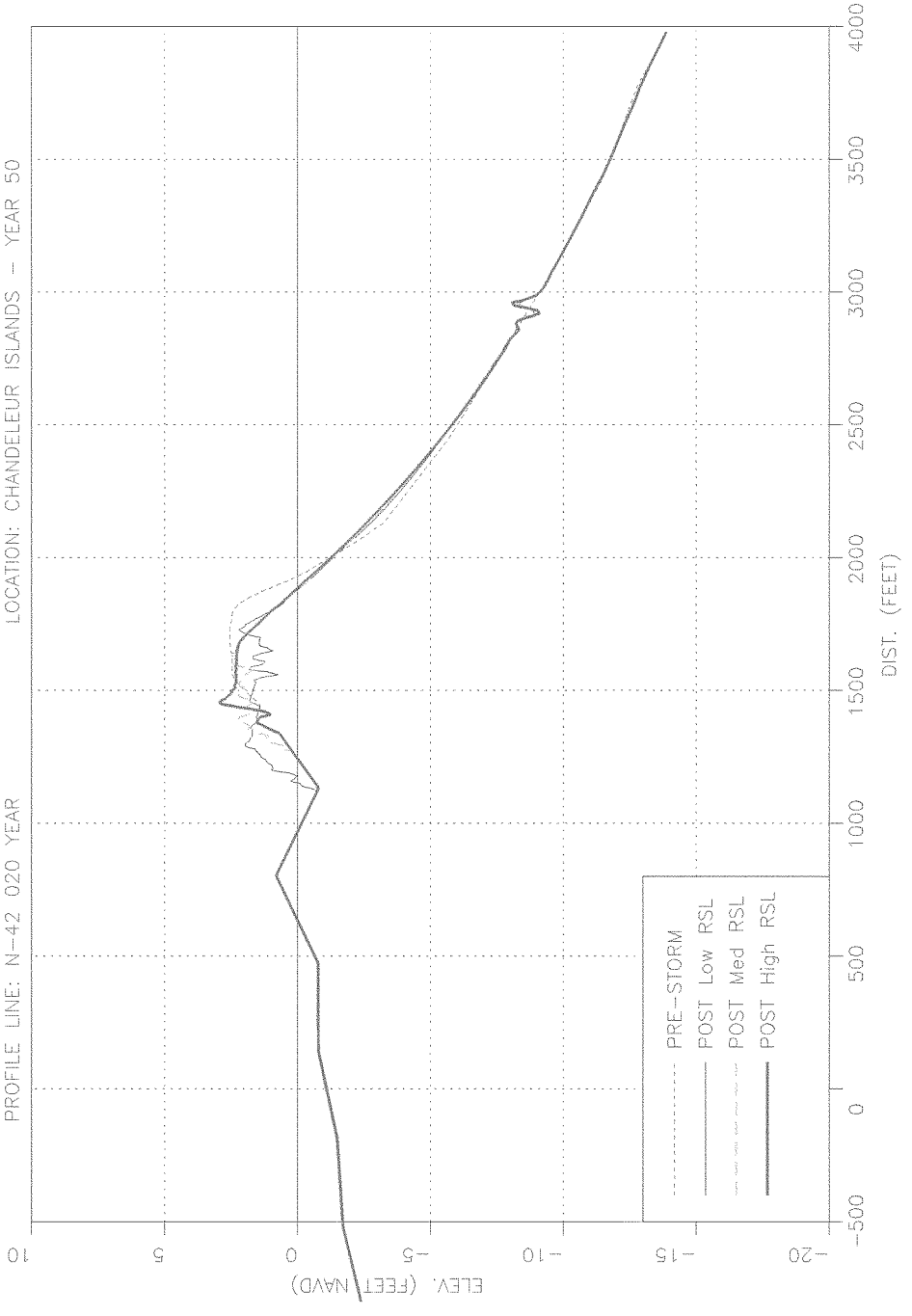

PROFILE LINE: N-42 002 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
POST Med RSL
POST High RSL
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

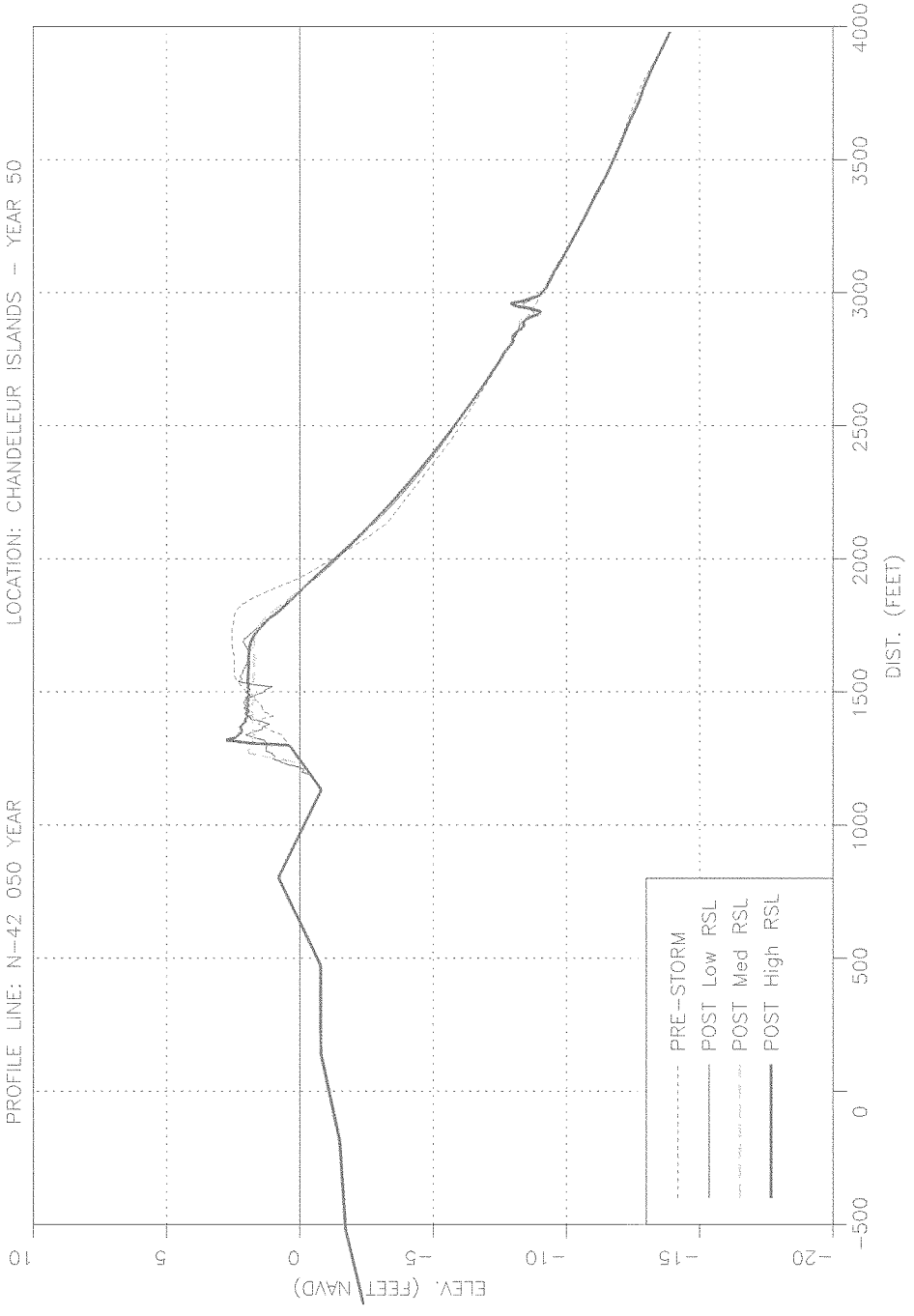

PROFILE LINE: N-42 003 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000
PRE-STORM
POST Low RSL
POST Med RSL
POST High RSL

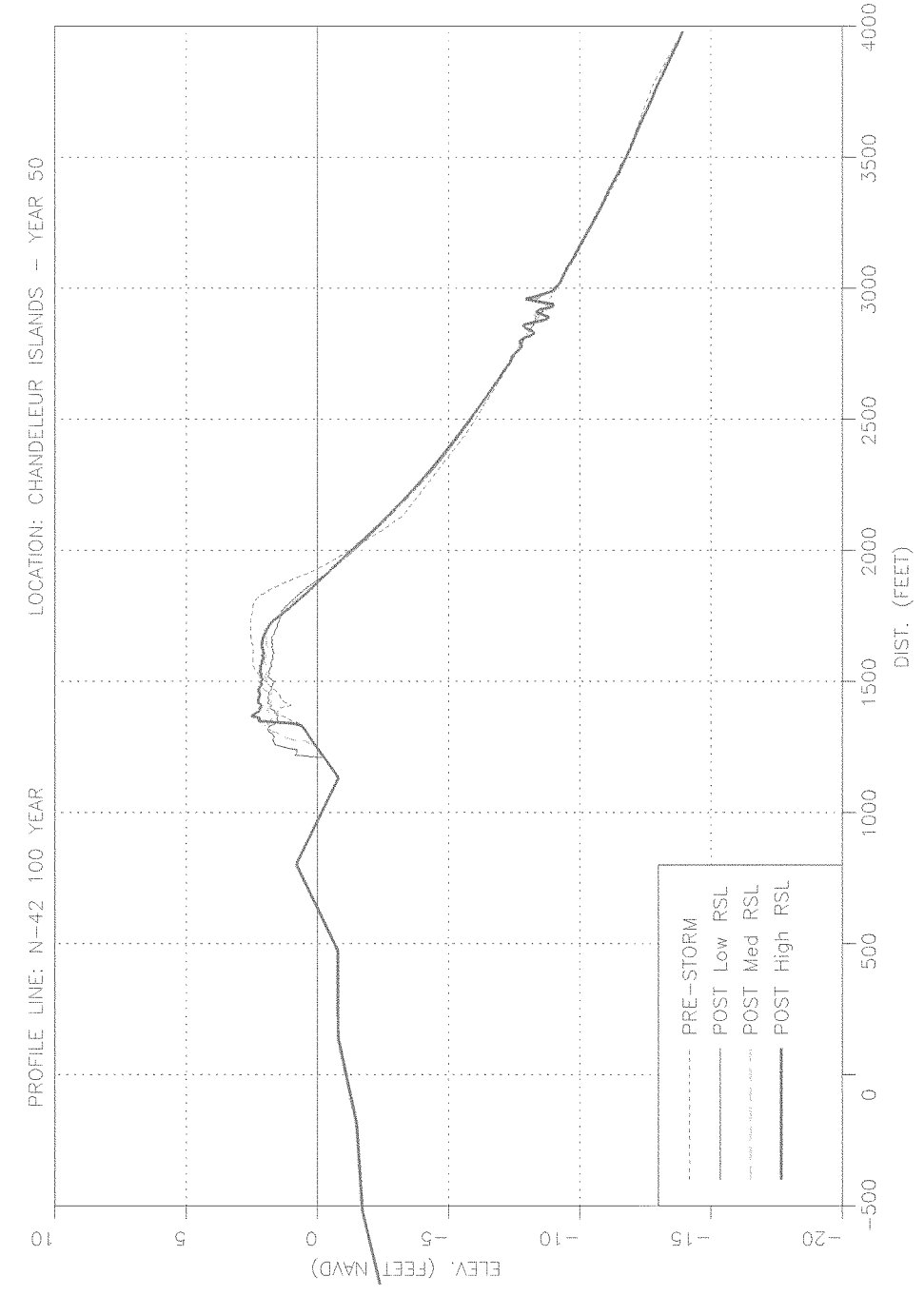

PROFILE LINE: N-42 004 YEAR
LOCATION: CHANDELEUR ISLANDS -- YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
POST Med RSL
POST High RSL
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

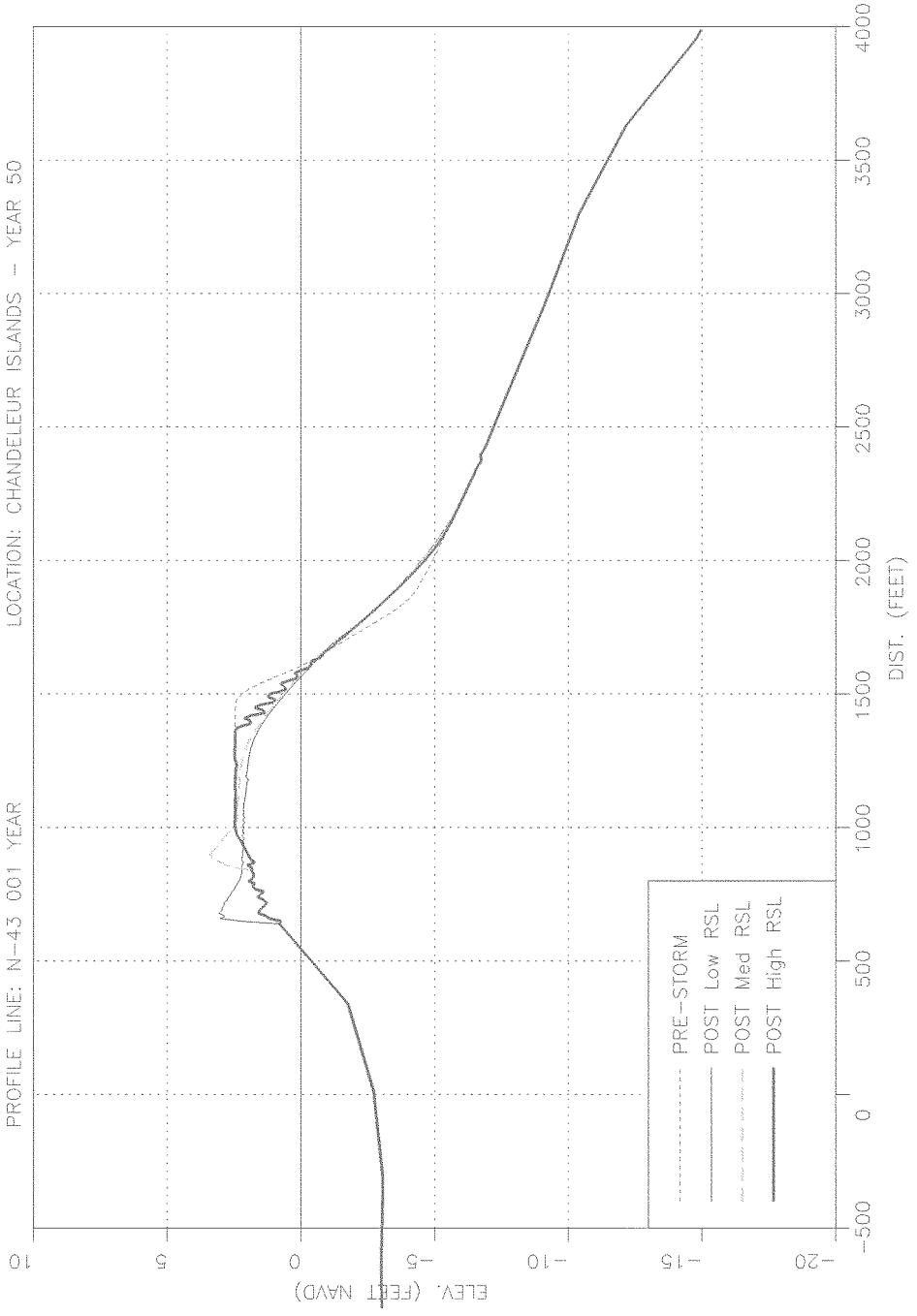

PROFILE LINE: N-42 005 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
POST Med RSL
POST High RSL
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

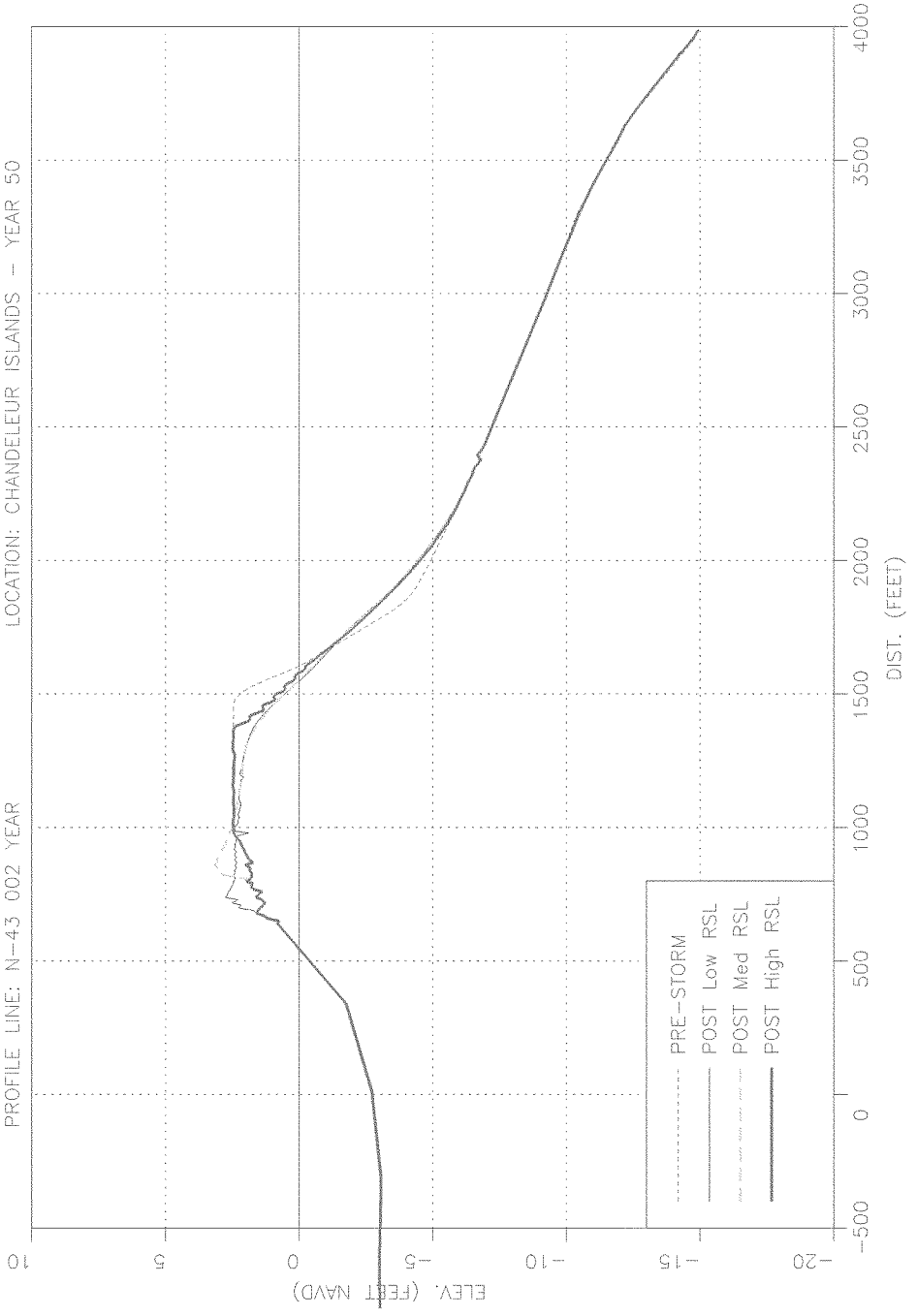

PROFILE LINE: N-42 010 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
POST Med RSL
POST High RSL
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

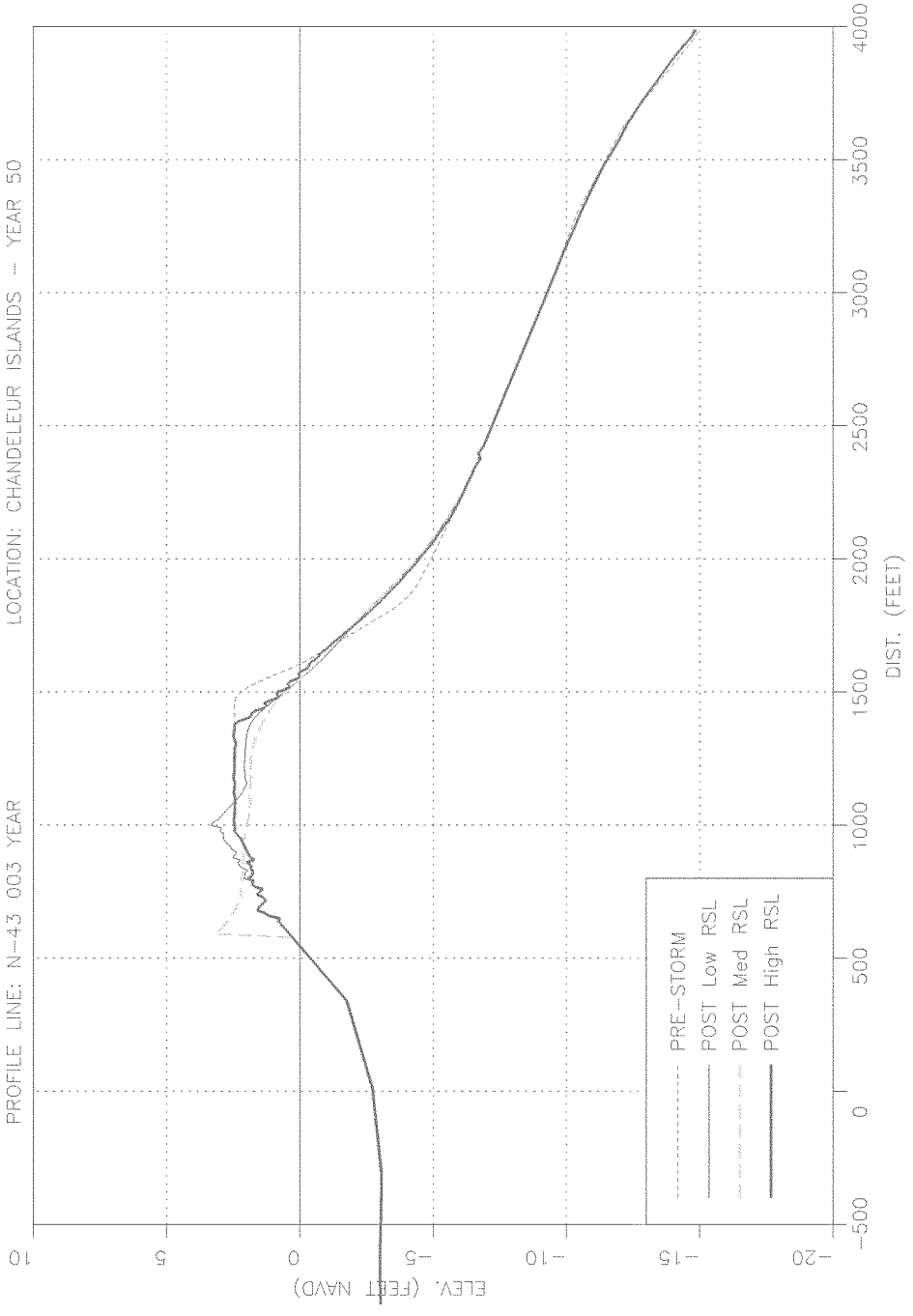

PROFILE LINE: N-42 020 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000
PRE-STORM
POST Low RSL
POST Med RSL
POST High RSL

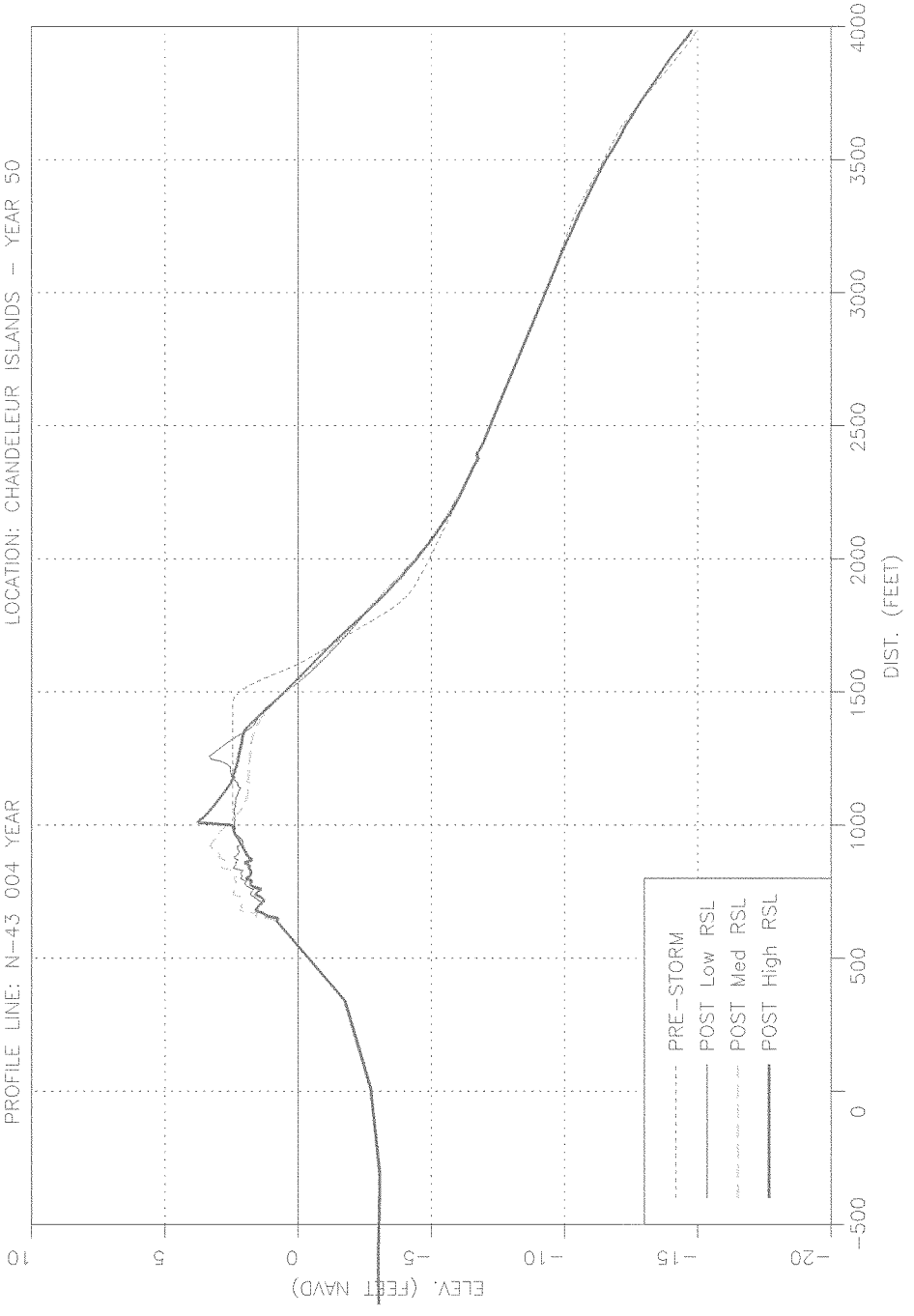

PROFILE LINE: N-42 050 YEAR
LOCATION: CHANDELEUR ISLANDS -- YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
POST Med RSL
POST High RSL
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

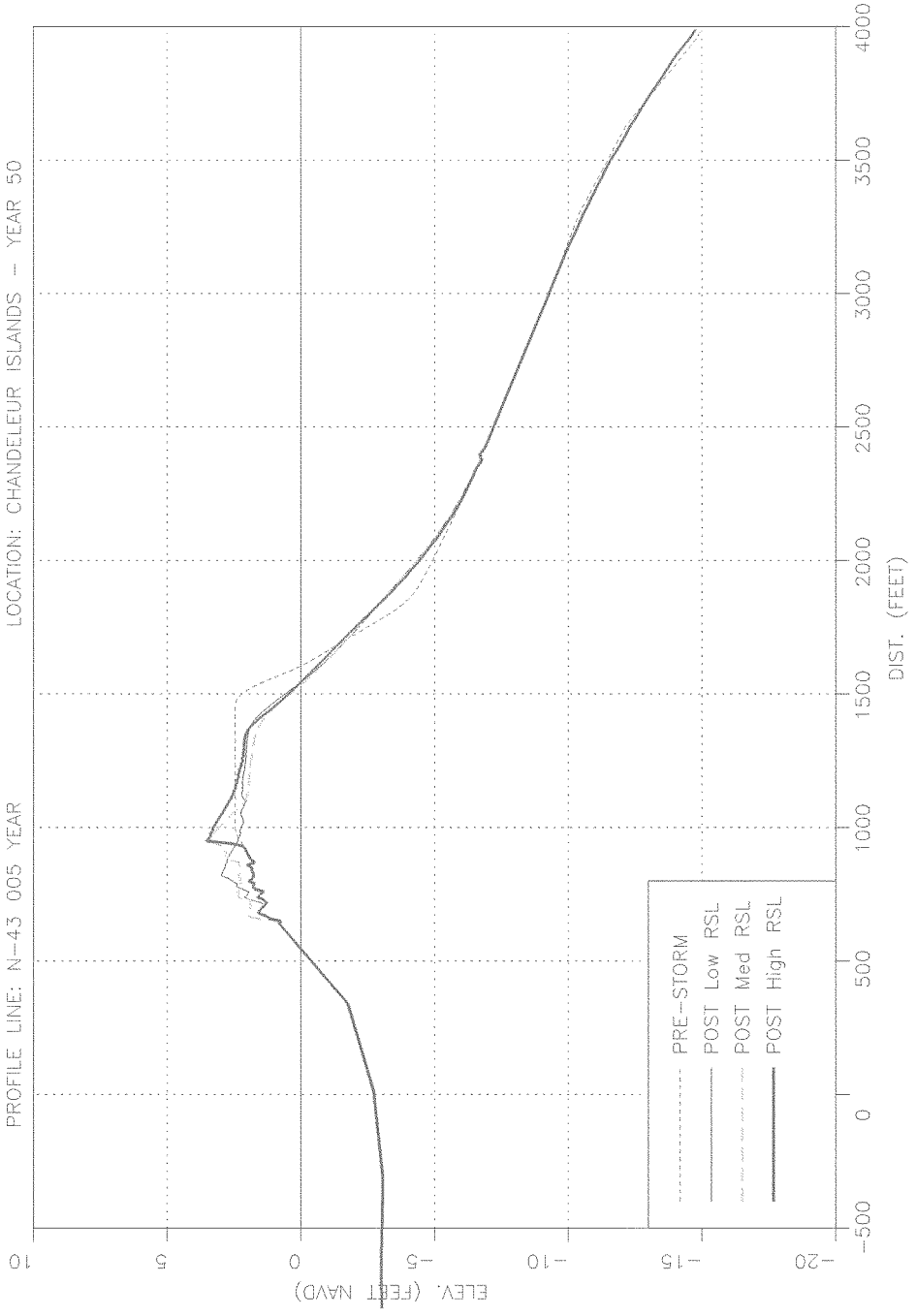

PROFILE LINE: N-42 100 YEAR
LOCATION: CHANDELEUR ISLANDS -- YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
POST Med RSL
POST High RSL
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

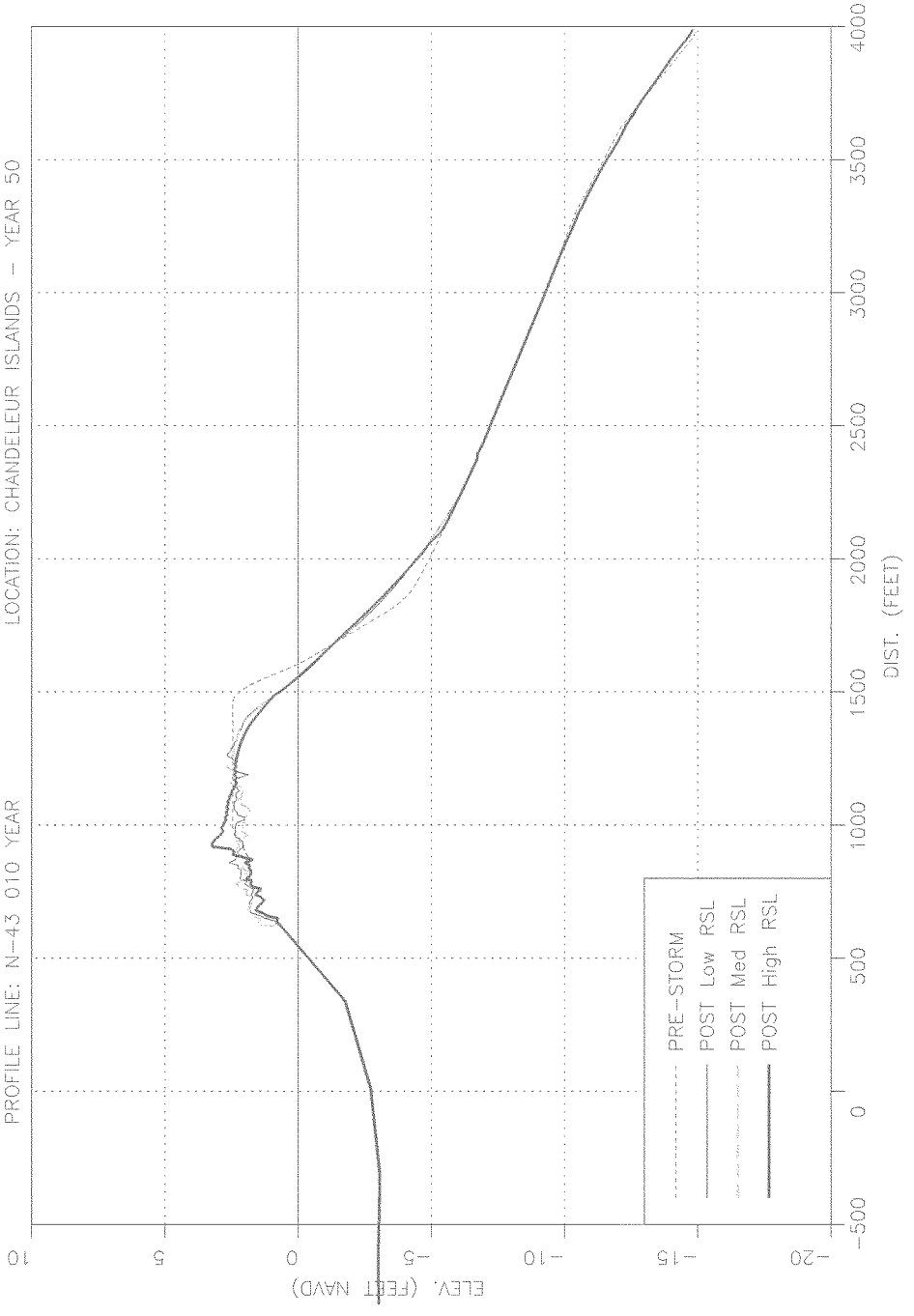

PROFILE LINE: N-43 001 YEAR
LOCATION: CHANDELEUR ISLANDS -- YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
POST Med RSL
POST High RSL
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

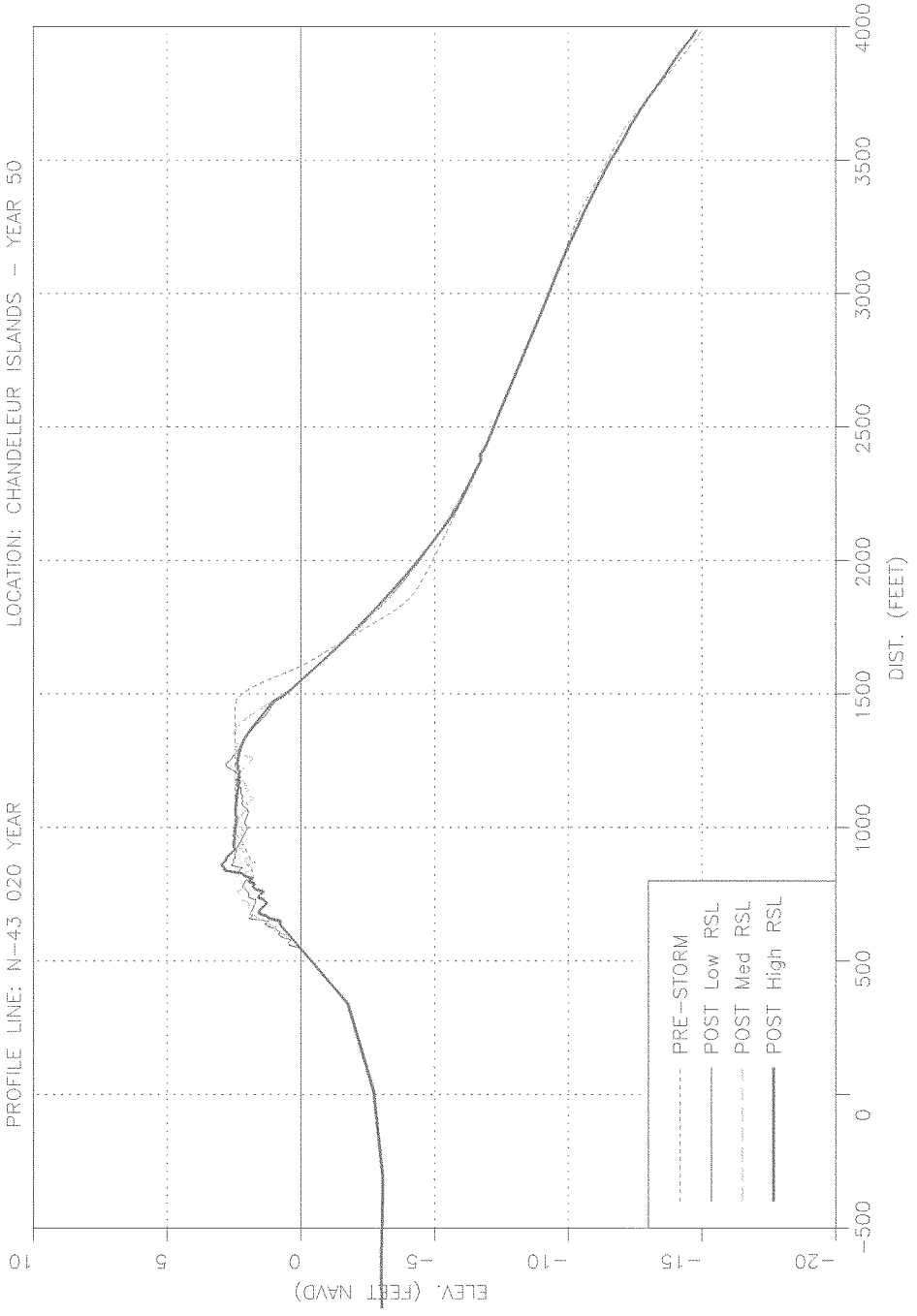

PROFILE LINE: N-43 002 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
POST Med RSL
POST High RSL
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

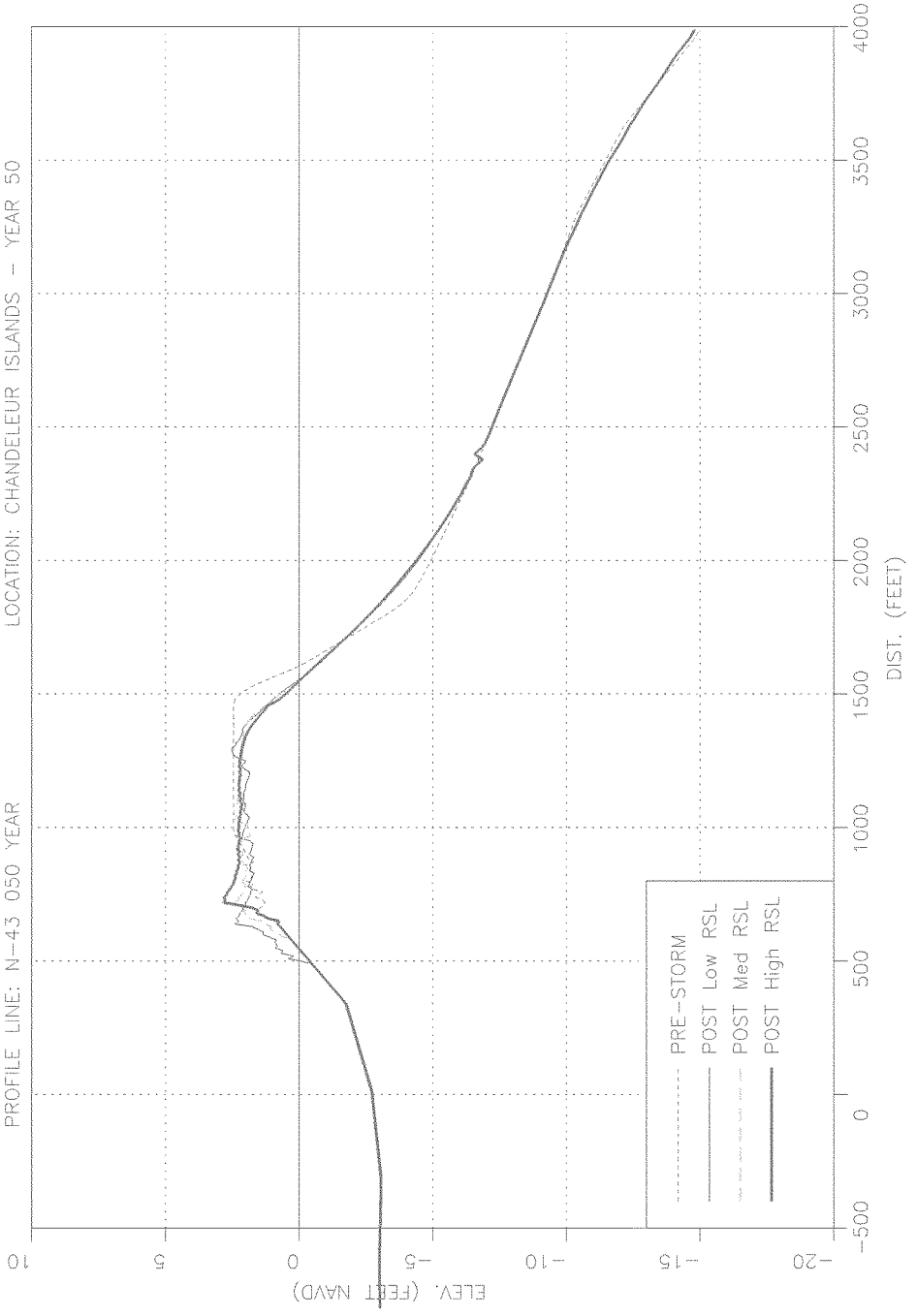

PROFILE LINE: N-43 003 YEAR
LOCATION: CHANDELEUR ISLANDS -- YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
POST Med RSL
POST High RSL
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

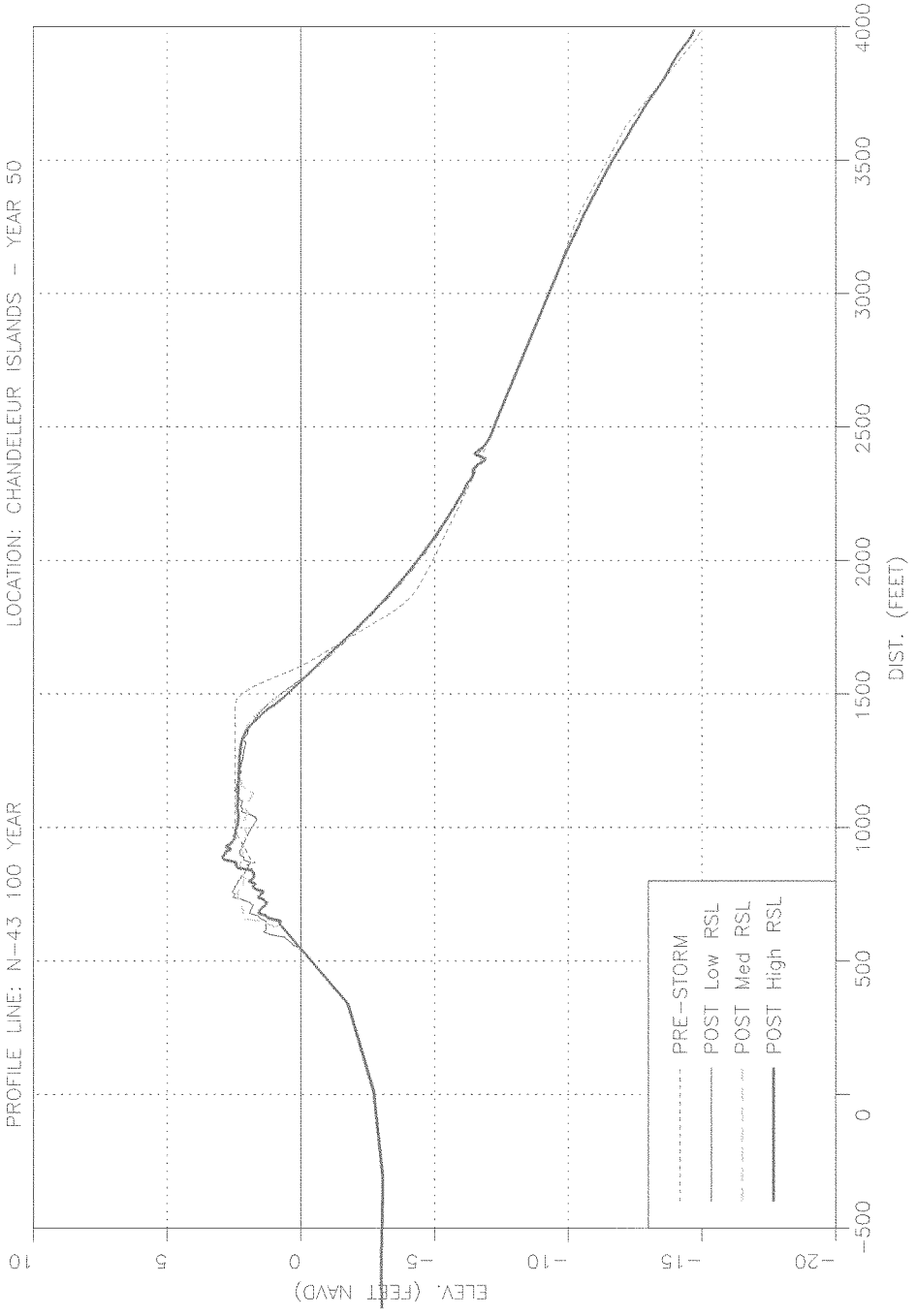

PROFILE LINE: N-43 004 YEAR
LOCATION: CHANDELEUR ISLANDS -- YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
POST Med RSL
POST High RSL
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000


PROFILE LINE: N-43 005 YEAR
LOCATION: CHANDELEUR ISLANDS -- YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
POST Med RSL
POST High RSL
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000


PROFILE LINE: N-43 010 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
POST Med RSL
POST High RSL
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000


PROFILE LINE: N-43 020 YEAR
LOCATION: CHANDELEUR ISLANDS -- YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
POST Med RSL
POST High RSL
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000


PROFILE LINE: N-43 050 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
POST Med RSL
POST High RSL
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

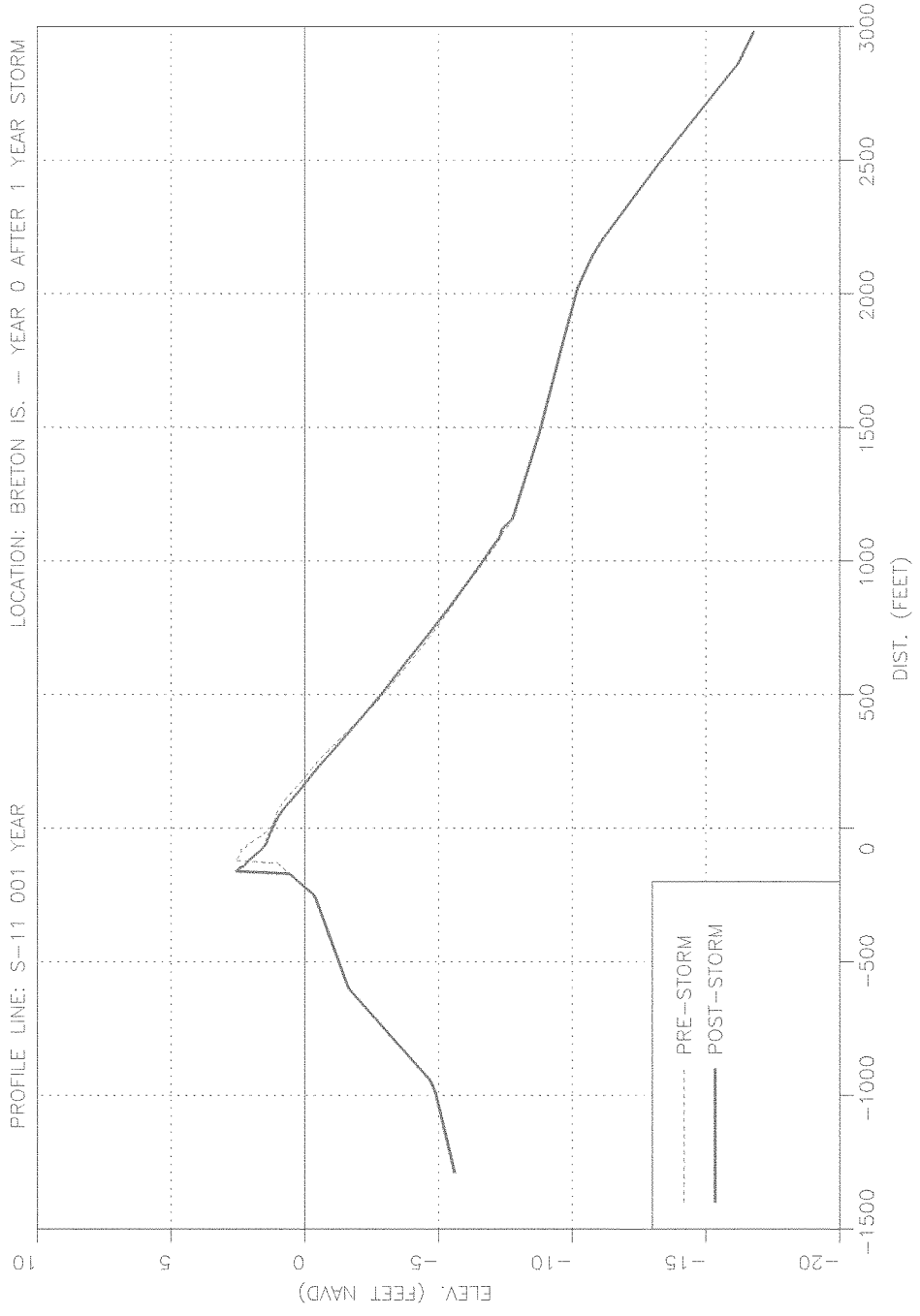

PROFILE LINE: N-43 100 YEAR
LOCATION: CHANDELEUR ISLANDS - YEAR 50
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
POST Med RSL
POST High RSL
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

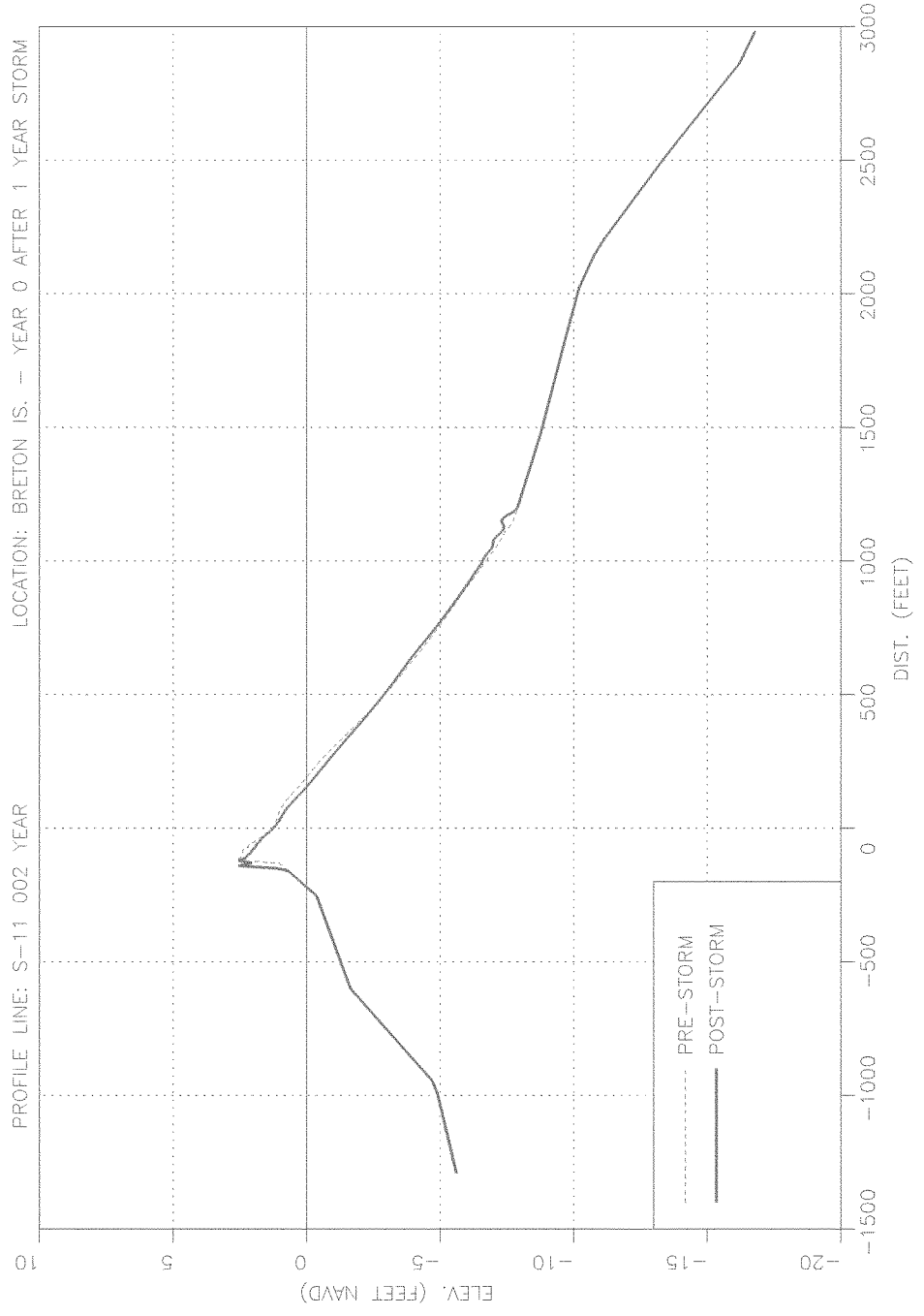
SUB-APPENDIX C-3

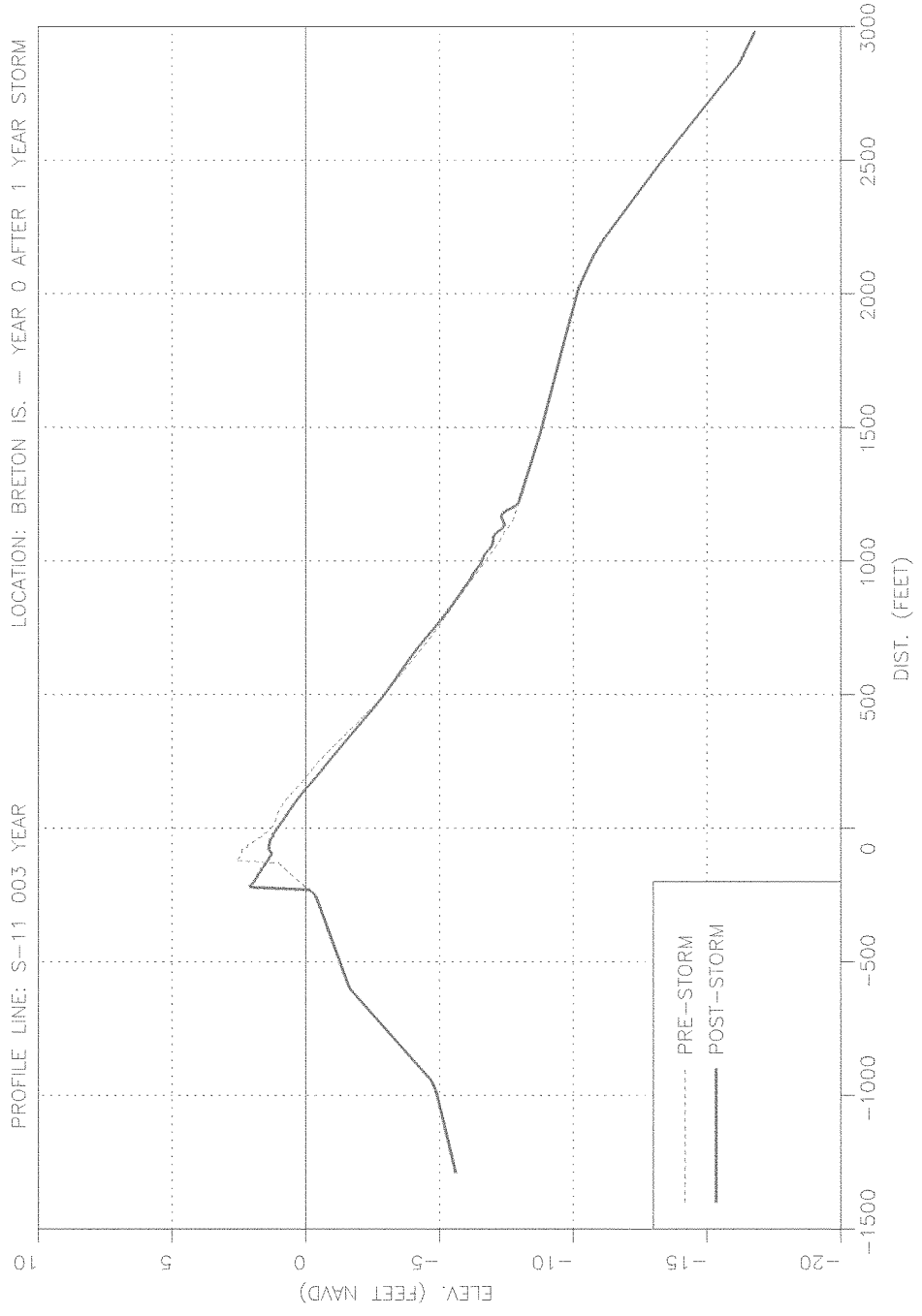
SBEACH PROFILES USING THE 1 YEAR POST-STORM PROFILE AS THE PRE-STORM CONDITION

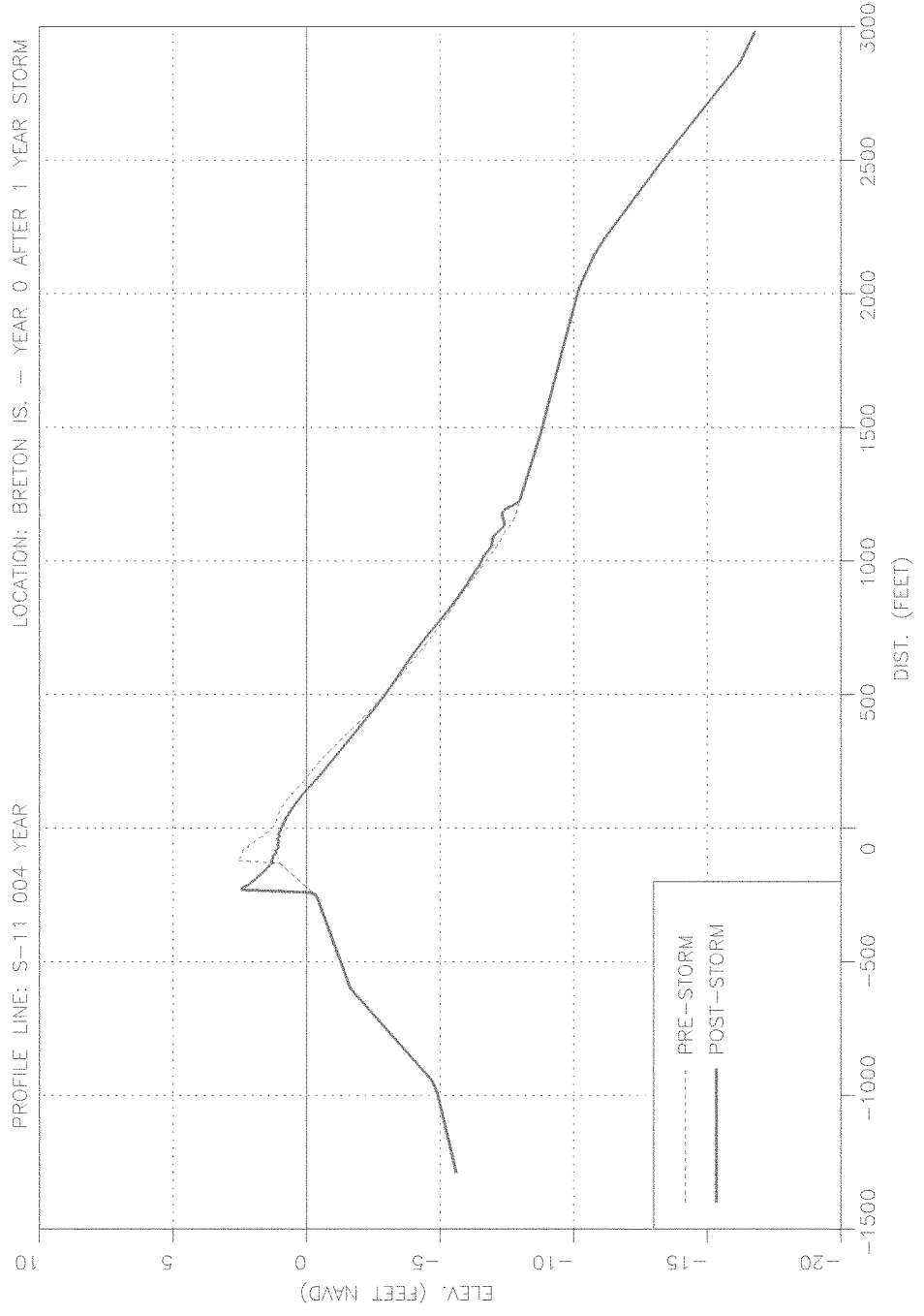
WITHOUT PROJECT CONDITIONS

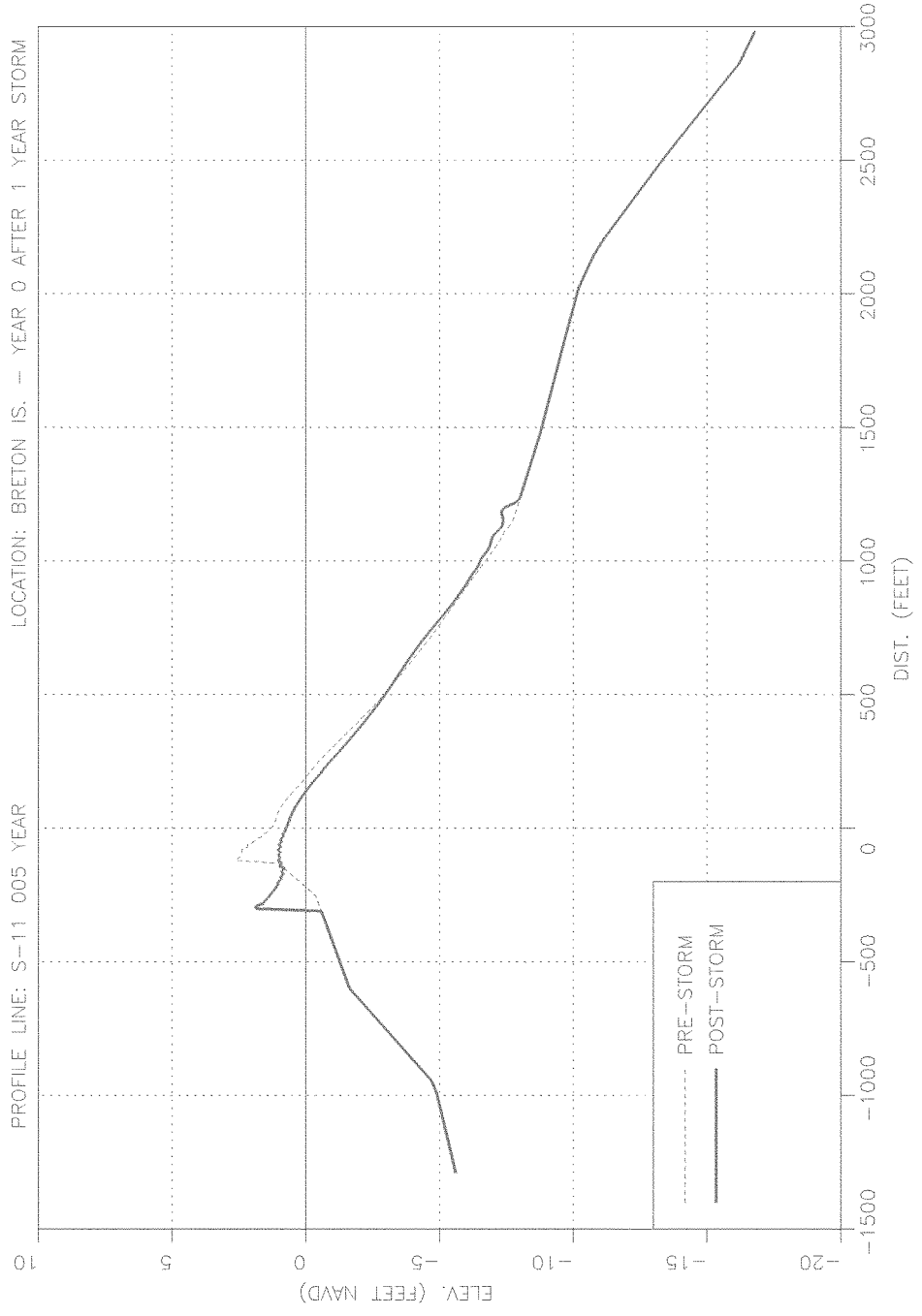
(Profiles are presented in electronic PDF format only)

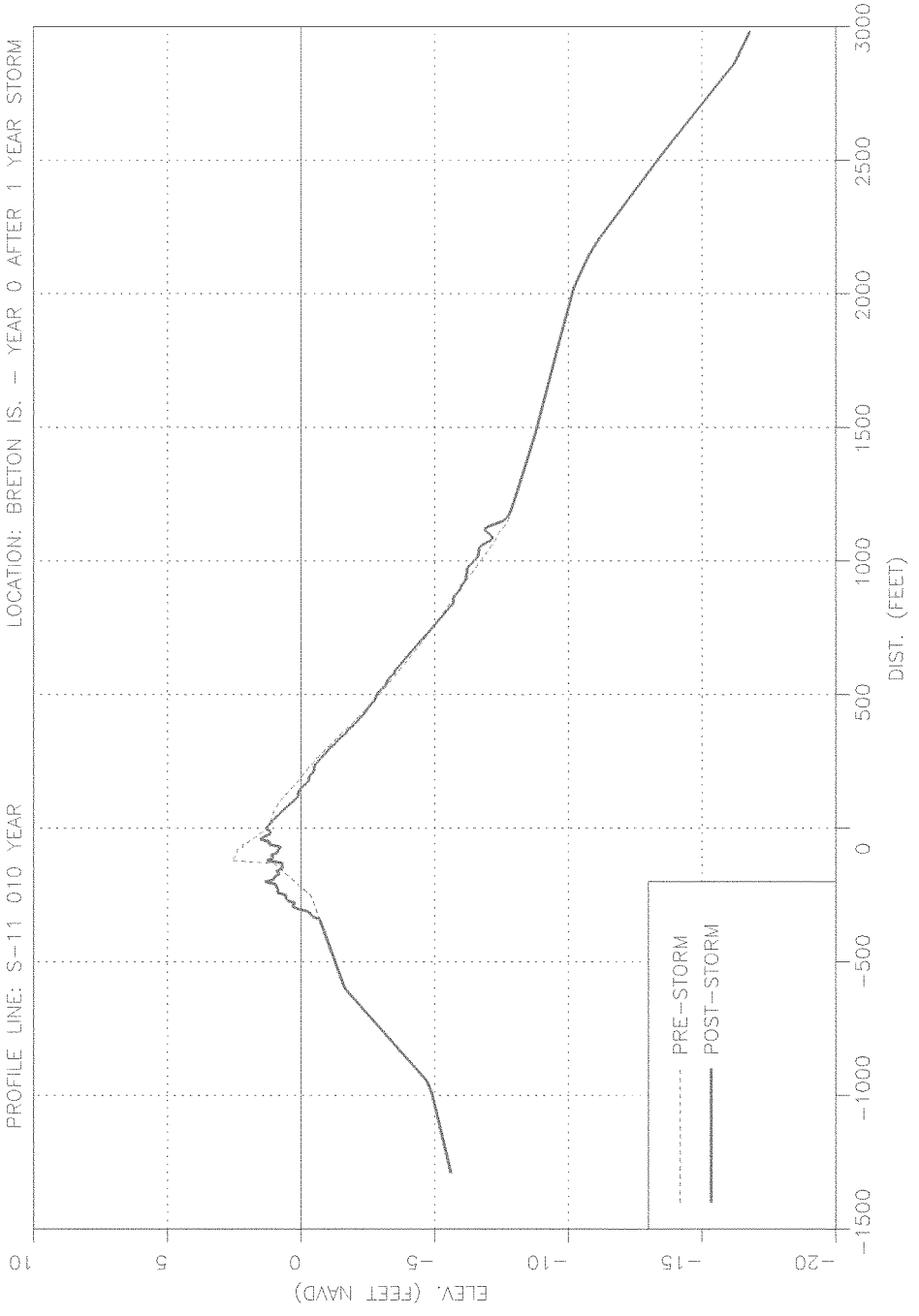

PROFILE LINE: S-11 001 YEAR
LOCATION: BRETON IS. -- YEAR 0 AFTER 1 YEAR STORM
ELEV. (FEET NAVD)
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000
DIST. (FEET)
PRE-STORM
POST-STORM

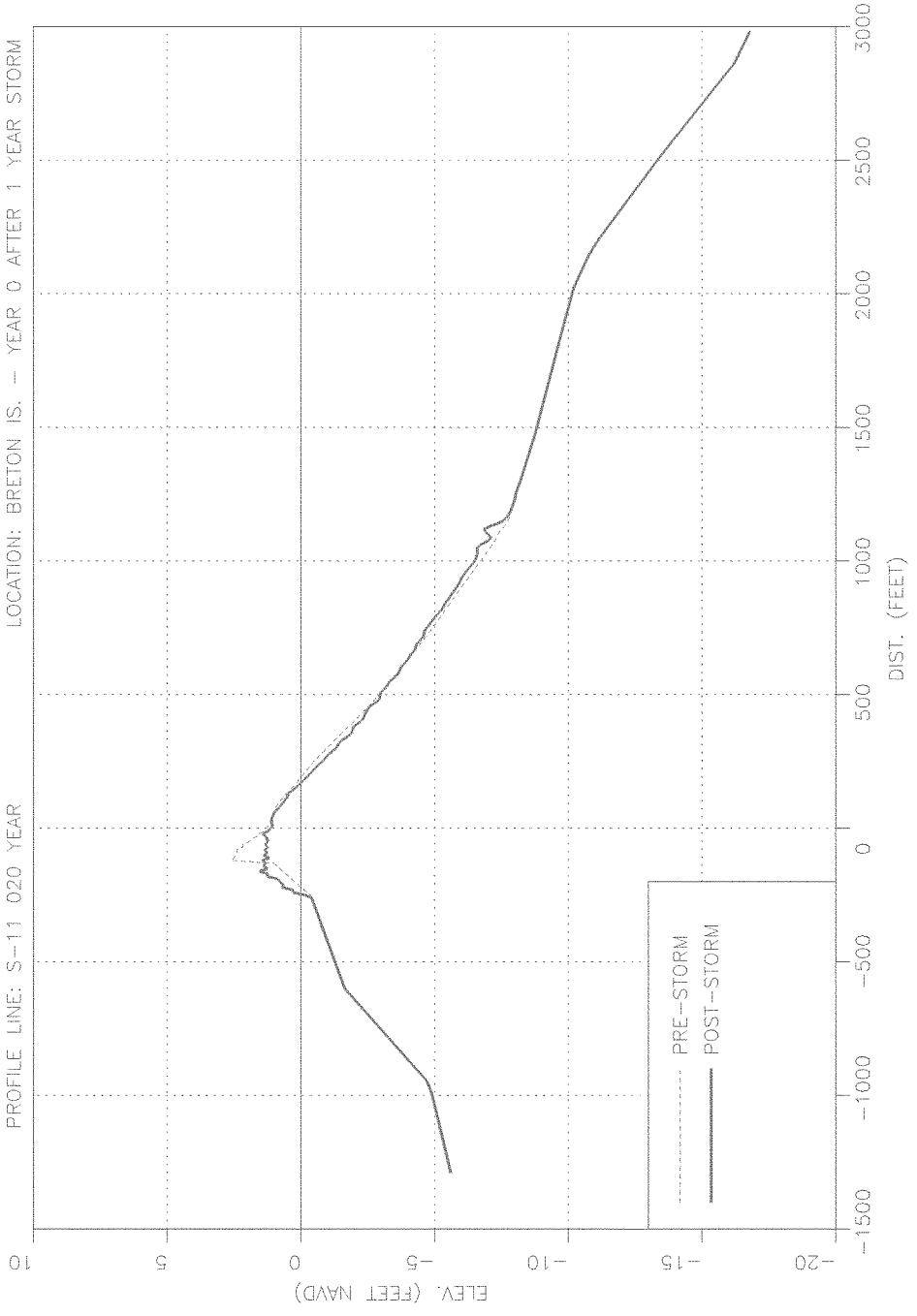

PROFILE LINE: S-11 002 YEAR
LOCATION: BRETON IS. -- YEAR 0 AFTER 1 YEAR STORM
PRE-STORM
POST-STORM
ELEV. (FEET NAVD)
DIST. (FEET)
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

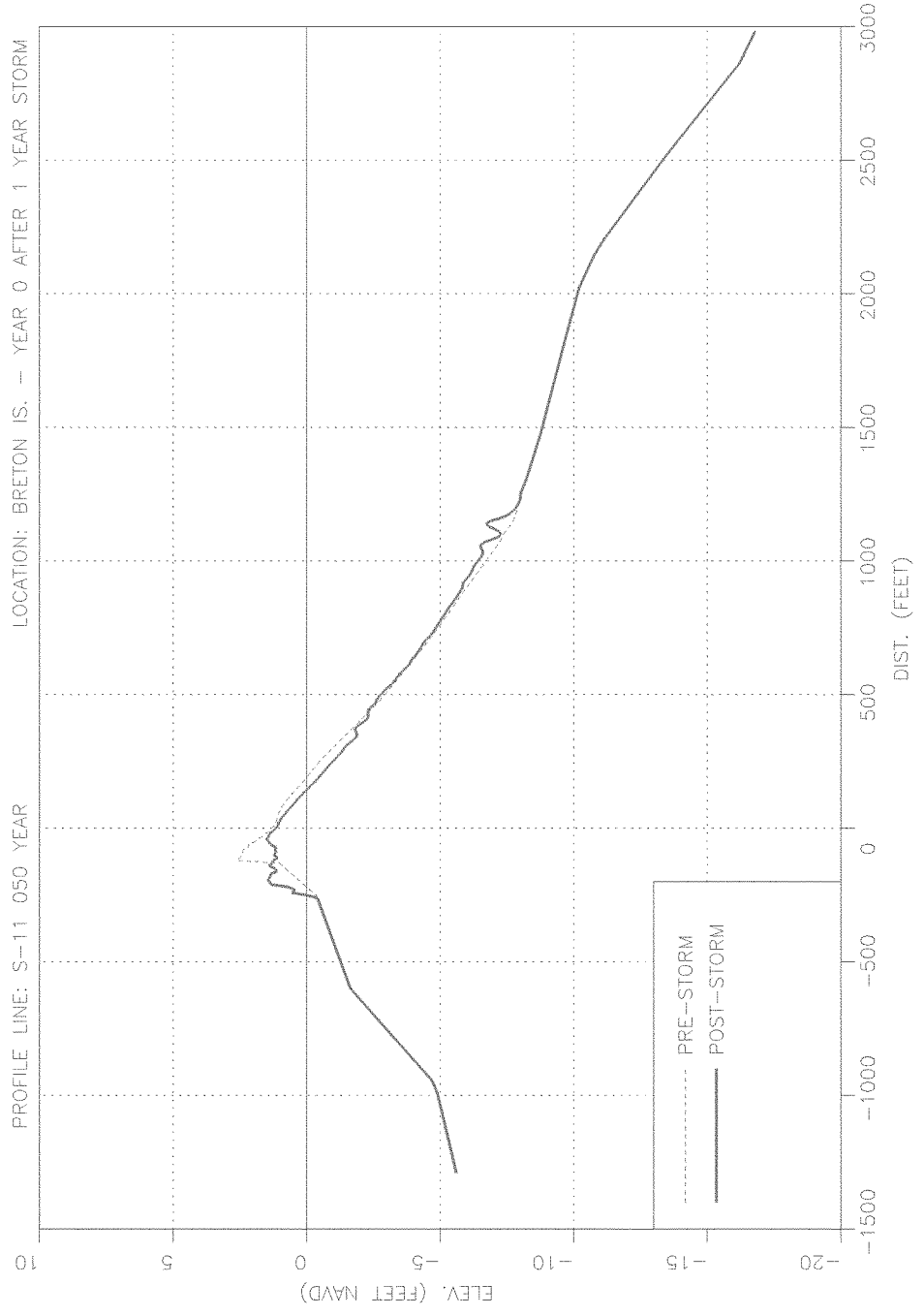

PROFILE LINE: S-11 003 YEAR
LOCATION: BRETON IS. -- YEAR 0 AFTER 1 YEAR STORM
ELEV. (FEET NAVD)
10
5
0
-5
-10
-15
-20
DIST. (FEET)
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000
PRE-STORM
POST-STORM

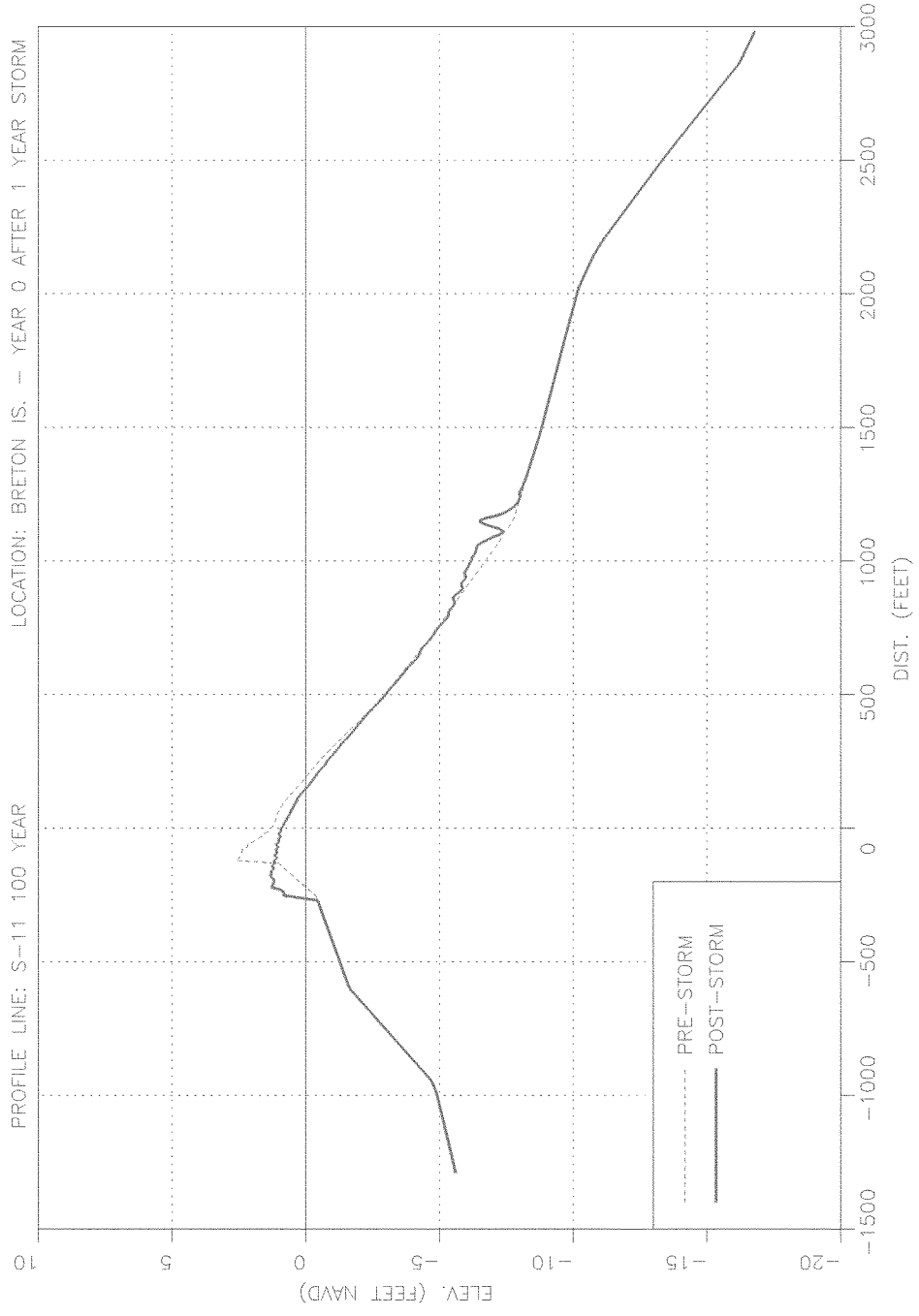

PROFILE LINE: S-11 004 YEAR
LOCATION: BRETON IS. -- YEAR 0 AFTER 1 YEAR STORM
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

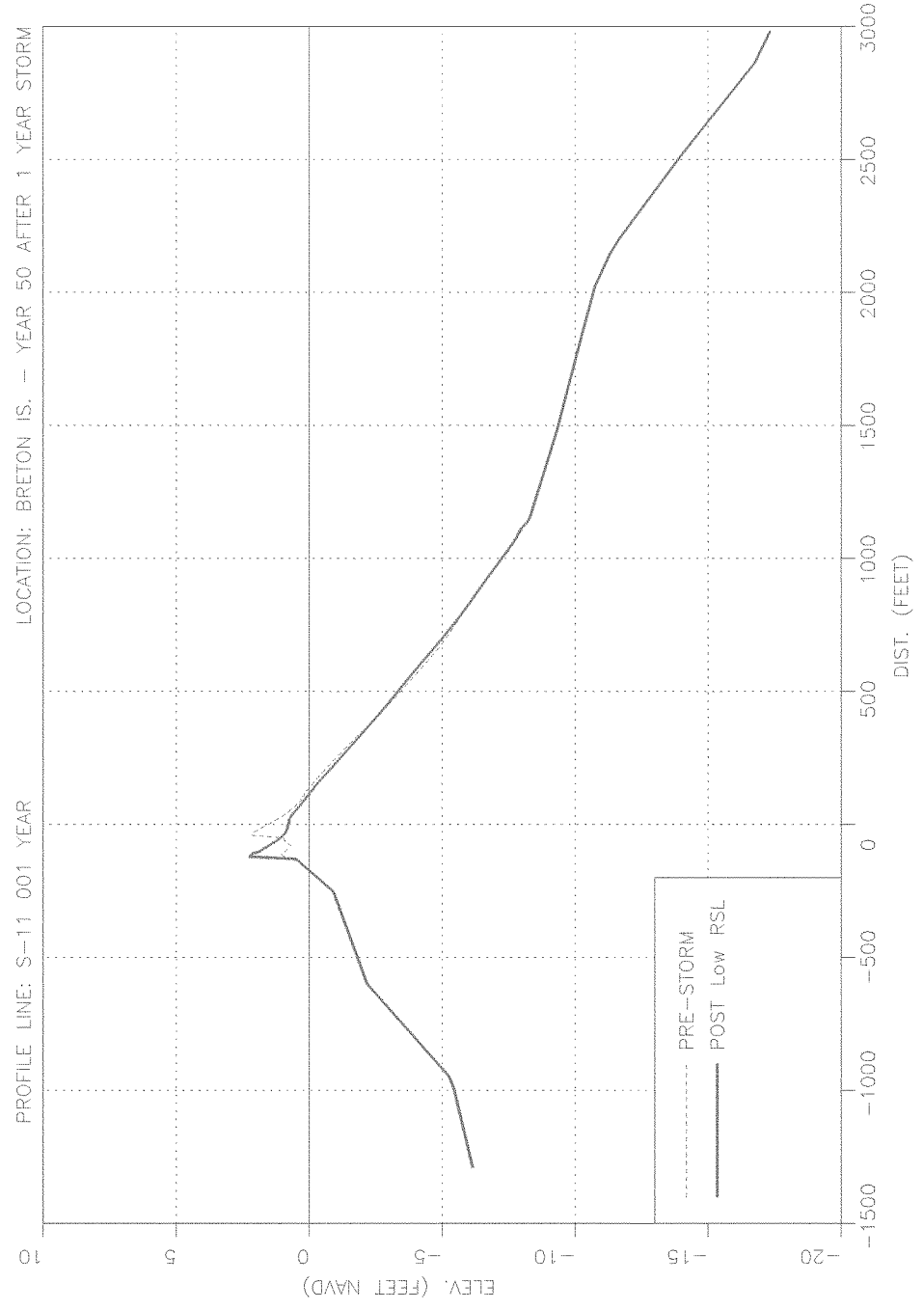

PROFILE LINE: S-11 005 YEAR
LOCATION: BRETON IS. -- YEAR 0 AFTER 1 YEAR STORM
ELEV. (FEET NAVD)
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000
DIST. (FEET)
PRE-STORM
POST-STORM

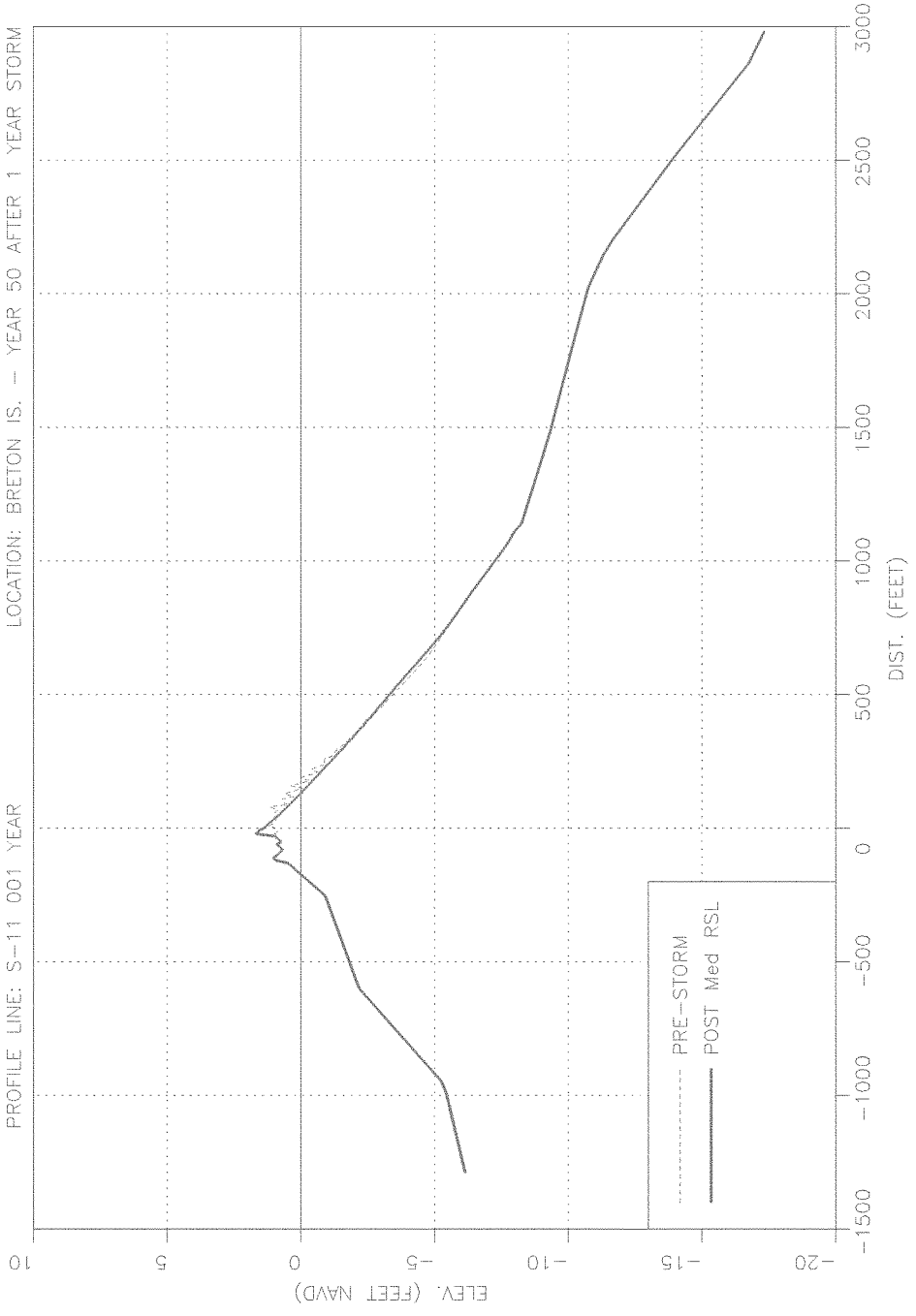

PROFILE LINE: S-11 010 YEAR
LOCATION: BRETON IS. -- YEAR 0 AFTER 1 YEAR STORM
PRE-STORM
POST-STORM
ELEV. (FEET NAVD)
DIST. (FEET)
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

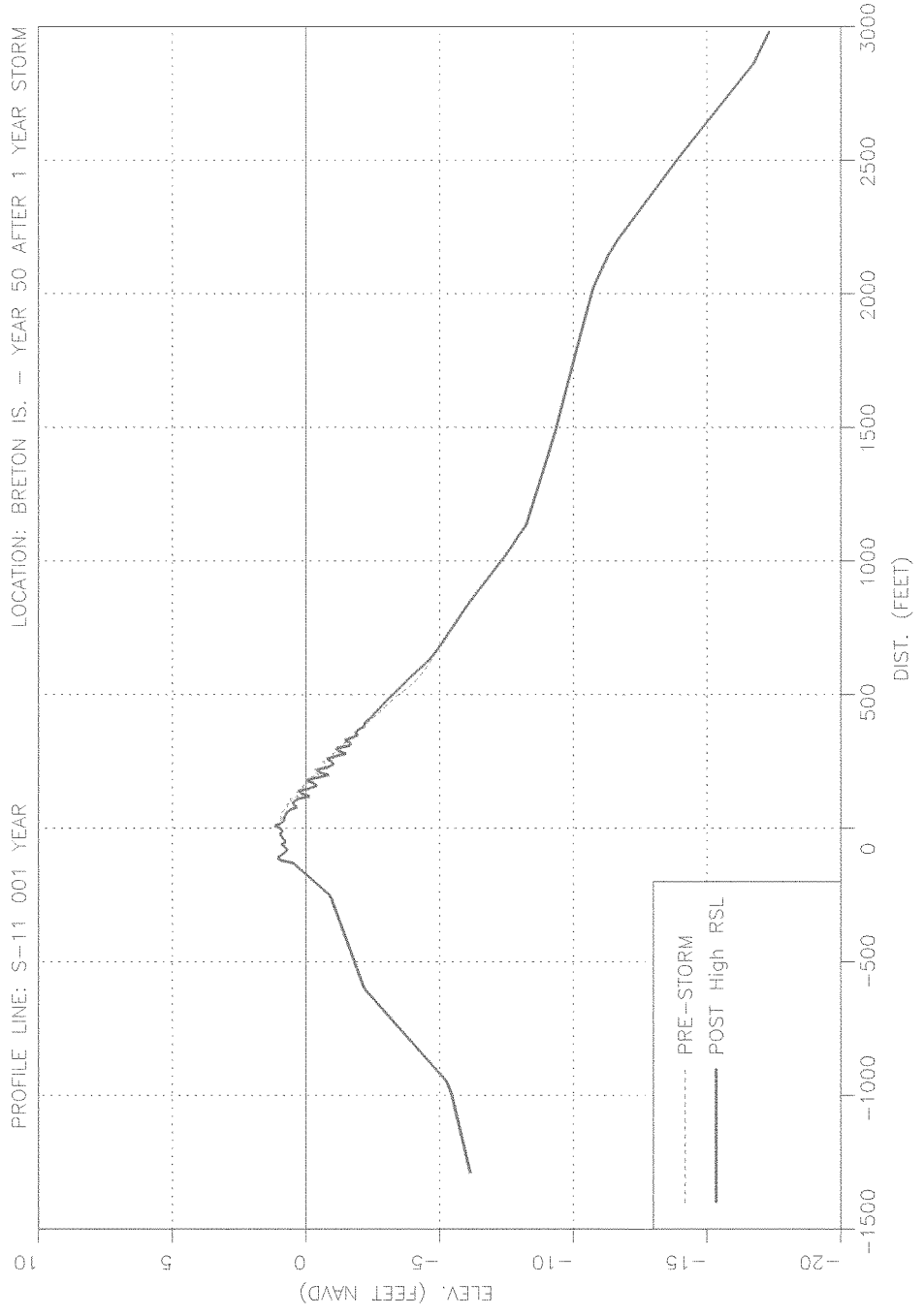

PROFILE LINE: S-11 020 YEAR
LOCATION: BRETON IS. -- YEAR 0 AFTER 1 YEAR STORM
ELEV. (FEET NAVD)
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000
DIST. (FEET)
PRE-STORM
POST-STORM

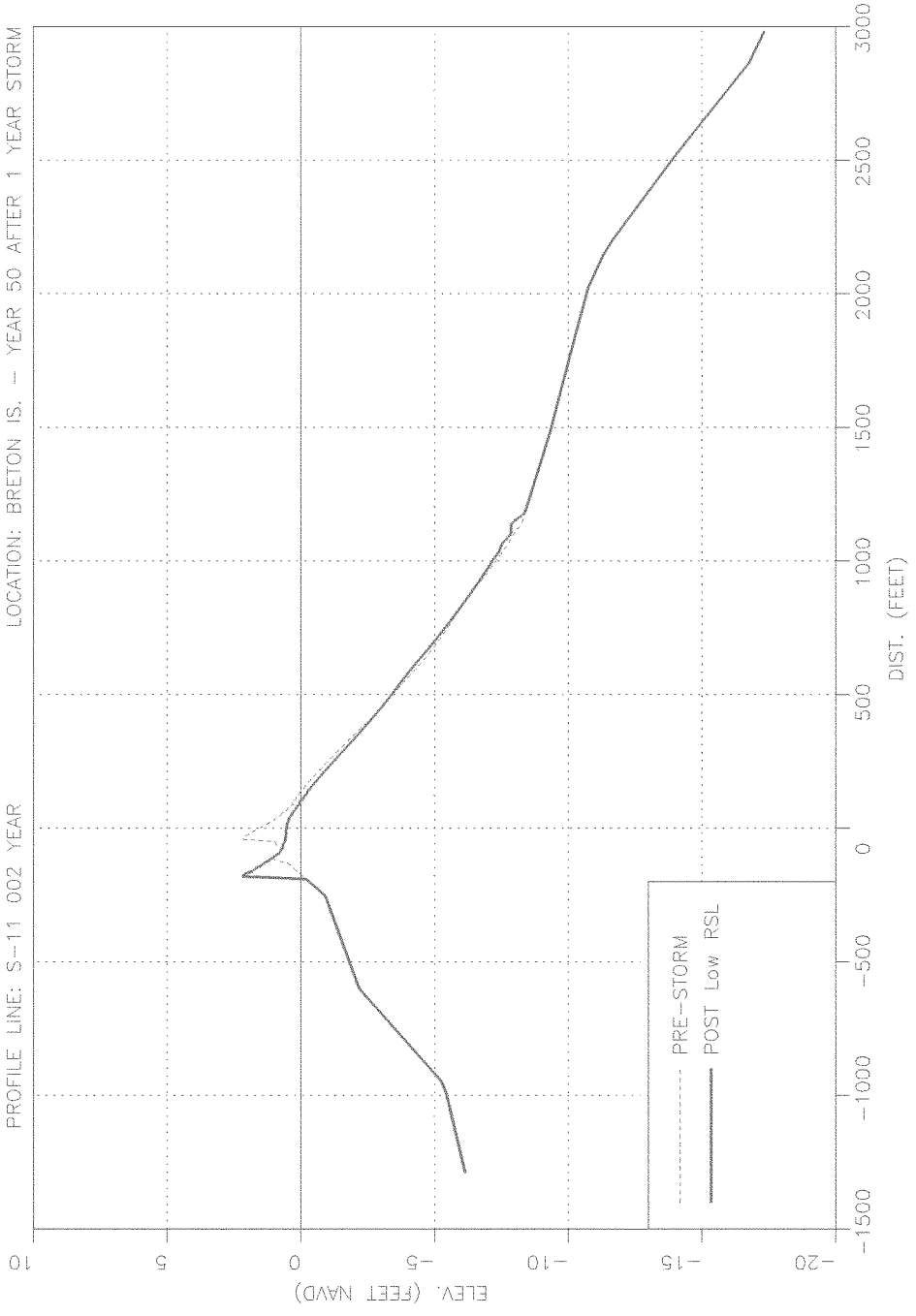

PROFILE LINE: S-11 050 YEAR
LOCATION: BRETON IS. -- YEAR 0 AFTER 1 YEAR STORM
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

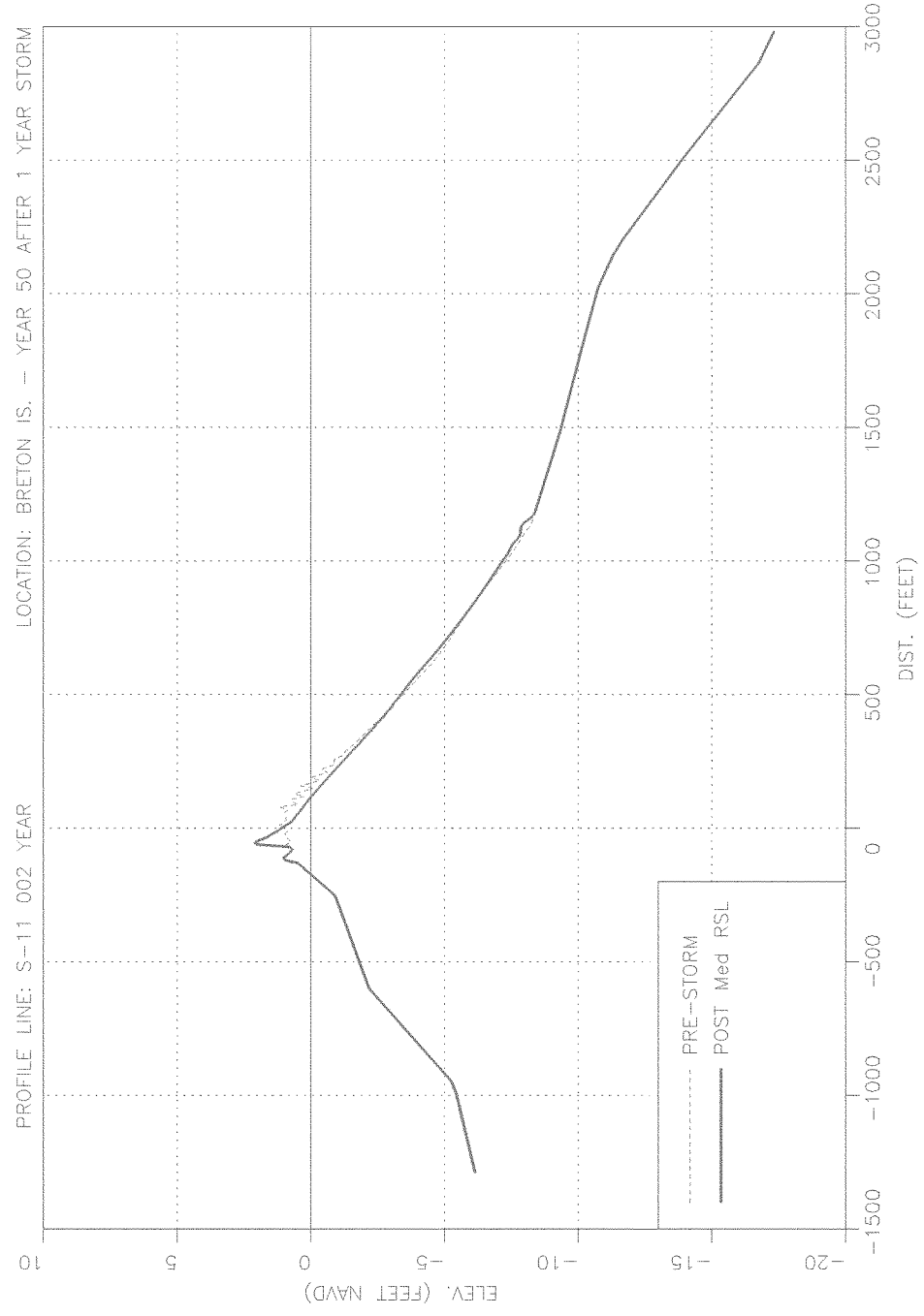

PROFILE LINE: S-11 100 YEAR
LOCATION: BRETON IS. -- YEAR 0 AFTER 1 YEAR STORM
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

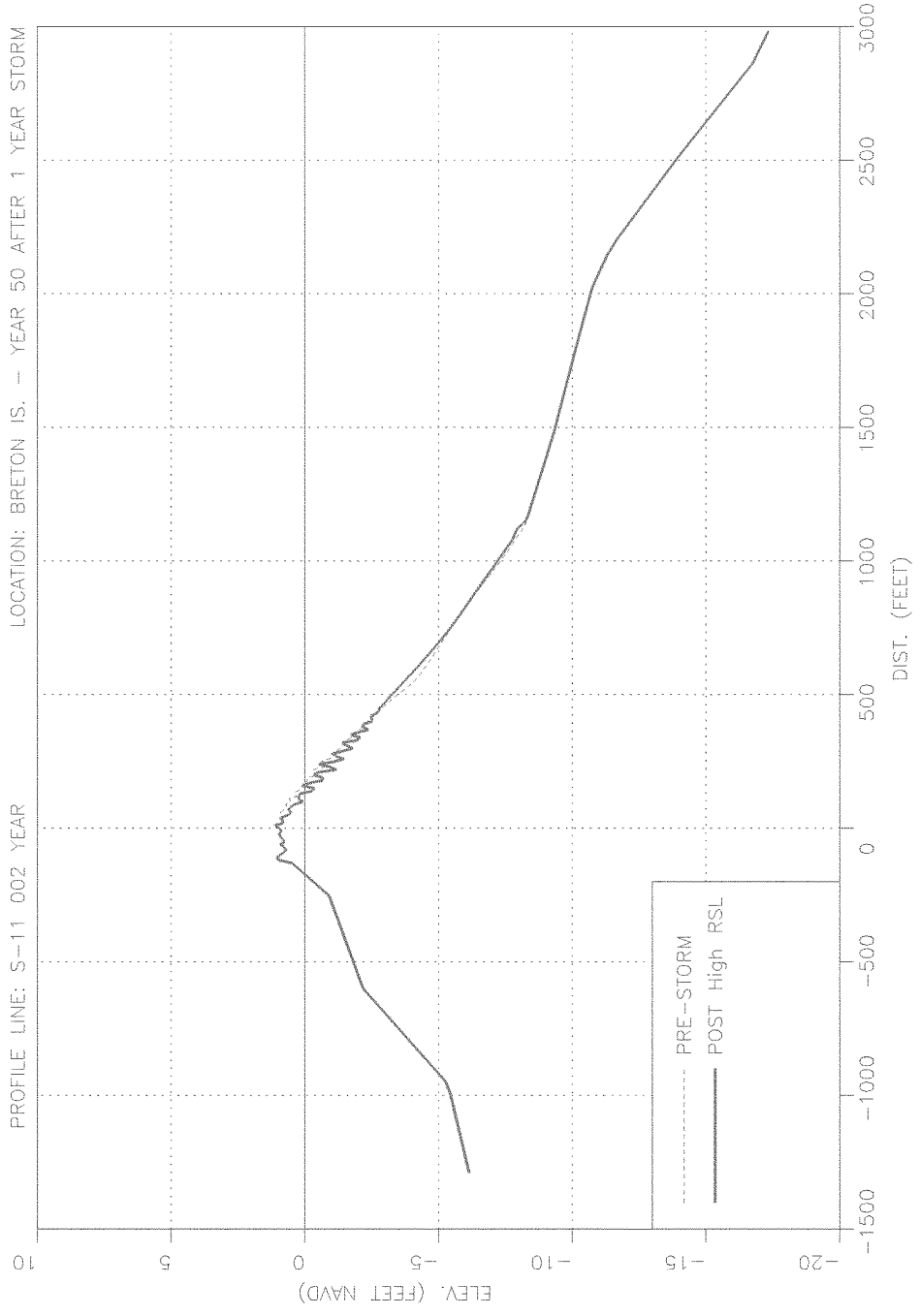

PROFILE LINE: S-11 001 YEAR
LOCATION: BRETON IS. - YEAR 50 AFTER 1 YEAR STORM
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

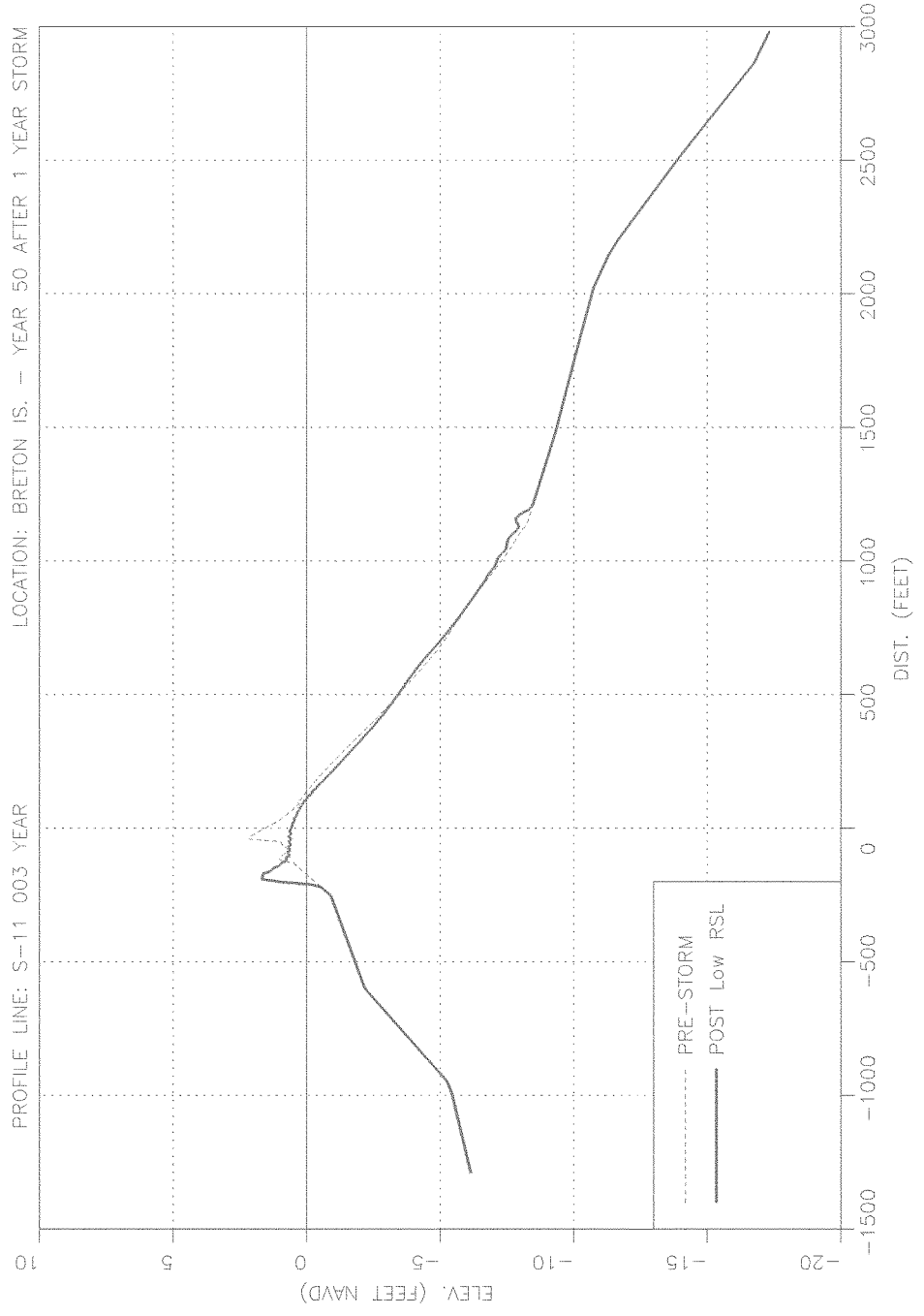

PROFILE LINE: S-11 001 YEAR
LOCATION: BRETON IS. - YEAR 50 AFTER 1 YEAR STORM
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Med RSL
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

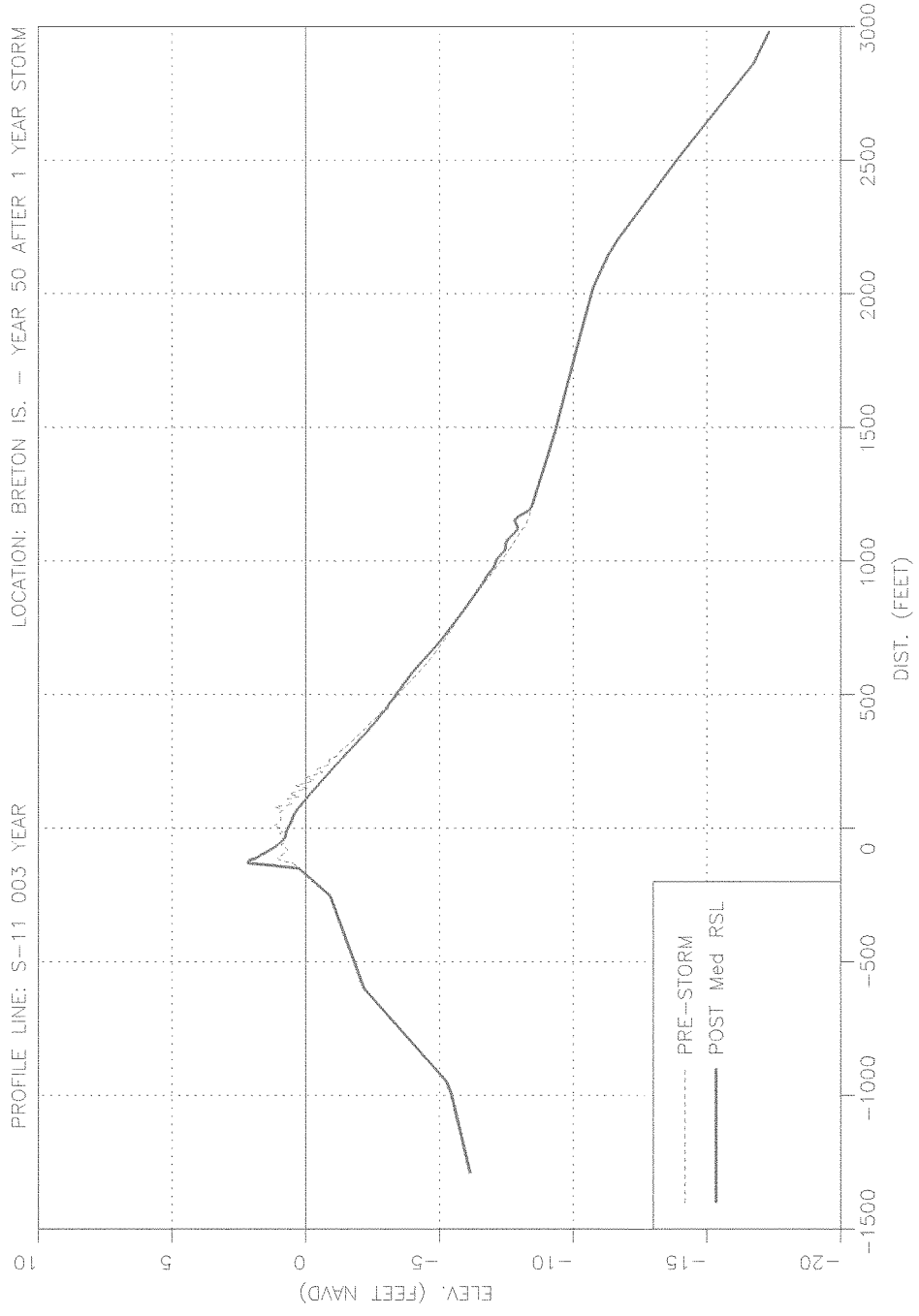

PROFILE LINE: S-11 001 YEAR
LOCATION: BRETON IS. - YEAR 50 AFTER 1 YEAR STORM
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST High RSL
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

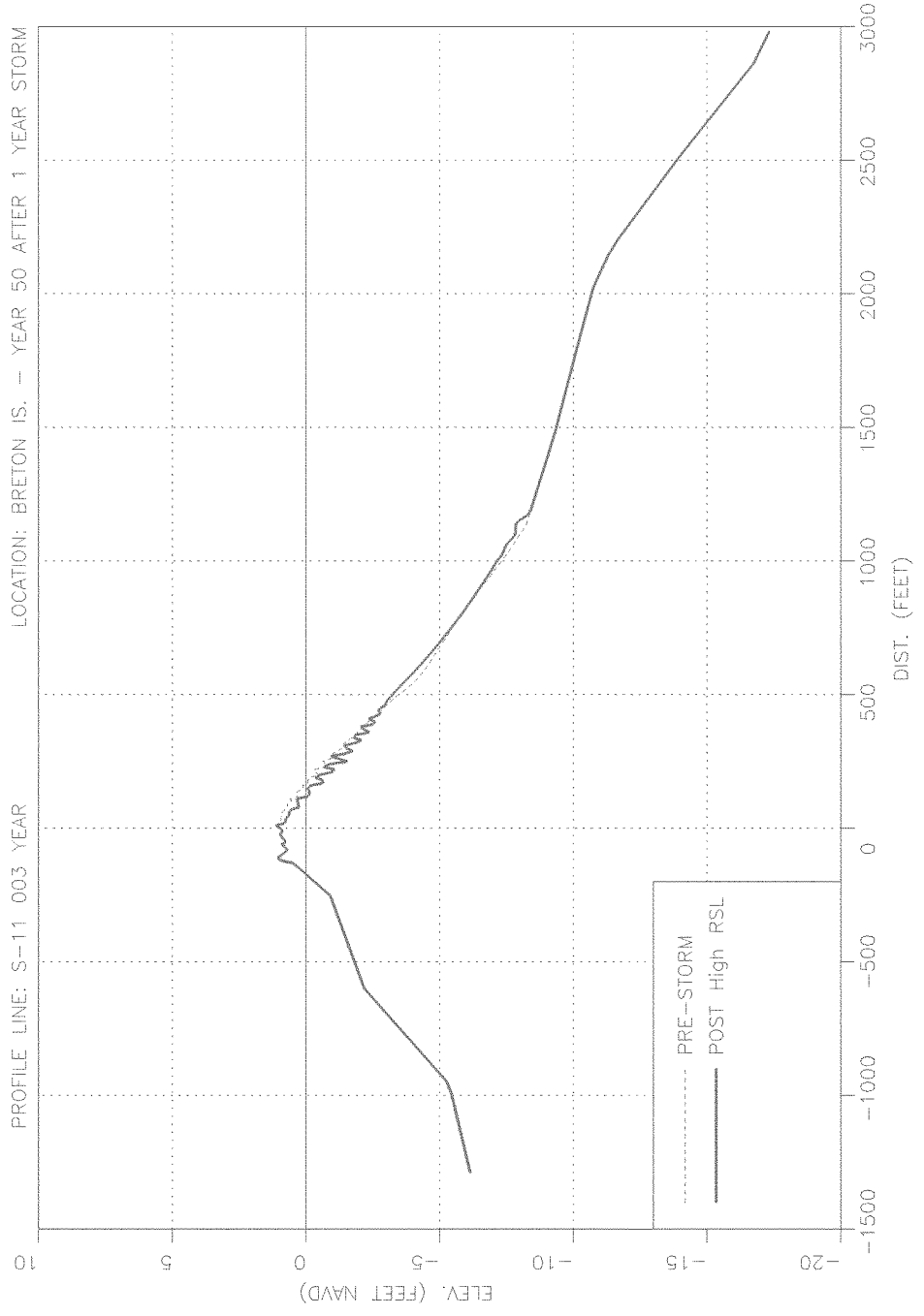

PROFILE LINE: S-11 002 YEAR
LOCATION: BRETON IS. - YEAR 50 AFTER 1 YEAR STORM
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

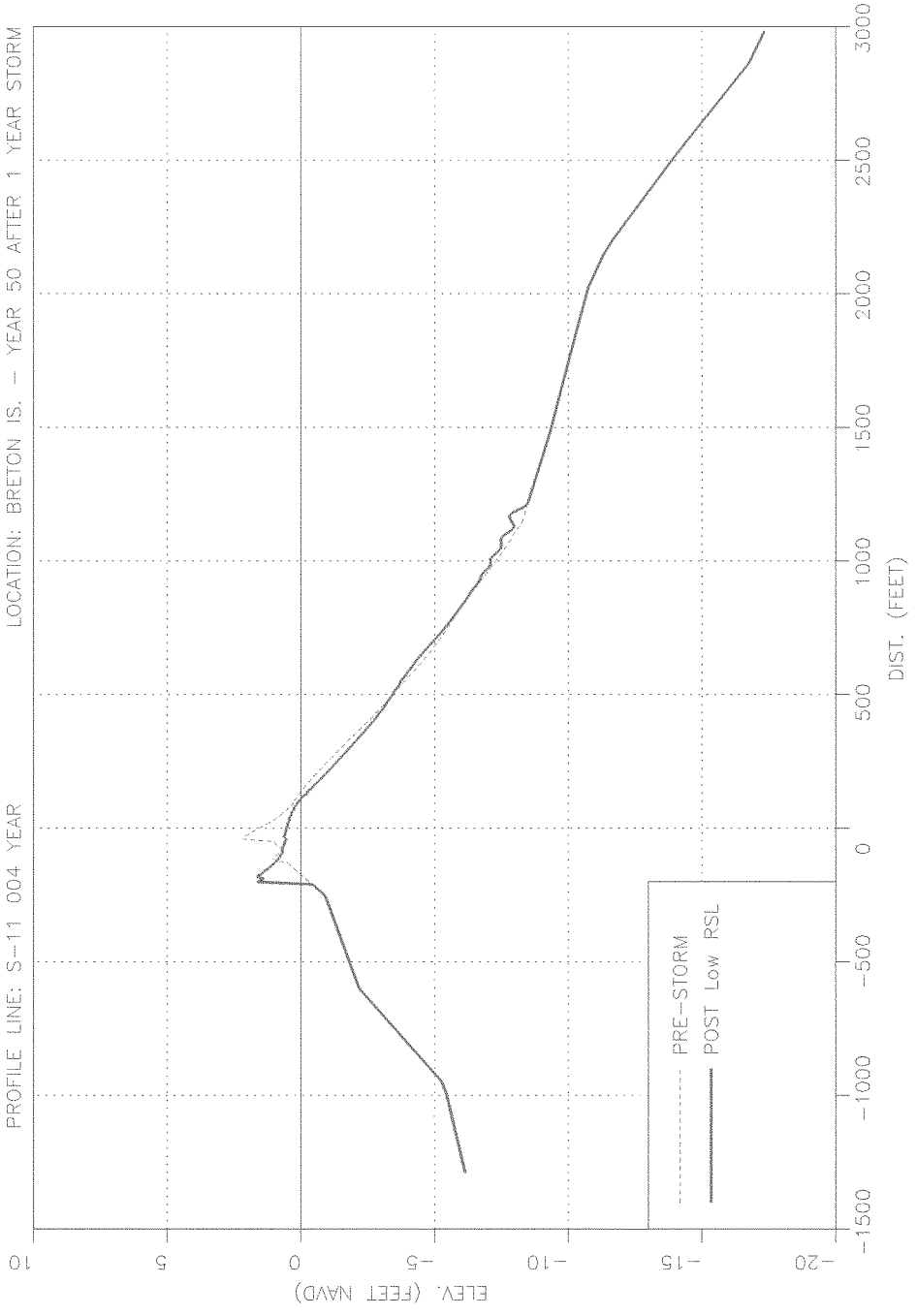

PROFILE LINE: S-11 002 YEAR
LOCATION: BRETON IS. - YEAR 50 AFTER 1 YEAR STORM
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Med RSL
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

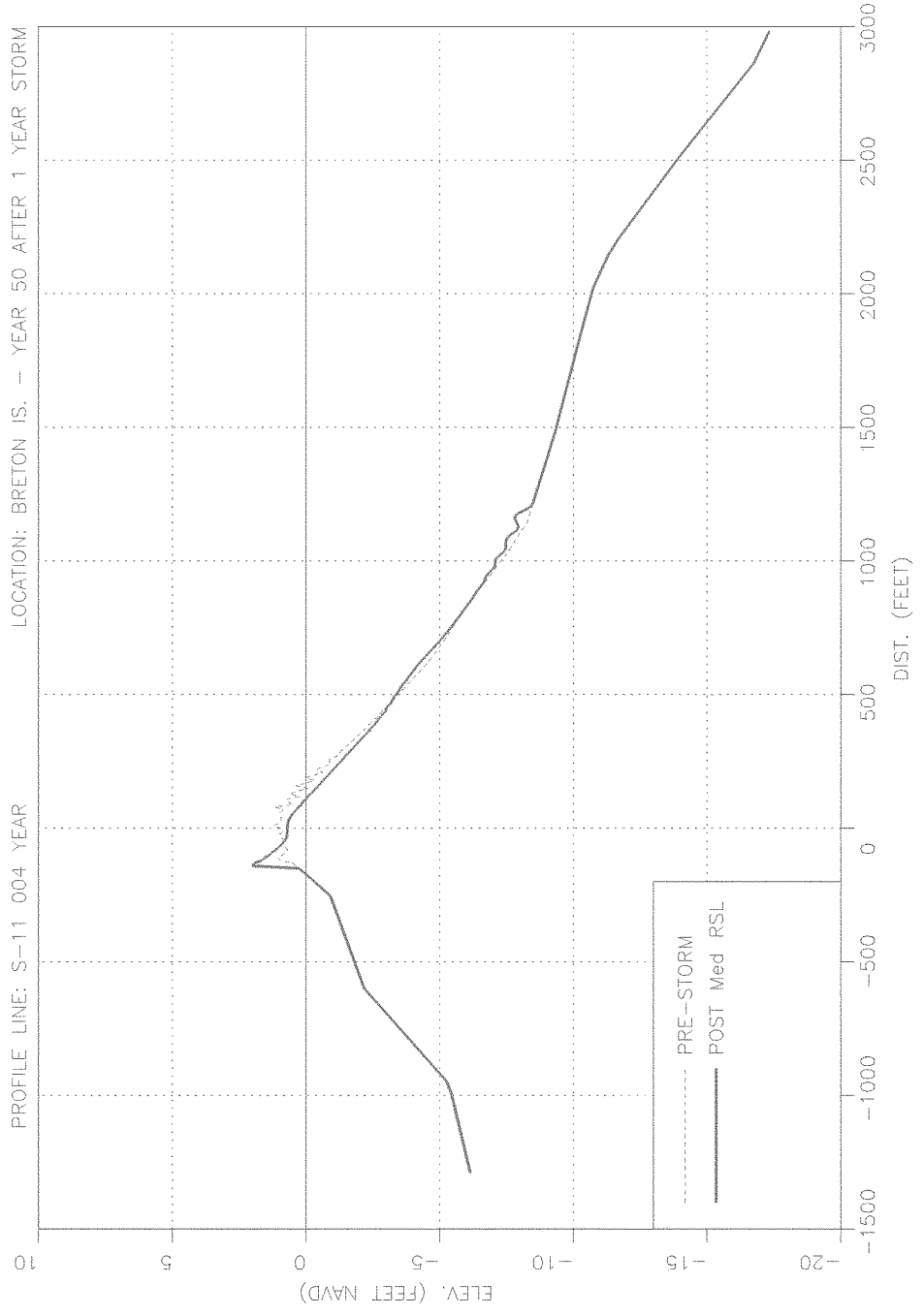

PROFILE LINE: S-11 002 YEAR
LOCATION: BRETON IS. - YEAR 50 AFTER 1 YEAR STORM
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST High RSL
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

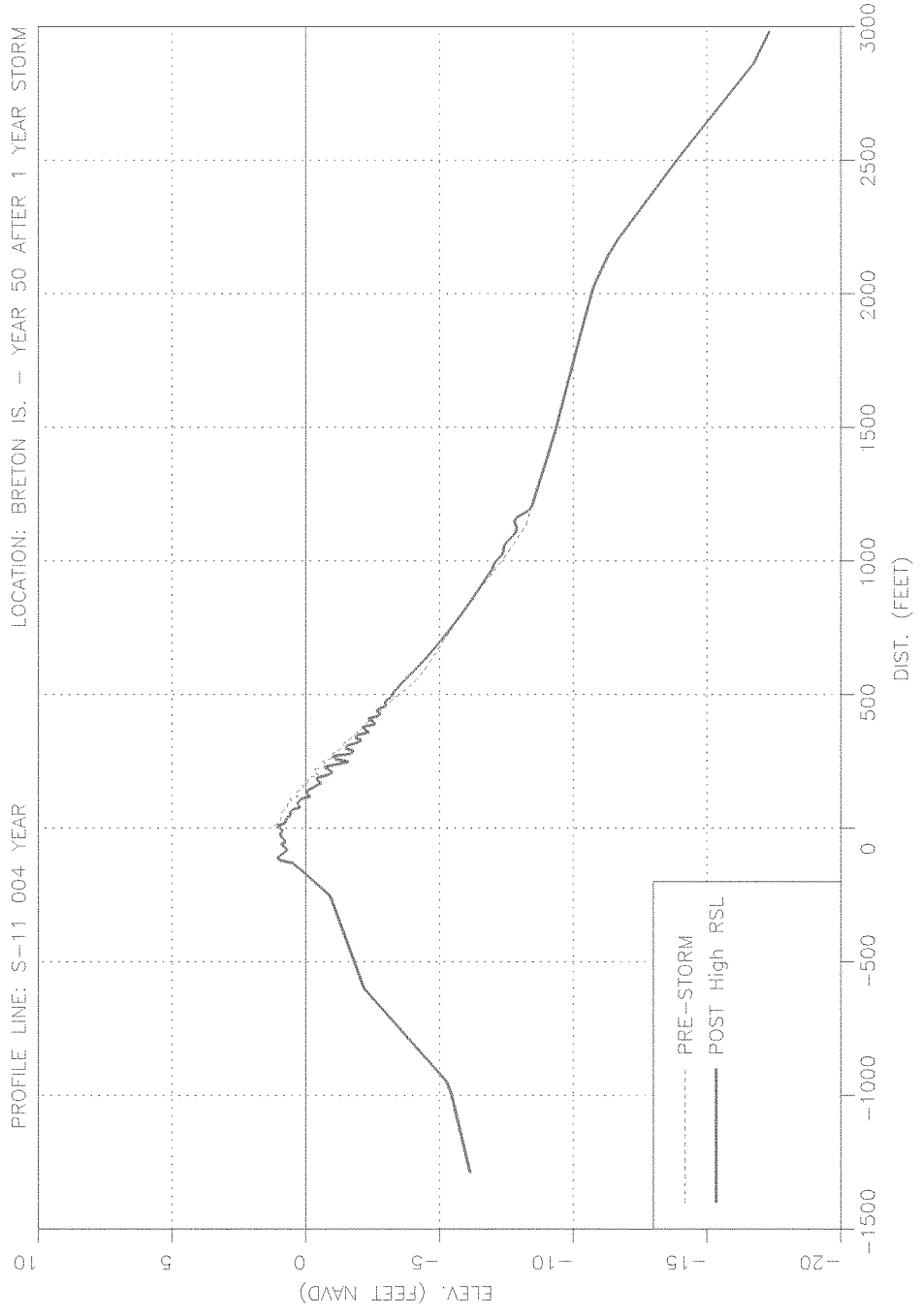

PROFILE LINE: S-11 003 YEAR
LOCATION: BRETON IS. - YEAR 50 AFTER 1 YEAR STORM
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

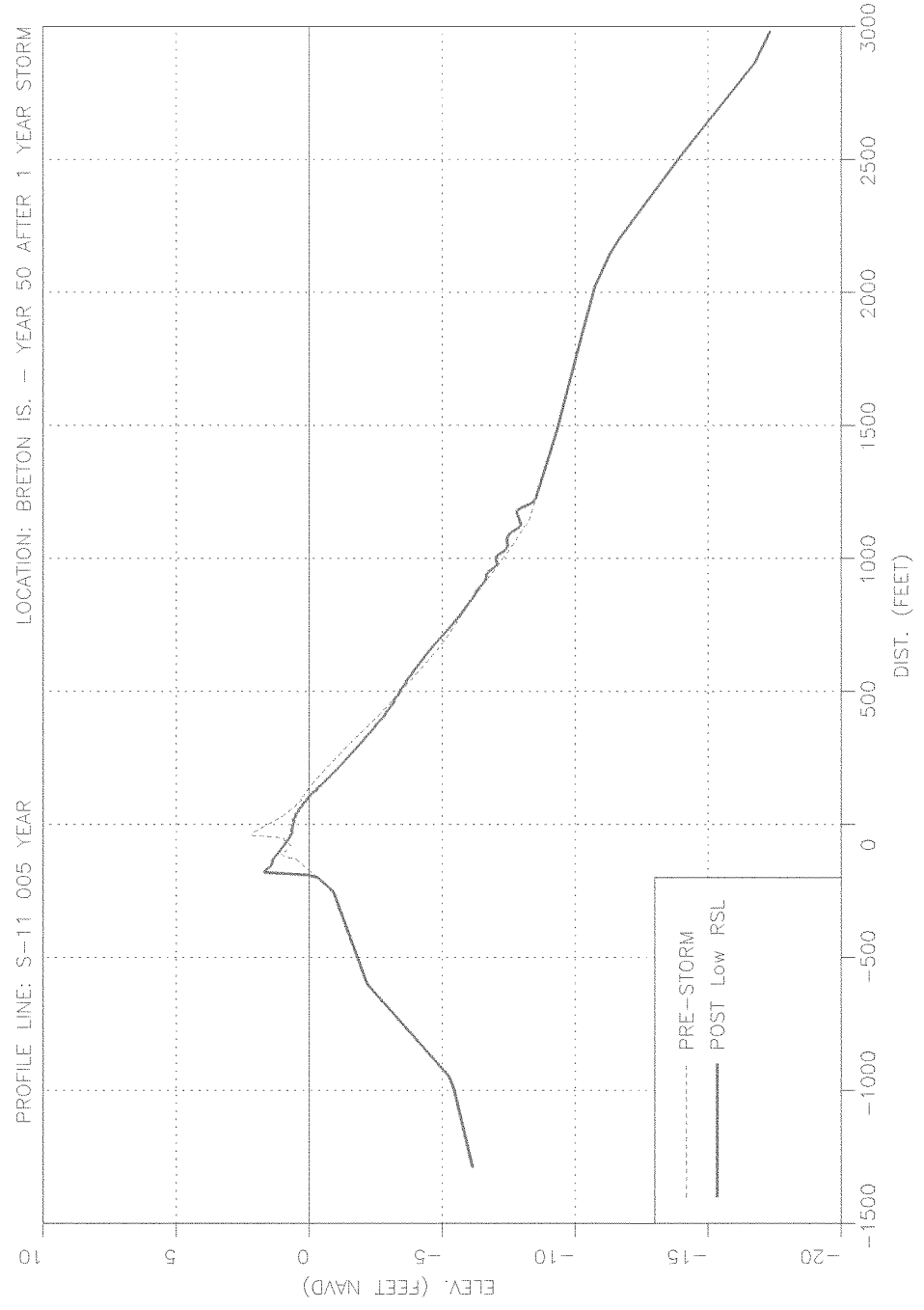

PROFILE LINE: S-11 003 YEAR
LOCATION: BRETON IS. - YEAR 50 AFTER 1 YEAR STORM
ELEV. (FEET NAVD)
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000
DIST. (FEET)
PRE-STORM
POST Med RSL

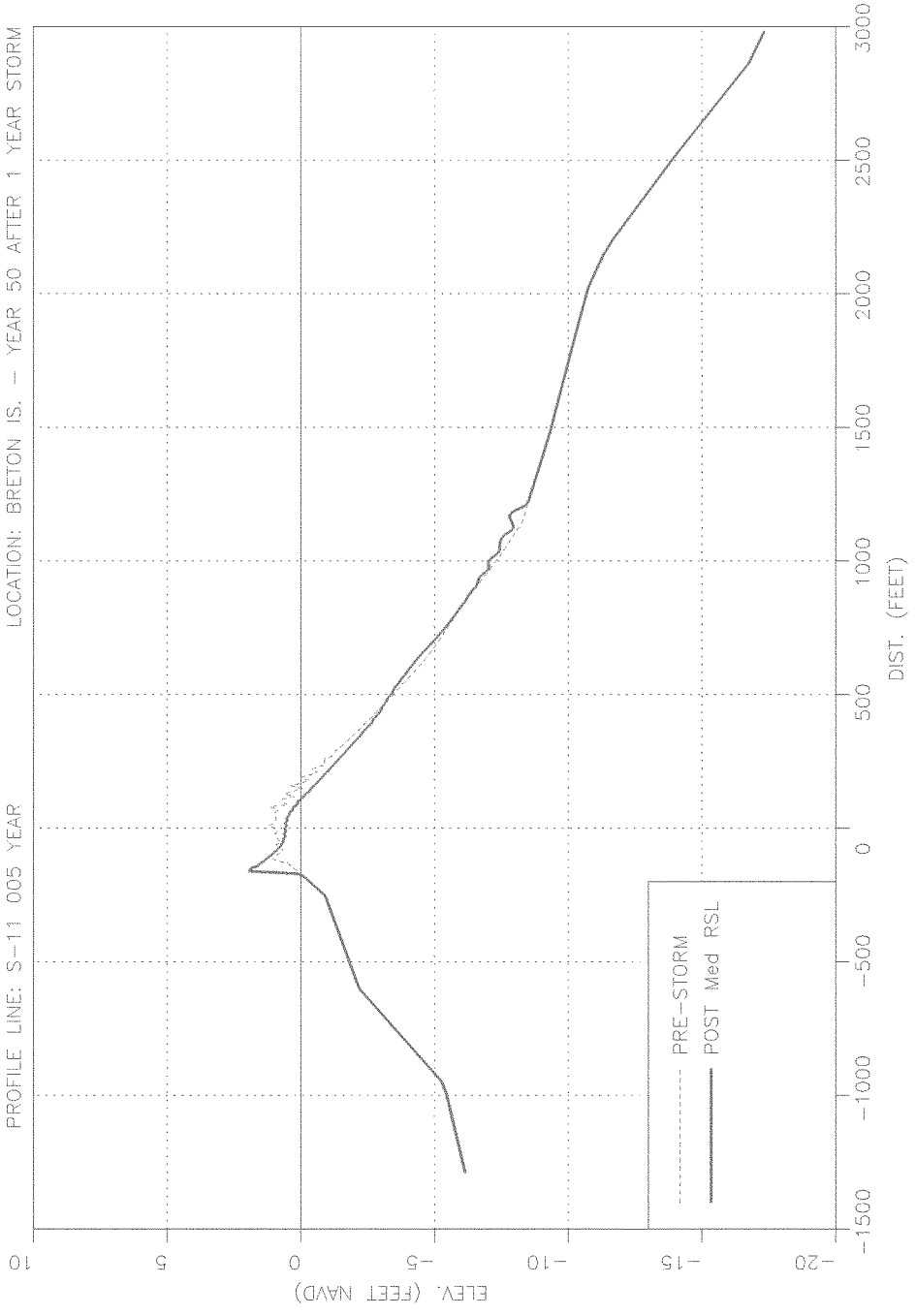

PROFILE LINE: S-11 003 YEAR
LOCATION: BRETON IS. - YEAR 50 AFTER 1 YEAR STORM
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST High RSL
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

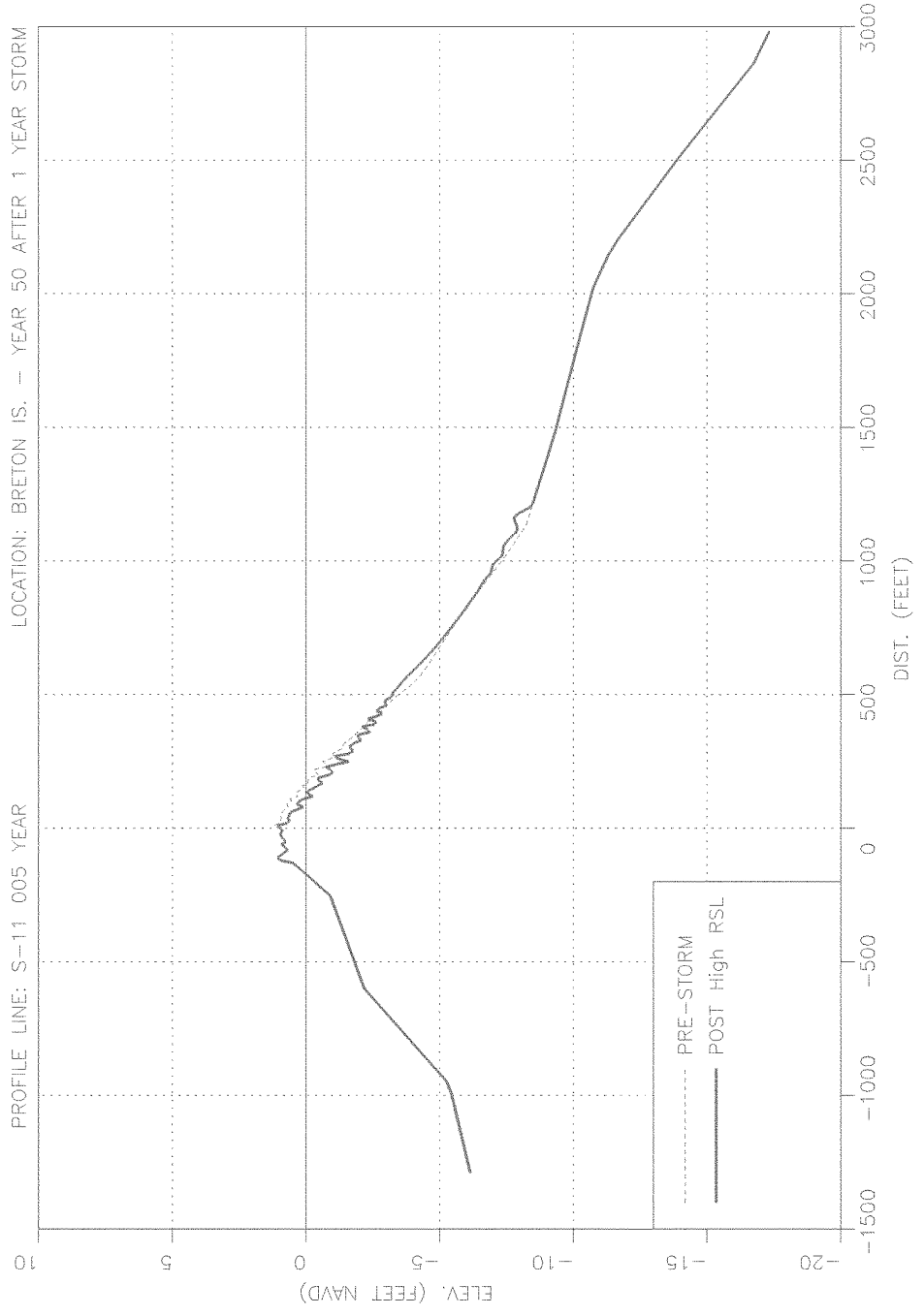

PROFILE LINE: S-11 004 YEAR
LOCATION: BRETON IS. - YEAR 50 AFTER 1 YEAR STORM
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

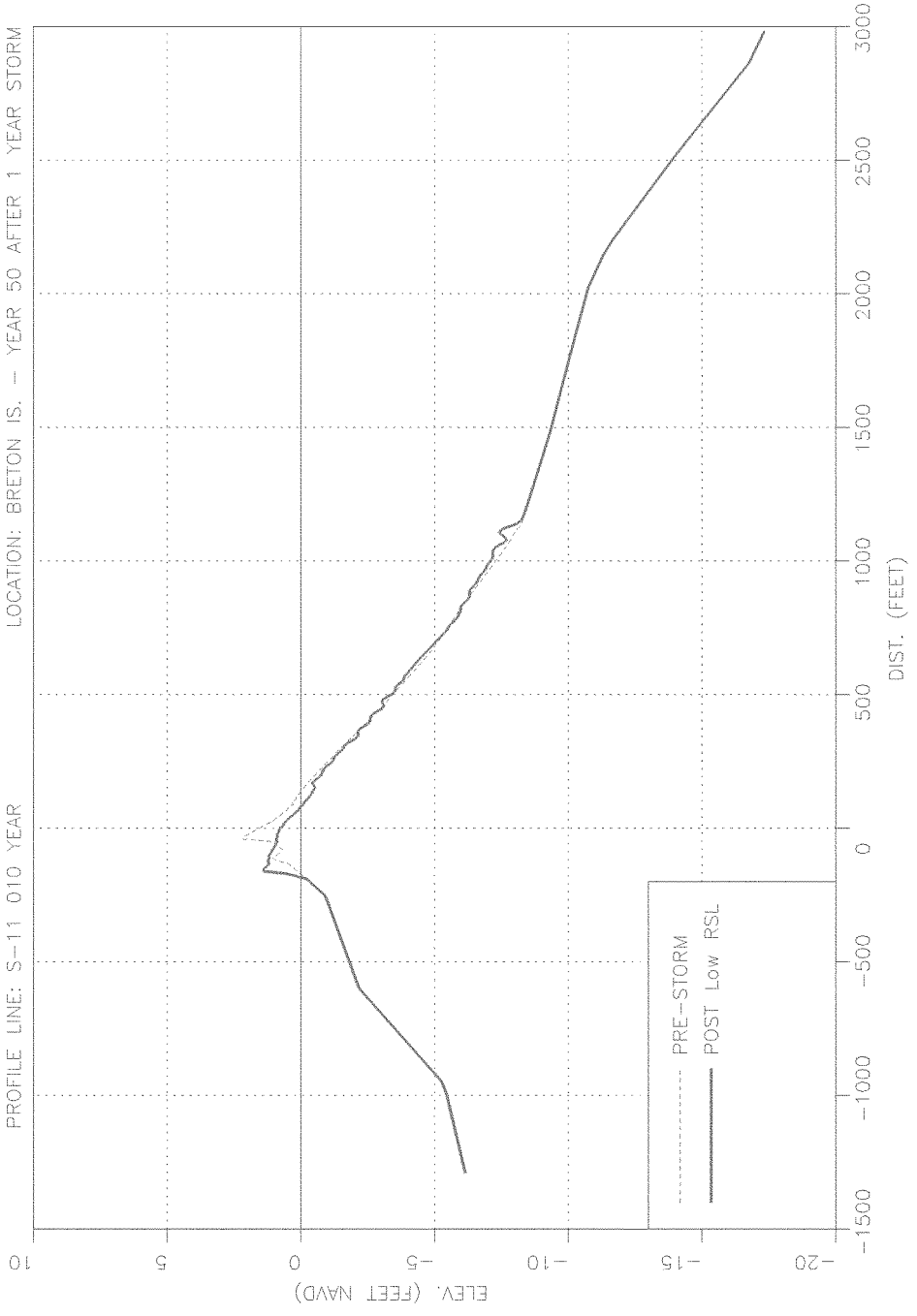

PROFILE LINE: S-11 004 YEAR
LOCATION: BRETON IS. - YEAR 50 AFTER 1 YEAR STORM
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Med RSL
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

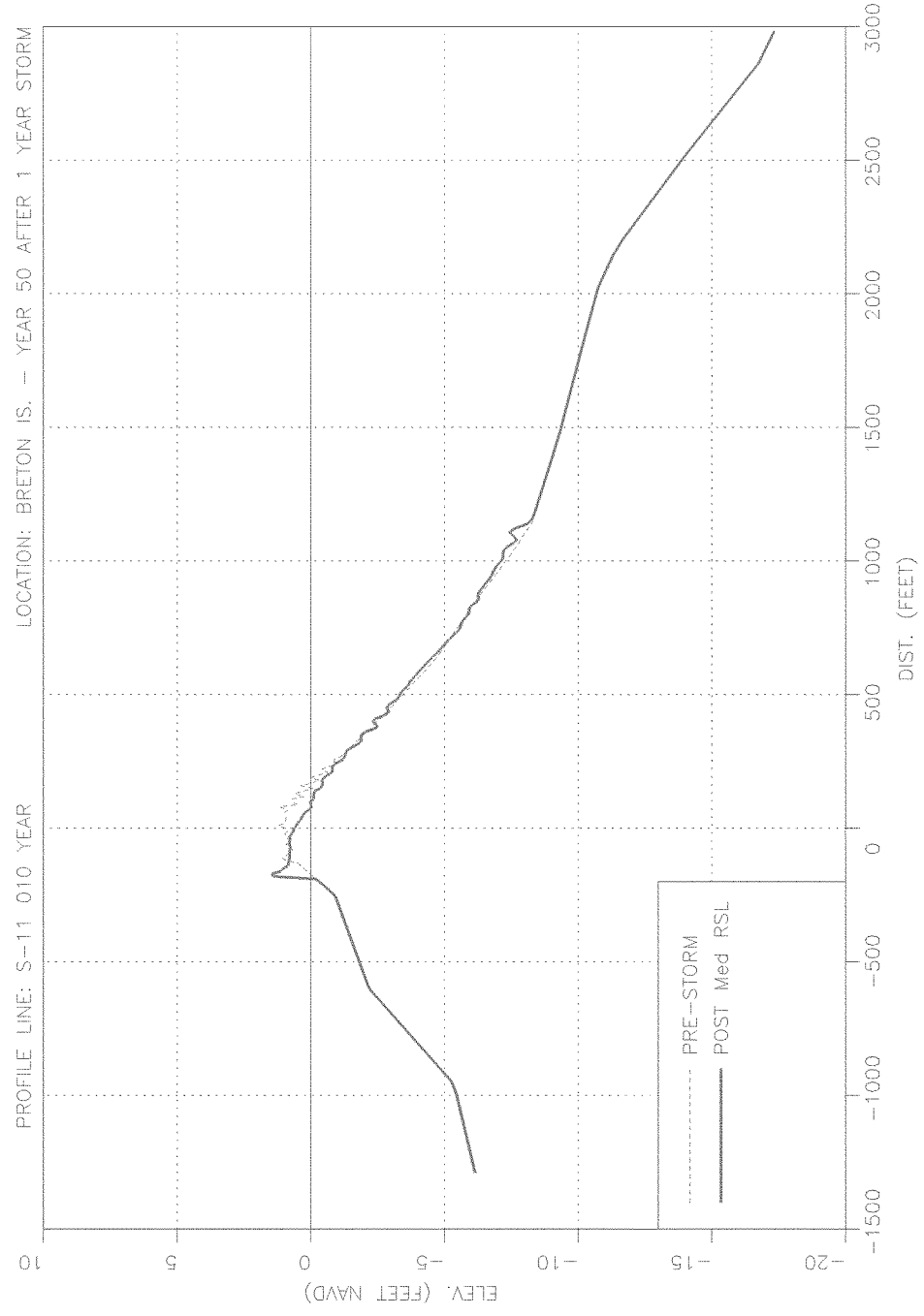

PROFILE LINE: S-11 004 YEAR
LOCATION: BRETON IS. - YEAR 50 AFTER 1 YEAR STORM
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST High RSL
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

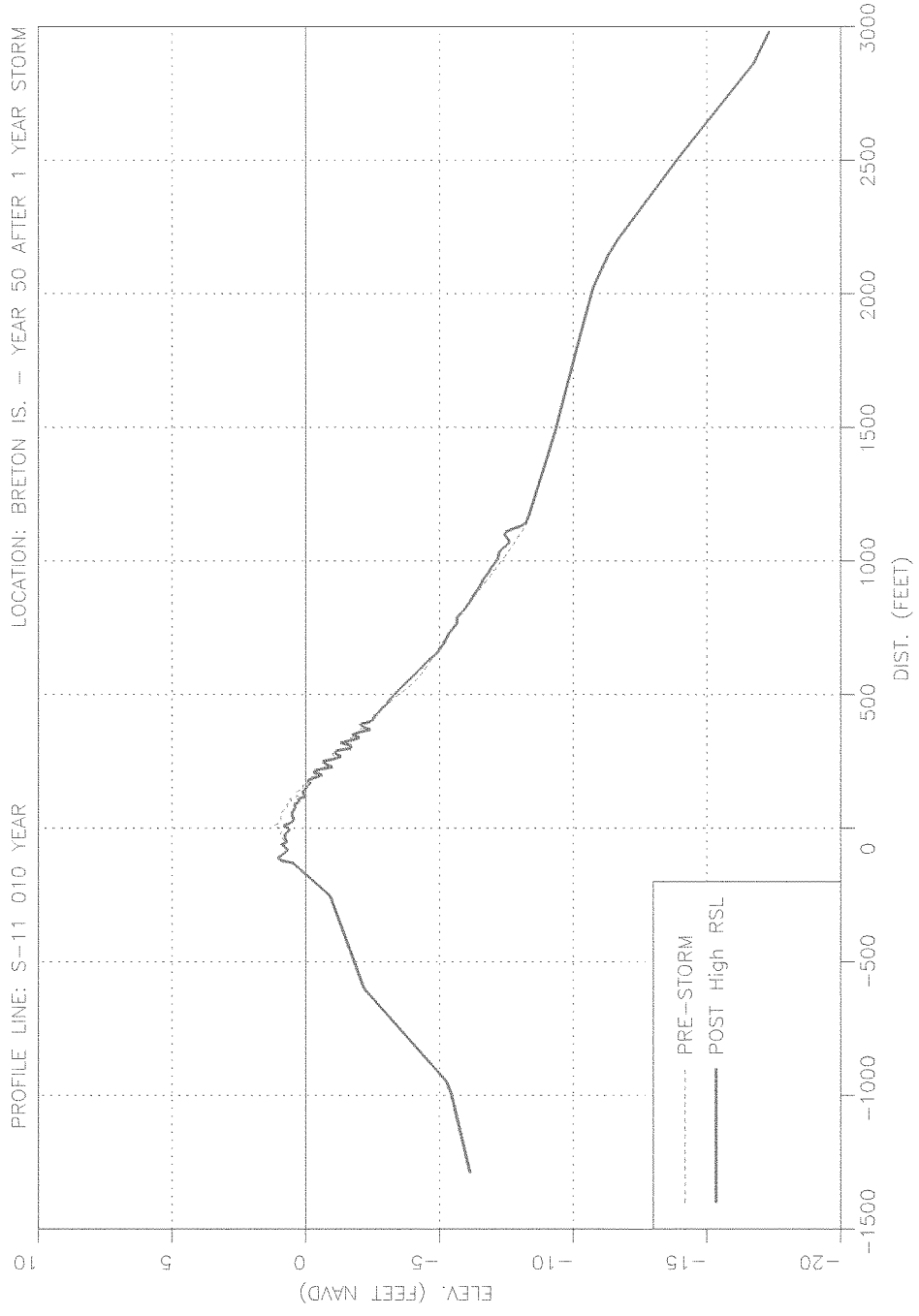

PROFILE LINE: S-11 005 YEAR
LOCATION: BRETON IS. - YEAR 50 AFTER 1 YEAR STORM
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

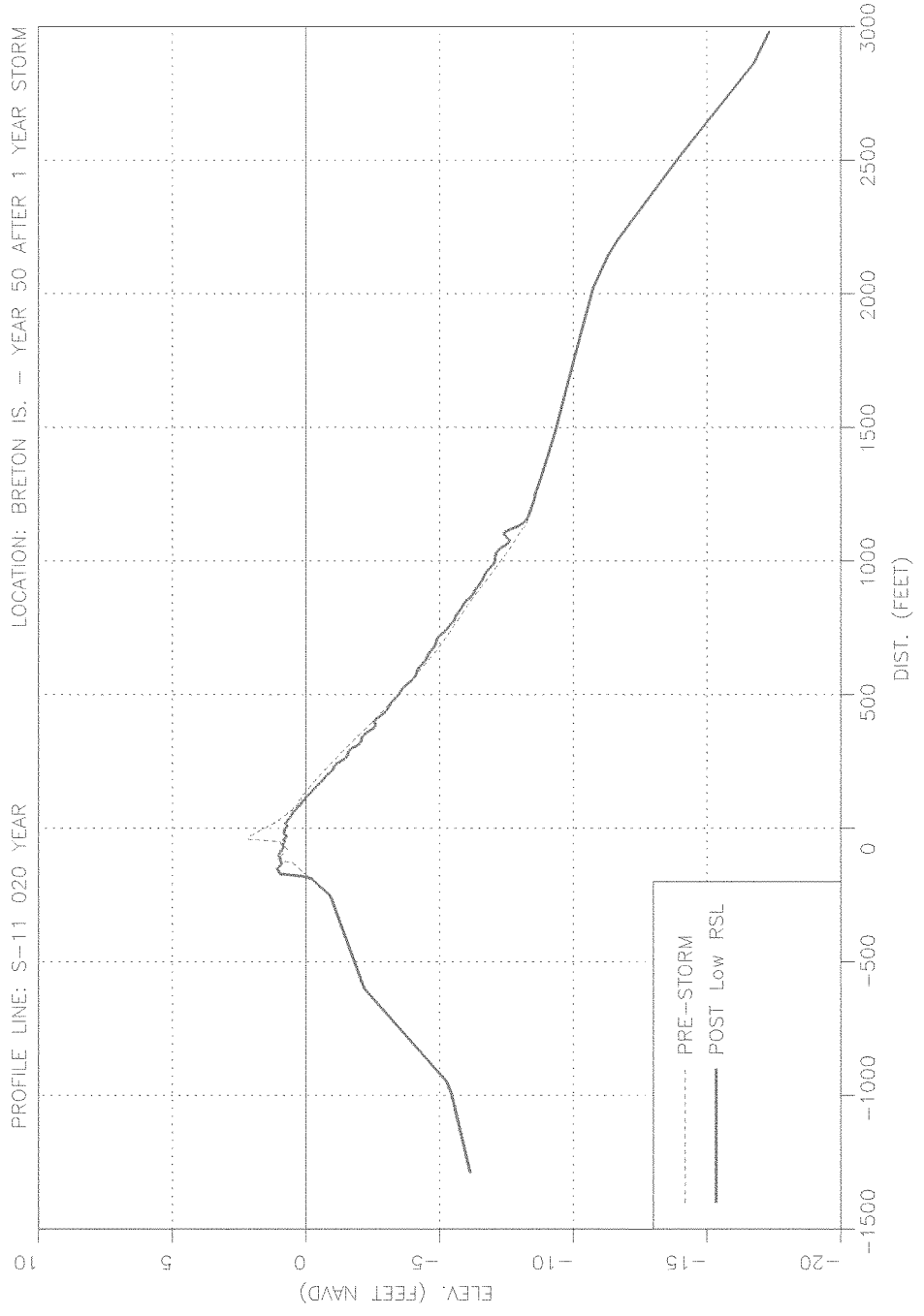

PROFILE LINE: S-11 005 YEAR
LOCATION: BRETON IS. - YEAR 50 AFTER 1 YEAR STORM
ELEV. (FEET NAVD)
10
5
0
-5
-10
-15
-20
DIST. (FEET)
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000
PRE-STORM
POST Med RSL

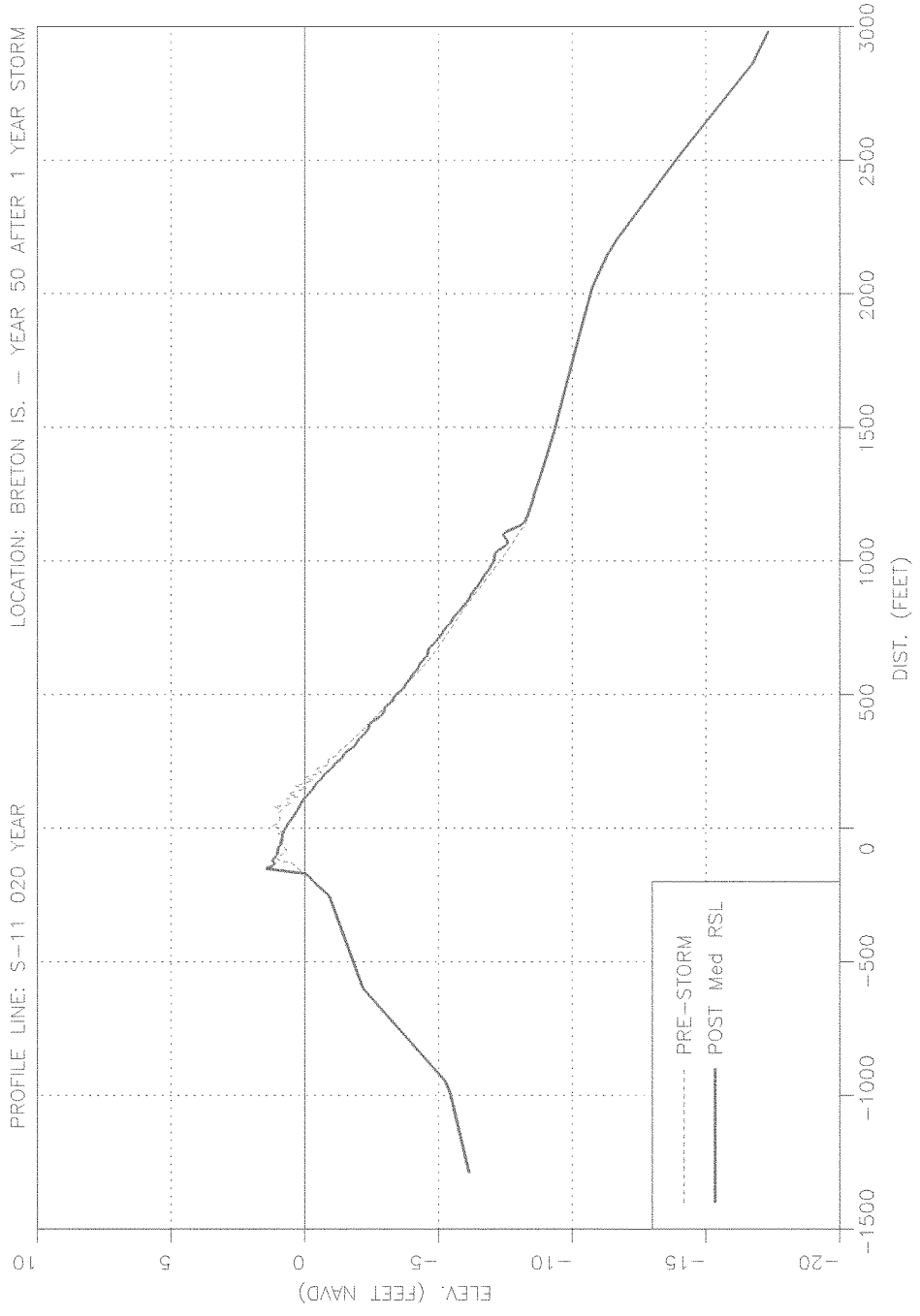

PROFILE LINE: S-11 005 YEAR
LOCATION: BRETON IS. - YEAR 50 AFTER 1 YEAR STORM
PRE-STORM
POST High RSL
ELEV. (FEET NAVD)
DIST. (FEET)
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

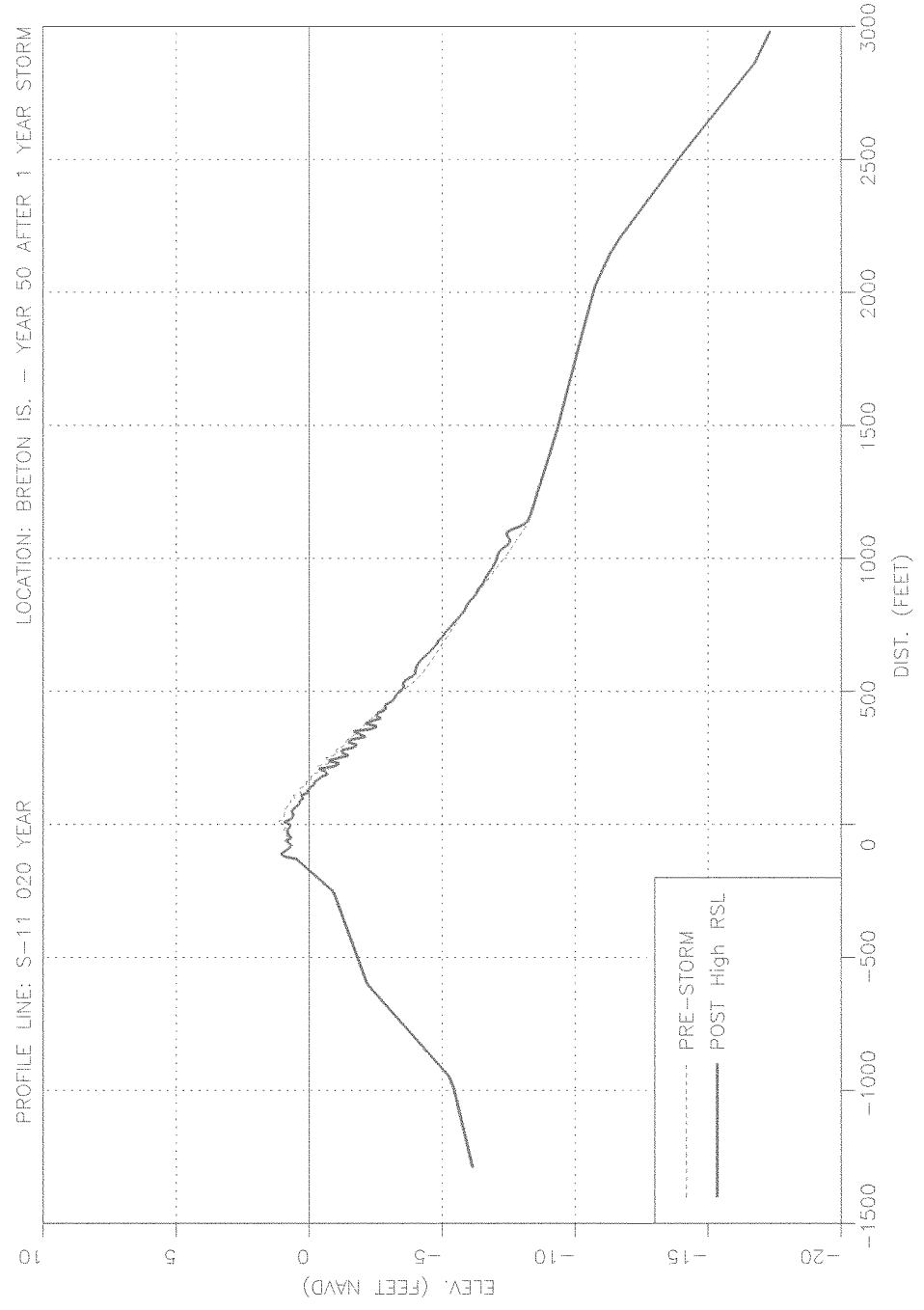

PROFILE LINE: S-11 010 YEAR
LOCATION: BRETON IS. - YEAR 50 AFTER 1 YEAR STORM
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

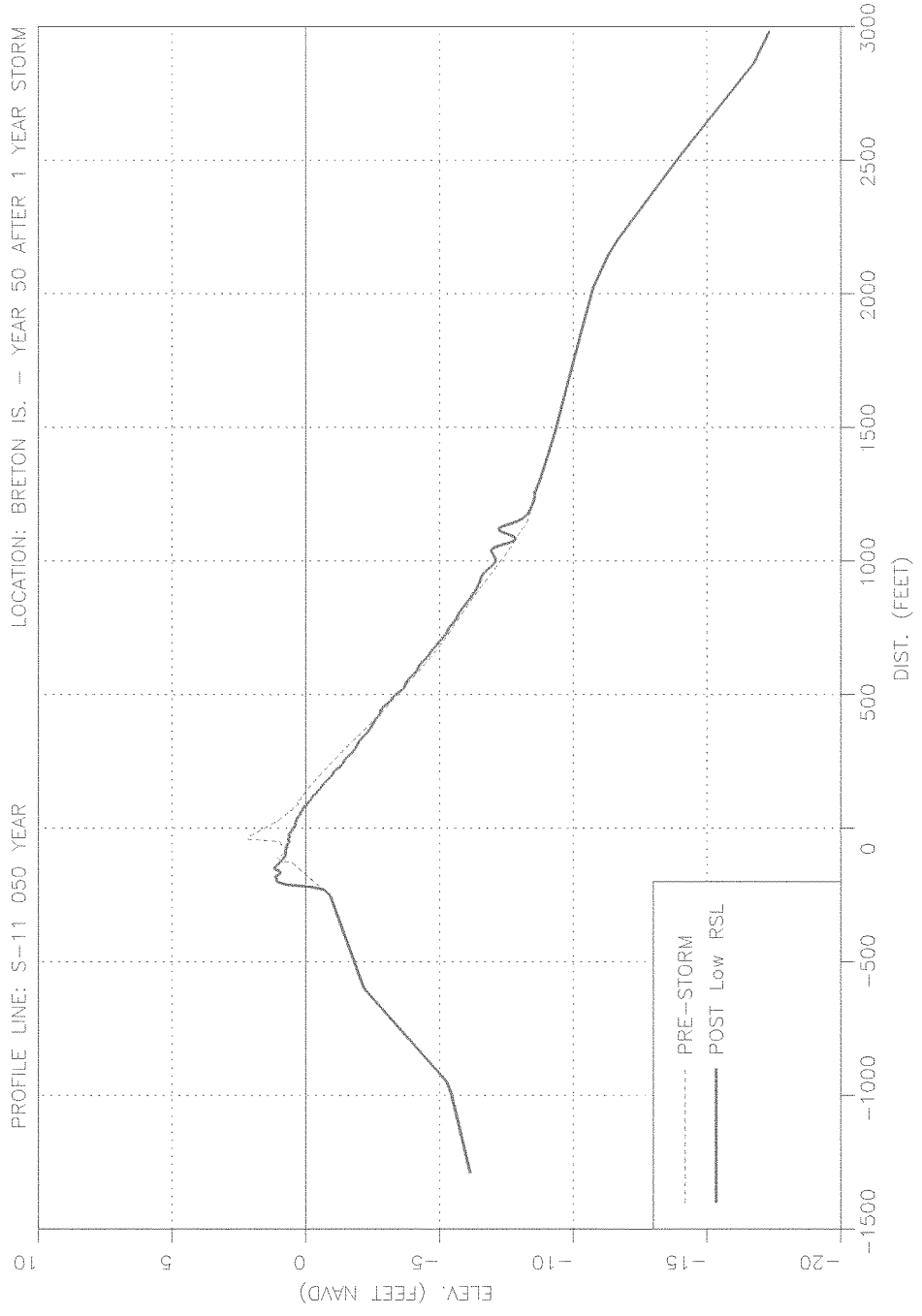

PROFILE LINE: S-11 010 YEAR
LOCATION: BRETON IS. - YEAR 50 AFTER 1 YEAR STORM
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Med RSL
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

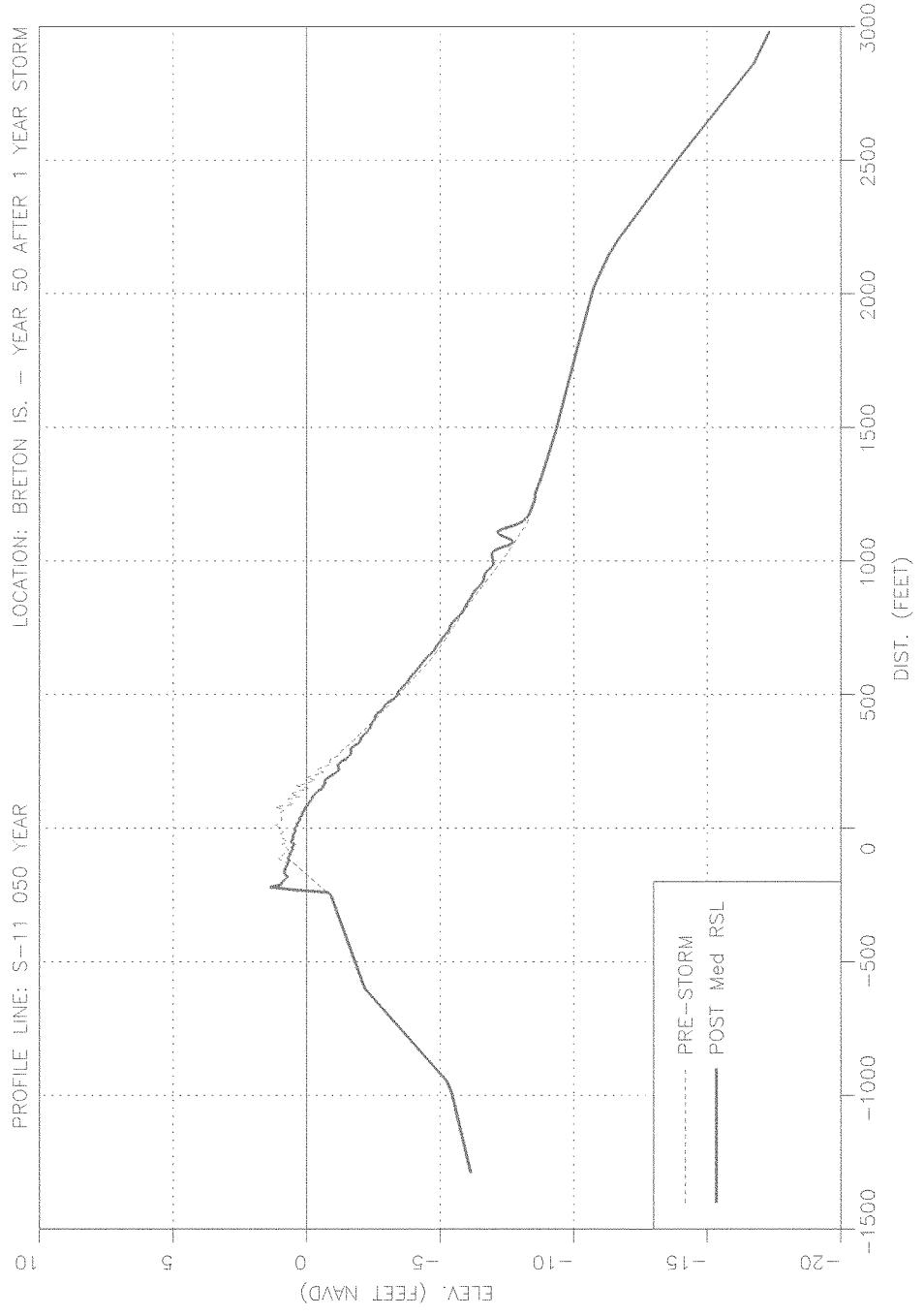

PROFILE LINE: S-11 010 YEAR
LOCATION: BRETON IS. - YEAR 50 AFTER 1 YEAR STORM
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST High RSL
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

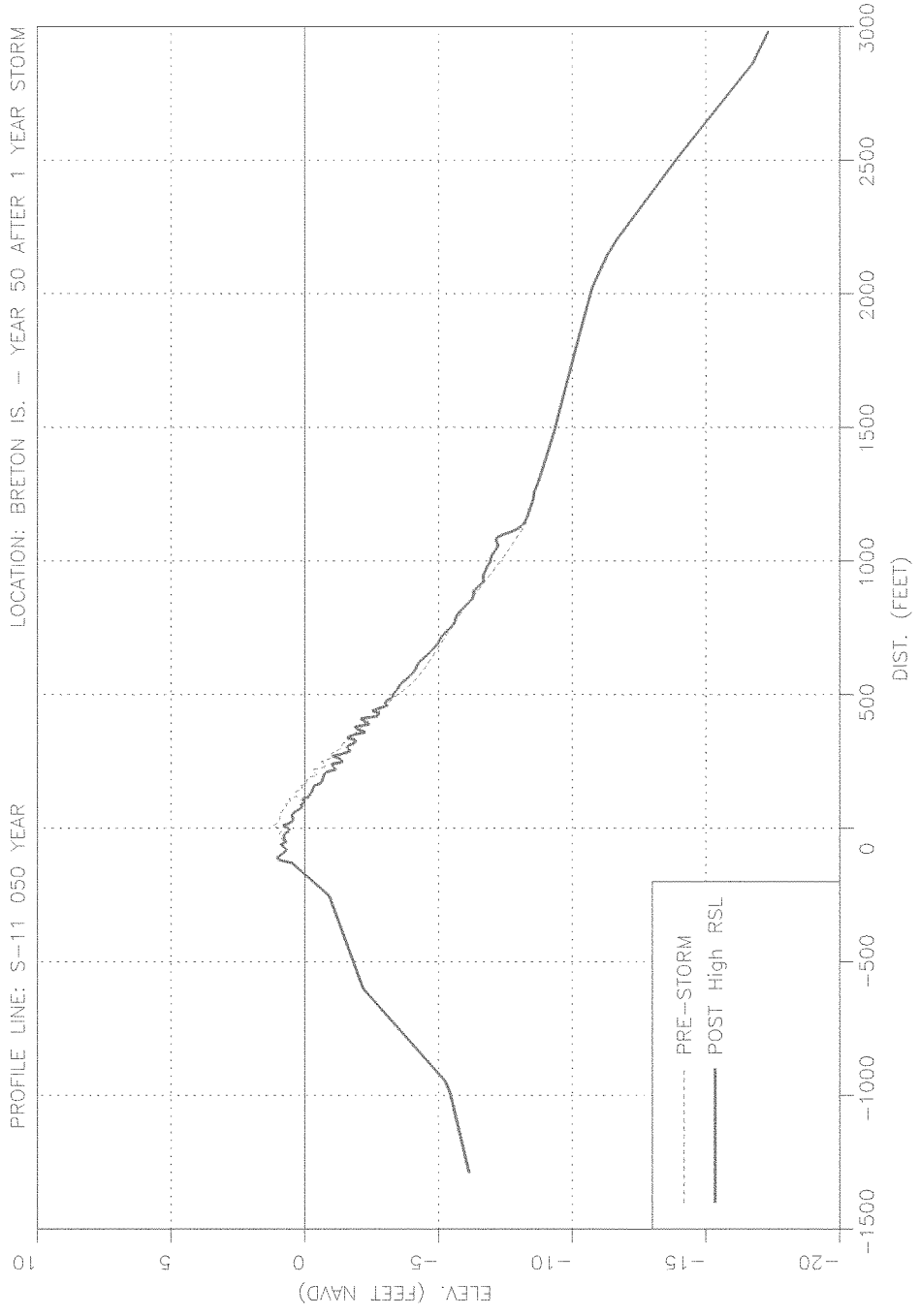

PROFILE LINE: S-11 020 YEAR
LOCATION: BRETON IS. - YEAR 50 AFTER 1 YEAR STORM
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

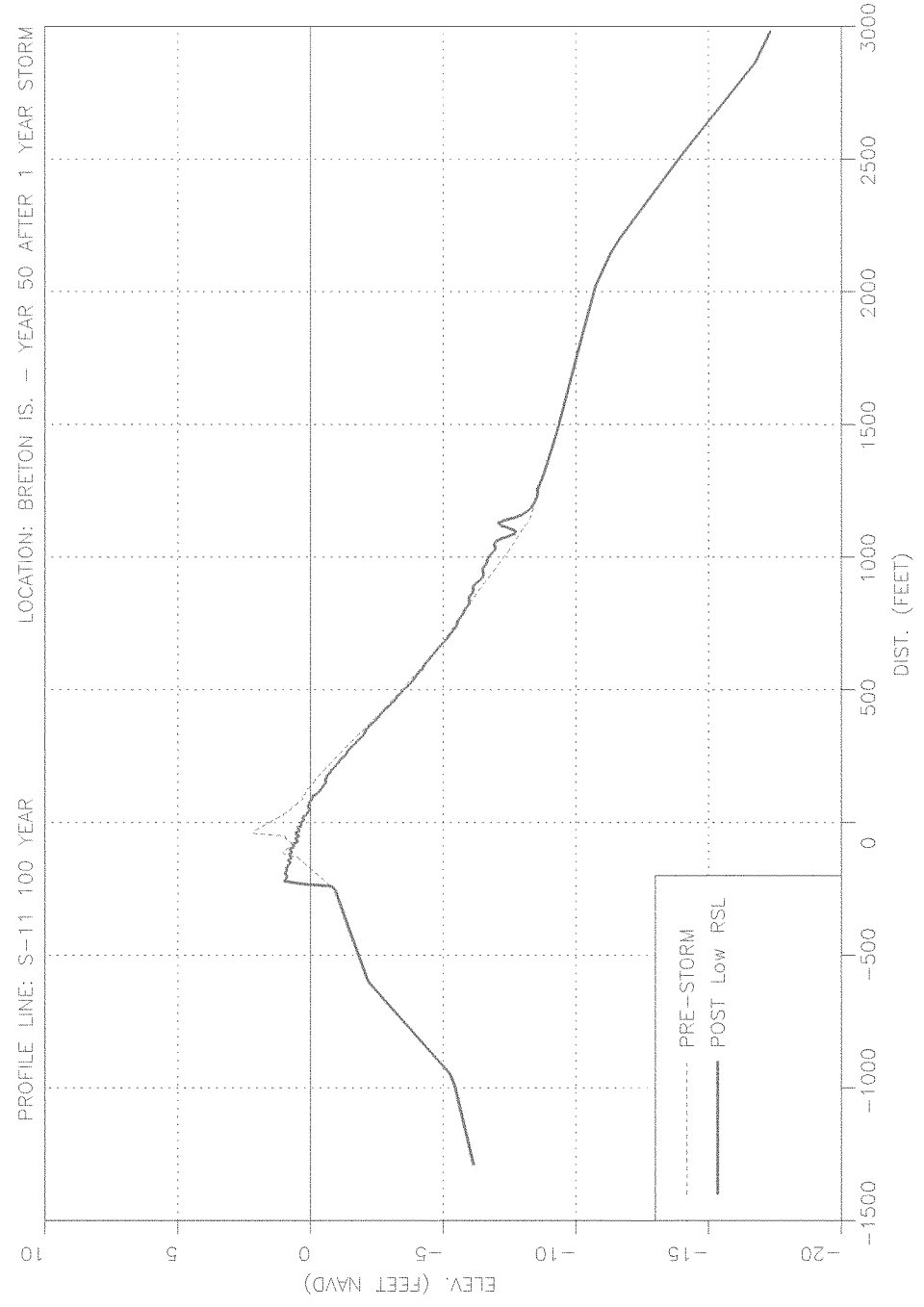

PROFILE LINE: S-11 020 YEAR
LOCATION: BRETON IS. - YEAR 50 AFTER 1 YEAR STORM
ELEV. (FEET NAVD)
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000
DIST. (FEET)
PRE-STORM
POST Med RSL

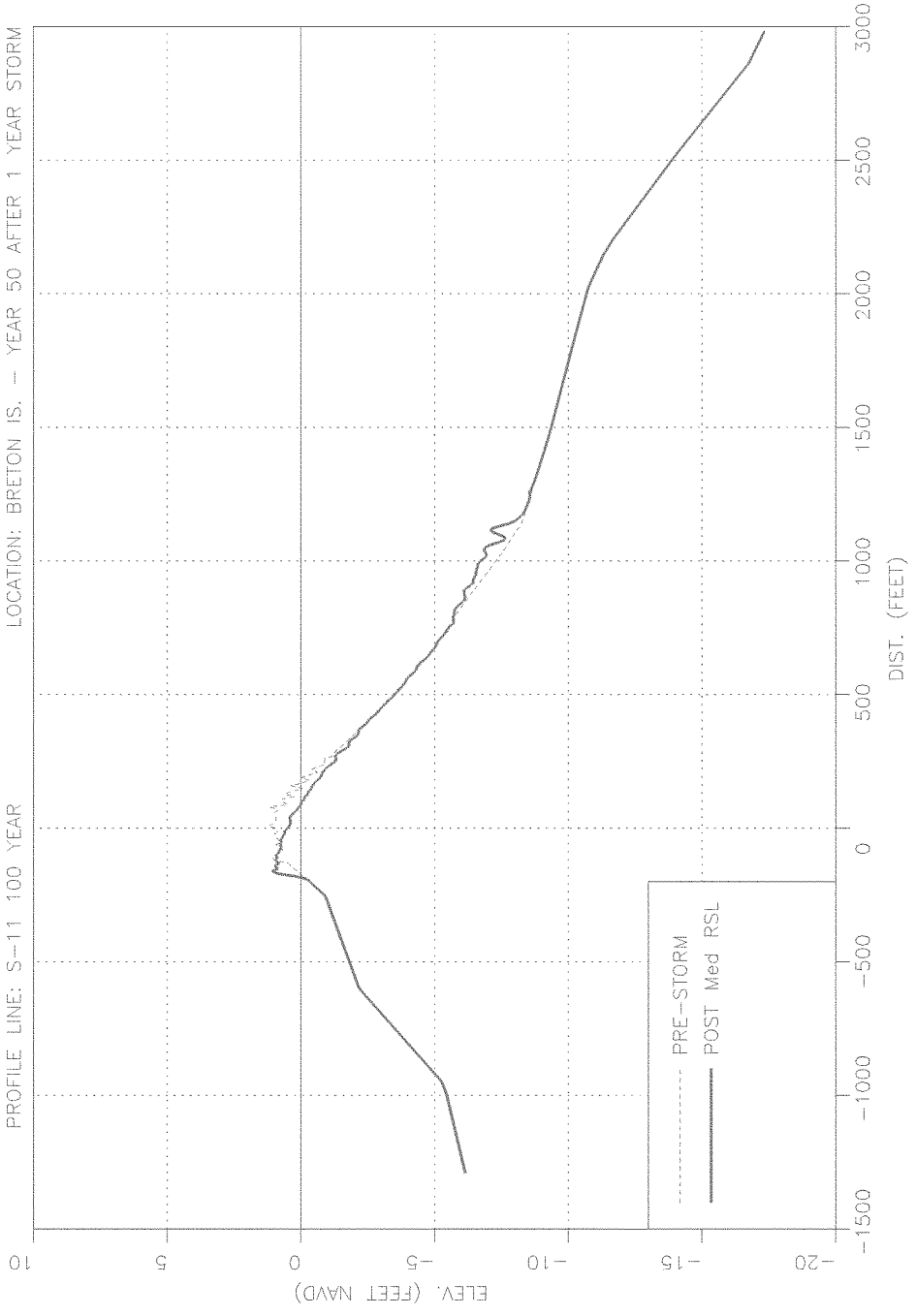

PROFILE LINE: S-11 020 YEAR
LOCATION: BRETON IS. - YEAR 50 AFTER 1 YEAR STORM
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST High RSL
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

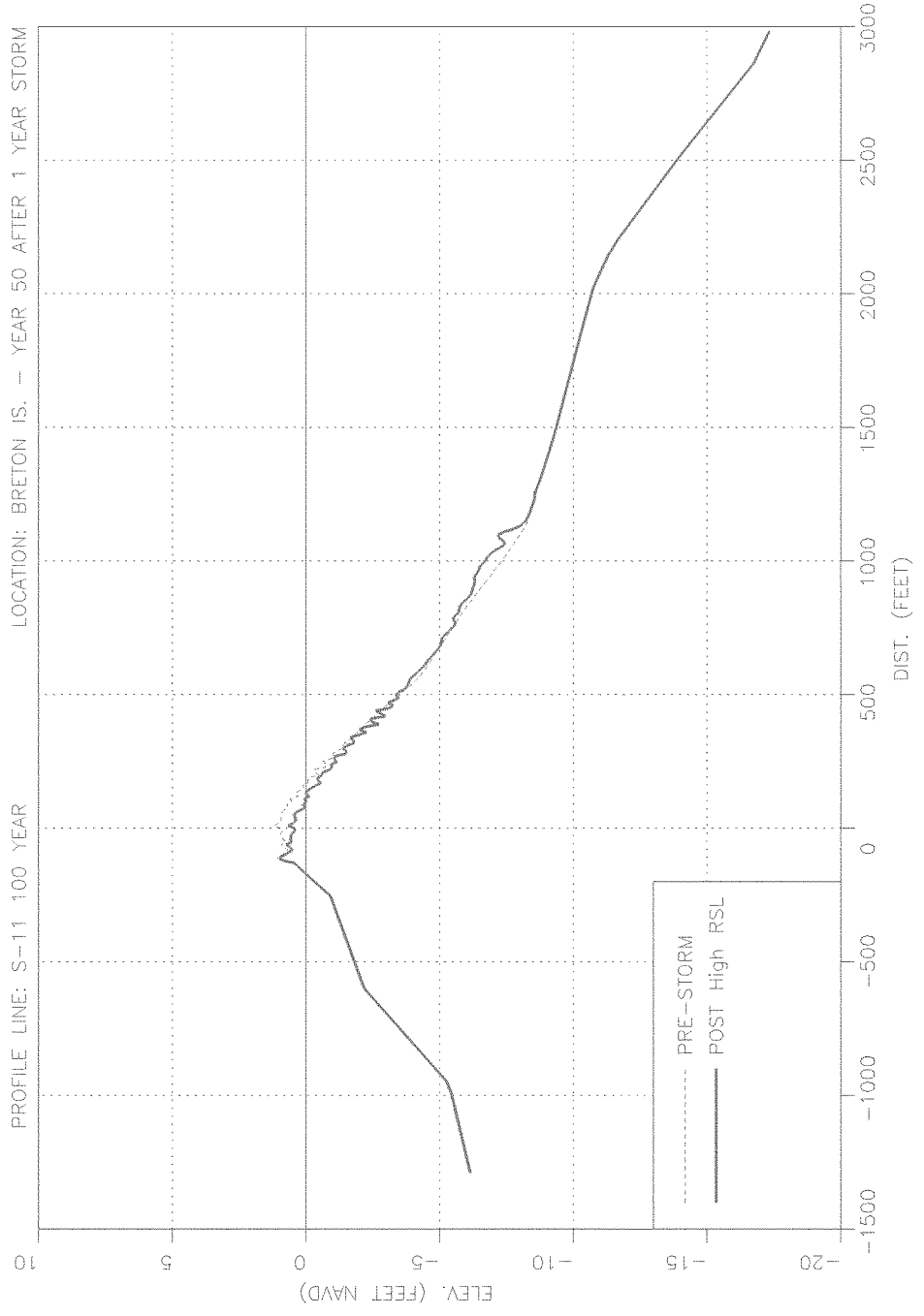

PROFILE LINE: S-11 050 YEAR
LOCATION: BRETON IS. - YEAR 50 AFTER 1 YEAR STORM
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

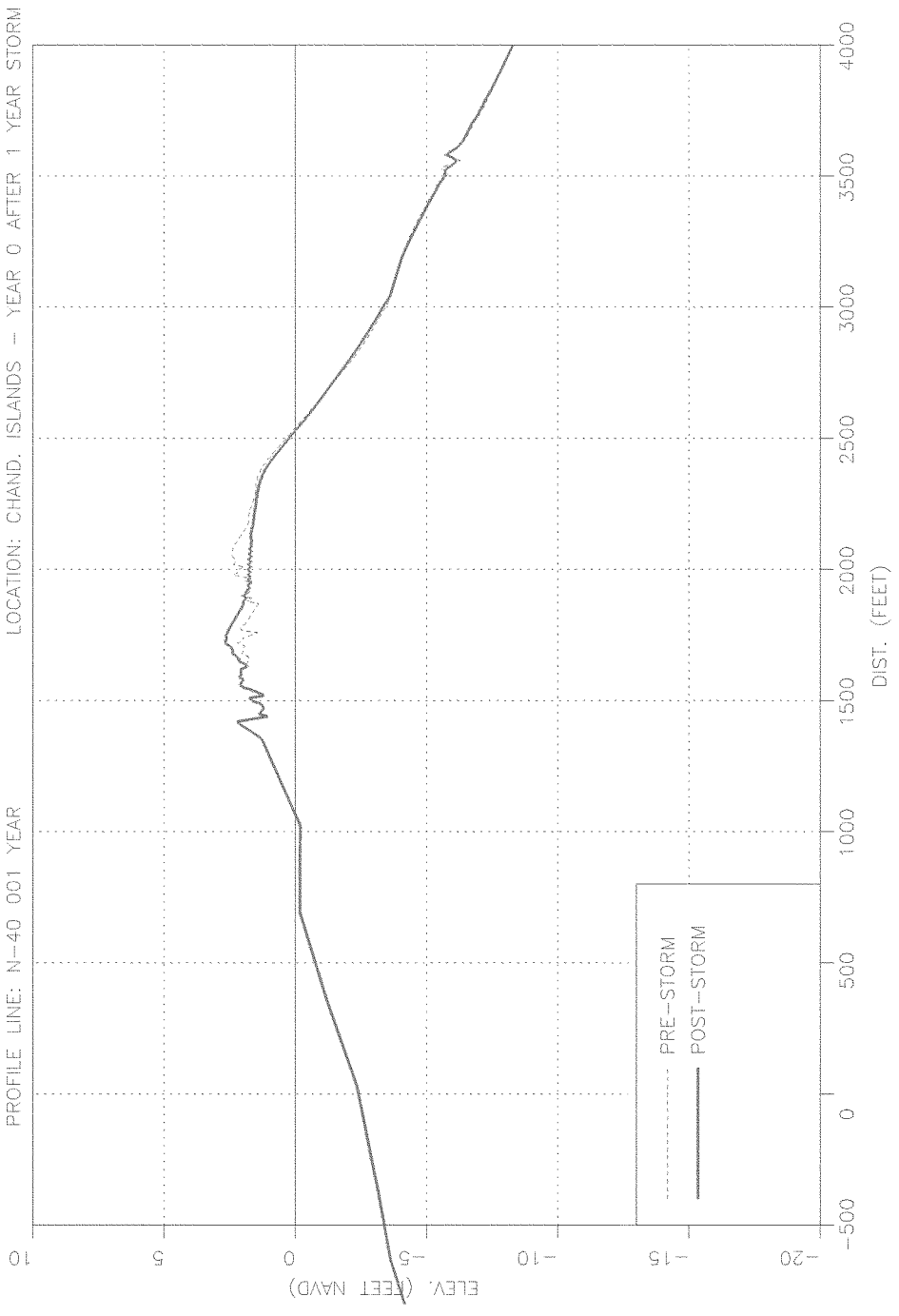

PROFILE LINE: S-11 050 YEAR
LOCATION: BRETON IS. - YEAR 50 AFTER 1 YEAR STORM
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Med RSL
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

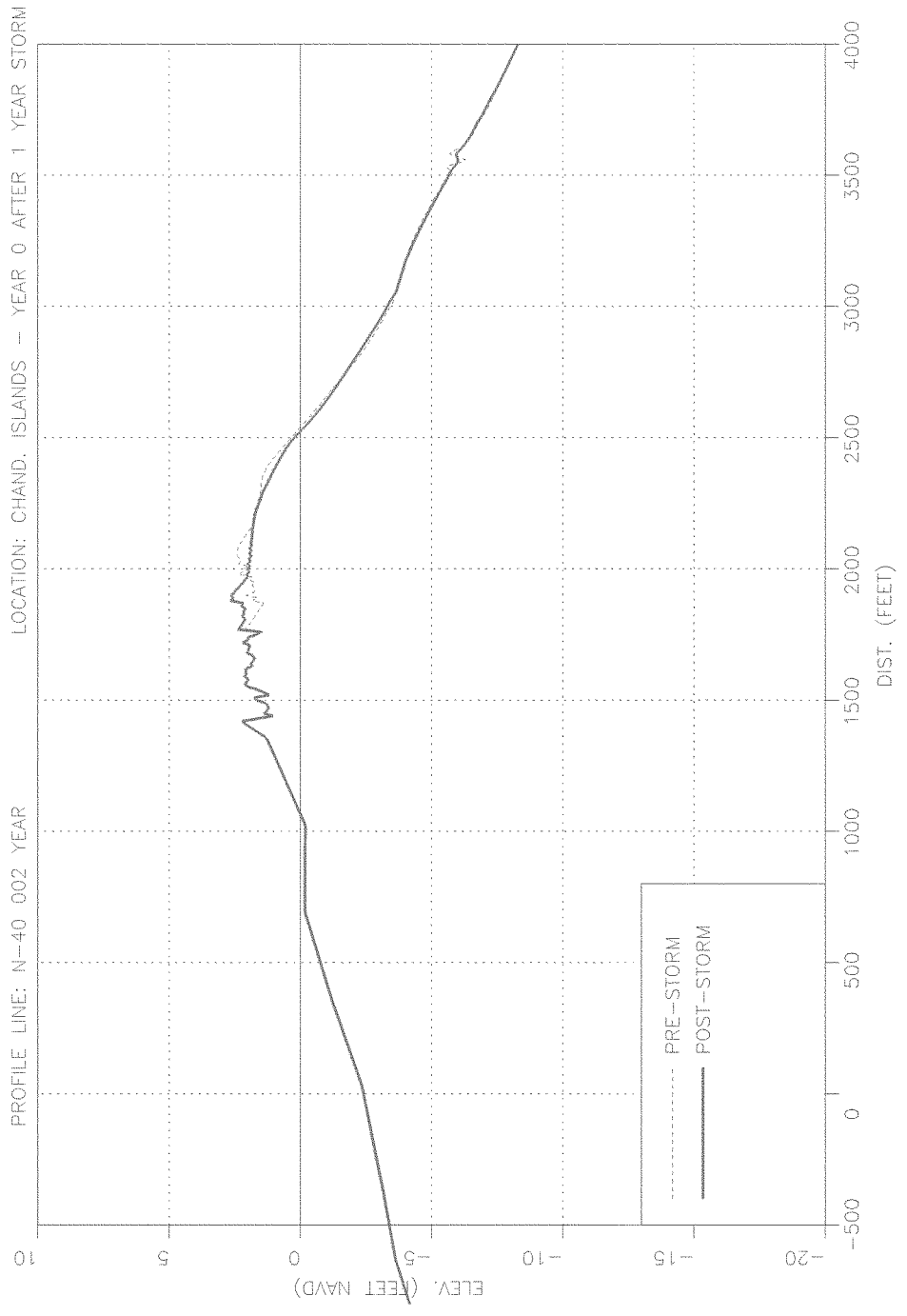

PROFILE LINE: S-11 050 YEAR
LOCATION: BRETON IS. - YEAR 50 AFTER 1 YEAR STORM
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST High RSL
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

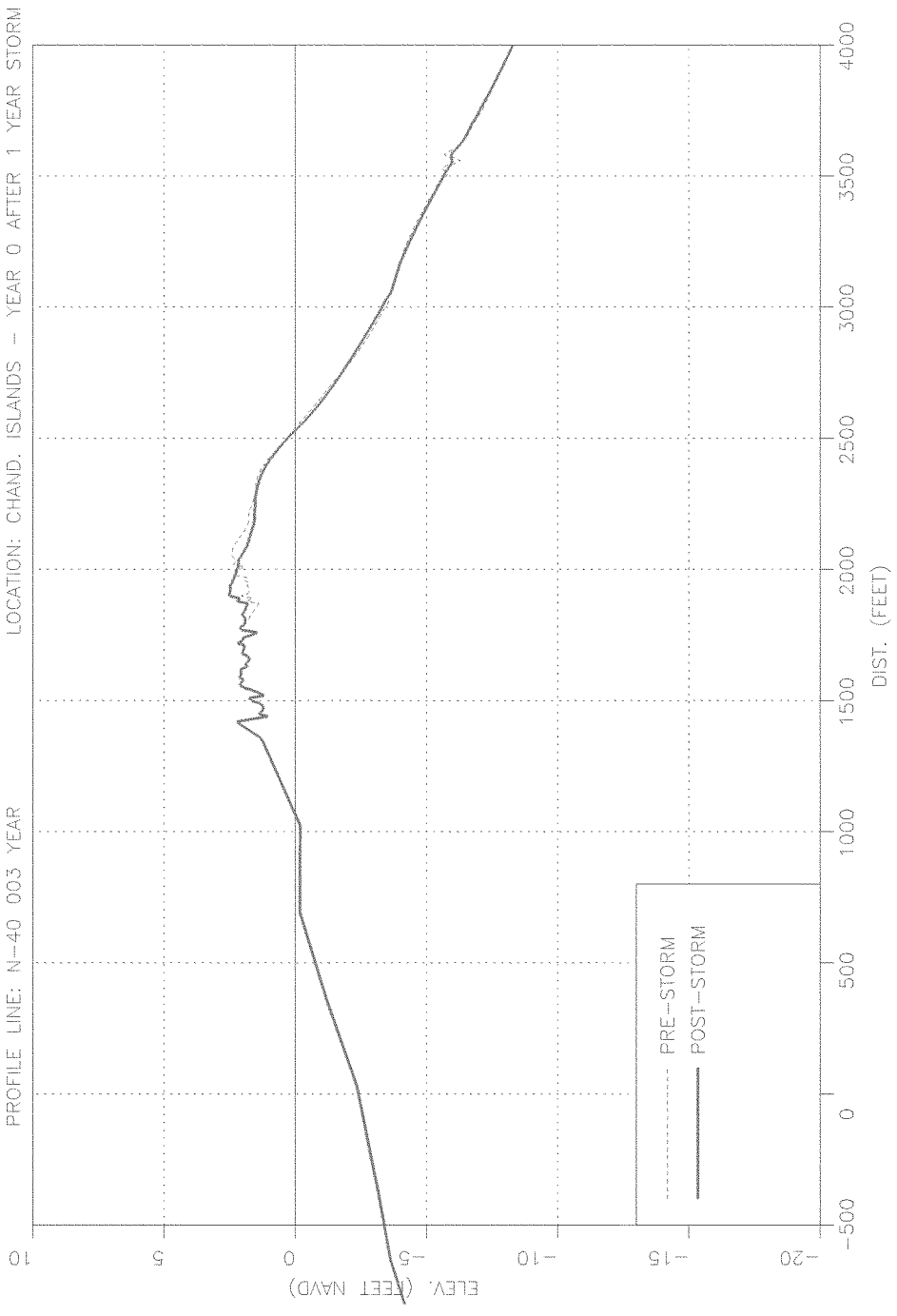

PROFILE LINE: S-11 100 YEAR
LOCATION: BRETON IS. - YEAR 50 AFTER 1 YEAR STORM
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

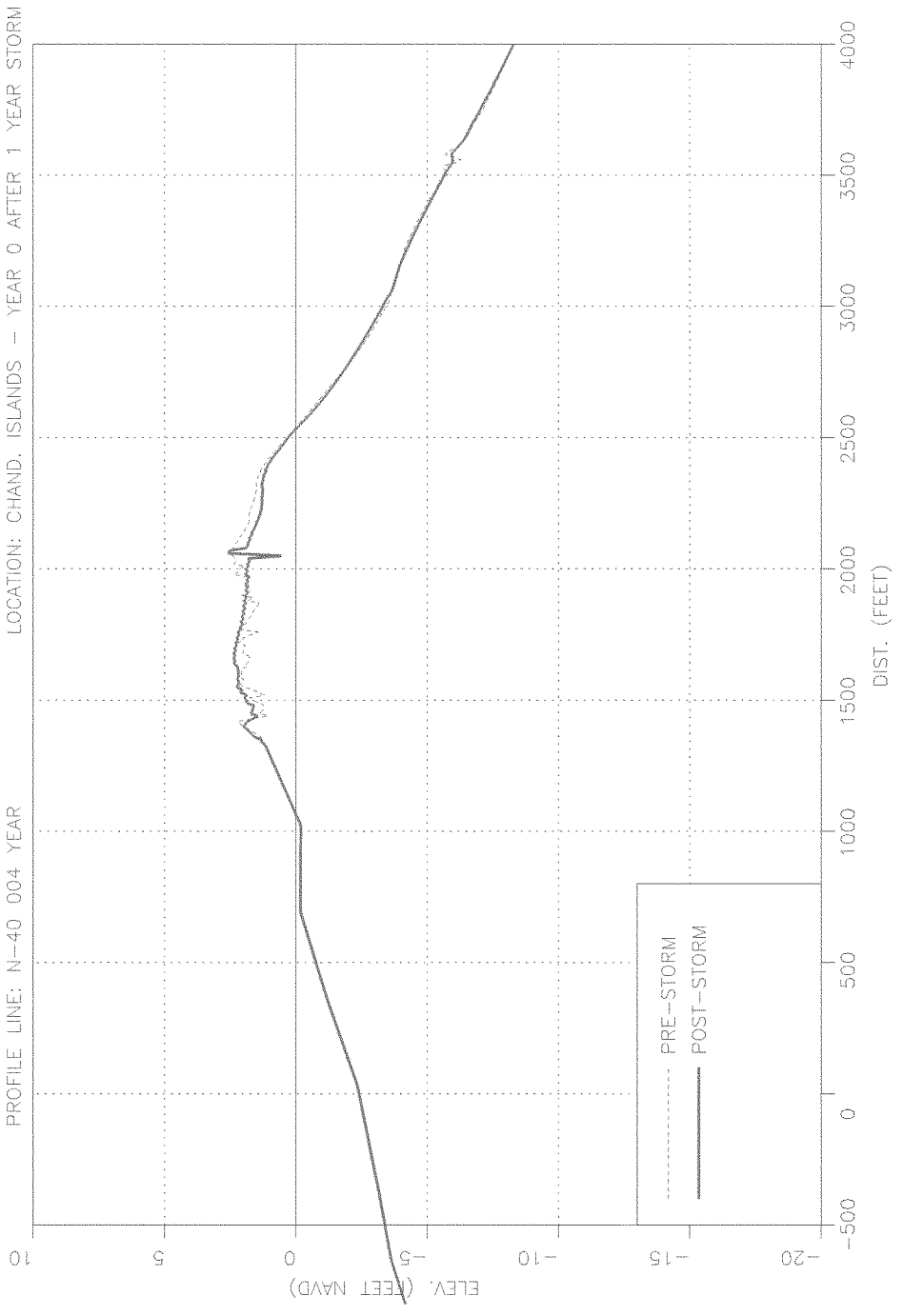

PROFILE LINE: S-11 100 YEAR
LOCATION: BRETON IS. - YEAR 50 AFTER 1 YEAR STORM
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Med RSL
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

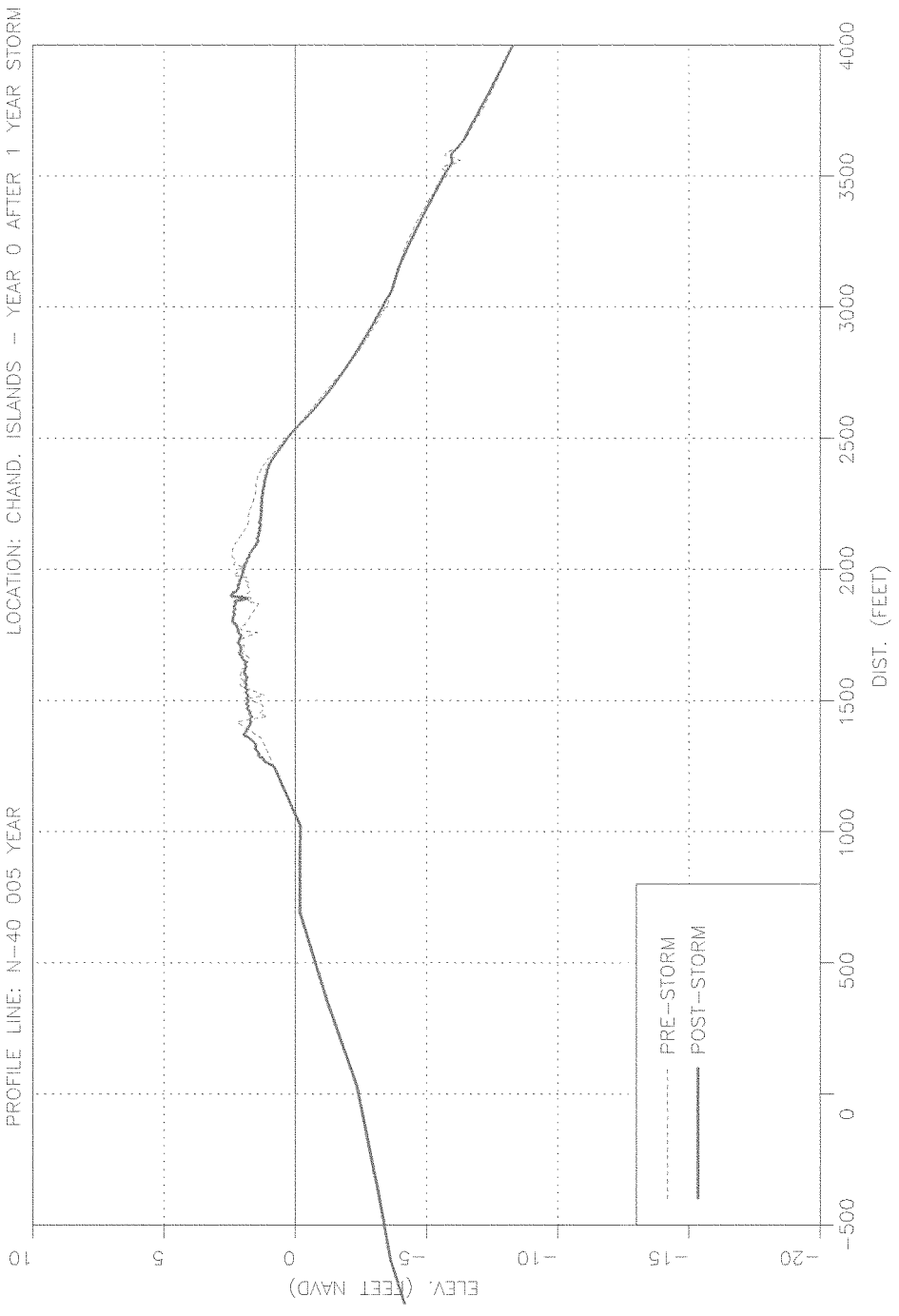

PROFILE LINE: S-11 100 YEAR
LOCATION: BRETON IS. - YEAR 50 AFTER 1 YEAR STORM
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST High RSL
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

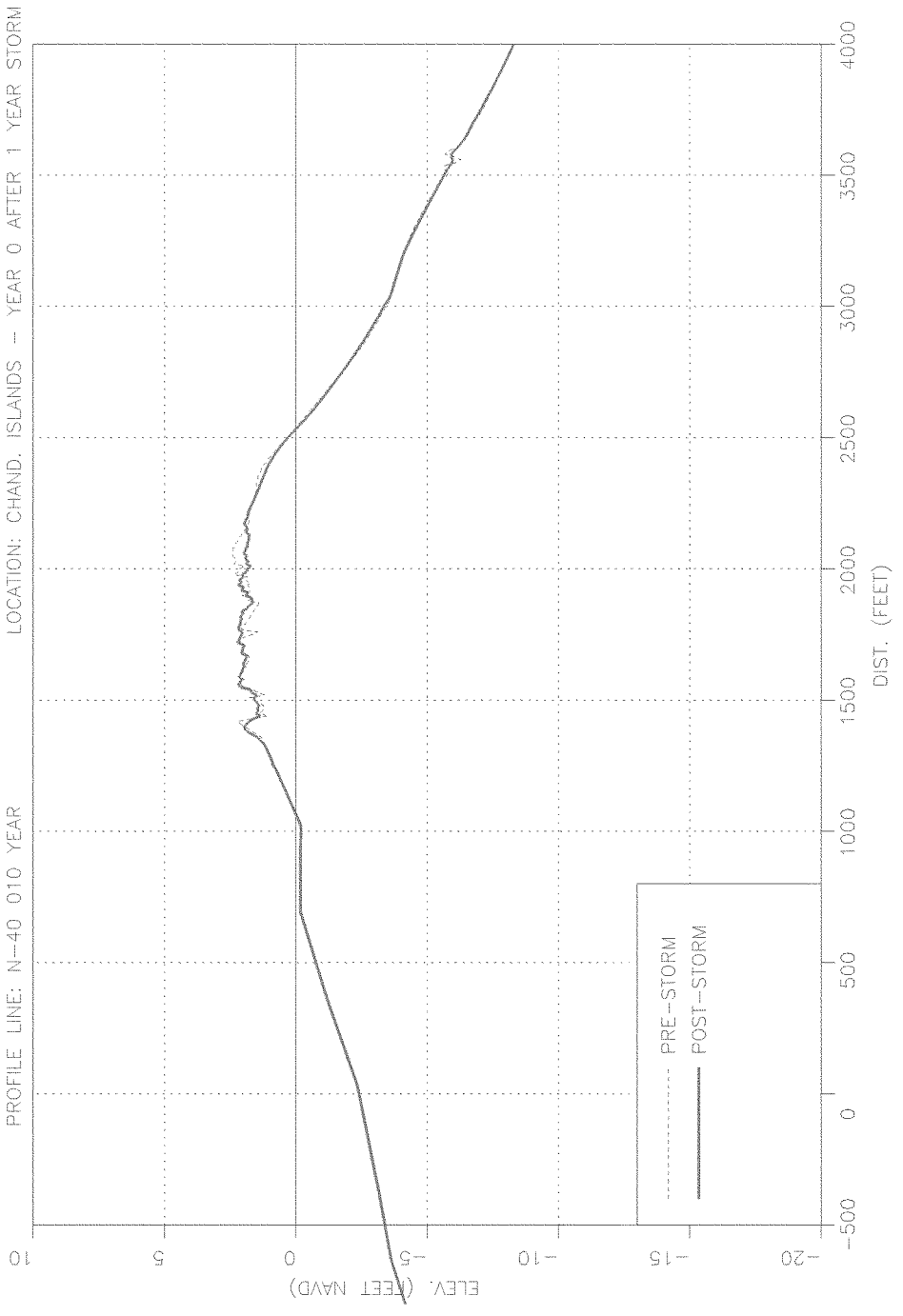

PROFILE LINE: N-40 001 YEAR
LOCATION: CHAND. ISLANDS - YEAR 0 AFTER 1 YEAR STORM
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

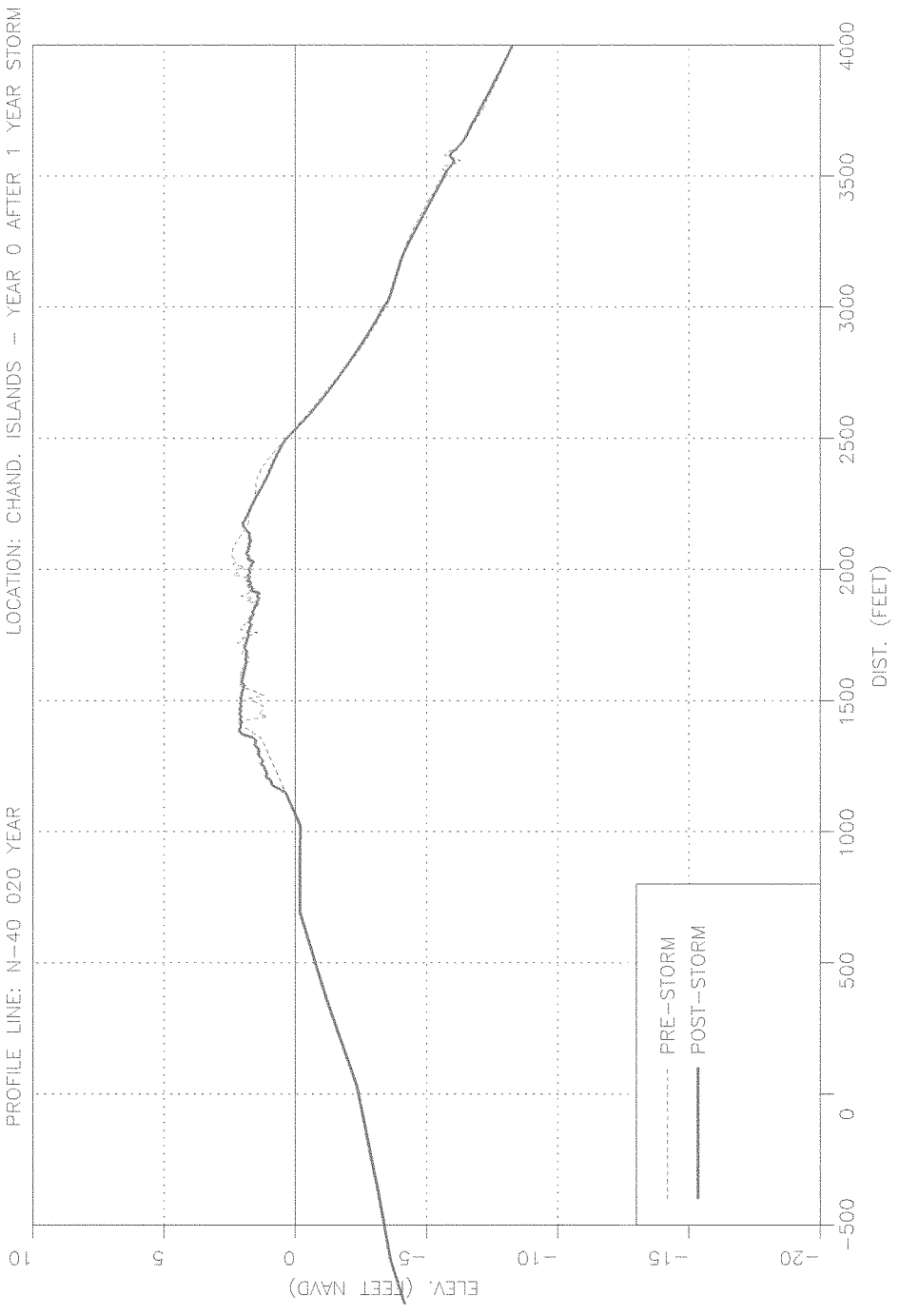

PROFILE LINE: N-40 002 YEAR
LOCATION: CHAND. ISLANDS - YEAR 0 AFTER 1 YEAR STORM
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

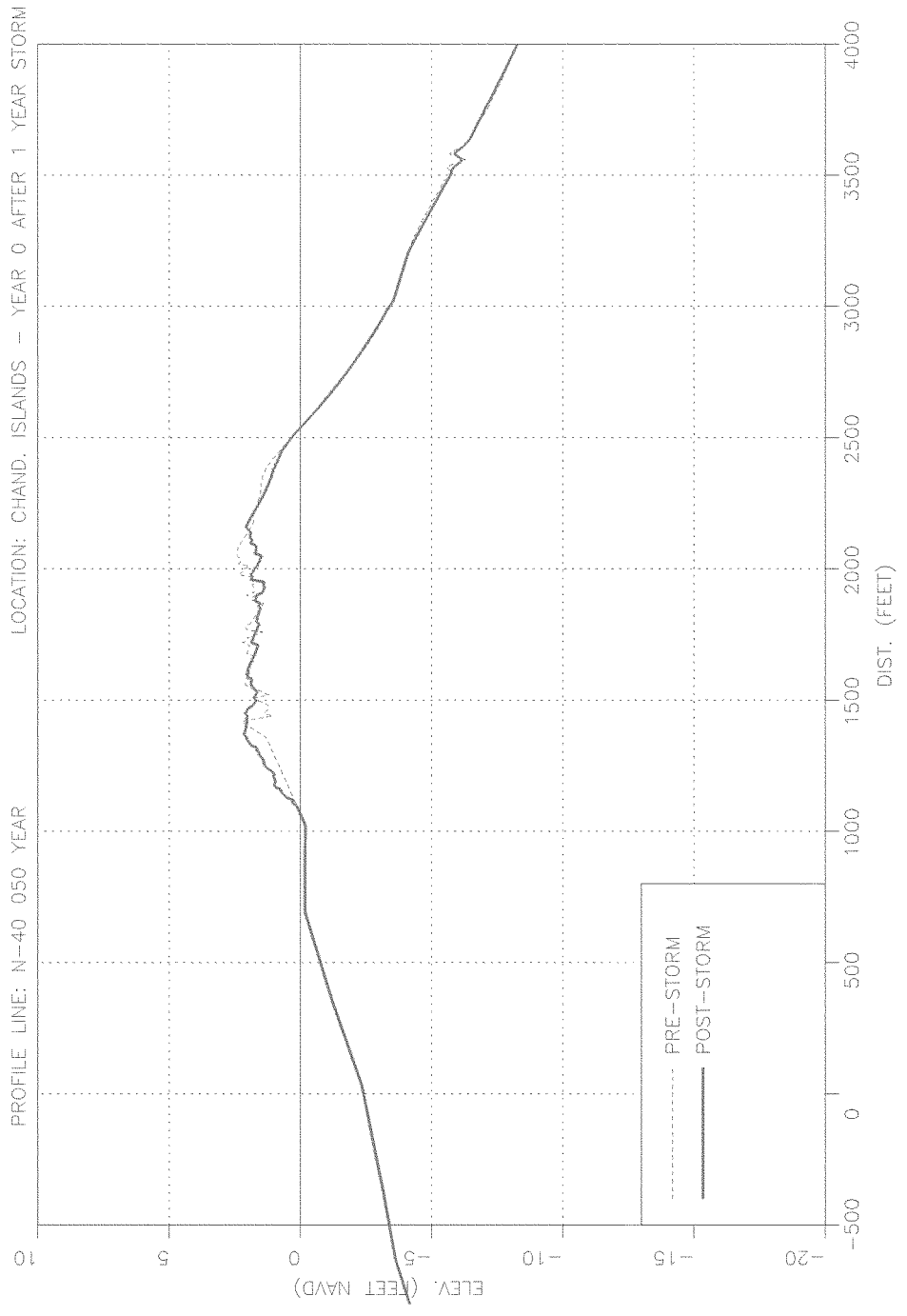

PROFILE LINE: N-40 003 YEAR
LOCATION: CHAND. ISLANDS - YEAR 0 AFTER 1 YEAR STORM
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

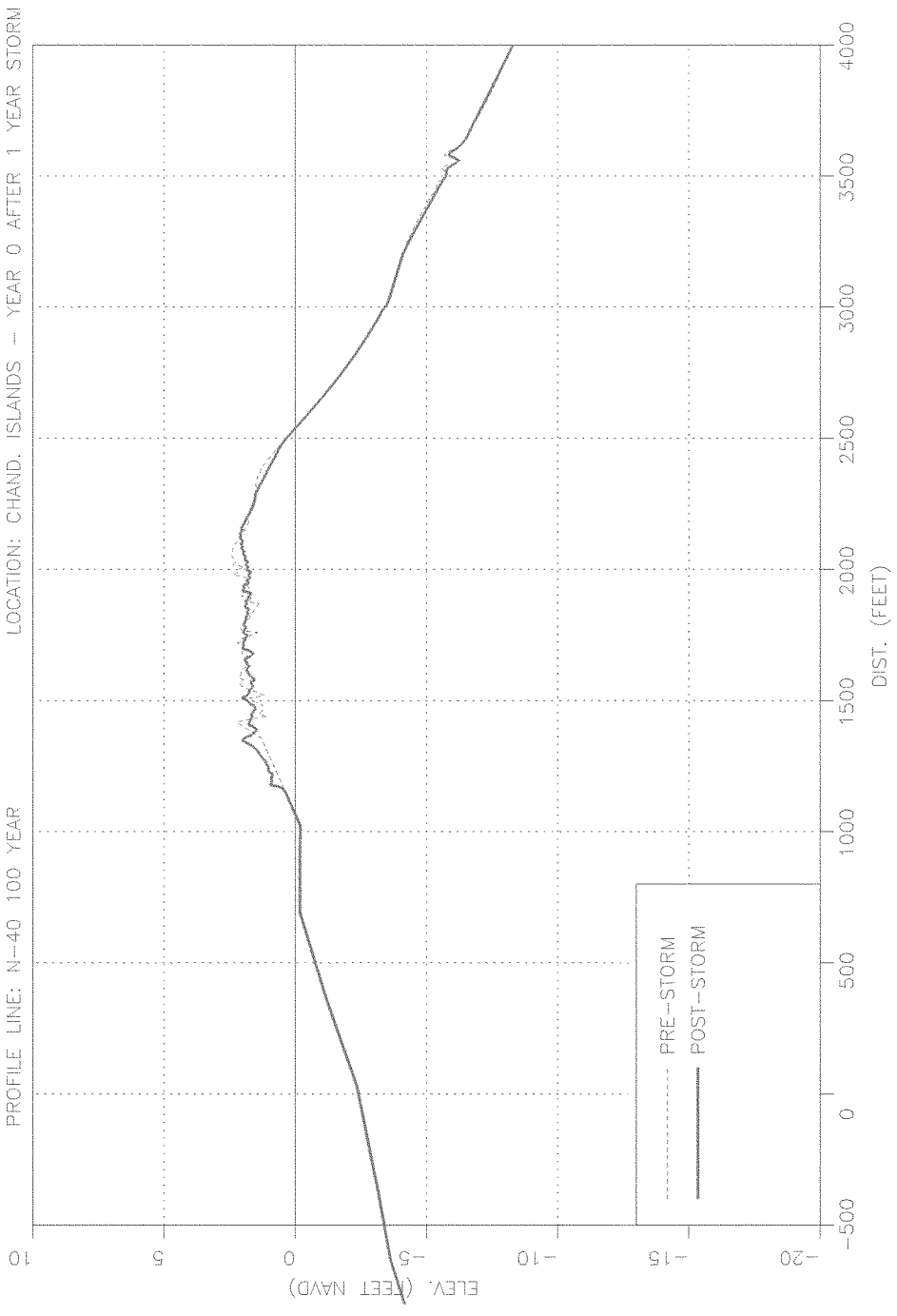

PROFILE LINE: N-40 004 YEAR
LOCATION: CHAND. ISLANDS - YEAR 0 AFTER 1 YEAR STORM
PRE-STORM
POST-STORM
ELEV. (FEET NAVD)
DIST. (FEET)
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

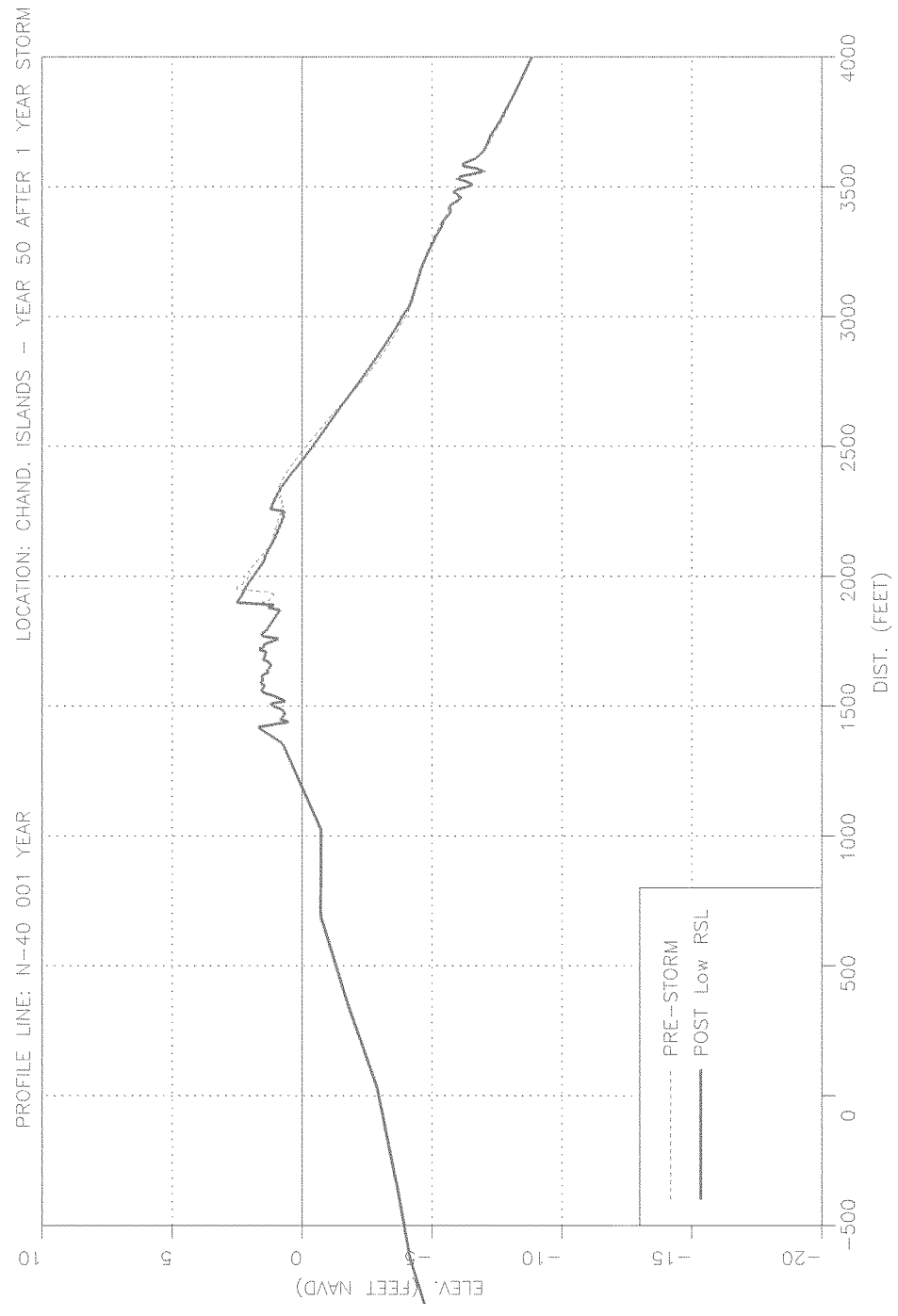

PROFILE LINE: N-40 005 YEAR
LOCATION: CHAND. ISLANDS -- YEAR 0 AFTER 1 YEAR STORM
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

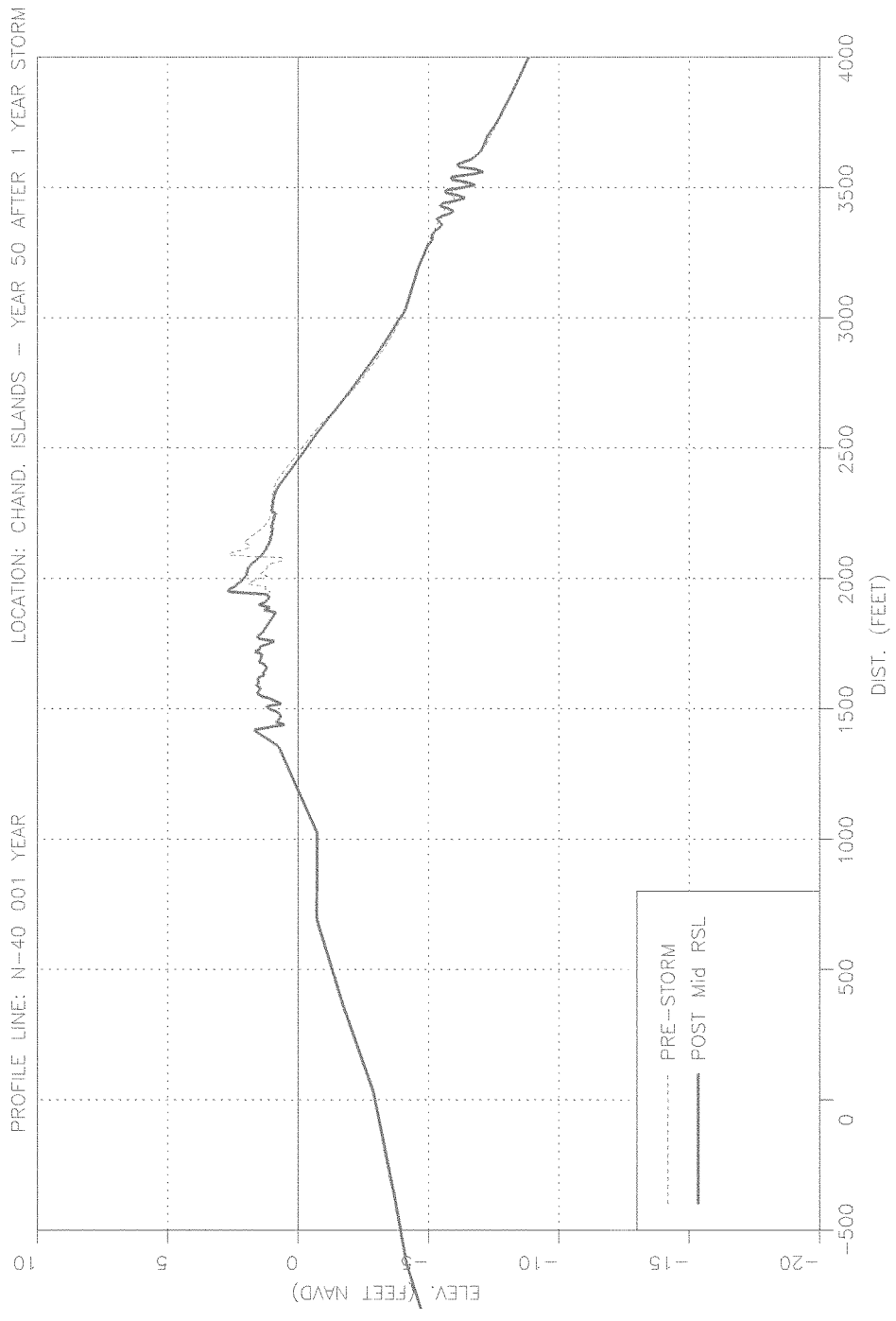

PROFILE LINE: N-40 010 YEAR
LOCATION: CHAND. ISLANDS -- YEAR 0 AFTER 1 YEAR STORM
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

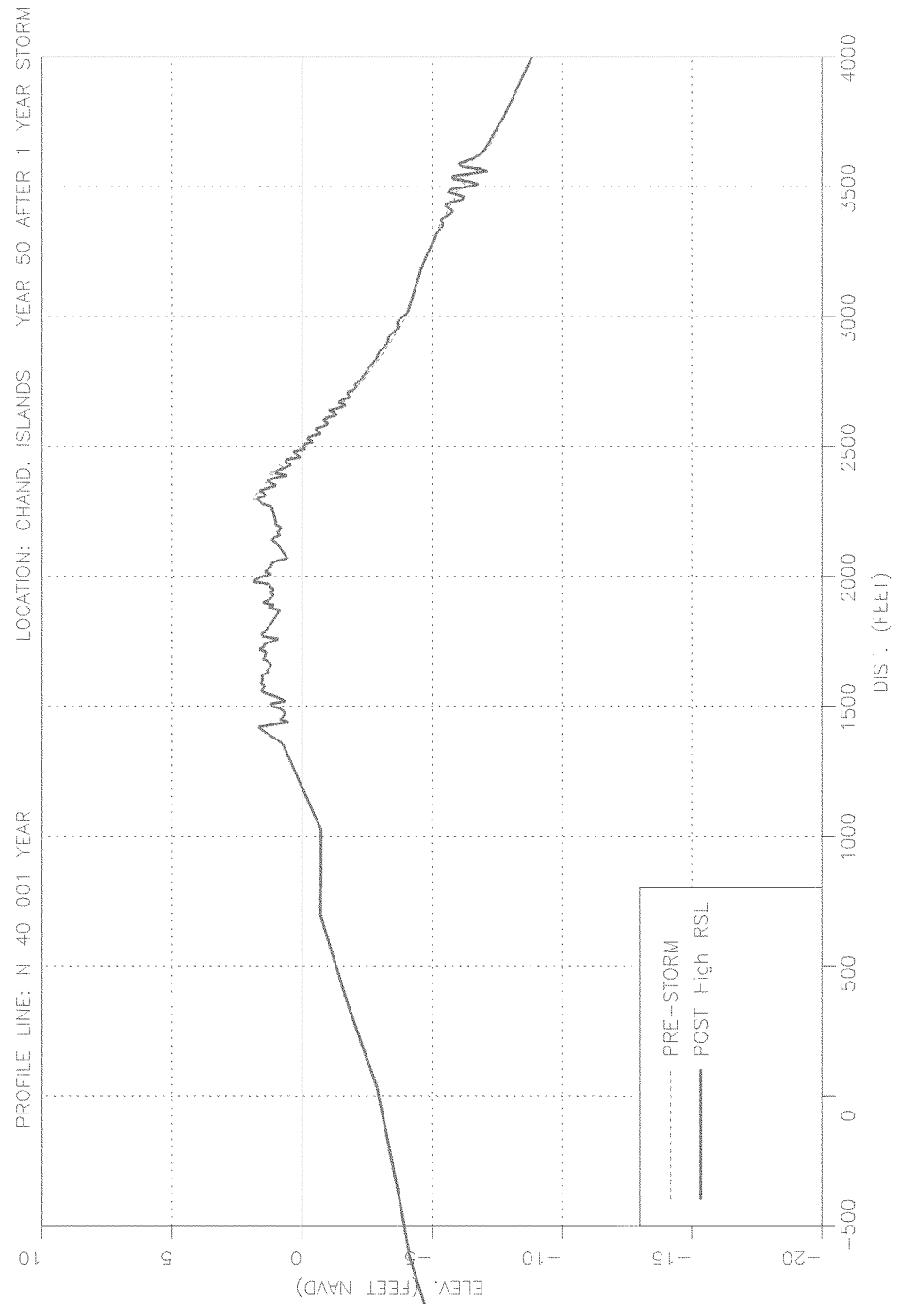

PROFILE LINE: N-40 020 YEAR
LOCATION: CHAND. ISLANDS - YEAR 0 AFTER 1 YEAR STORM
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

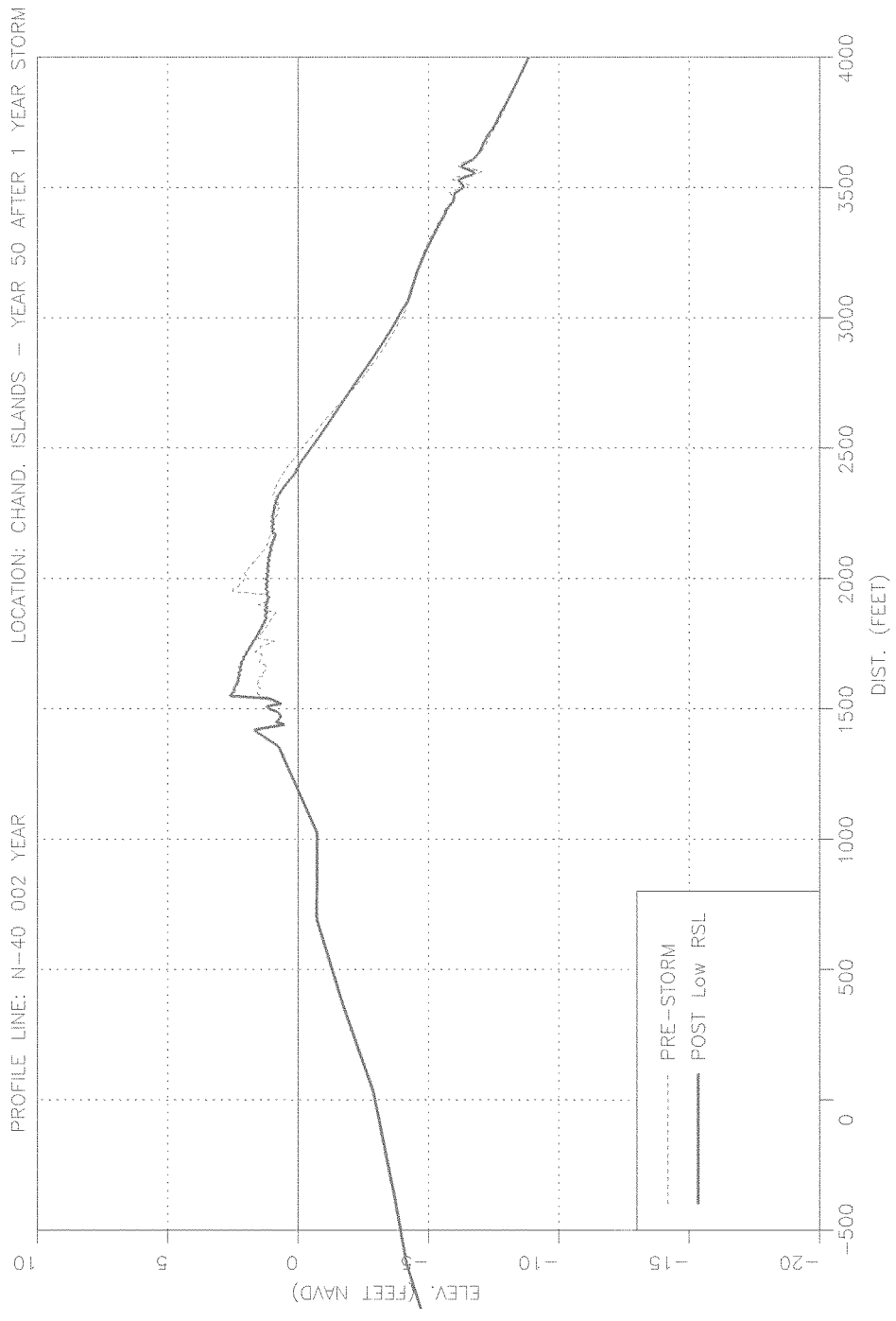

PROFILE LINE: N-40 050 YEAR
LOCATION: CHAND. ISLANDS - YEAR 0 AFTER 1 YEAR STORM
PRE-STORM
POST-STORM
ELEV. (FEET NAVD)
DIST. (FEET)
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

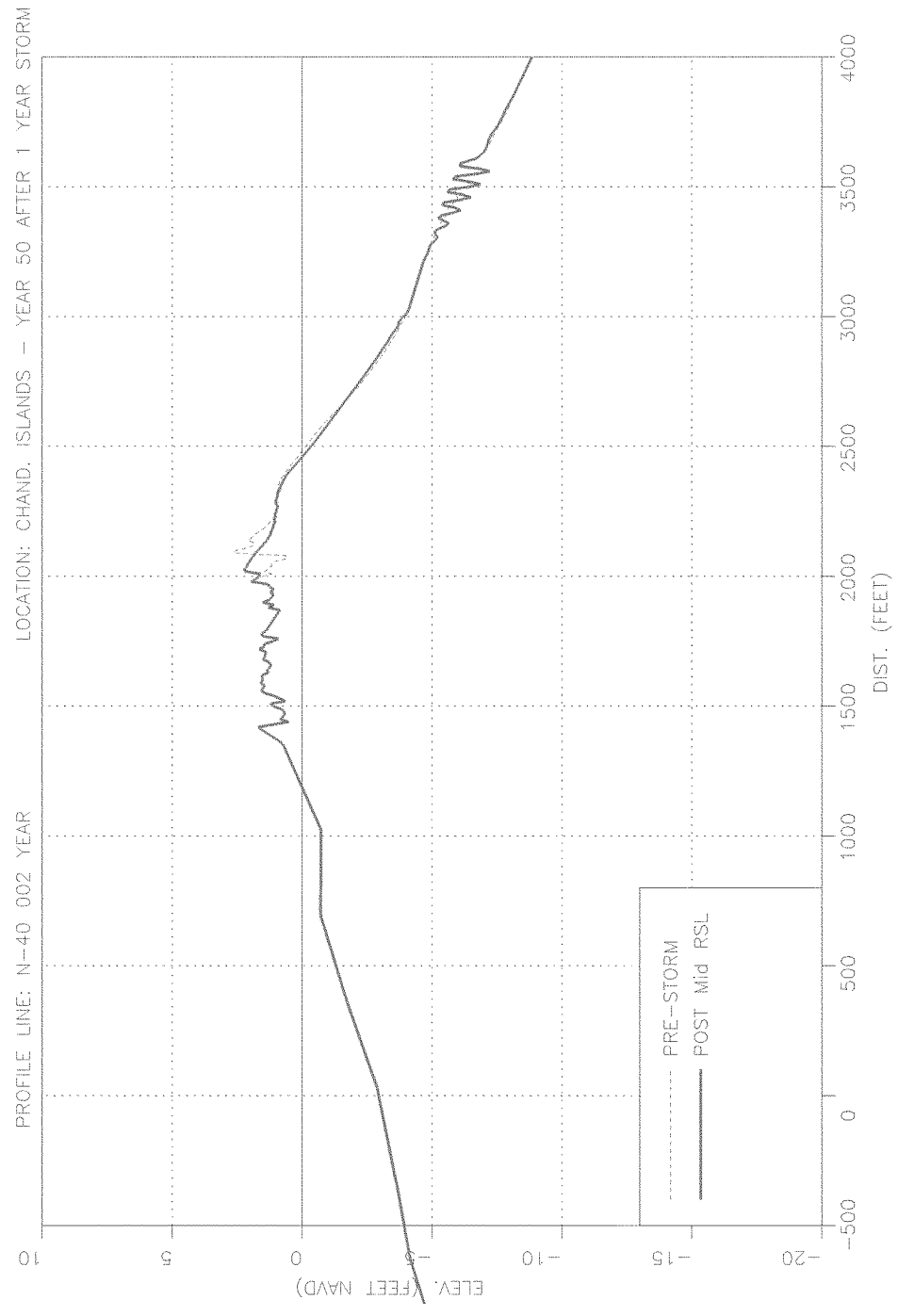

PROFILE LINE: N-40 100 YEAR
LOCATION: CHAND. ISLANDS - YEAR 0 AFTER 1 YEAR STORM
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

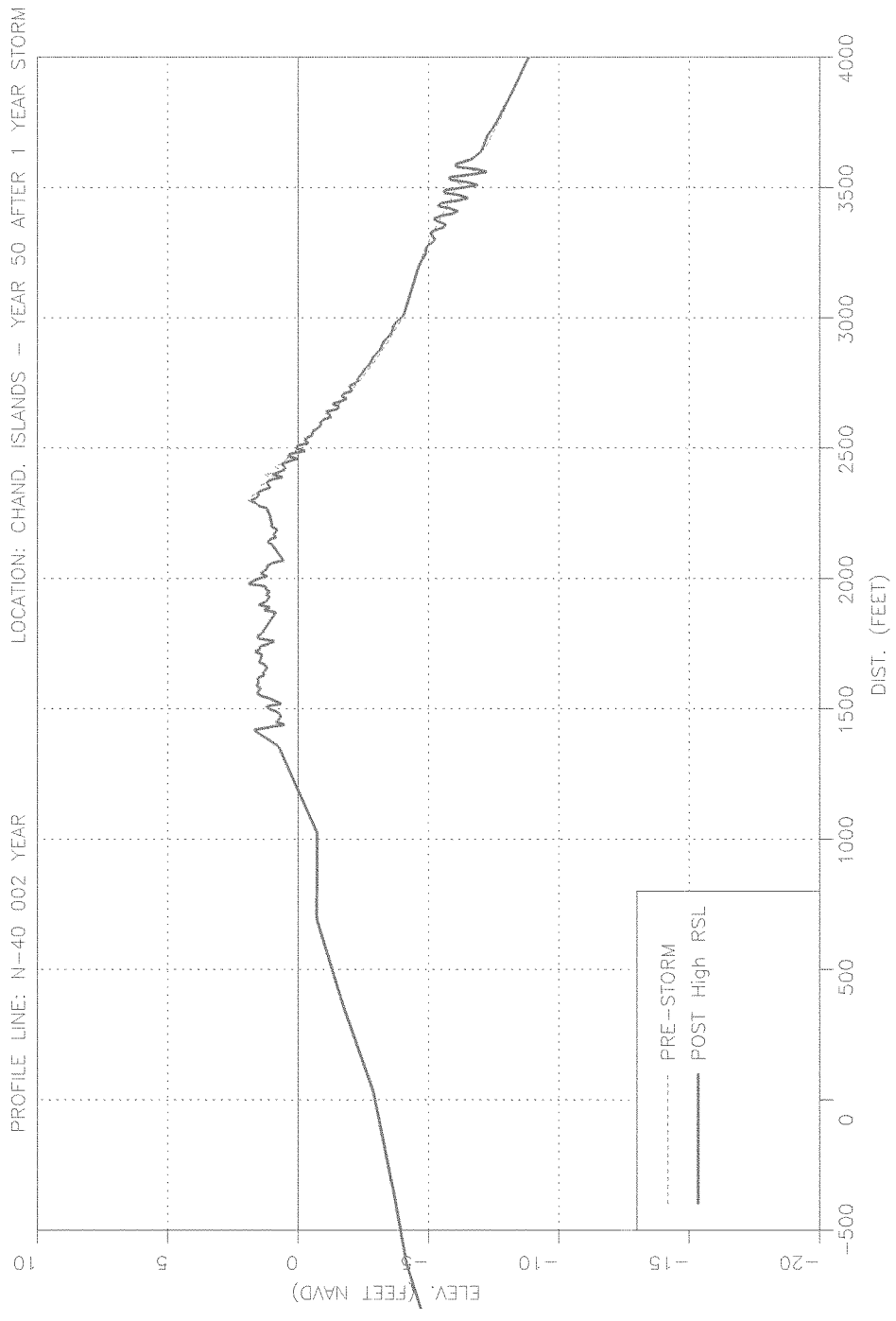

PROFILE LINE: N-40 001 YEAR
LOCATION: CHAND. ISLANDS -- YEAR 50 AFTER 1 YEAR STORM
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

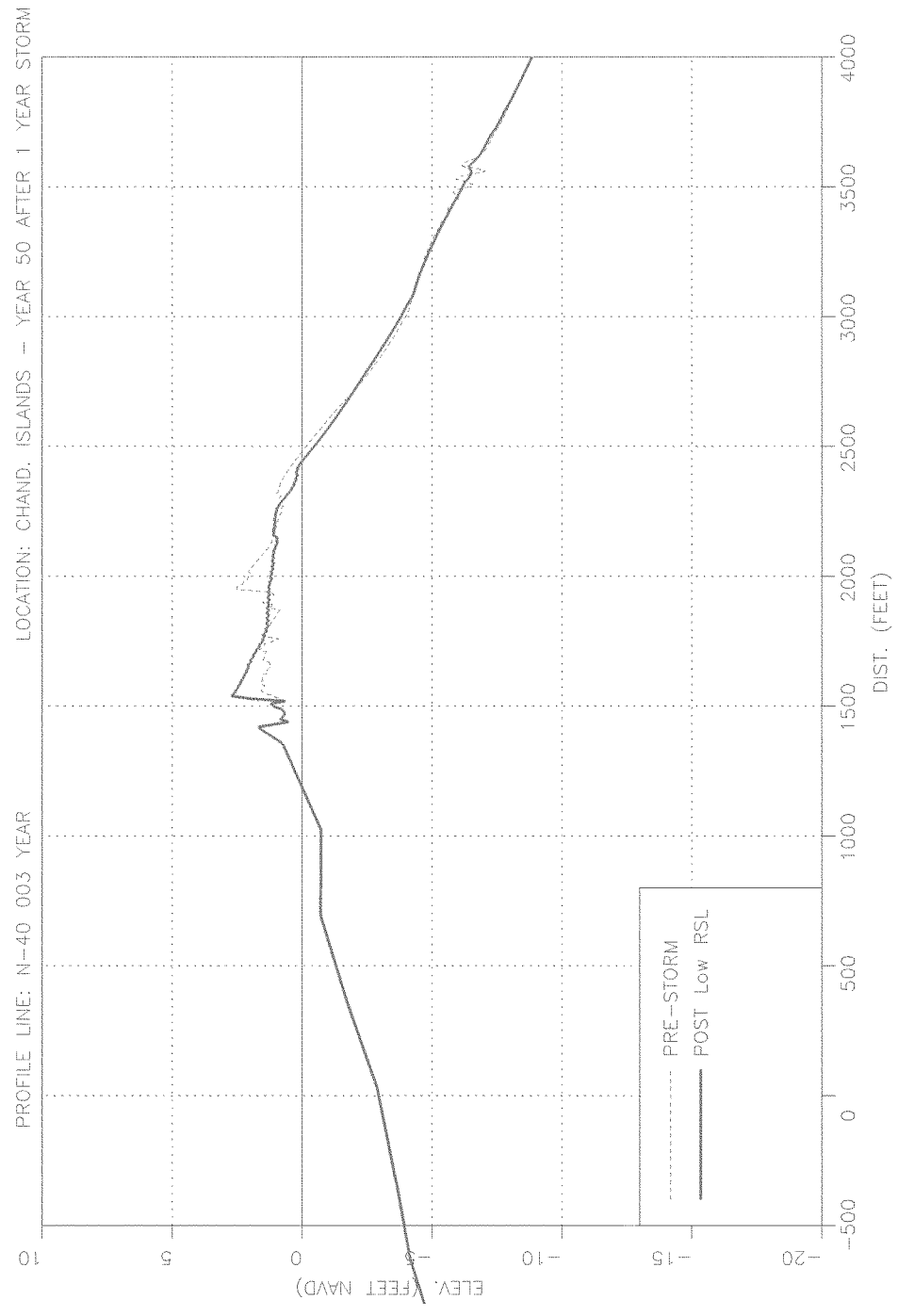

PROFILE LINE: N-40 001 YEAR
LOCATION: CHAND. ISLANDS -- YEAR 50 AFTER 1 YEAR STORM
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Mid RSL
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

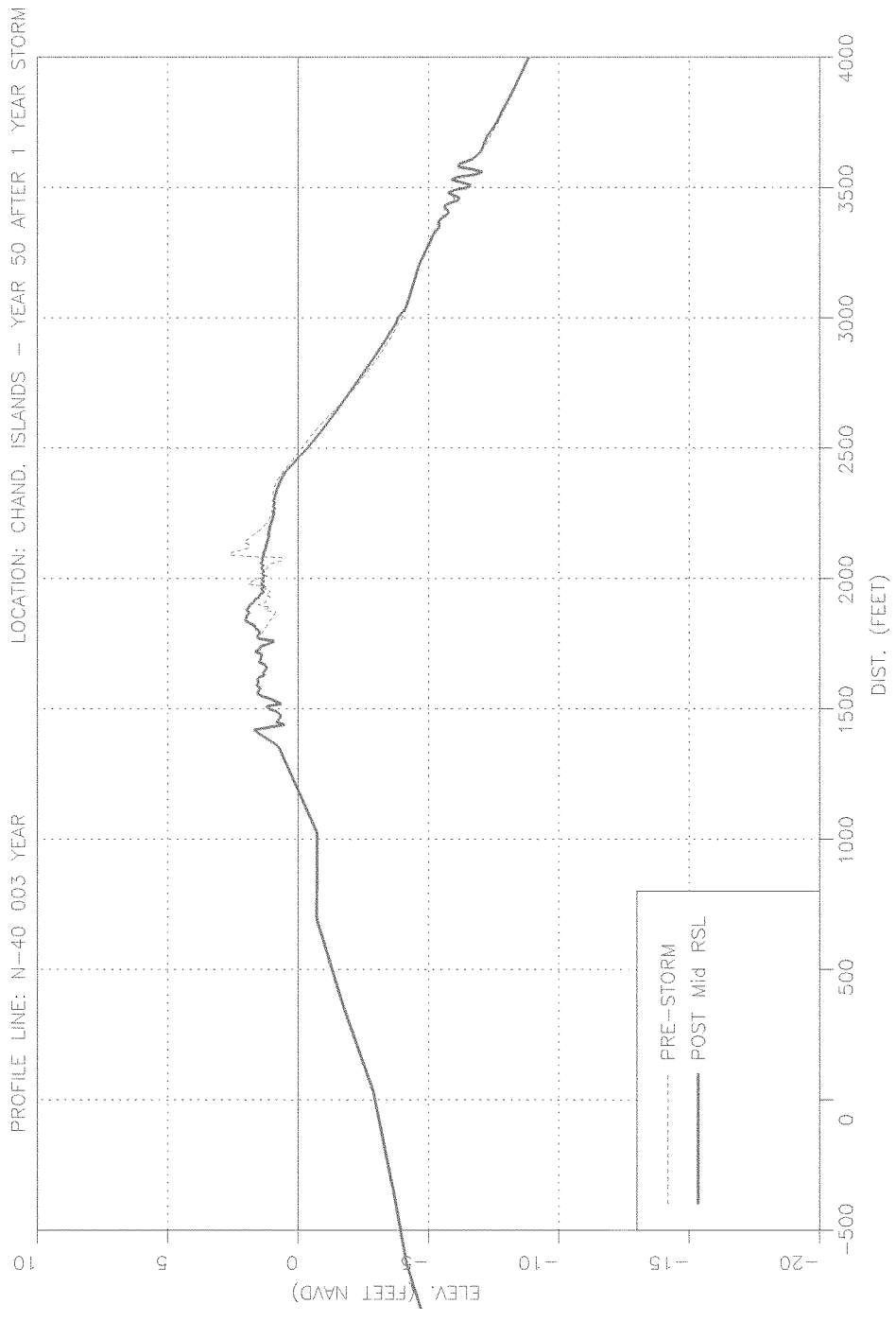

PROFILE LINE: N-40 001 YEAR
LOCATION: CHAND. ISLANDS - YEAR 50 AFTER 1 YEAR STORM
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST High RSL
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

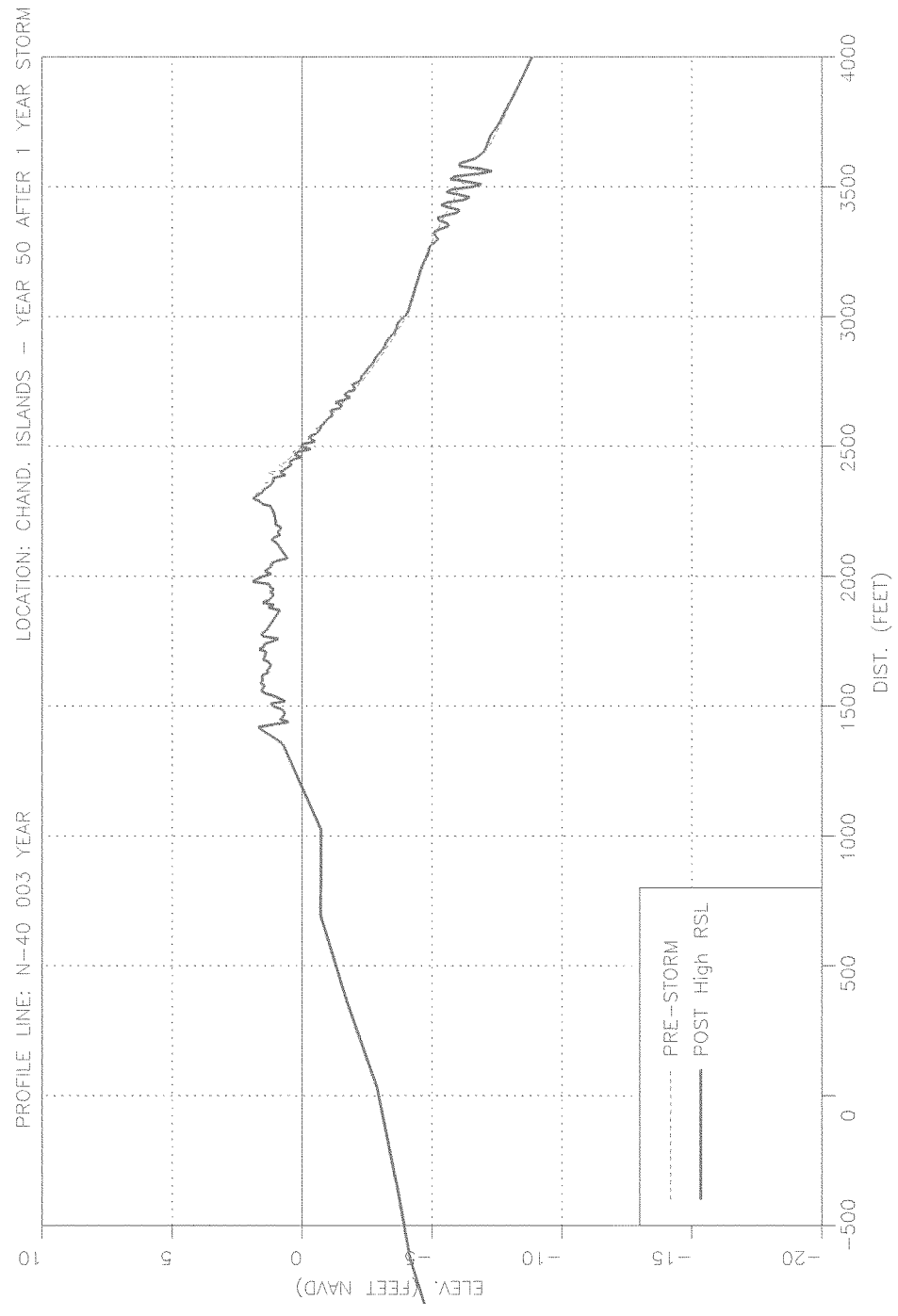

PROFILE LINE: N-40 002 YEAR
LOCATION: CHAND. ISLANDS - YEAR 50 AFTER 1 YEAR STORM
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

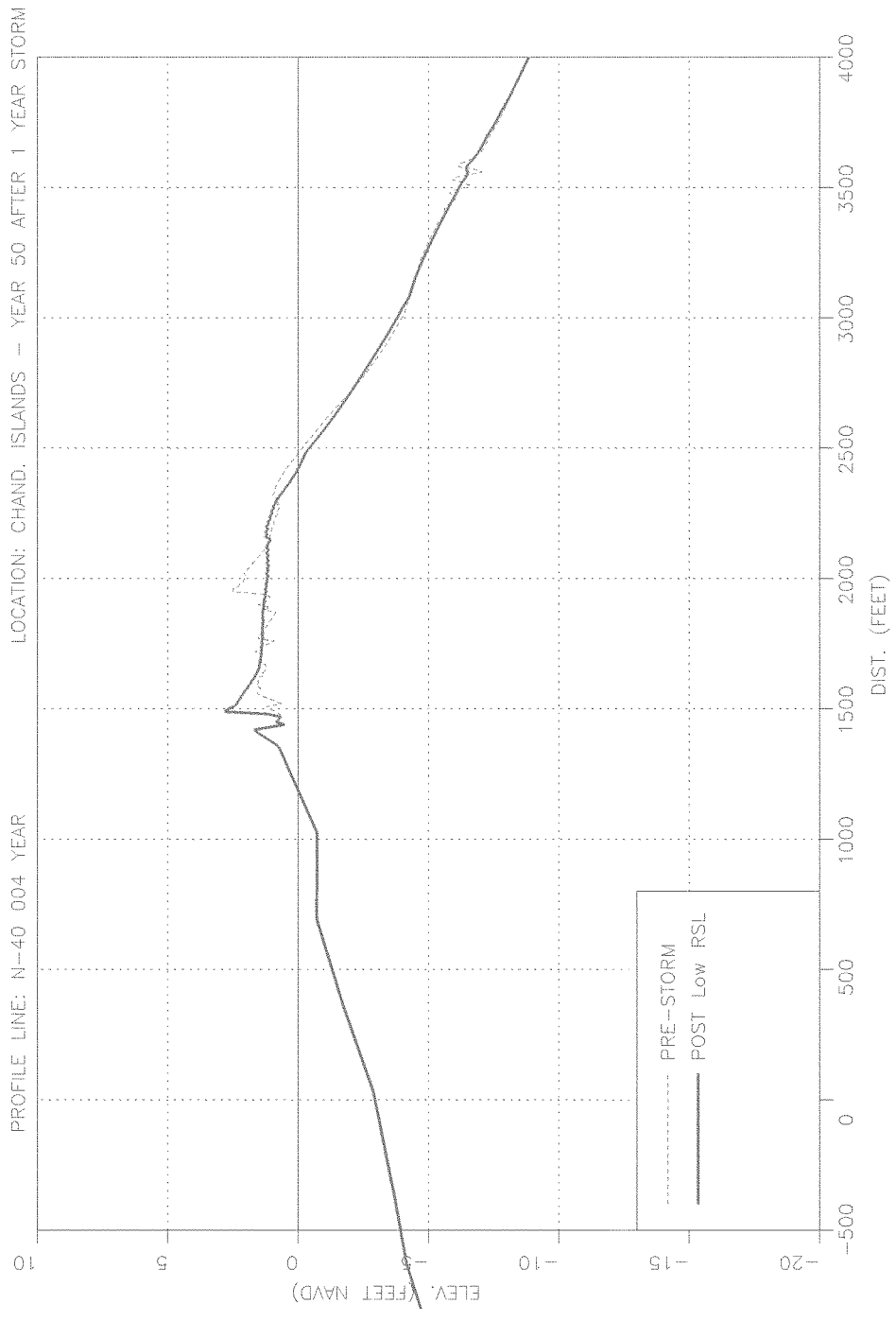

PROFILE LINE: N-40 002 YEAR
LOCATION: CHAND. ISLANDS - YEAR 50 AFTER 1 YEAR STORM
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Mid RSL
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

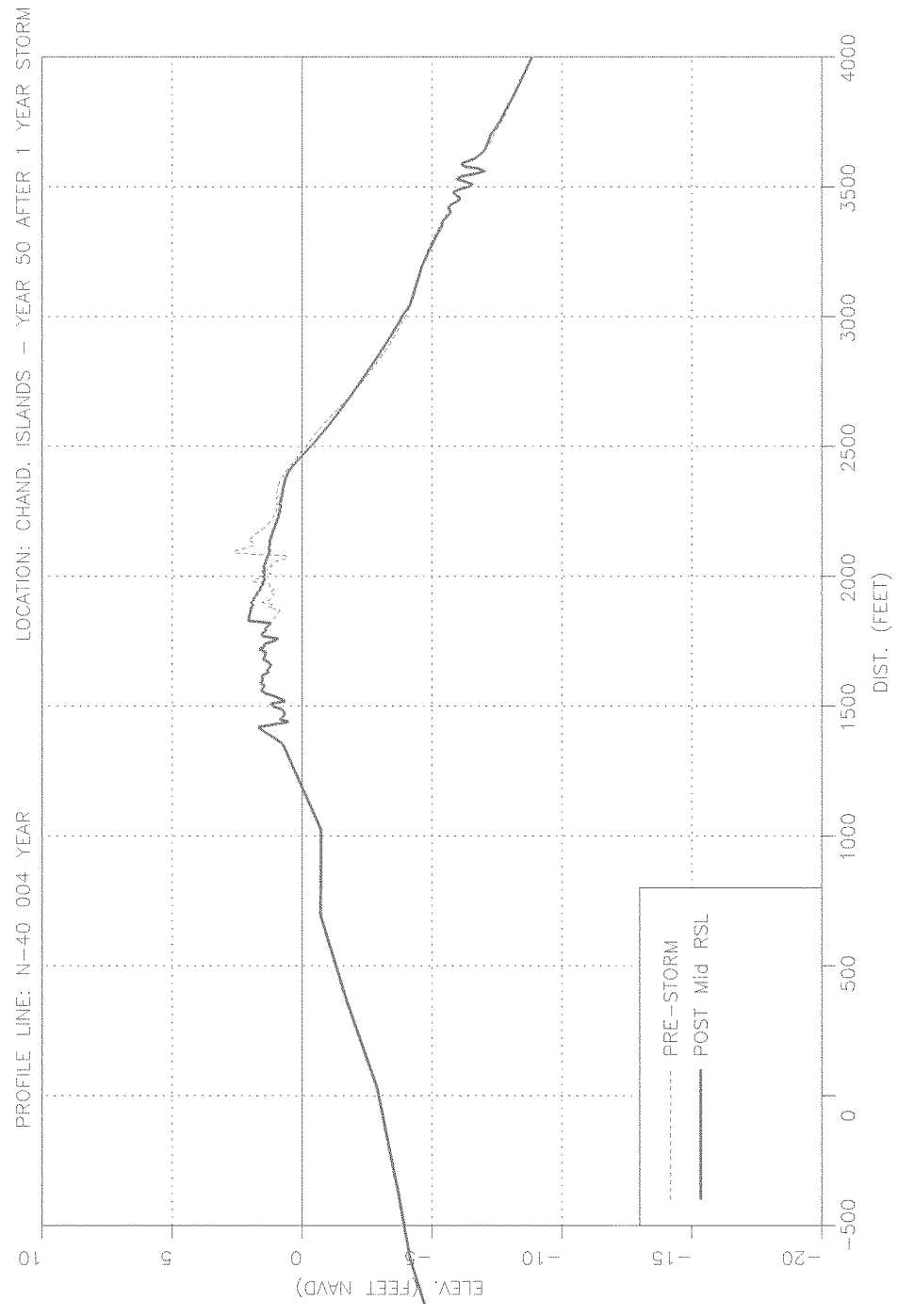

PROFILE LINE: N-40 002 YEAR
LOCATION: CHAND. ISLANDS - YEAR 50 AFTER 1 YEAR STORM
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST High RSL
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

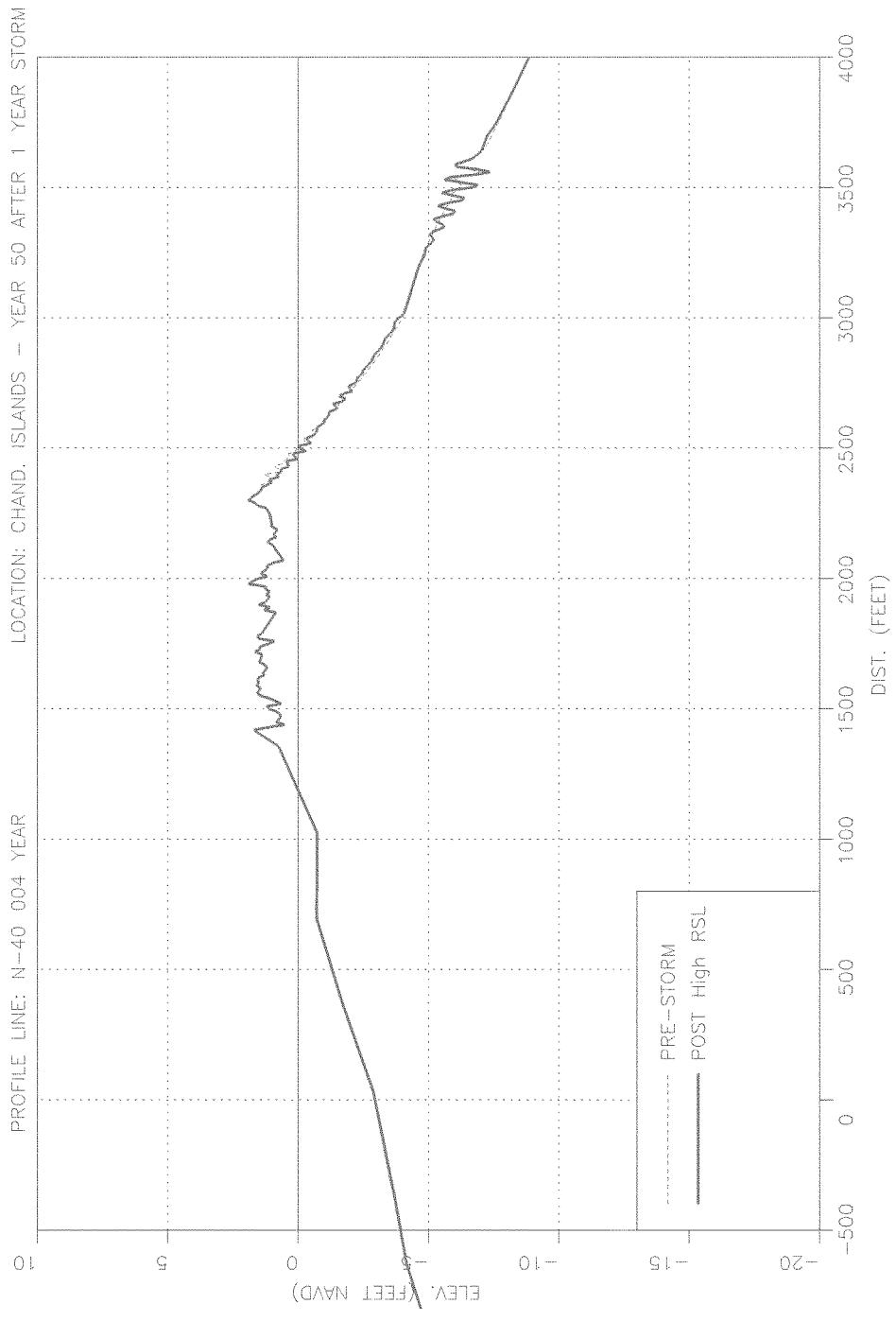

PROFILE LINE: N-40 003 YEAR
LOCATION: CHAND. ISLANDS - YEAR 50 AFTER 1 YEAR STORM
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

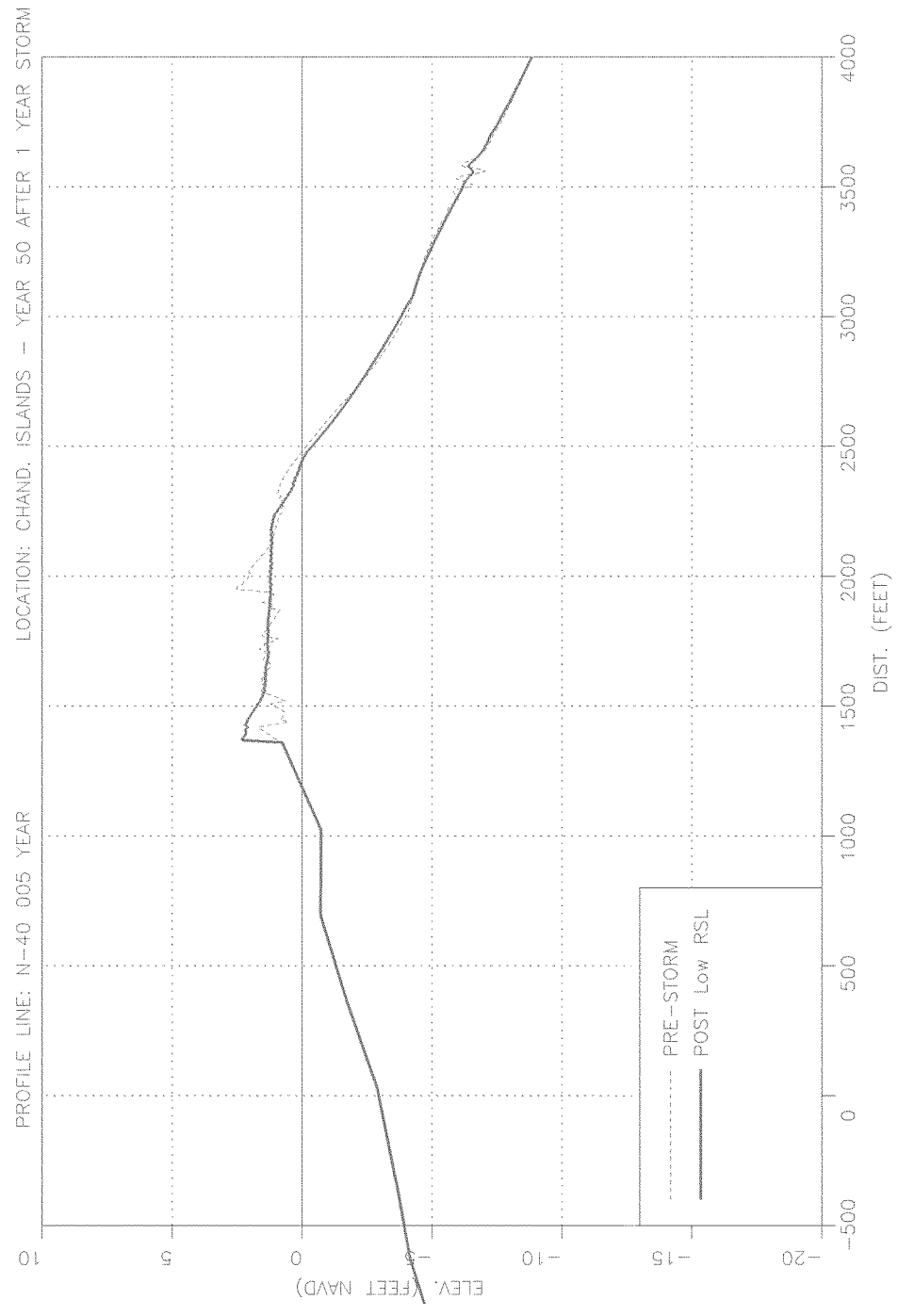

PROFILE LINE: N-40 003 YEAR
LOCATION: CHAND. ISLANDS - YEAR 50 AFTER 1 YEAR STORM
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Mid RSL
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

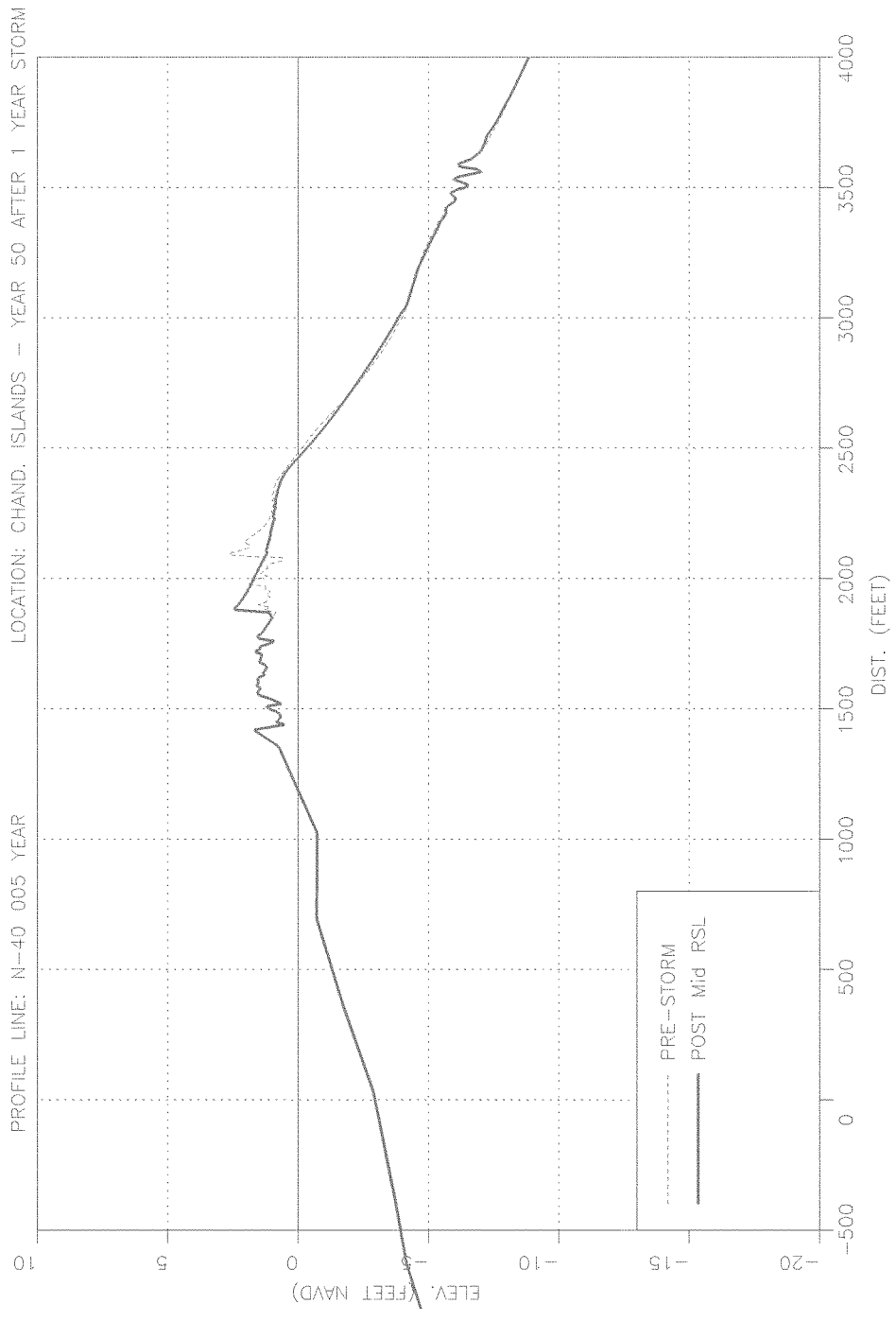

PROFILE LINE: N-40 003 YEAR
LOCATION: CHAND. ISLANDS -- YEAR 50 AFTER 1 YEAR STORM
PRE-STORM
POST High RSL
ELEV. (FEET NAVD)
DIST. (FEET)
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

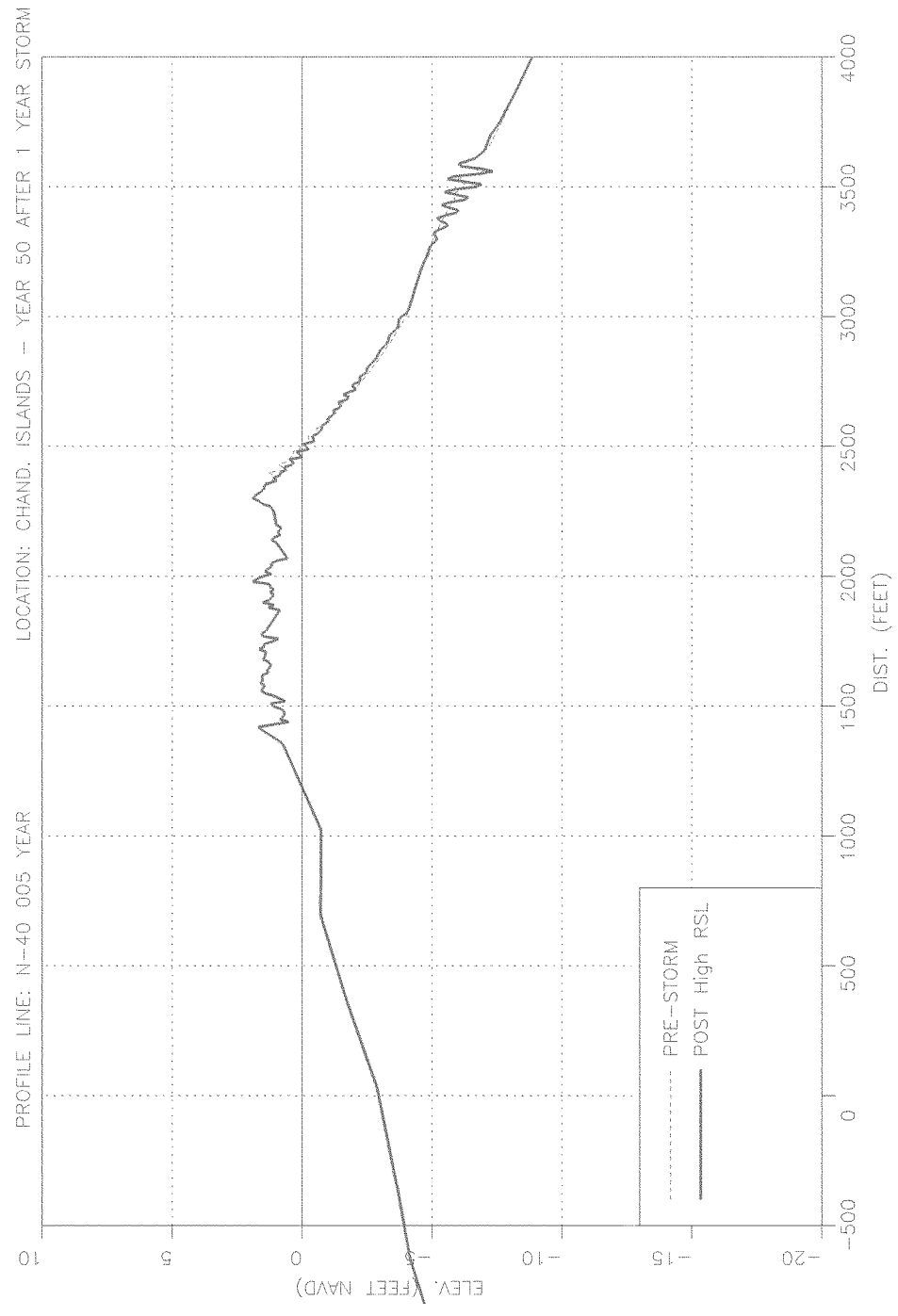

PROFILE LINE: N-40 004 YEAR
LOCATION: CHAND. ISLANDS - YEAR 50 AFTER 1 YEAR STORM
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

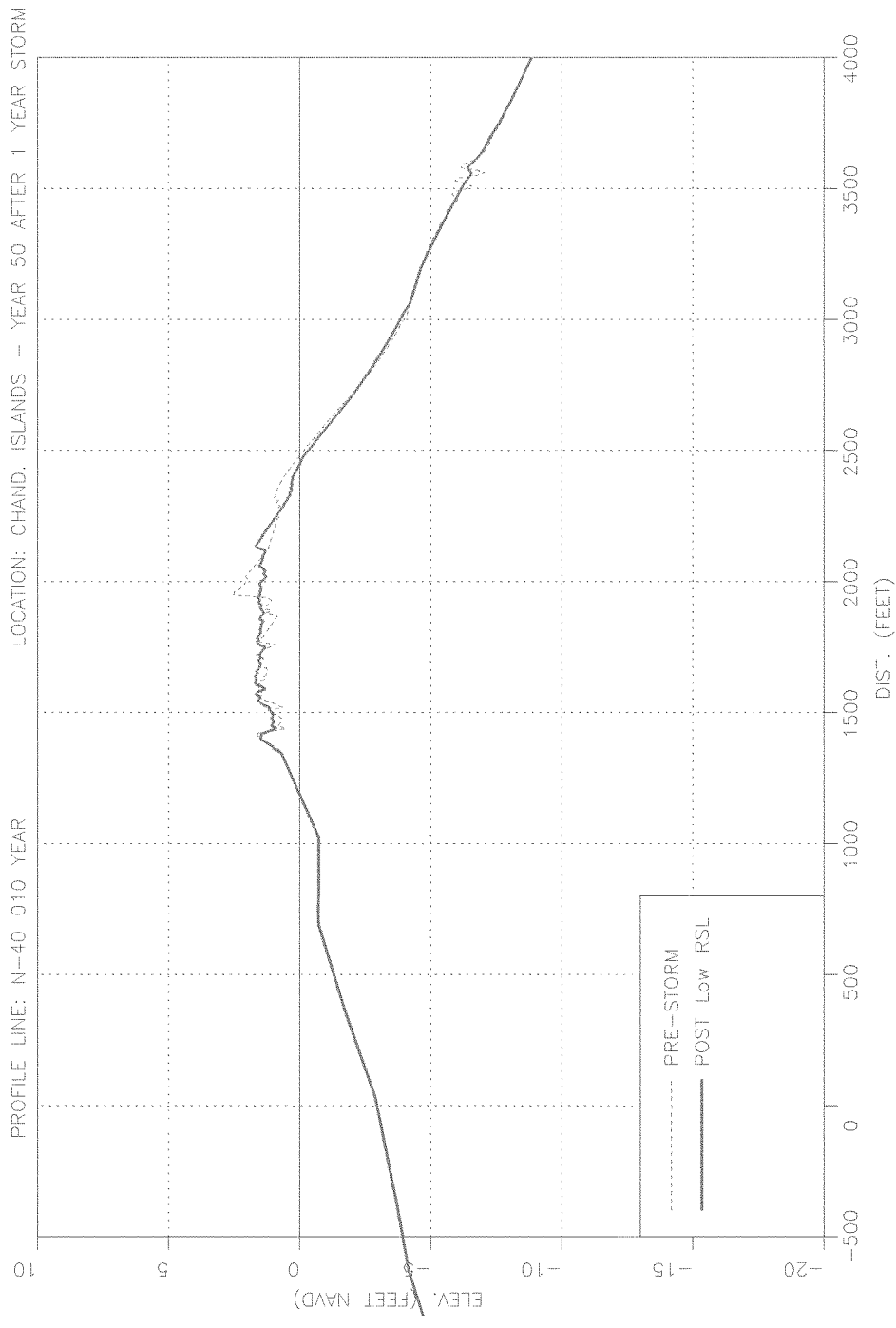

PROFILE LINE: N-40 004 YEAR
LOCATION: CHAND. ISLANDS - YEAR 50 AFTER 1 YEAR STORM
PRE-STORM
POST Mid RSL
ELEV. (FEET NAVD)
DIST. (FEET)
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

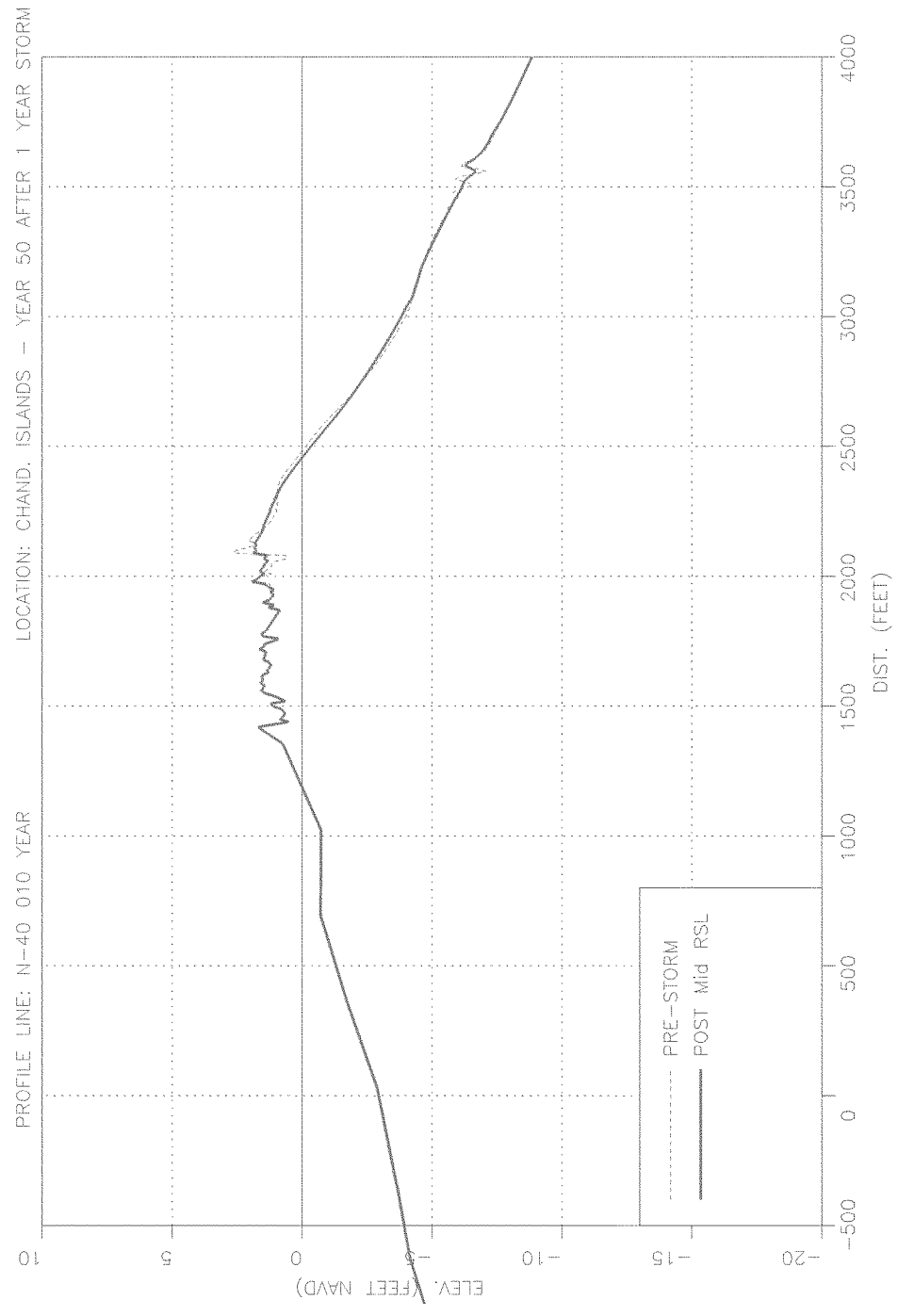

PROFILE LINE: N-40 004 YEAR
LOCATION: CHAND. ISLANDS - YEAR 50 AFTER 1 YEAR STORM
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST High RSL
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

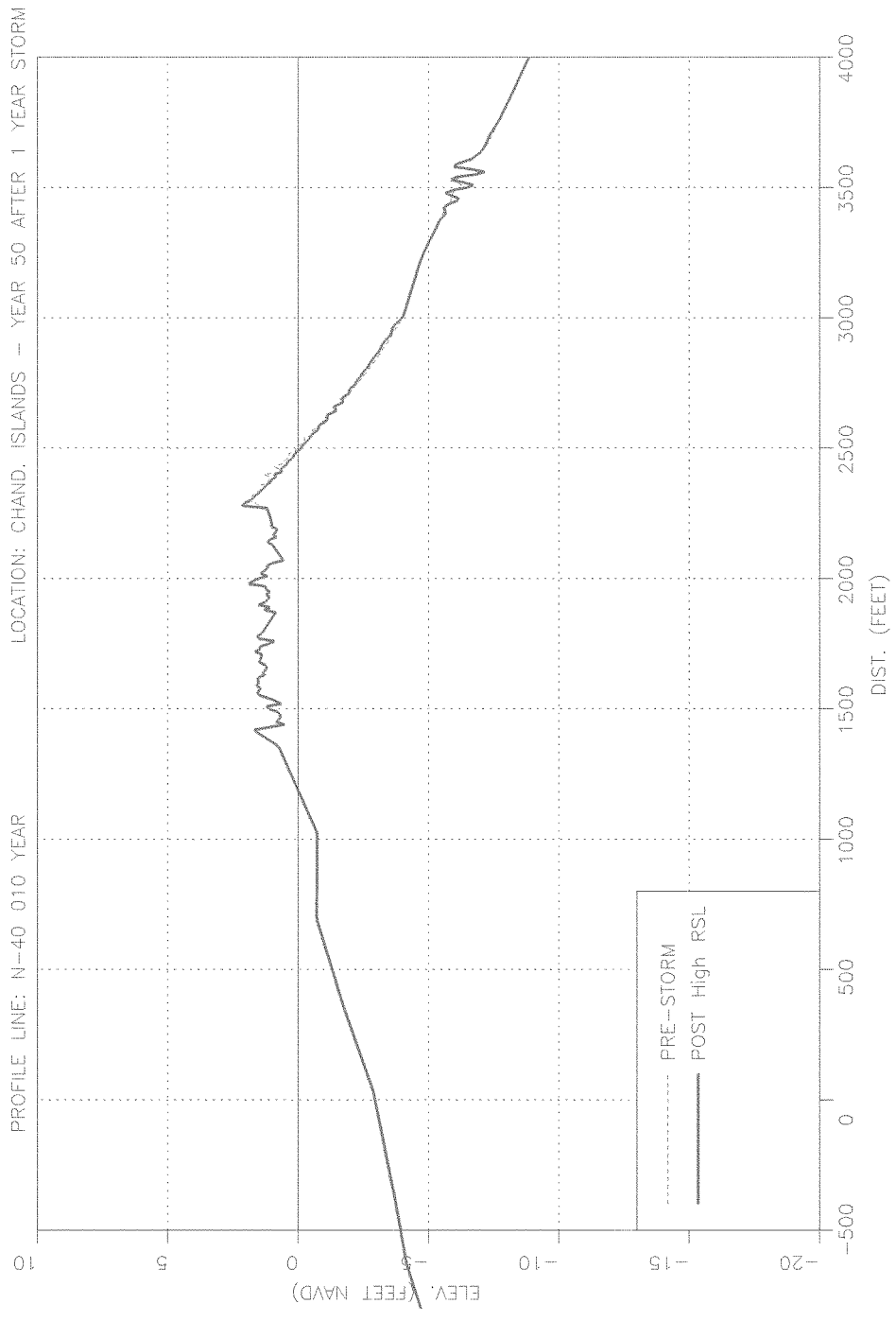

PROFILE LINE: N-40 005 YEAR
LOCATION: CHAND. ISLANDS - YEAR 50 AFTER 1 YEAR STORM
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

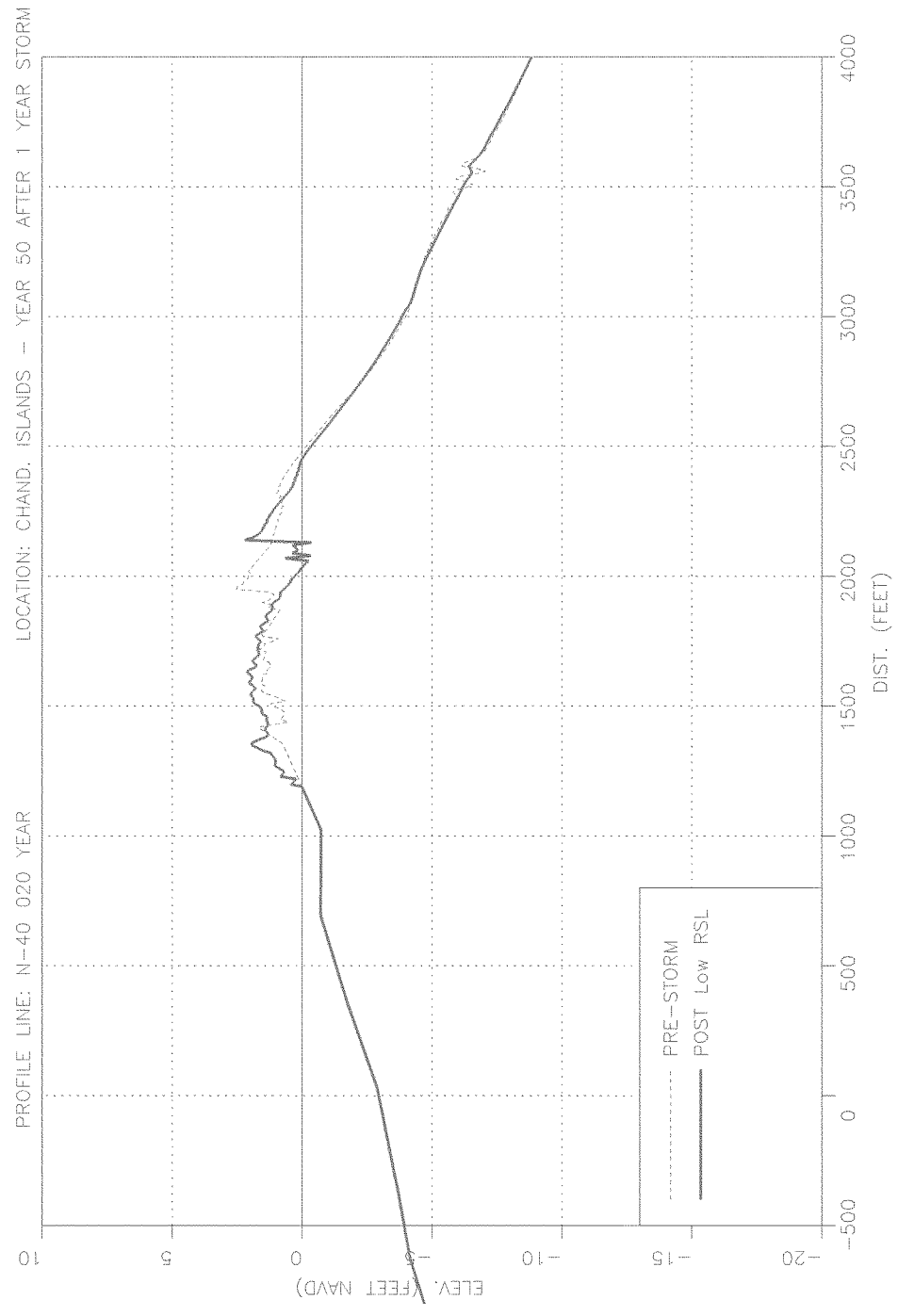

PROFILE LINE: N-40 005 YEAR
LOCATION: CHAND. ISLANDS -- YEAR 50 AFTER 1 YEAR STORM
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Mid RSL
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

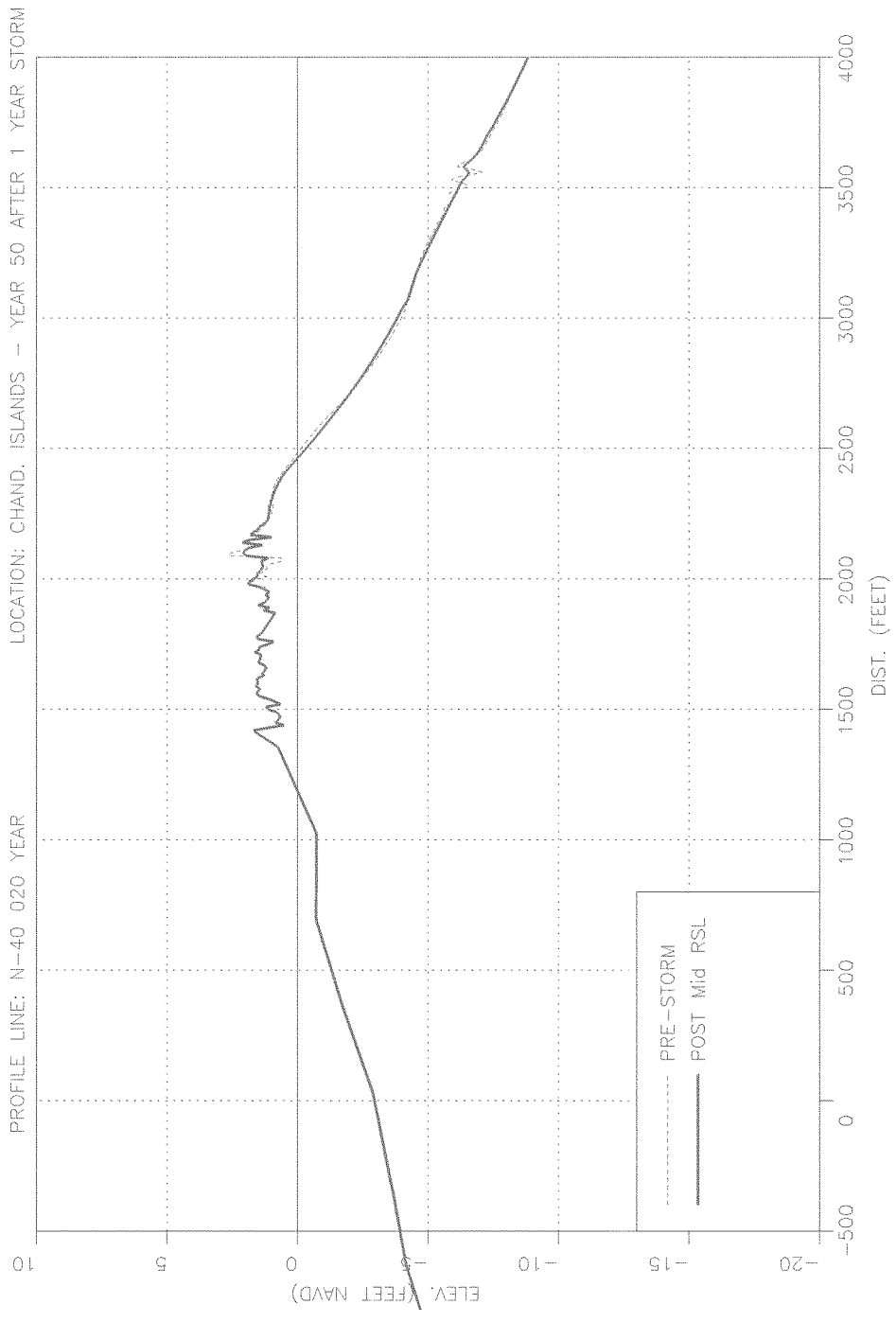

PROFILE LINE: N-40 005 YEAR
LOCATION: CHAND. ISLANDS - YEAR 50 AFTER 1 YEAR STORM
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST High RSL
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

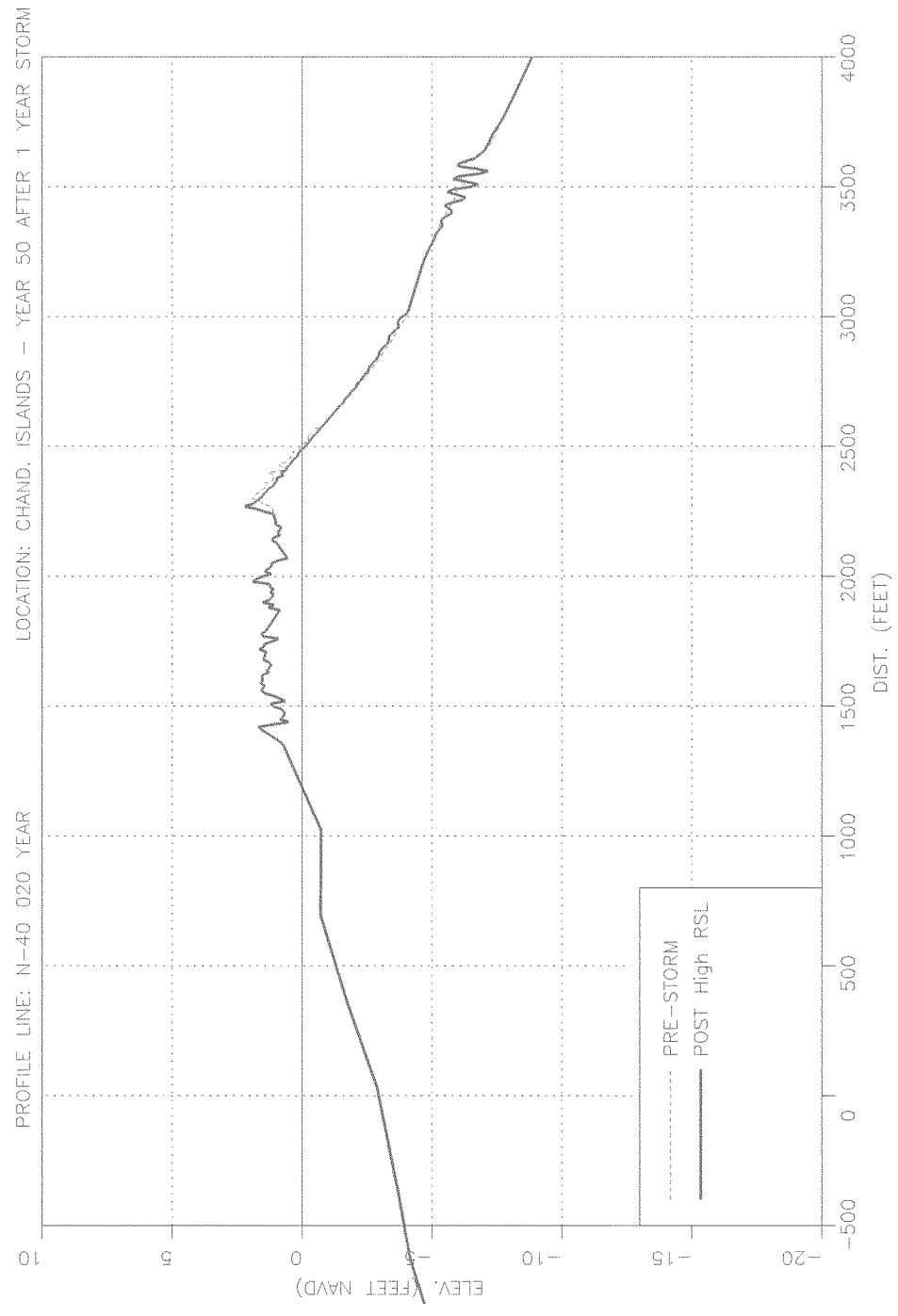

PROFILE LINE: N-40 010 YEAR
LOCATION: CHAND. ISLANDS - YEAR 50 AFTER 1 YEAR STORM
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

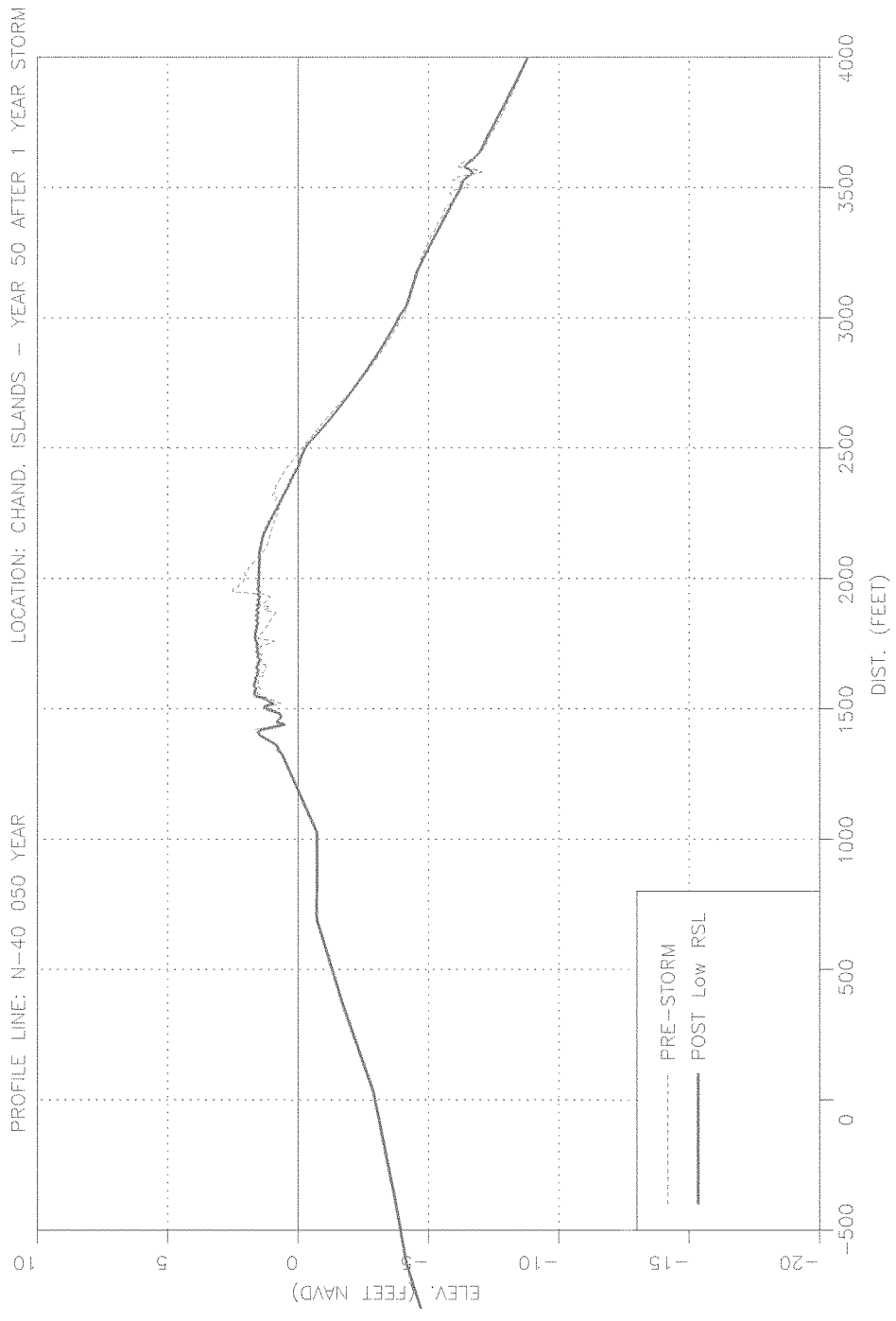

PROFILE LINE: N-40 010 YEAR
LOCATION: CHAND. ISLANDS - YEAR 50 AFTER 1 YEAR STORM
PRE-STORM
POST Mid RSL
ELEV. (FEET NAVD)
DIST. (FEET)
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

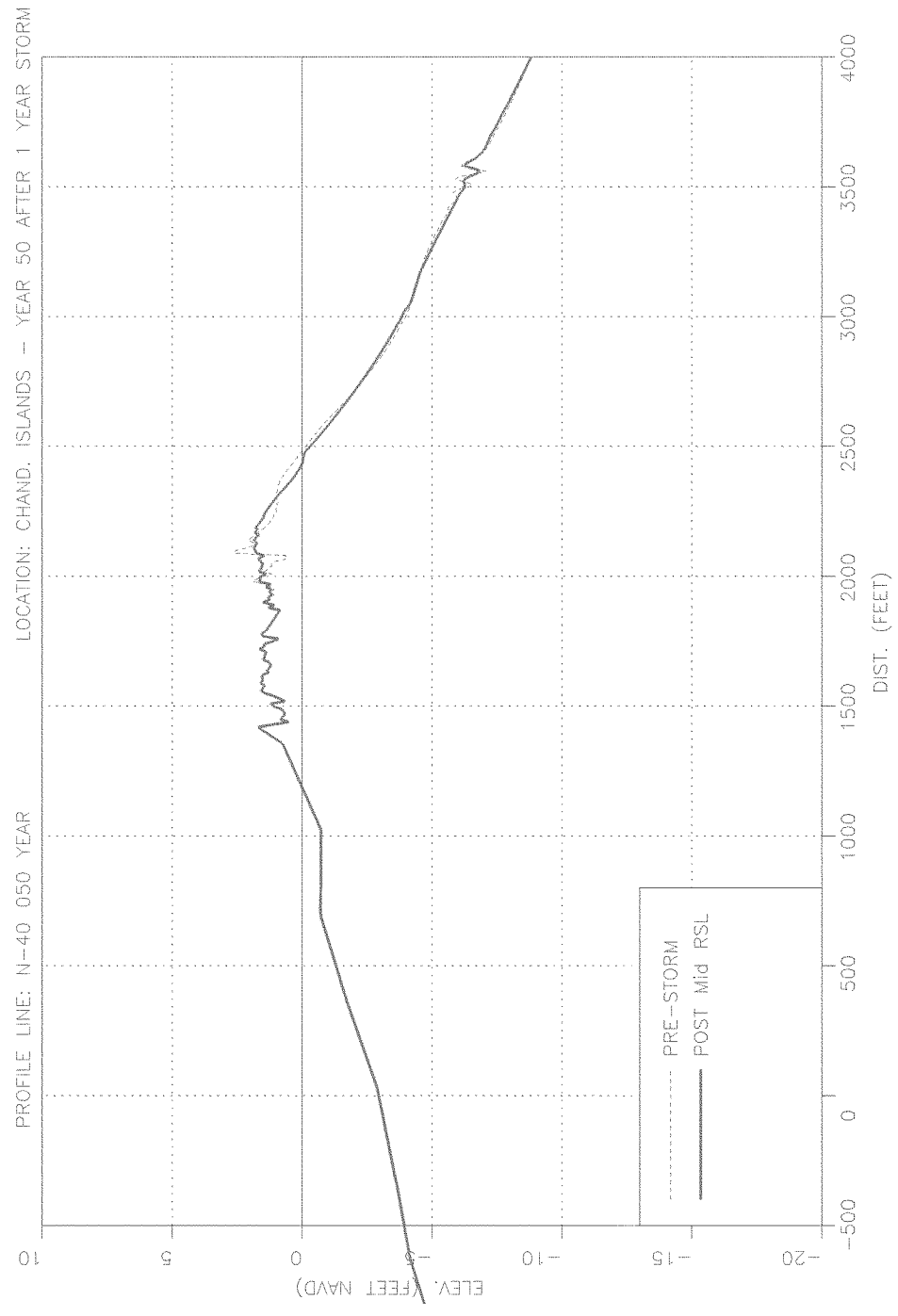

PROFILE LINE: N-40 010 YEAR
LOCATION: CHAND. ISLANDS - YEAR 50 AFTER 1 YEAR STORM
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST High RSL
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

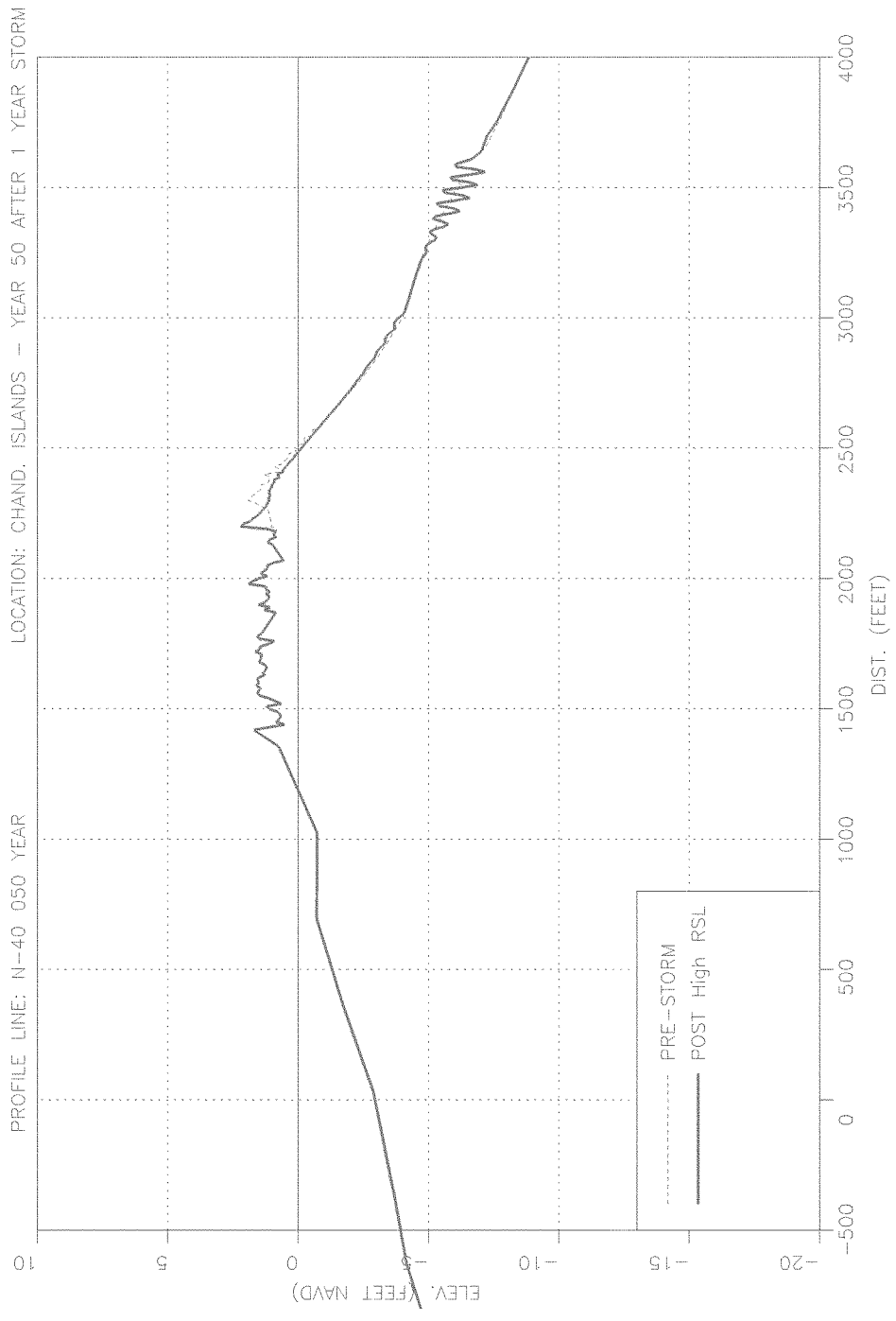

PROFILE LINE: N-40 020 YEAR
LOCATION: CHAND. ISLANDS -- YEAR 50 AFTER 1 YEAR STORM
PRE-STORM
POST Low RSL
ELEV. (FEET NAVD)
DIST. (FEET)
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

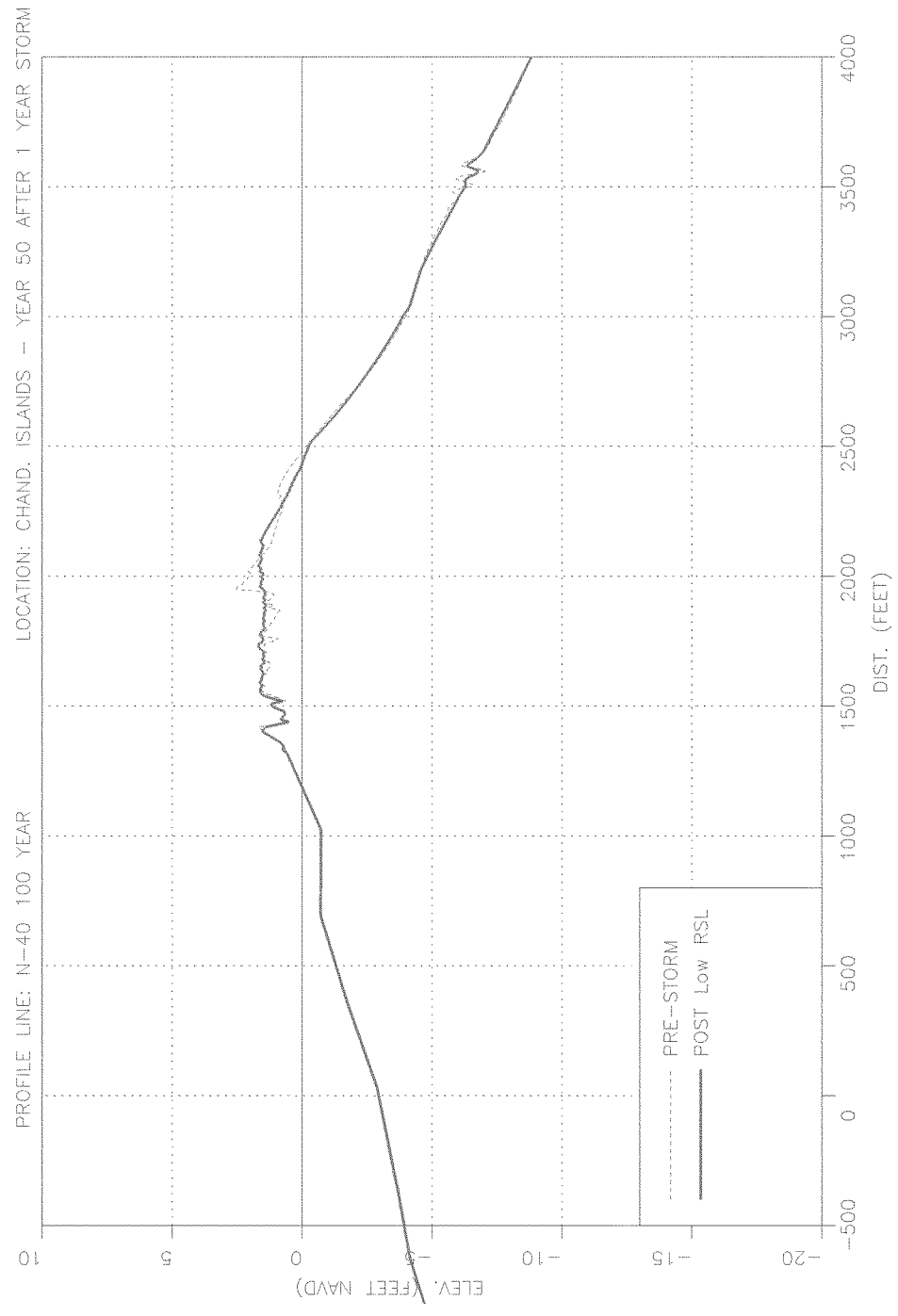

PROFILE LINE: N-40 020 YEAR
LOCATION: CHAND. ISLANDS - YEAR 50 AFTER 1 YEAR STORM
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Mid RSL
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

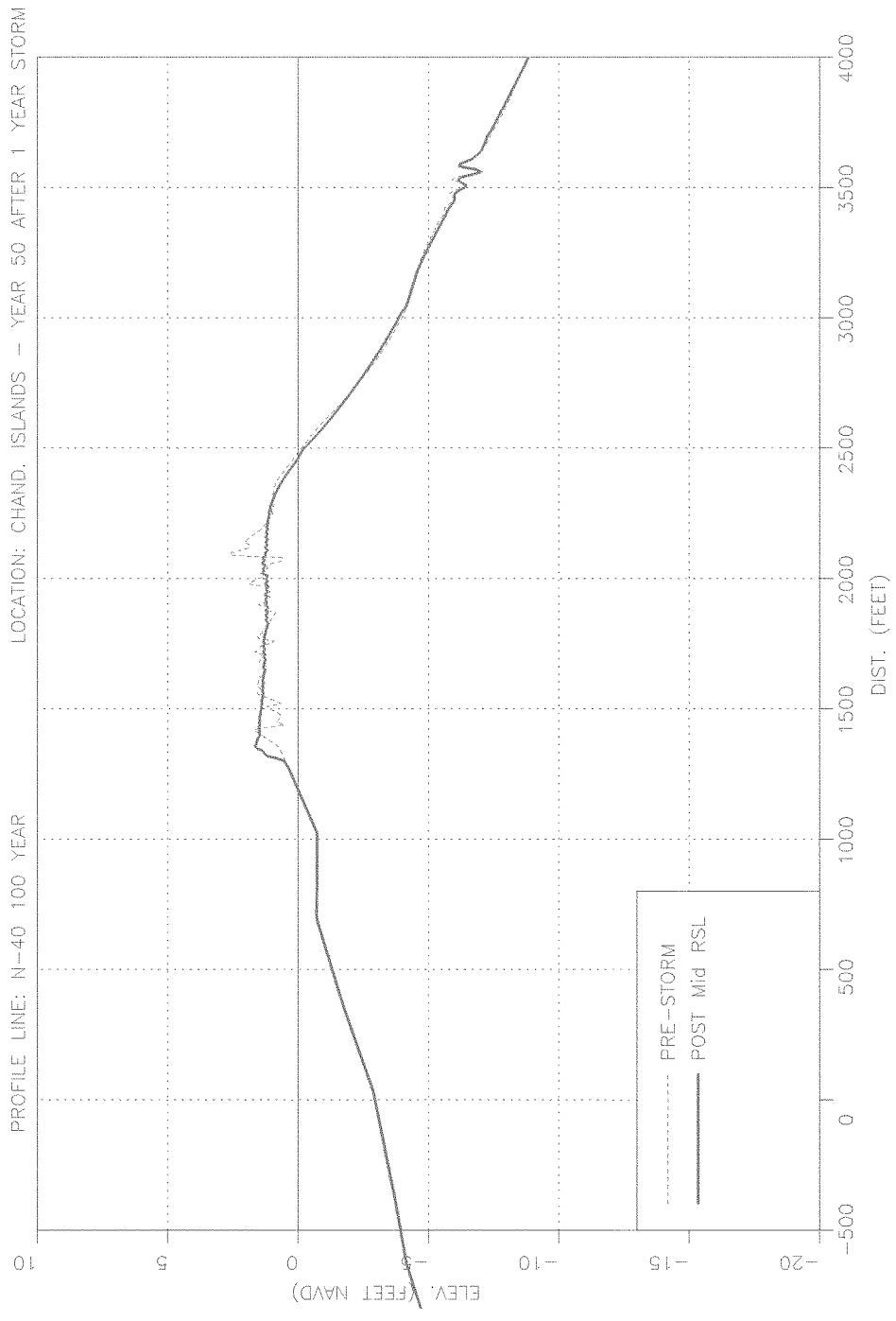

PROFILE LINE: N-40 020 YEAR
LOCATION: CHAND. ISLANDS - YEAR 50 AFTER 1 YEAR STORM
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST High RSL
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

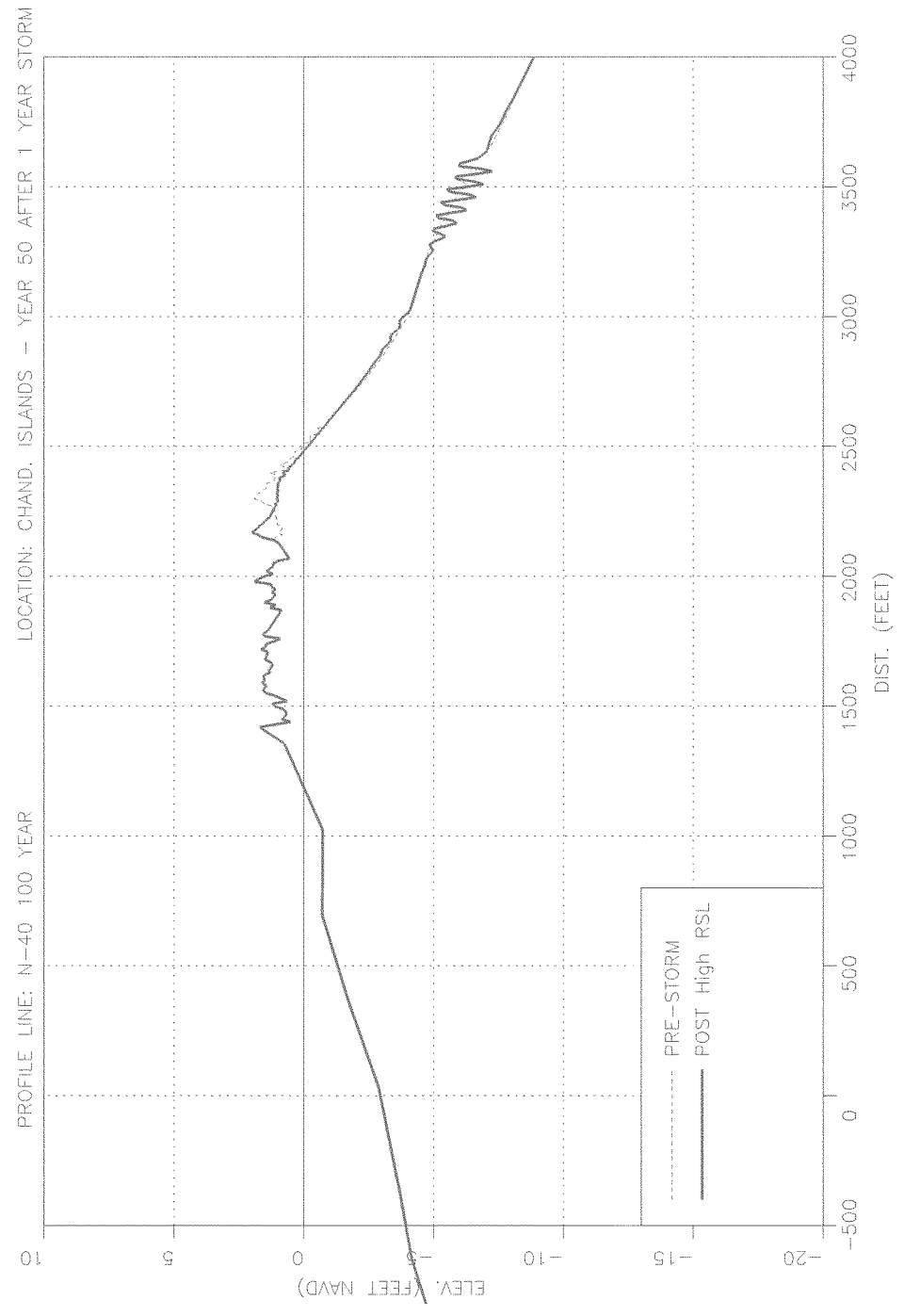

PROFILE LINE: N-40 050 YEAR
LOCATION: CHAND. ISLANDS - YEAR 50 AFTER 1 YEAR STORM
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000


PROFILE LINE: N-40 050 YEAR
LOCATION: CHAND. ISLANDS - YEAR 50 AFTER 1 YEAR STORM
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Mid RSL
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000


PROFILE LINE: N-40 050 YEAR
LOCATION: CHAND. ISLANDS - YEAR 50 AFTER 1 YEAR STORM
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST High RSL
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000


PROFILE LINE: N-40 100 YEAR
LOCATION: CHAND. ISLANDS -- YEAR 50 AFTER 1 YEAR STORM
PRE-STORM
POST Low RSL
ELEV. (FEET NAVD)
DIST. (FEET)
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000


PROFILE LINE: N-40 100 YEAR
LOCATION: CHAND. ISLANDS - YEAR 50 AFTER 1 YEAR STORM
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Mid RSL
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

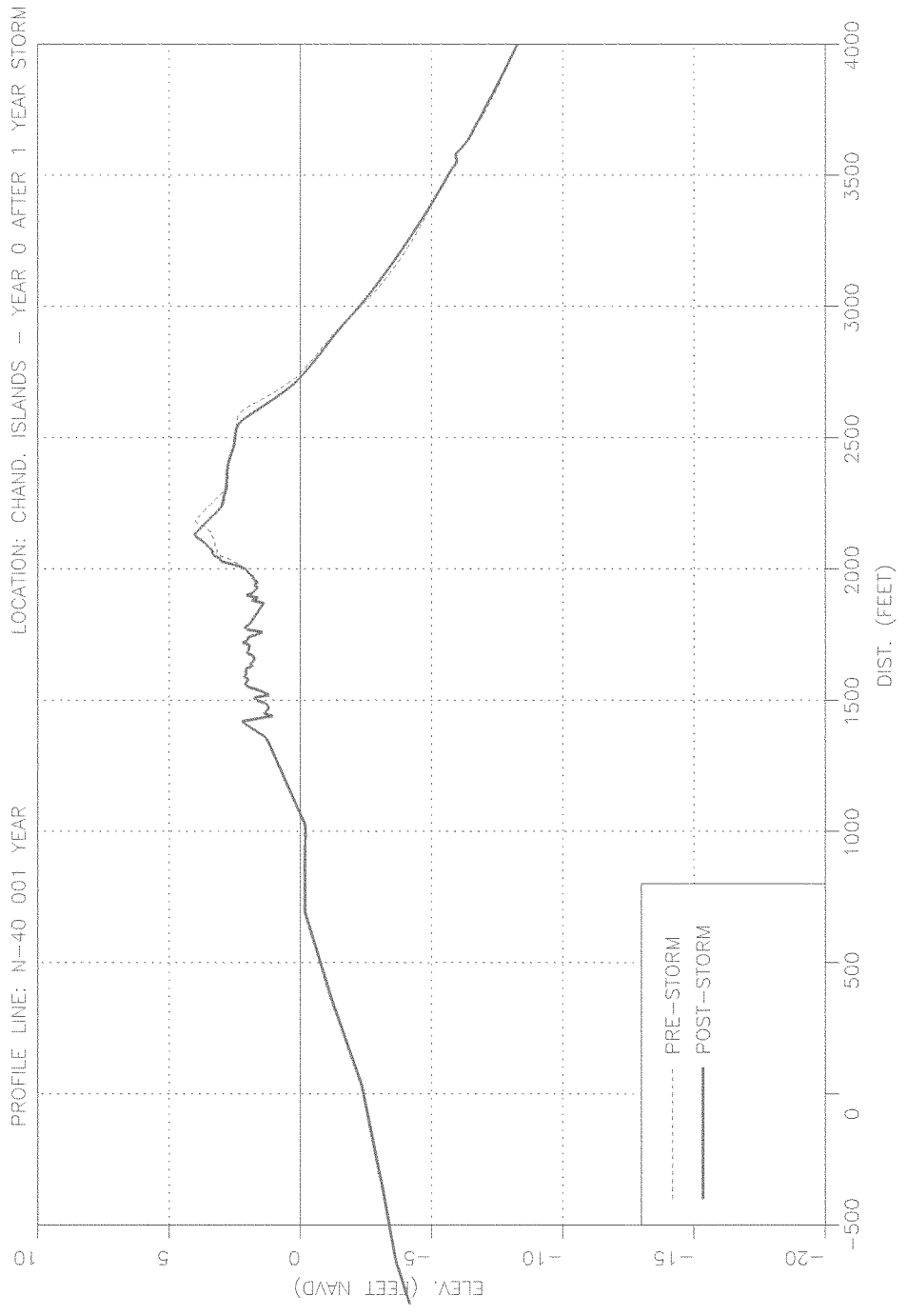

PROFILE LINE: N-40 100 YEAR
LOCATION: CHAND. ISLANDS - YEAR 50 AFTER 1 YEAR STORM
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST High RSL
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

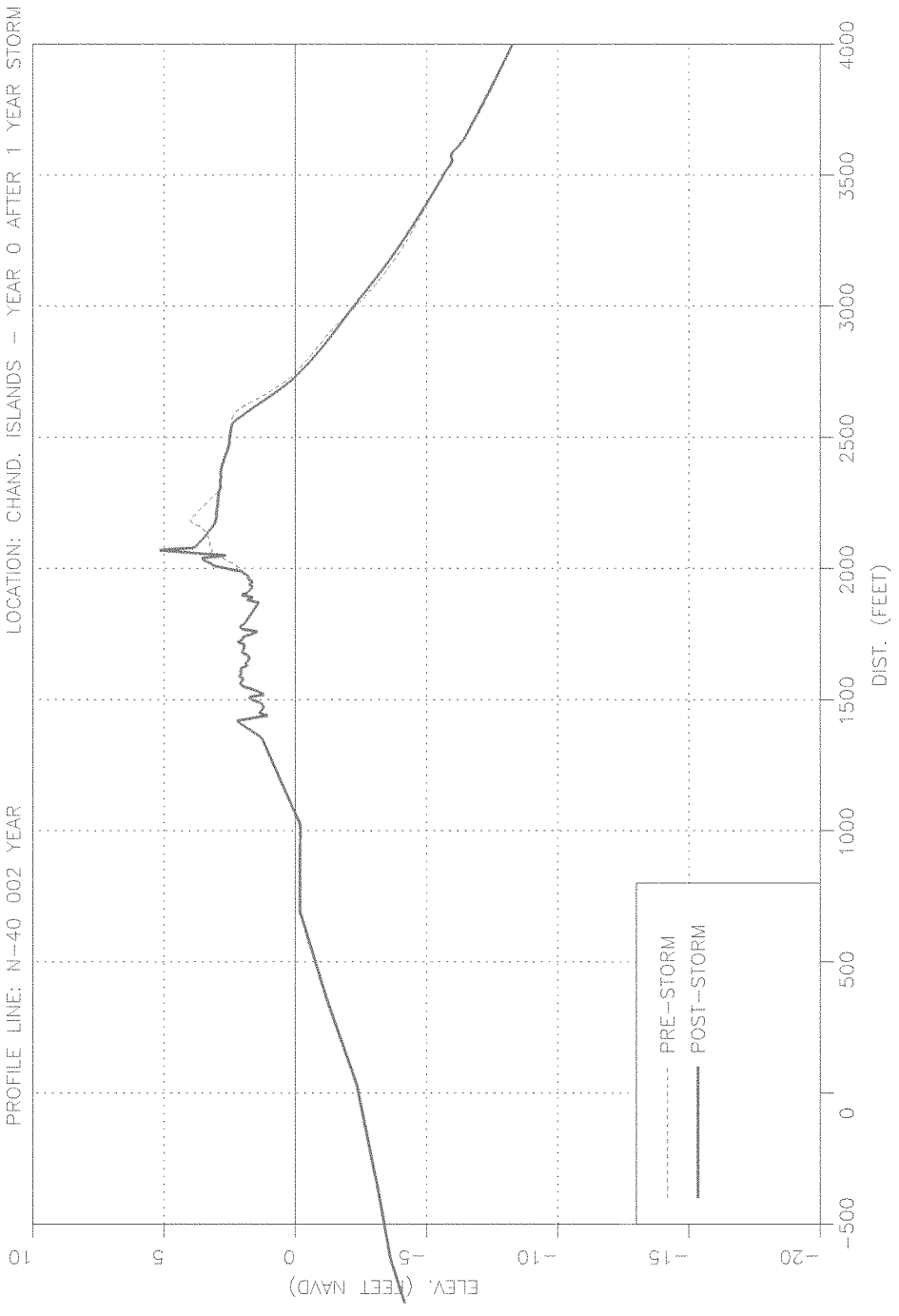
SUB-APPENDIX C-4

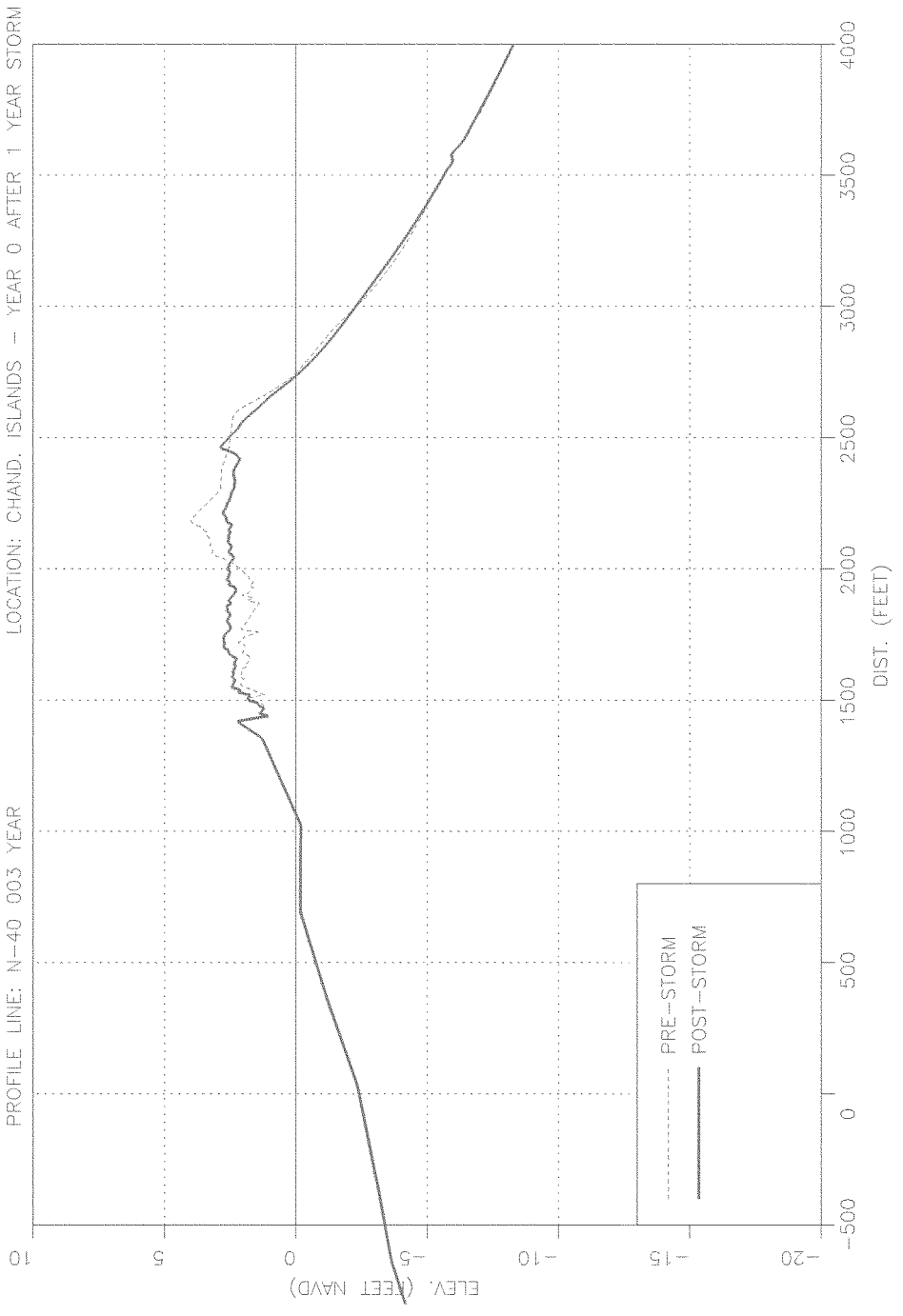
SBEACH PROFILES USING THE 1 YEAR POST-STORM PROFILE AS THE PRE-STORM CONDITION

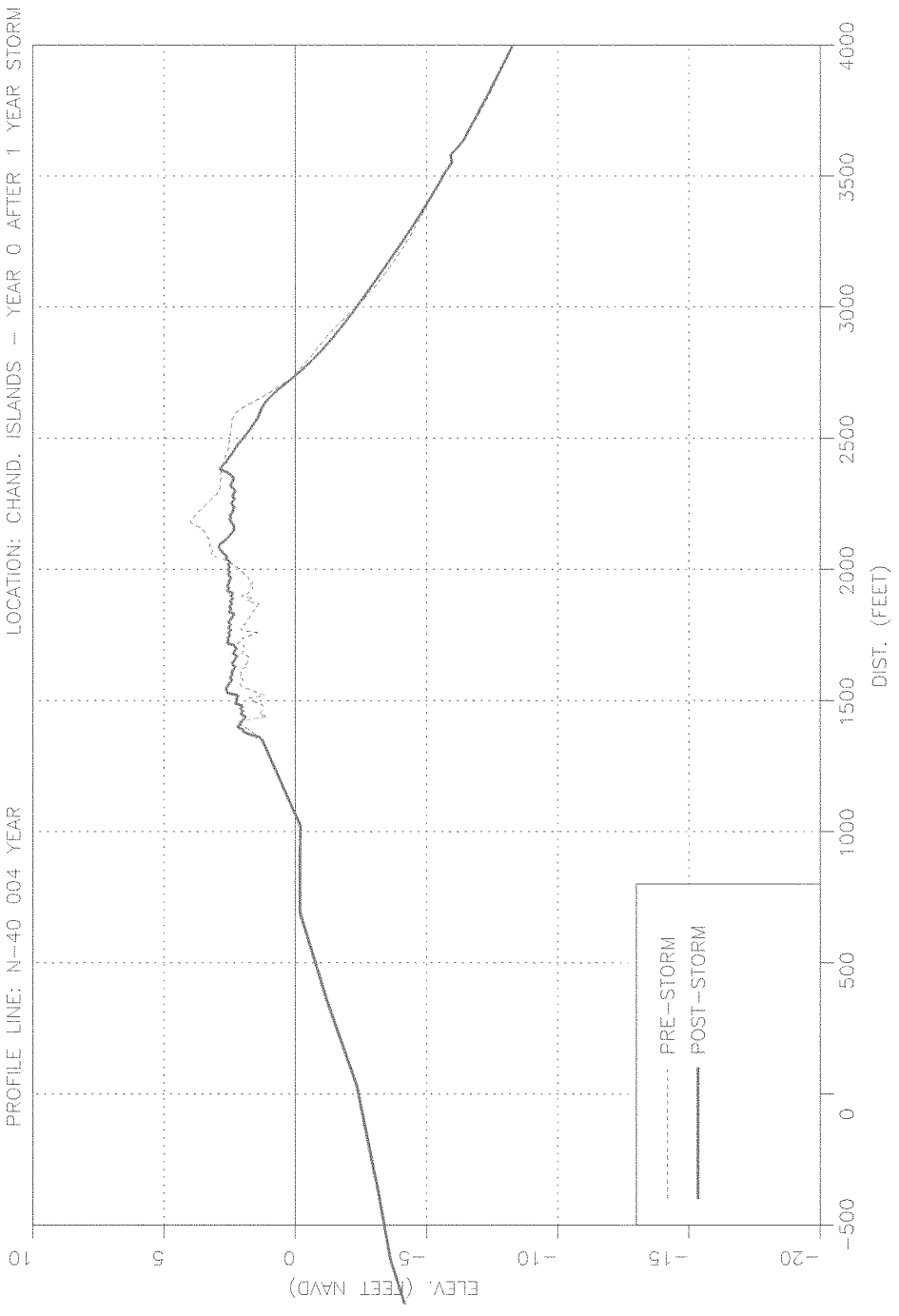
WITH PROJECT CONDITIONS

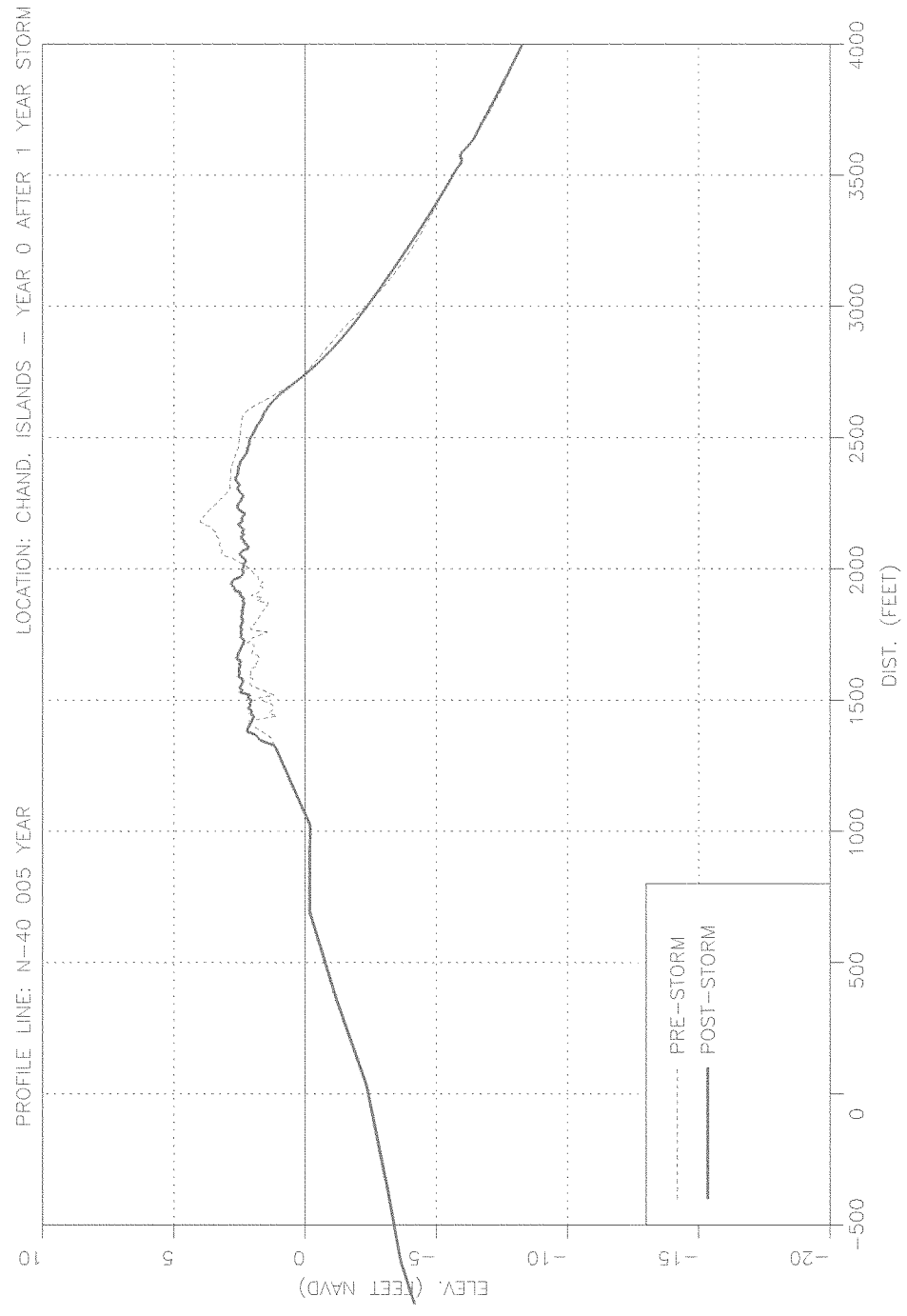
(Profiles are presented in electronic PDF format only)

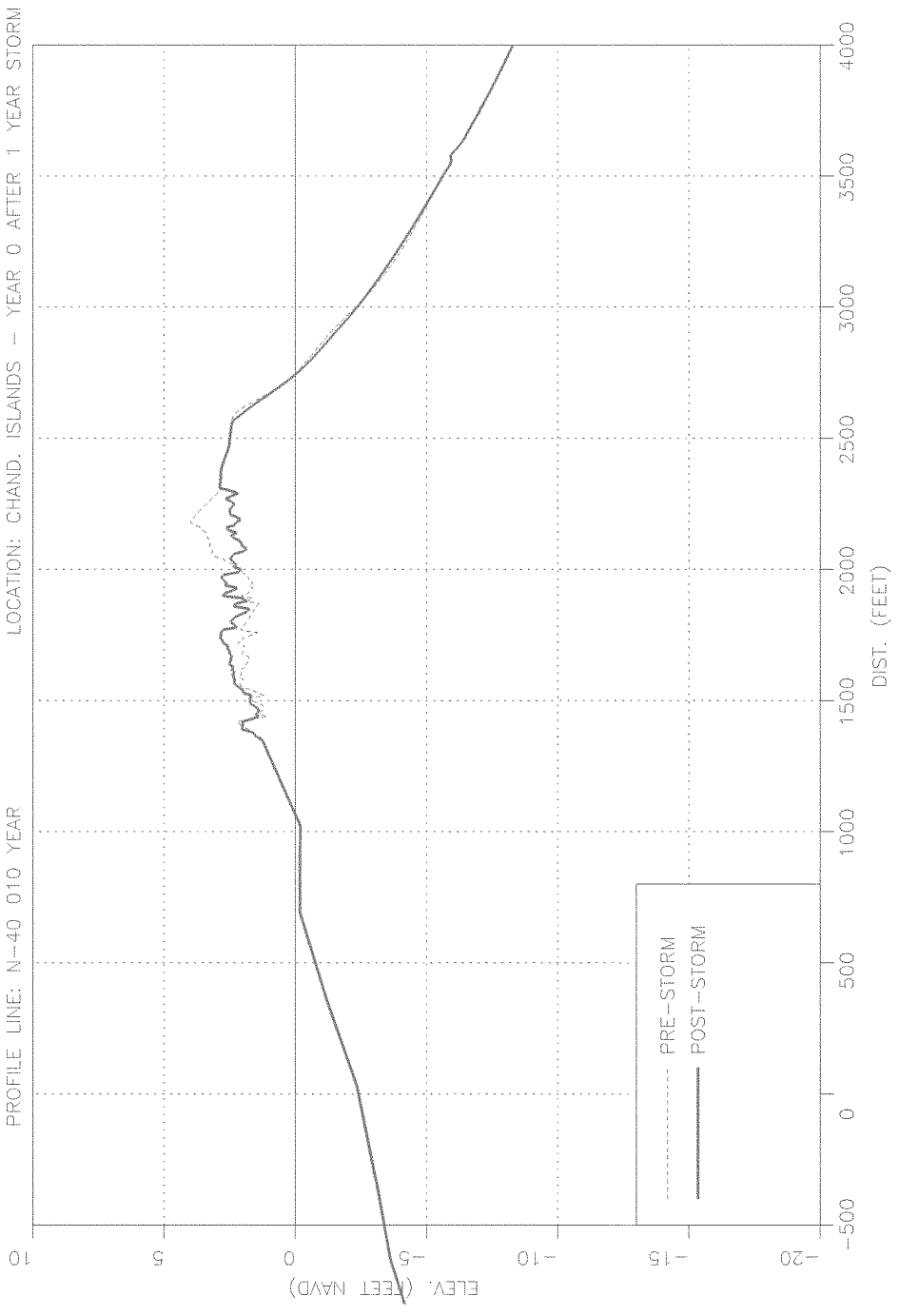

PROFILE LINE: N-40 001 YEAR
LOCATION: CHAND. ISLANDS - YEAR 0 AFTER 1 YEAR STORM
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

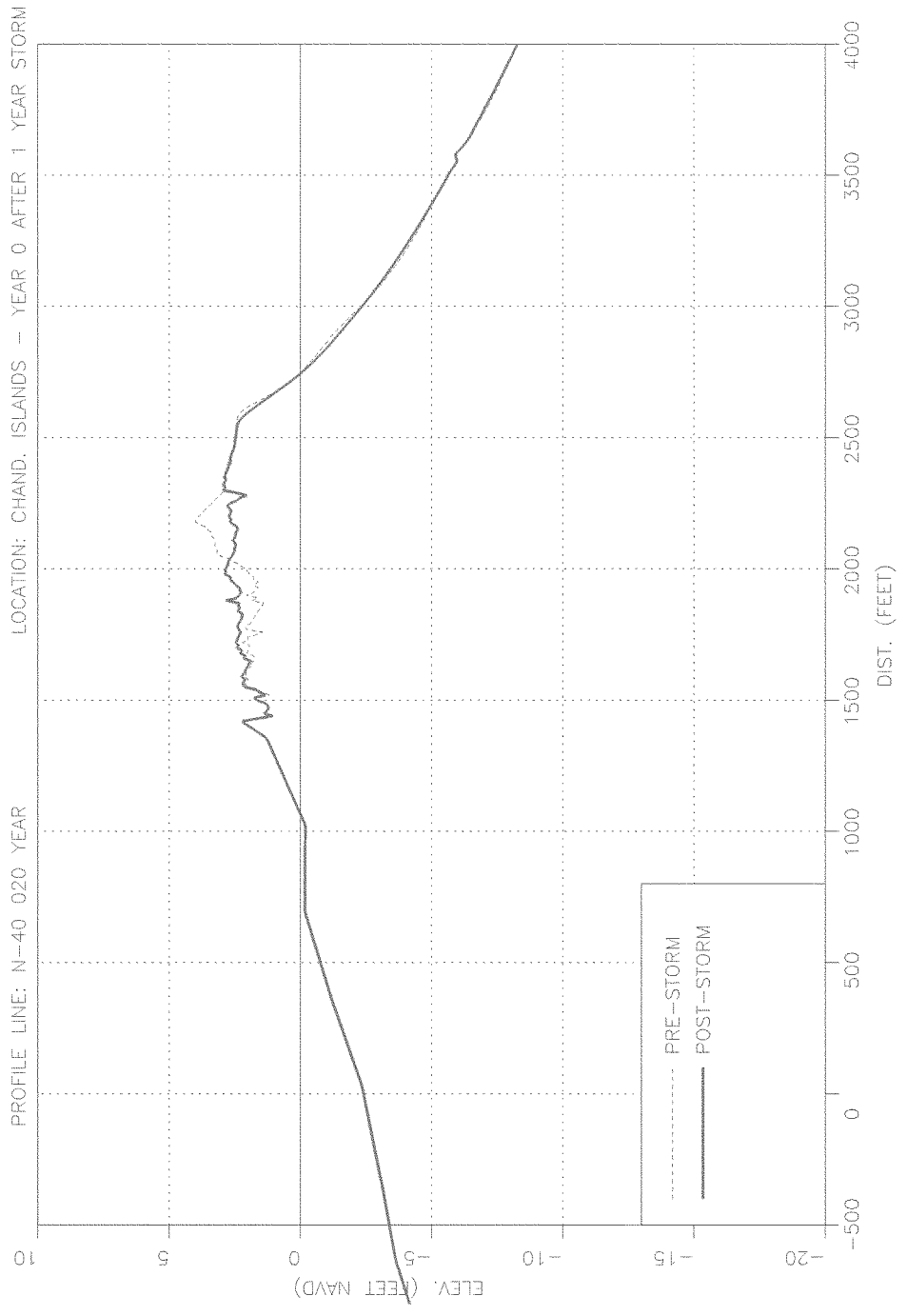

PROFILE LINE: N-40 002 YEAR
LOCATION: CHAND. ISLANDS - YEAR 0 AFTER 1 YEAR STORM
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

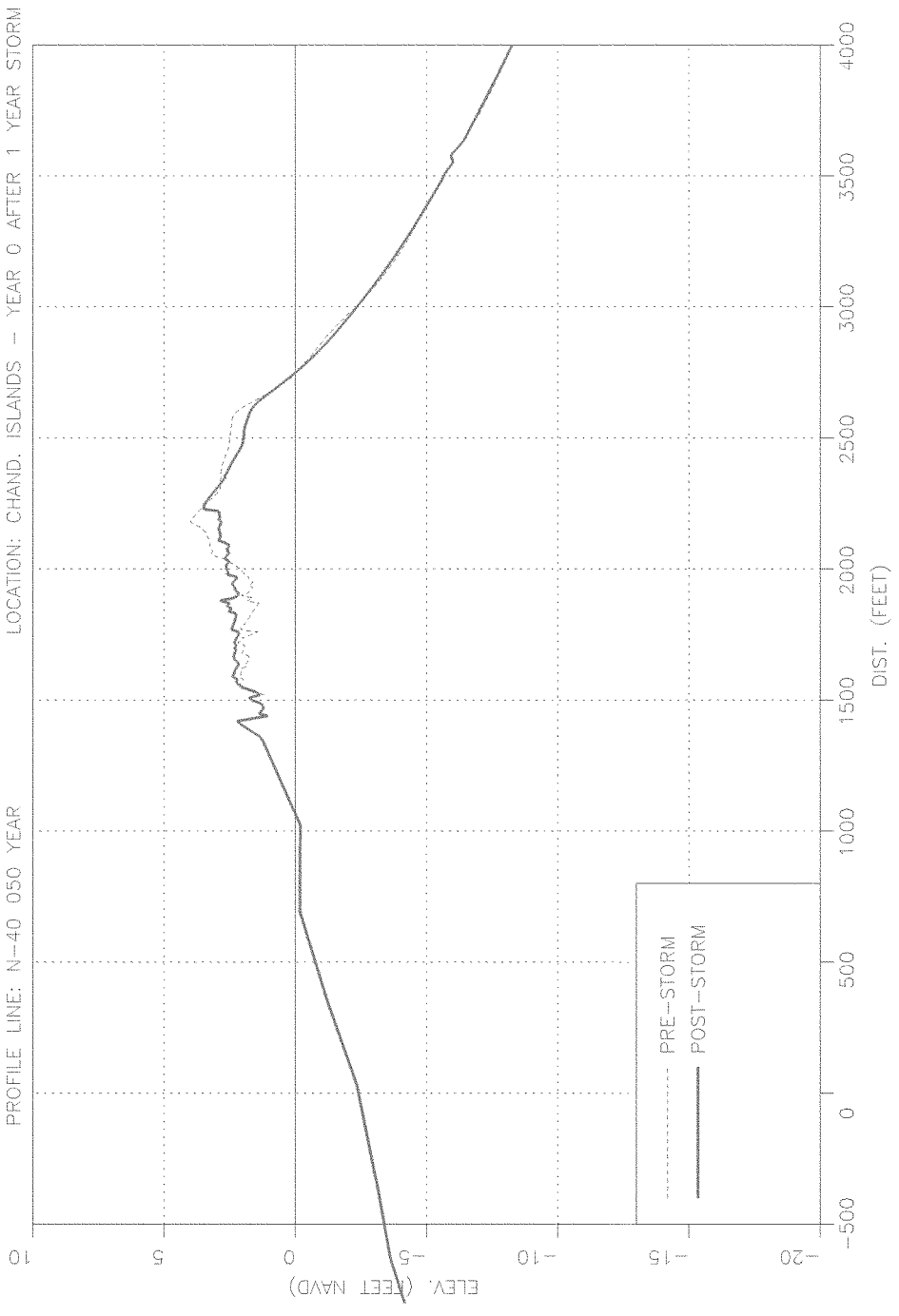

PROFILE LINE: N-40 003 YEAR
LOCATION: CHAND. ISLANDS - YEAR 0 AFTER 1 YEAR STORM
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

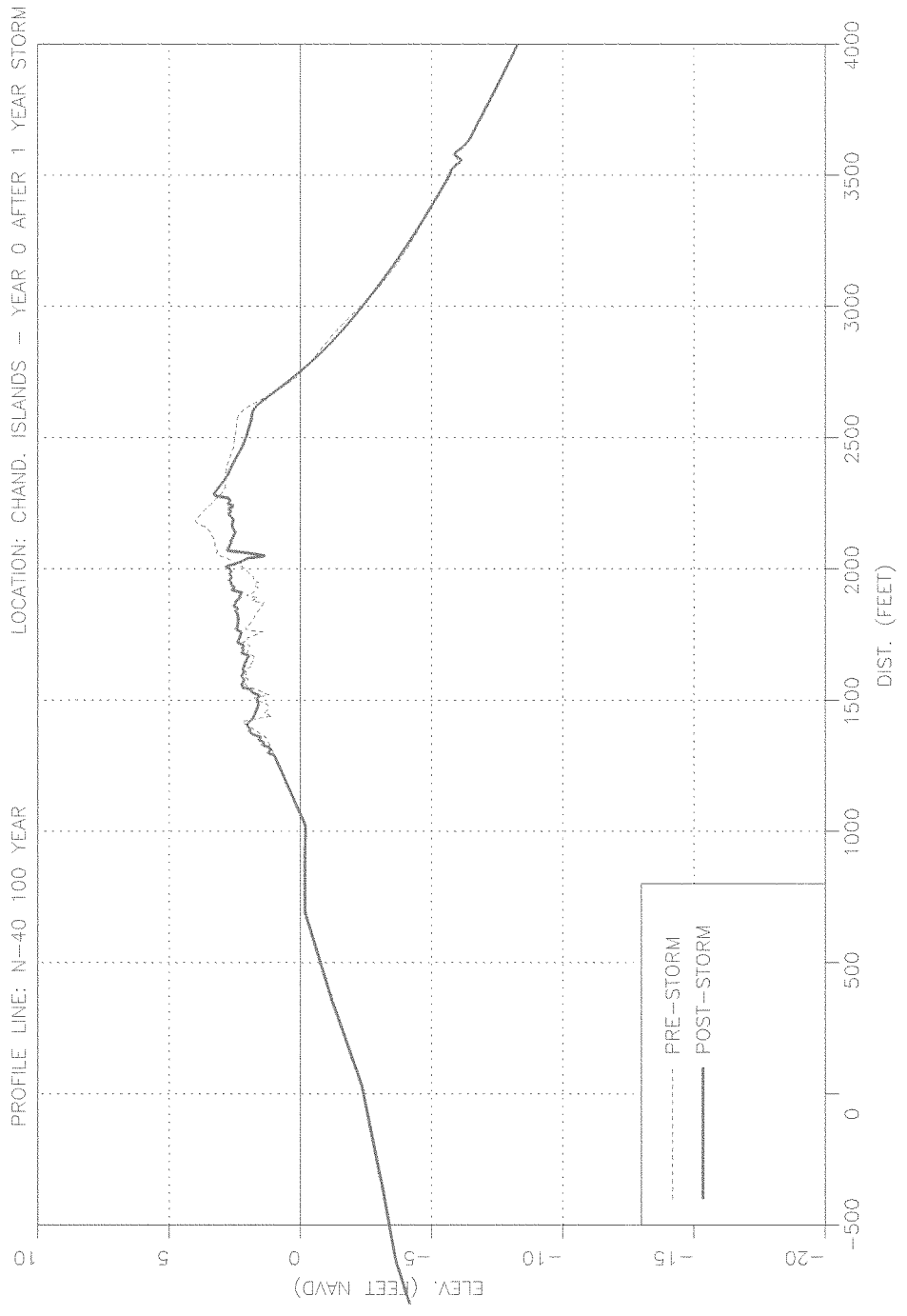

PROFILE LINE: N-40 004 YEAR
LOCATION: CHAND. ISLANDS - YEAR 0 AFTER 1 YEAR STORM
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

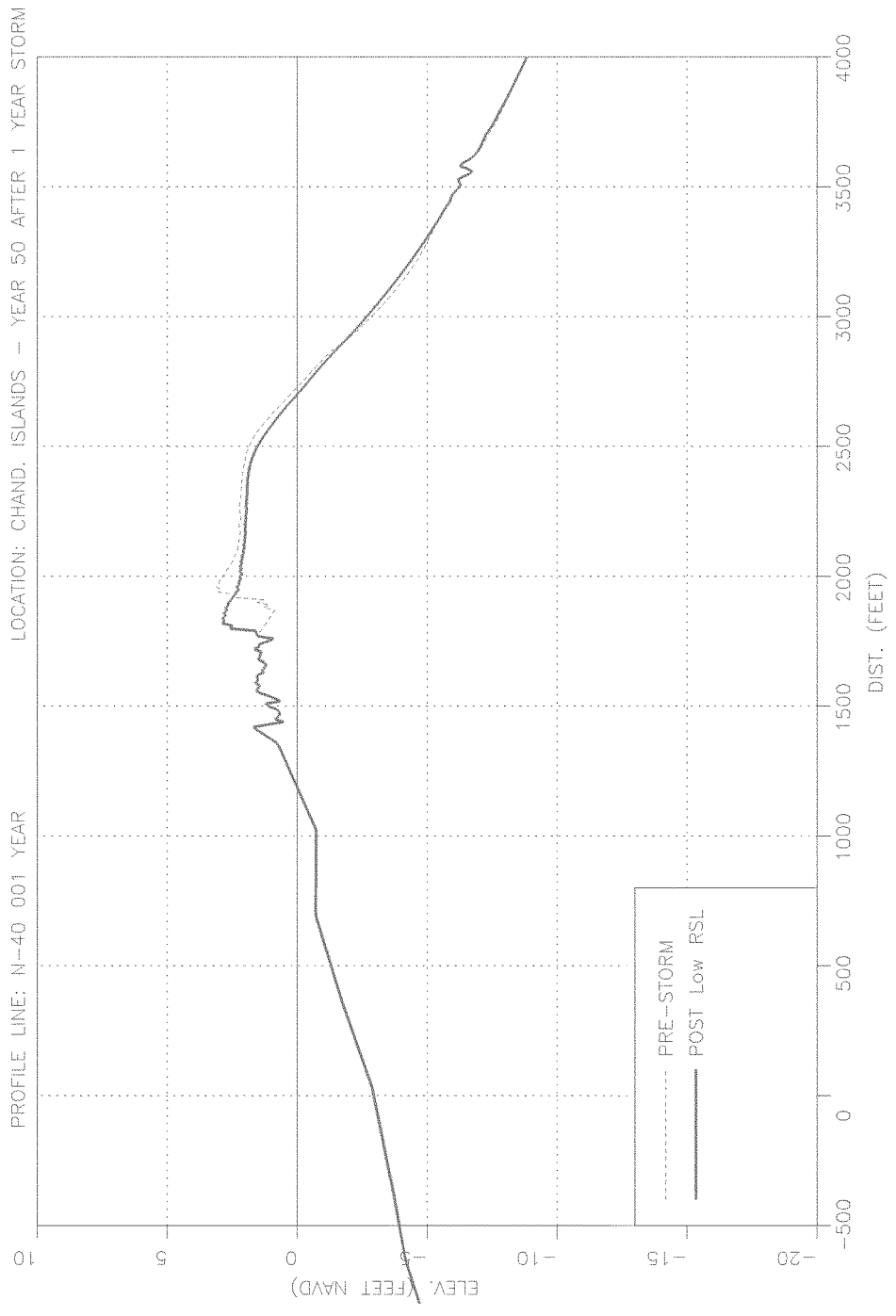

PROFILE LINE: N-40 005 YEAR
LOCATION: CHAND. ISLANDS - YEAR 0 AFTER 1 YEAR STORM
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

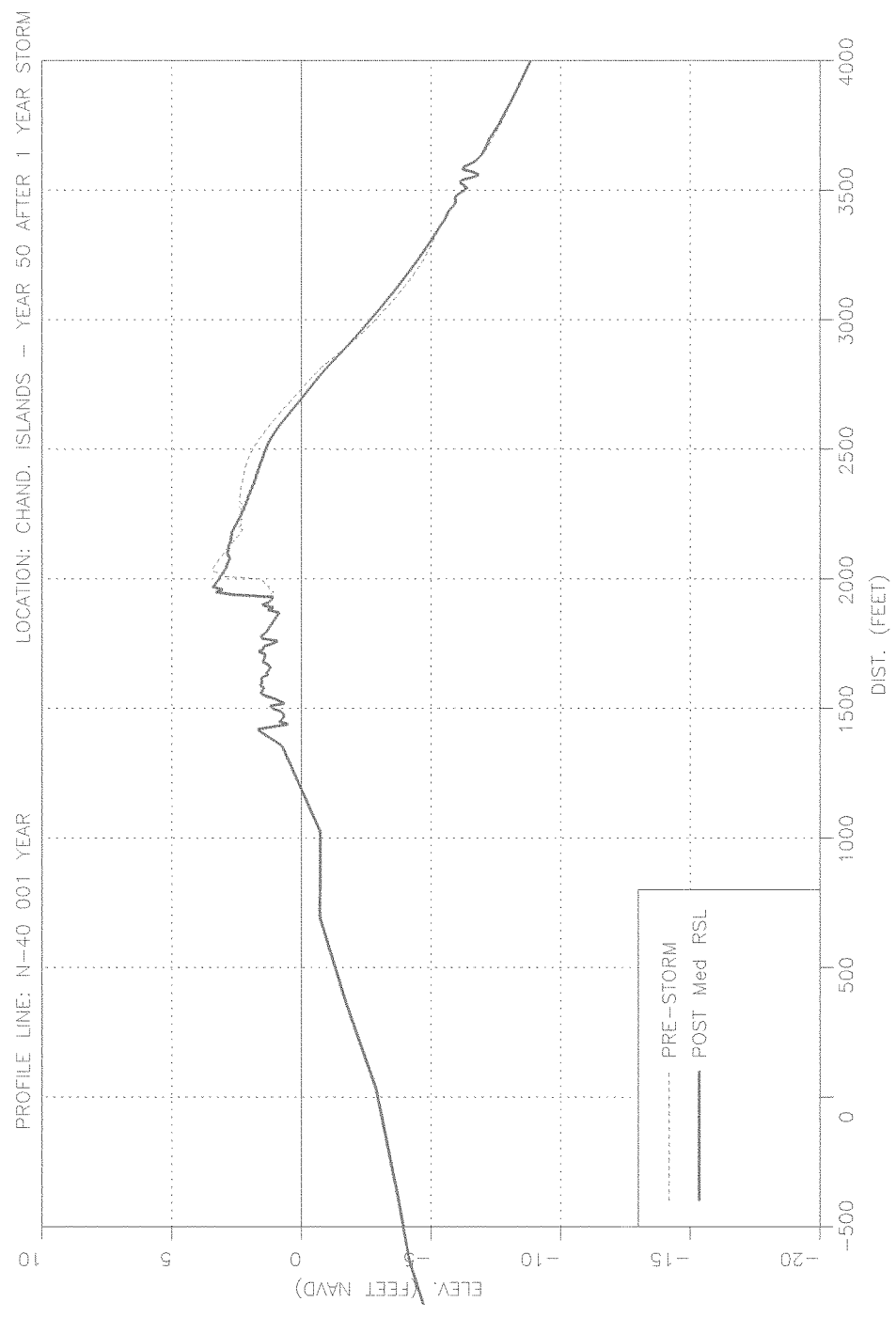

PROFILE LINE: N-40 010 YEAR
LOCATION: CHAND. ISLANDS -- YEAR 0 AFTER 1 YEAR STORM
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

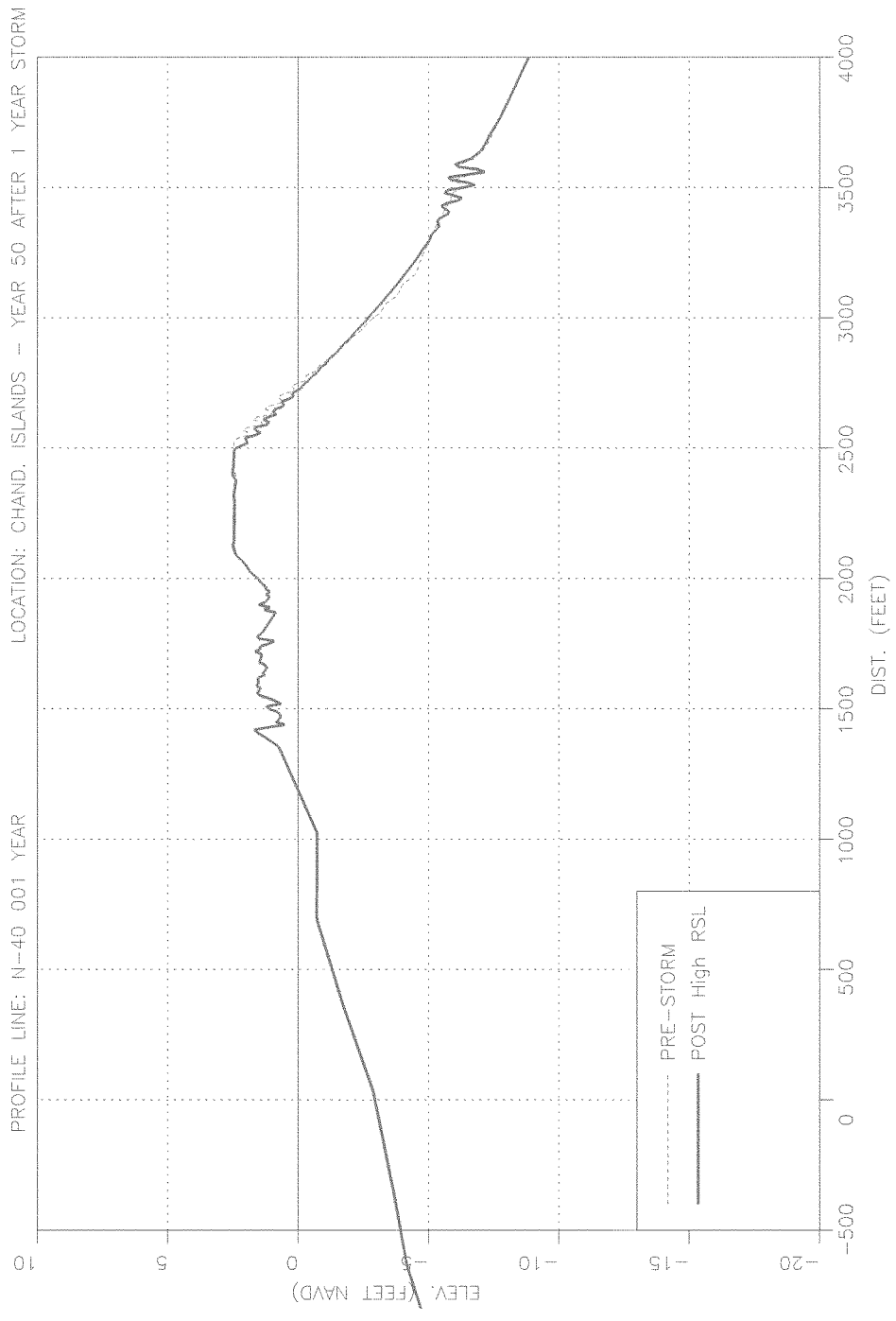

PROFILE LINE: N-40 020 YEAR
LOCATION: CHAND. ISLANDS - YEAR 0 AFTER 1 YEAR STORM
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

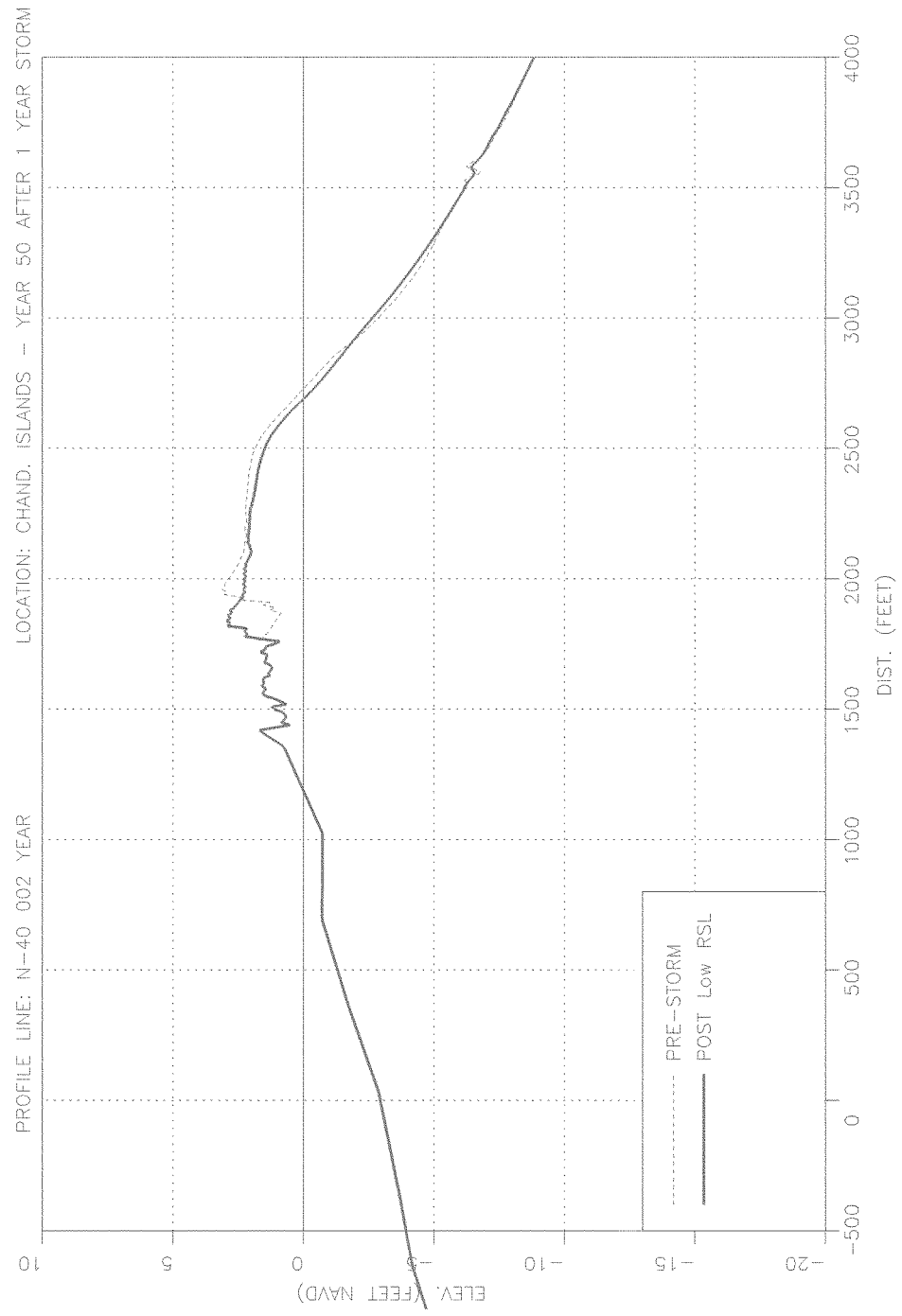

PROFILE LINE: N-40 050 YEAR
LOCATION: CHAND. ISLANDS -- YEAR 0 AFTER 1 YEAR STORM
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

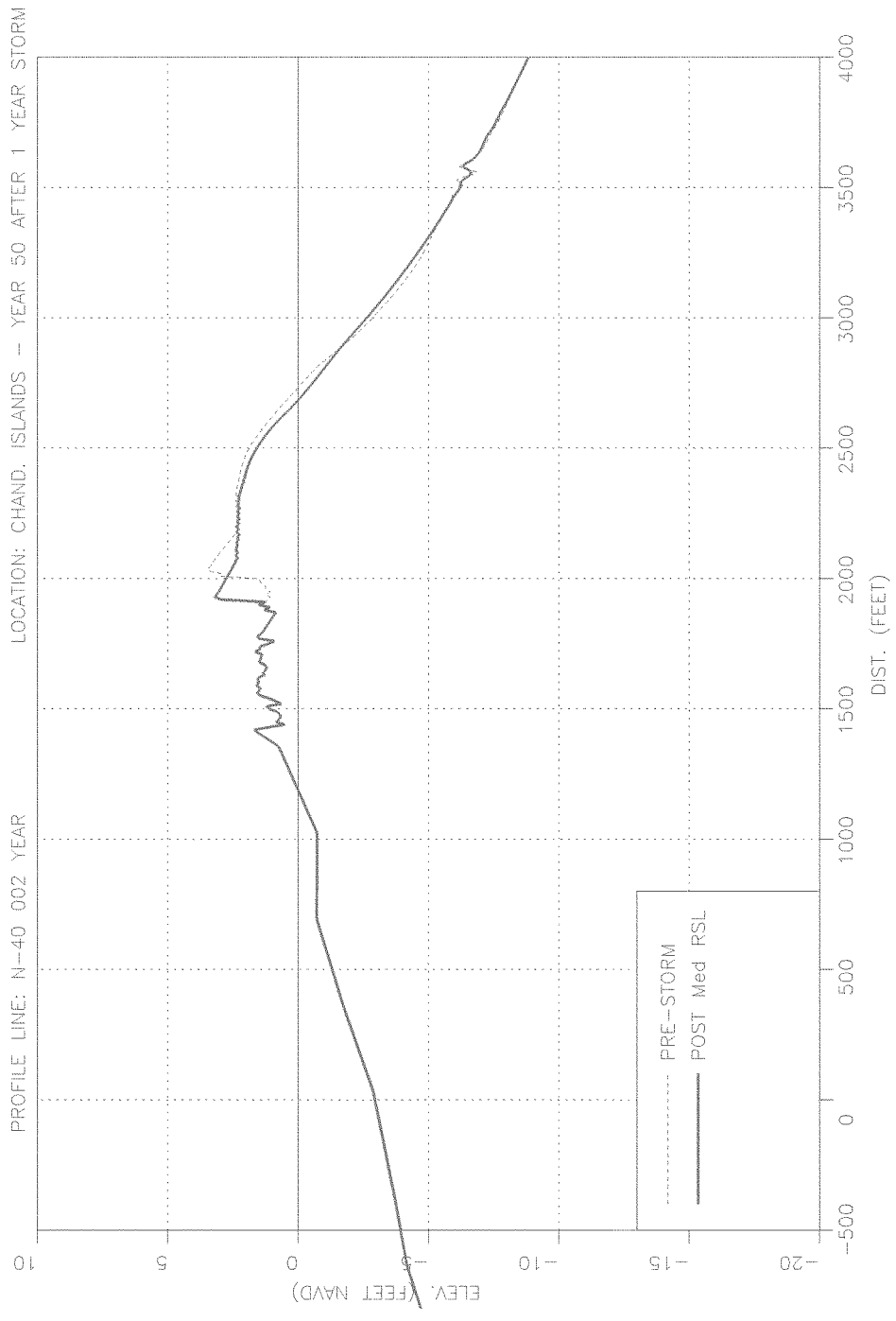

PROFILE LINE: N--40 100 YEAR
LOCATION: CHAND. ISLANDS -- YEAR 0 AFTER 1 YEAR STORM
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

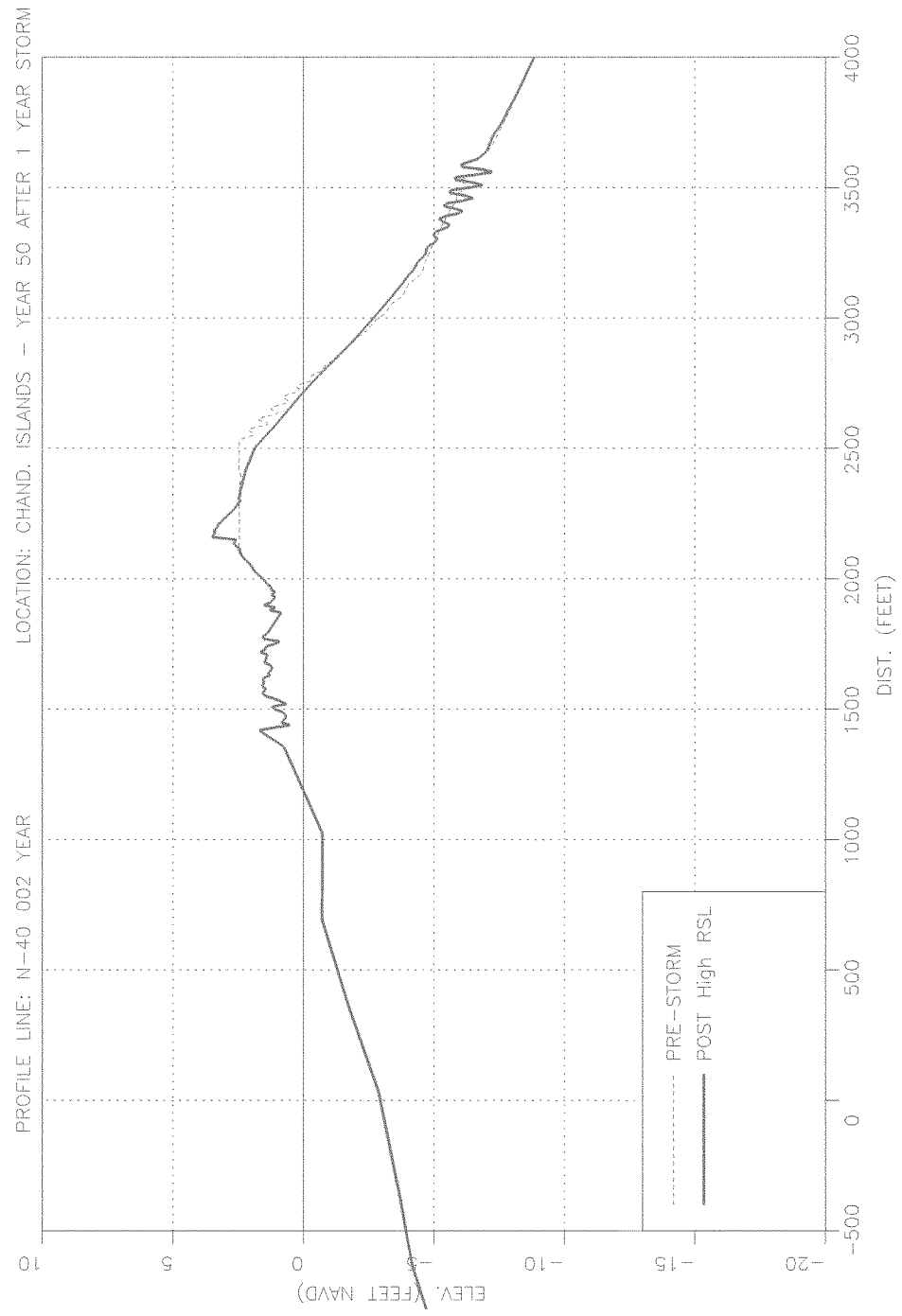

PROFILE LINE: N-40 001 YEAR
LOCATION: CHAND. ISLANDS - YEAR 50 AFTER 1 YEAR STORM
ELEV. (FEET NAVD)
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000
DIST. (FEET)
PRE-STORM
POST Low RSL

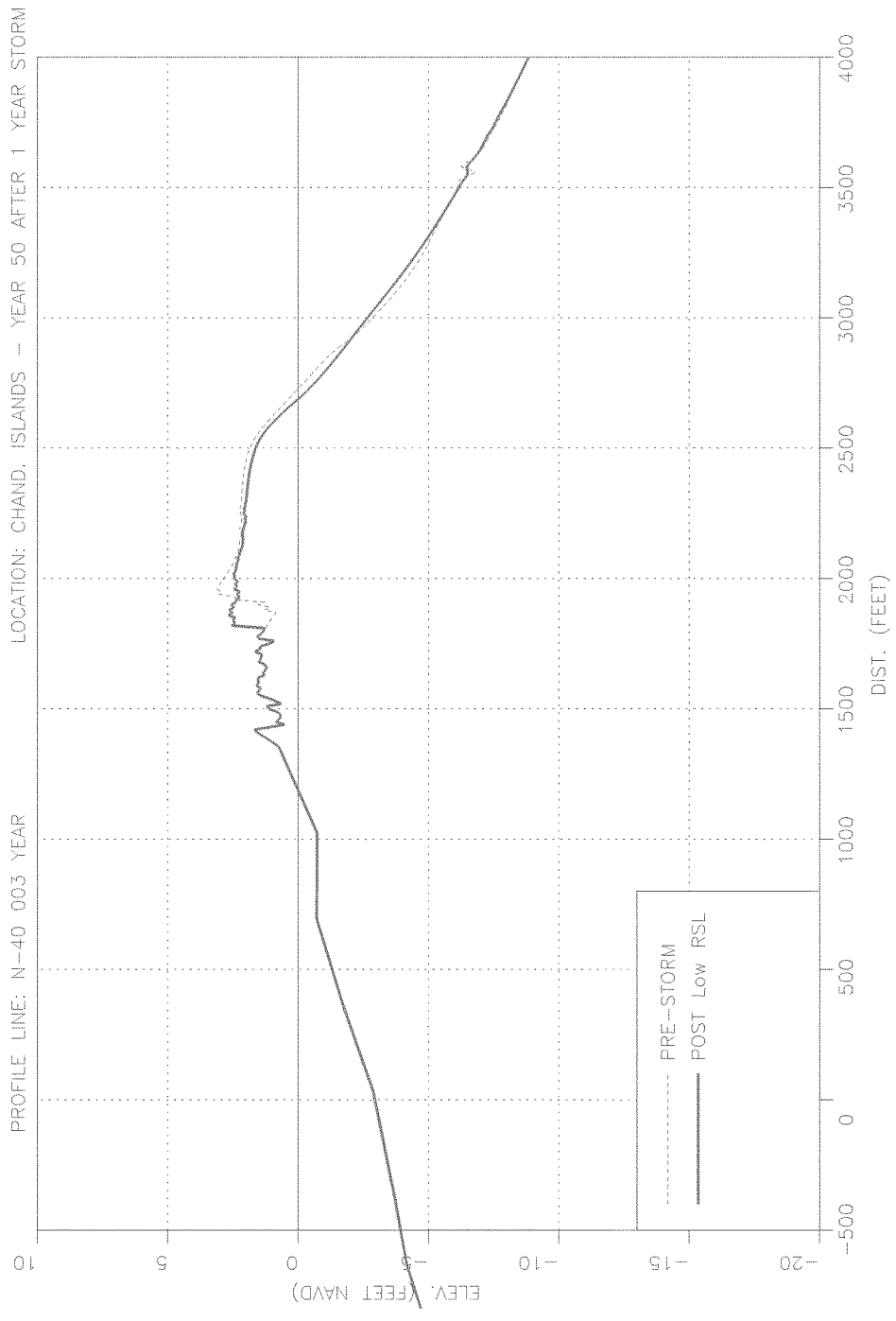

PROFILE LINE: N-40 001 YEAR
LOCATION: CHAND. ISLANDS - YEAR 50 AFTER 1 YEAR STORM
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Med RSL
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

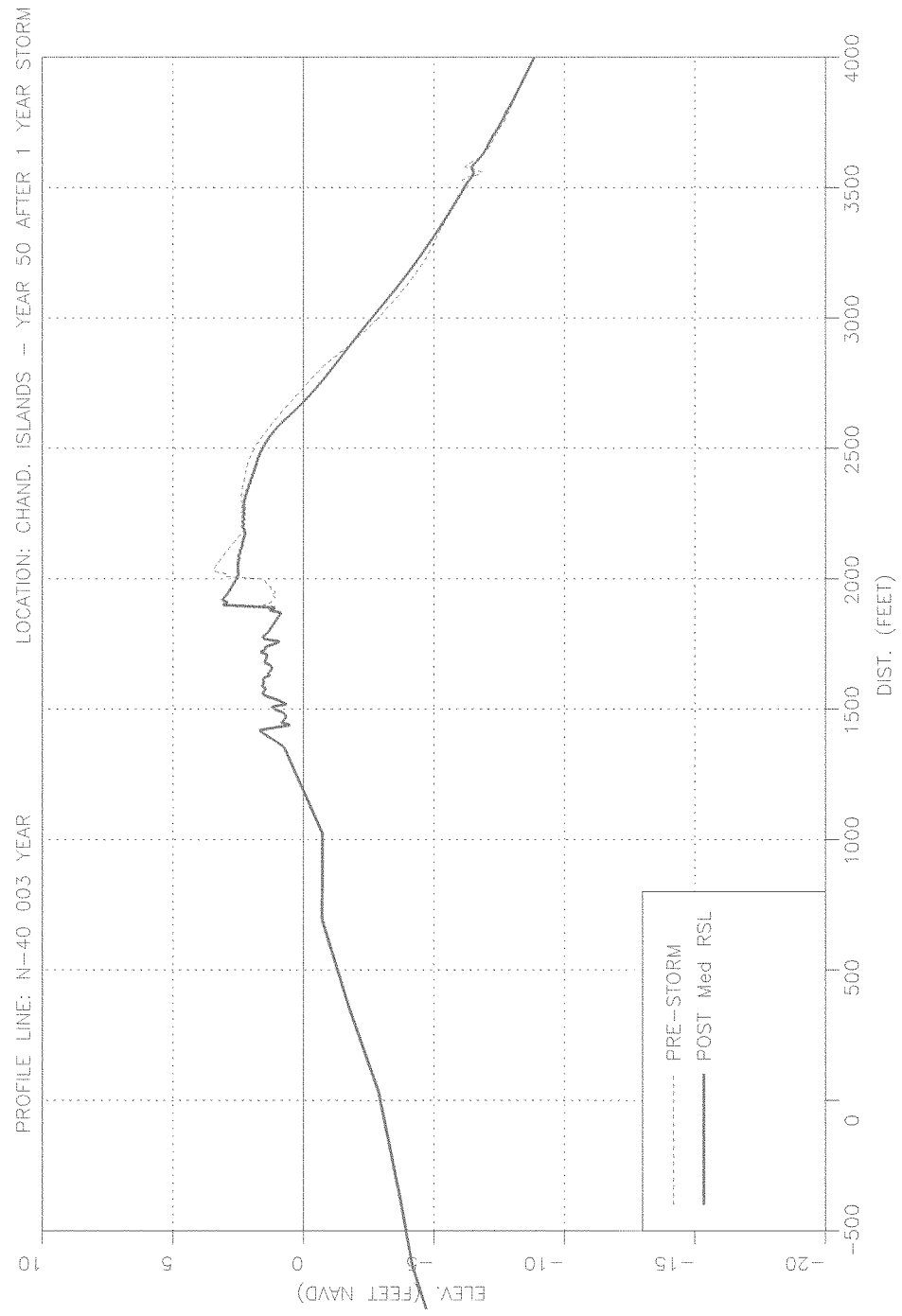

PROFILE LINE: N-40 001 YEAR
LOCATION: CHAND. ISLANDS -- YEAR 50 AFTER 1 YEAR STORM
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST High RSL
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

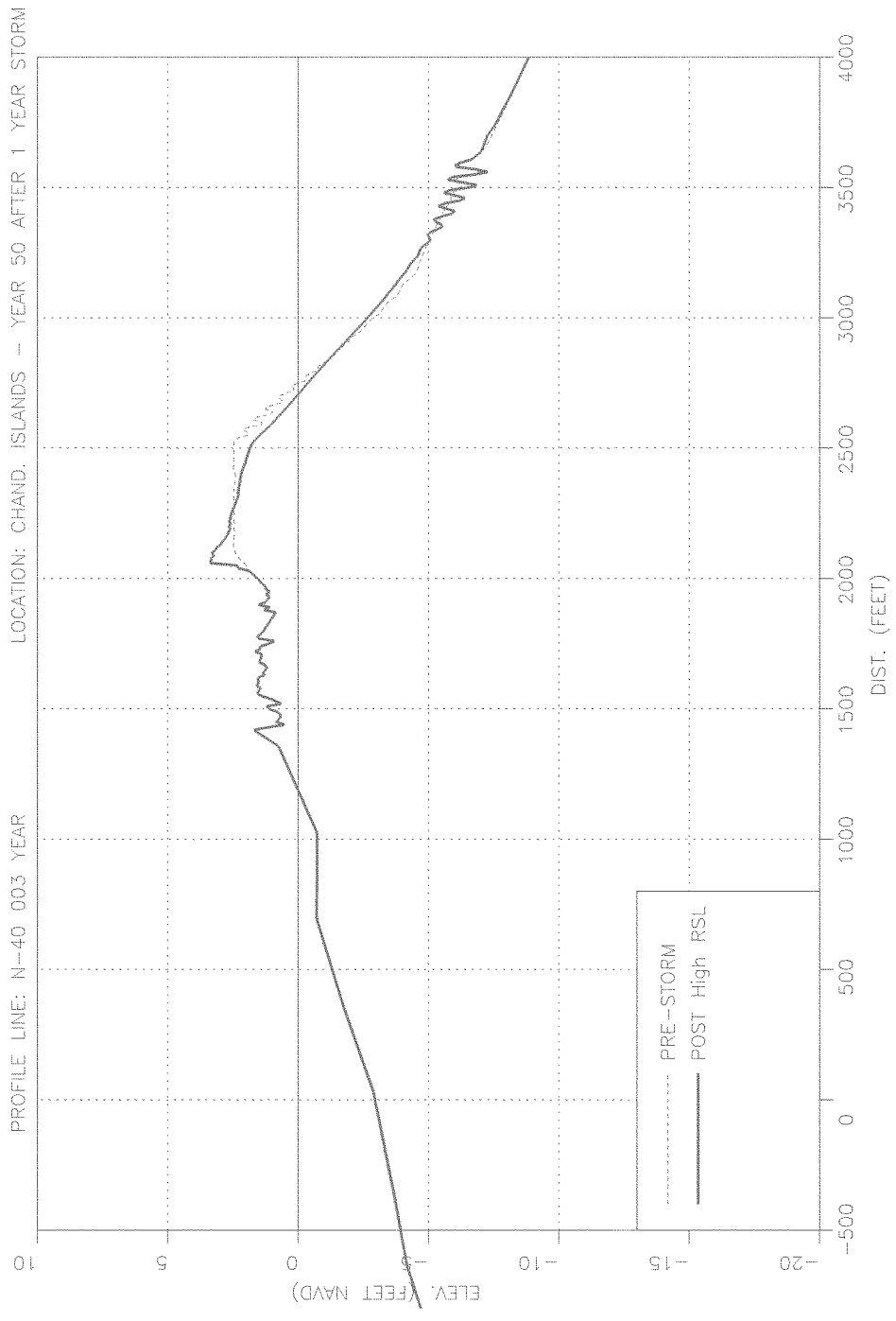

PROFILE LINE: N-40 002 YEAR
LOCATION: CHAND. ISLANDS - YEAR 50 AFTER 1 YEAR STORM
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

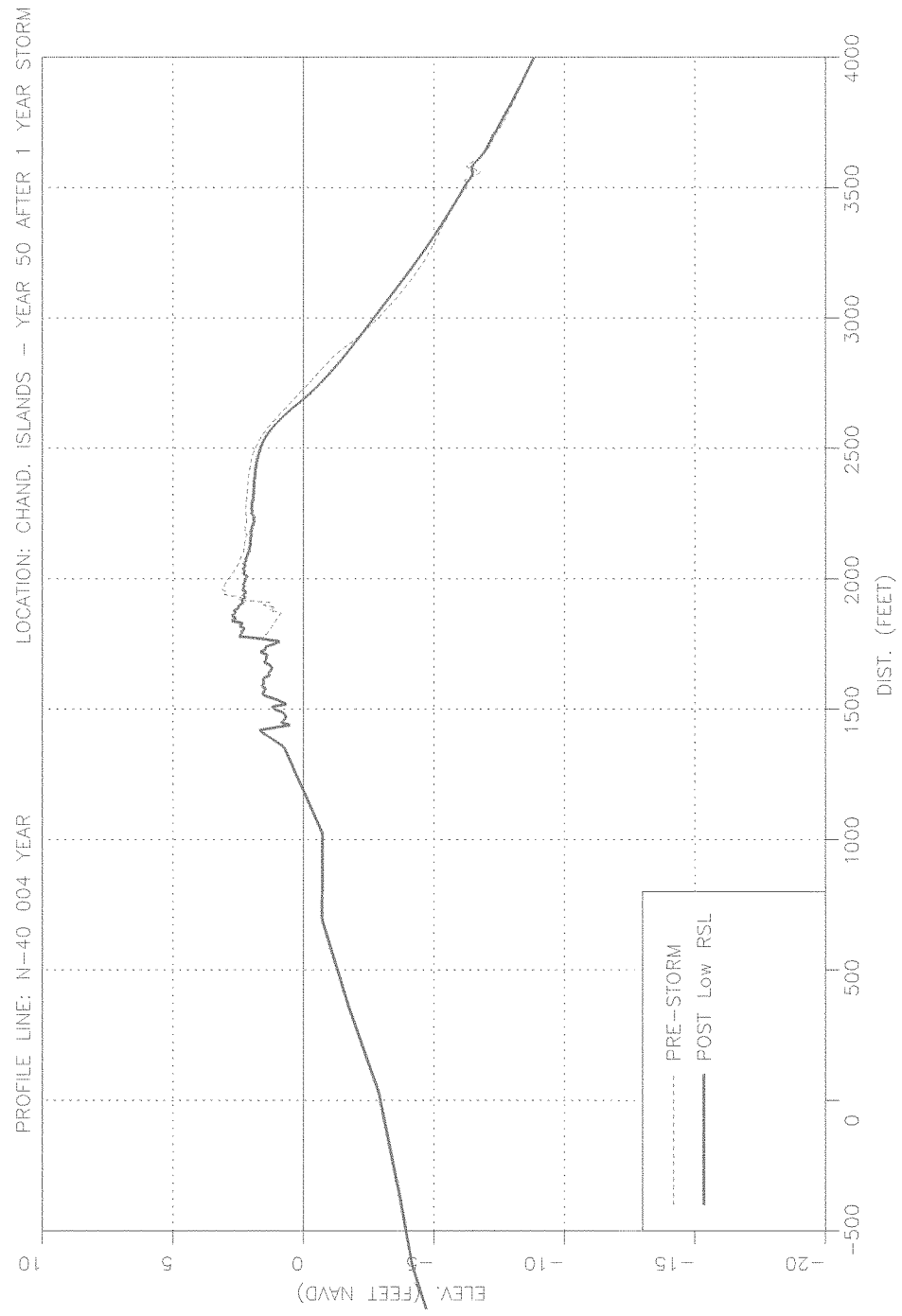

PROFILE LINE: N-40 002 YEAR
LOCATION: CHAND. ISLANDS -- YEAR 50 AFTER 1 YEAR STORM
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Med RSL
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

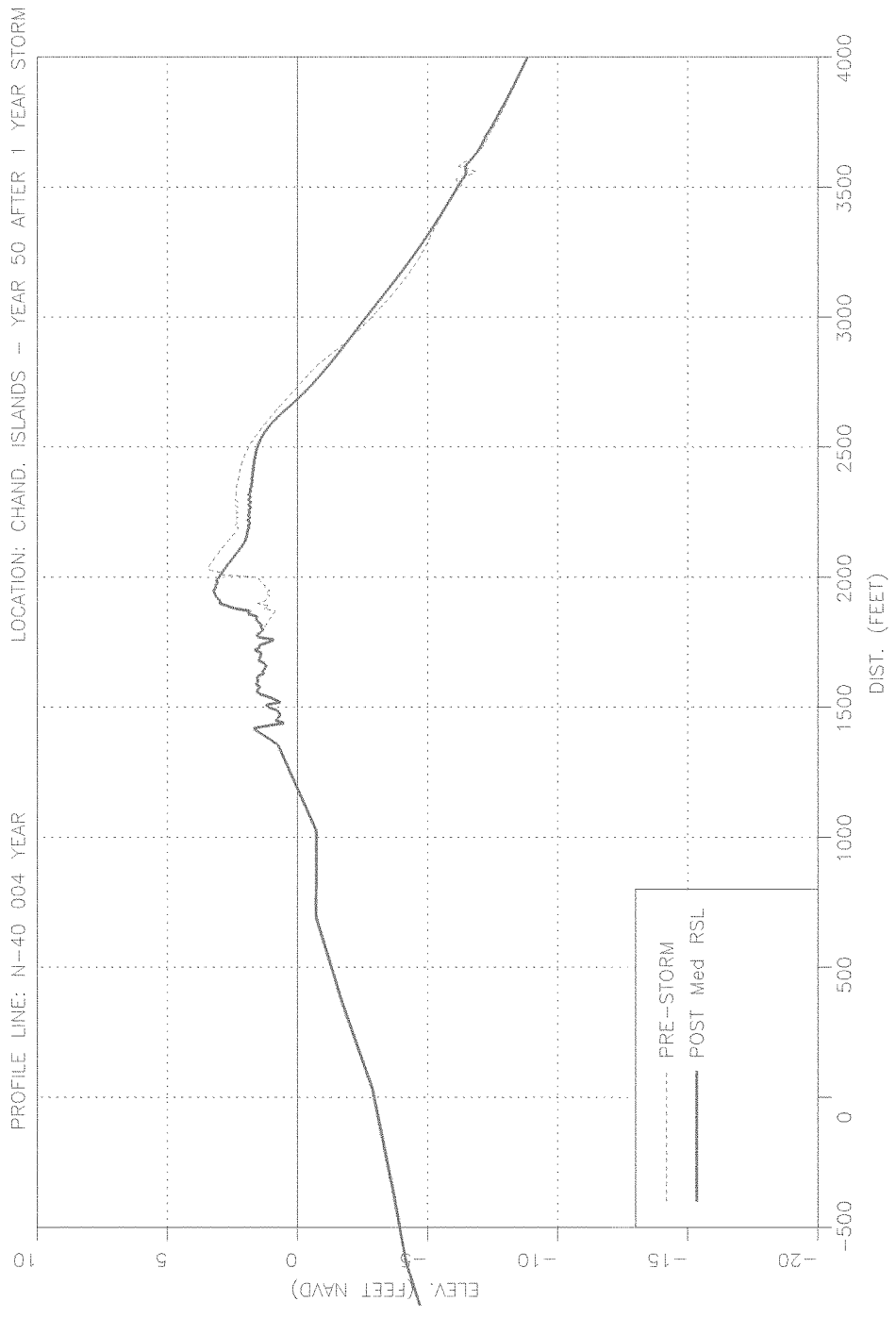

PROFILE LINE: N-40 002 YEAR
LOCATION: CHAND. ISLANDS - YEAR 50 AFTER 1 YEAR STORM
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST High RSL
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

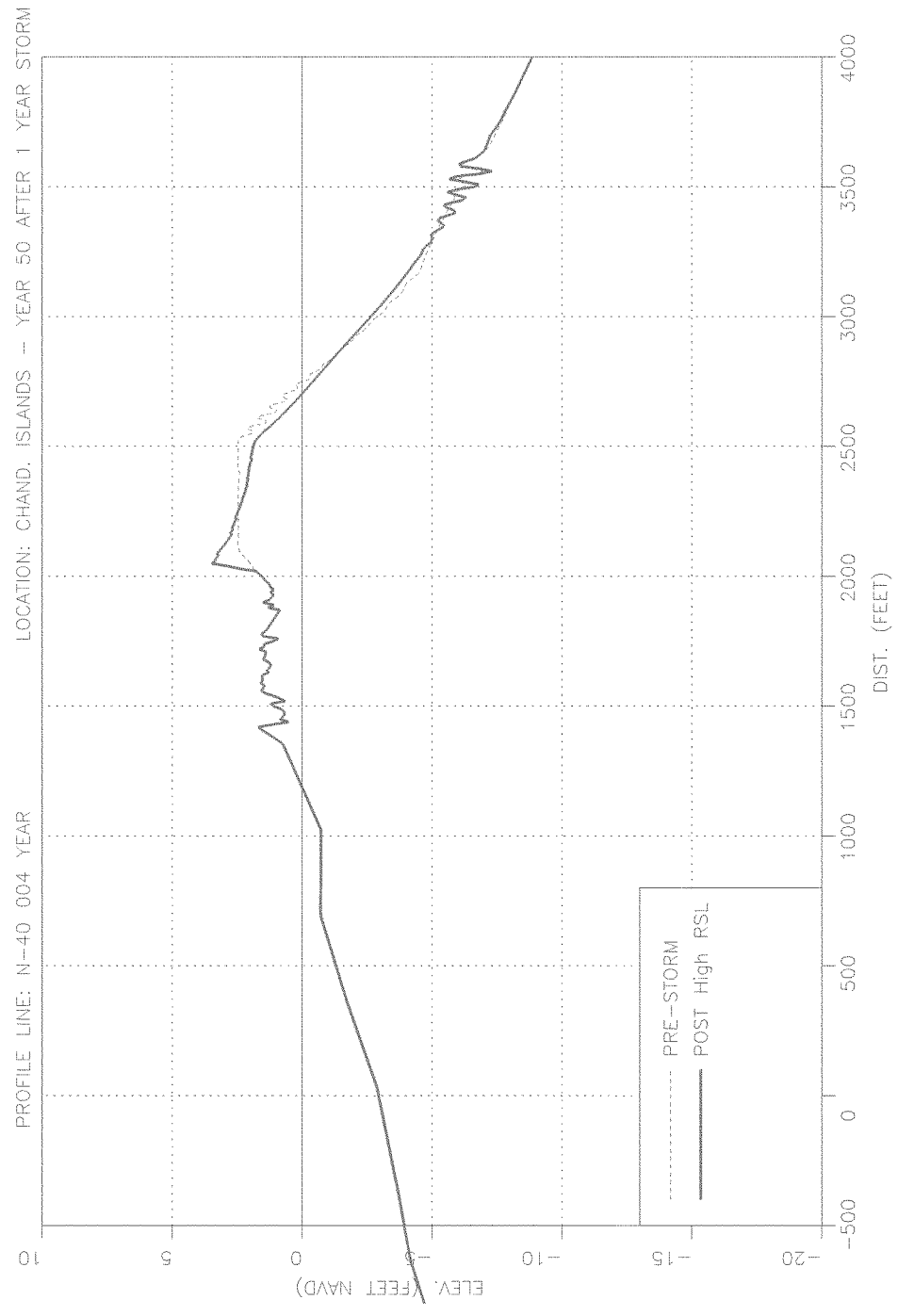

PROFILE LINE: N-40 003 YEAR
LOCATION: CHAND. ISLANDS - YEAR 50 AFTER 1 YEAR STORM
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

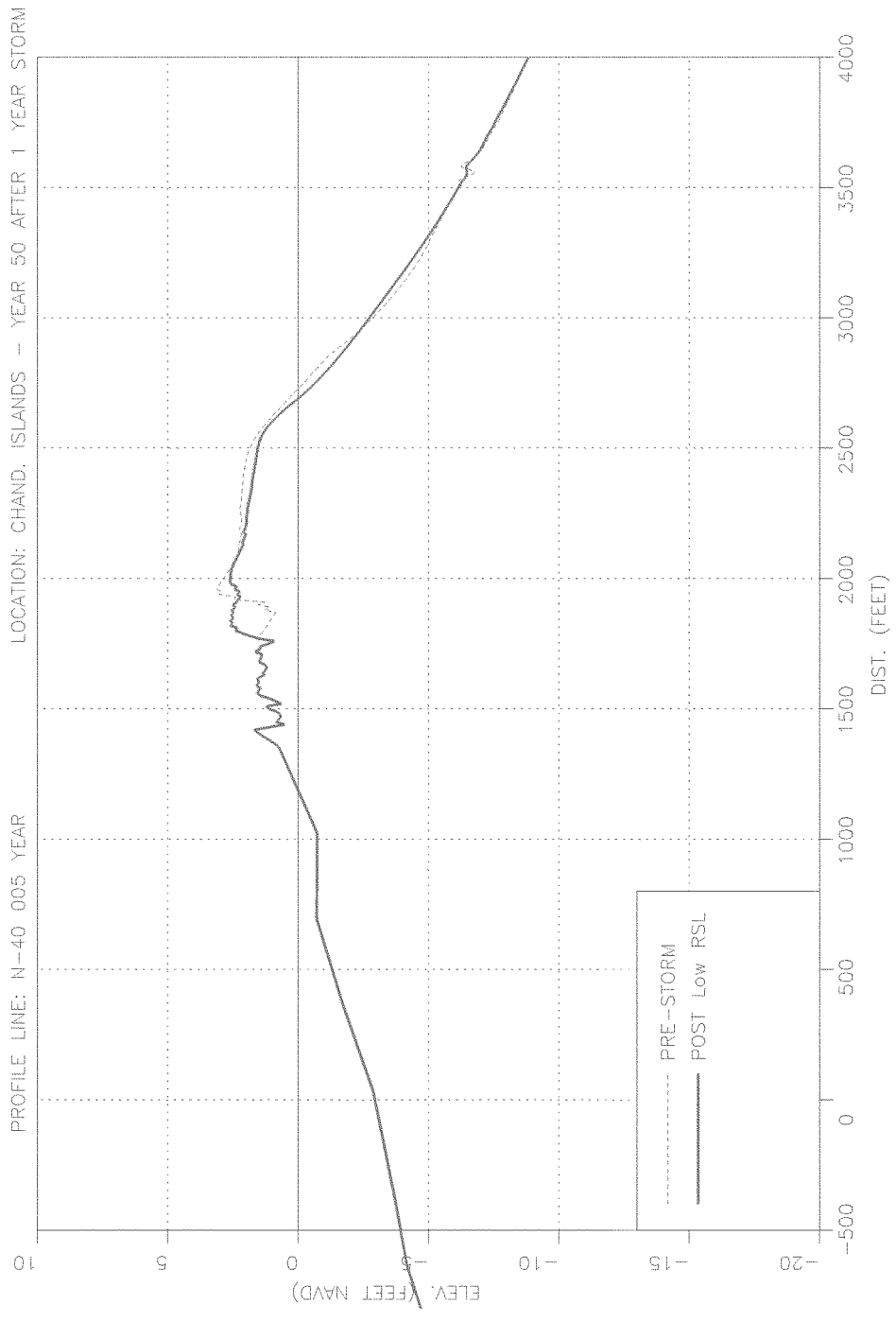

PROFILE LINE: N-40 003 YEAR
LOCATION: CHAND. ISLANDS -- YEAR 50 AFTER 1 YEAR STORM
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Med RSL
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

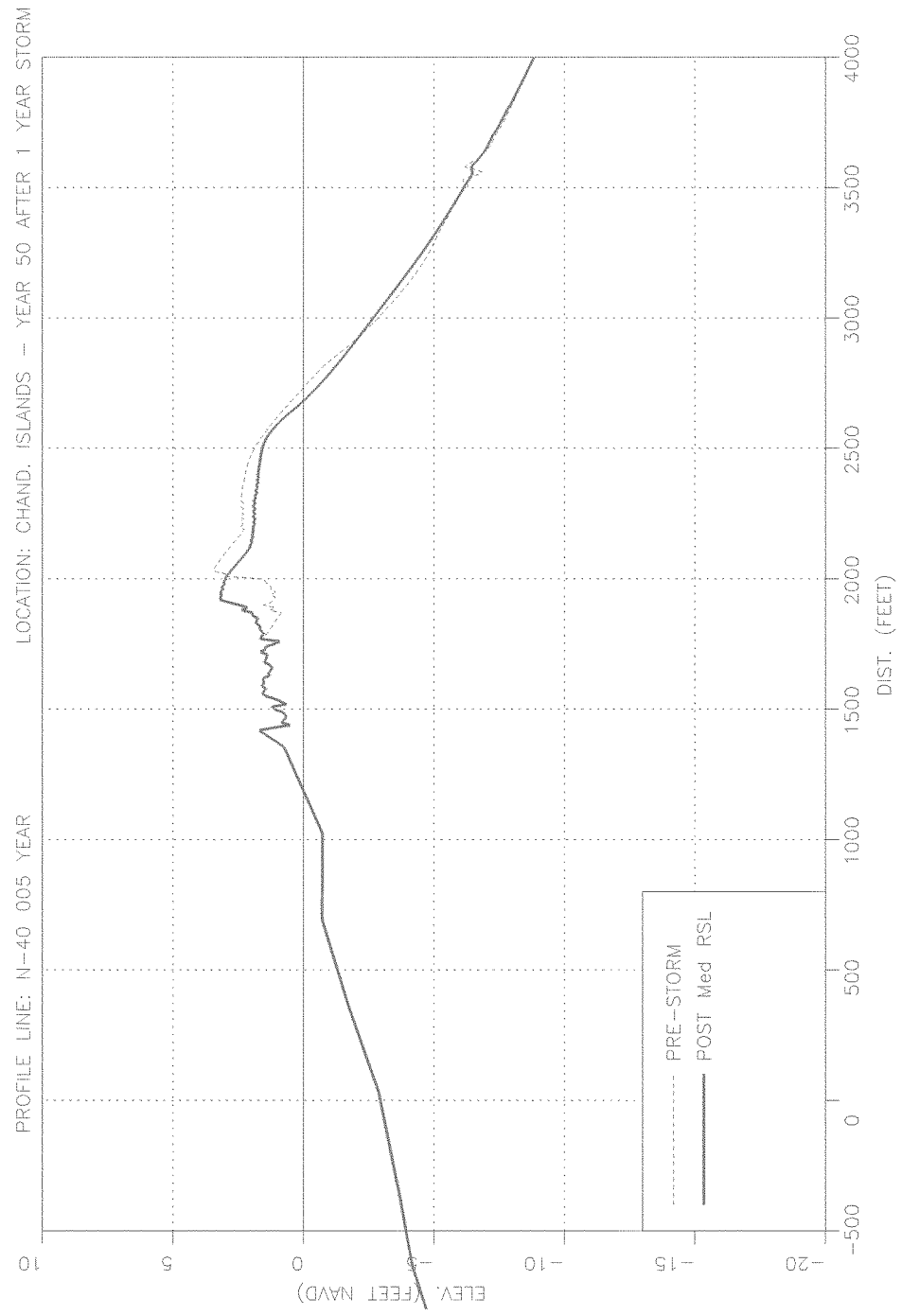

PROFILE LINE: N-40 003 YEAR
LOCATION: CHAND. ISLANDS - YEAR 50 AFTER 1 YEAR STORM
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST High RSL
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

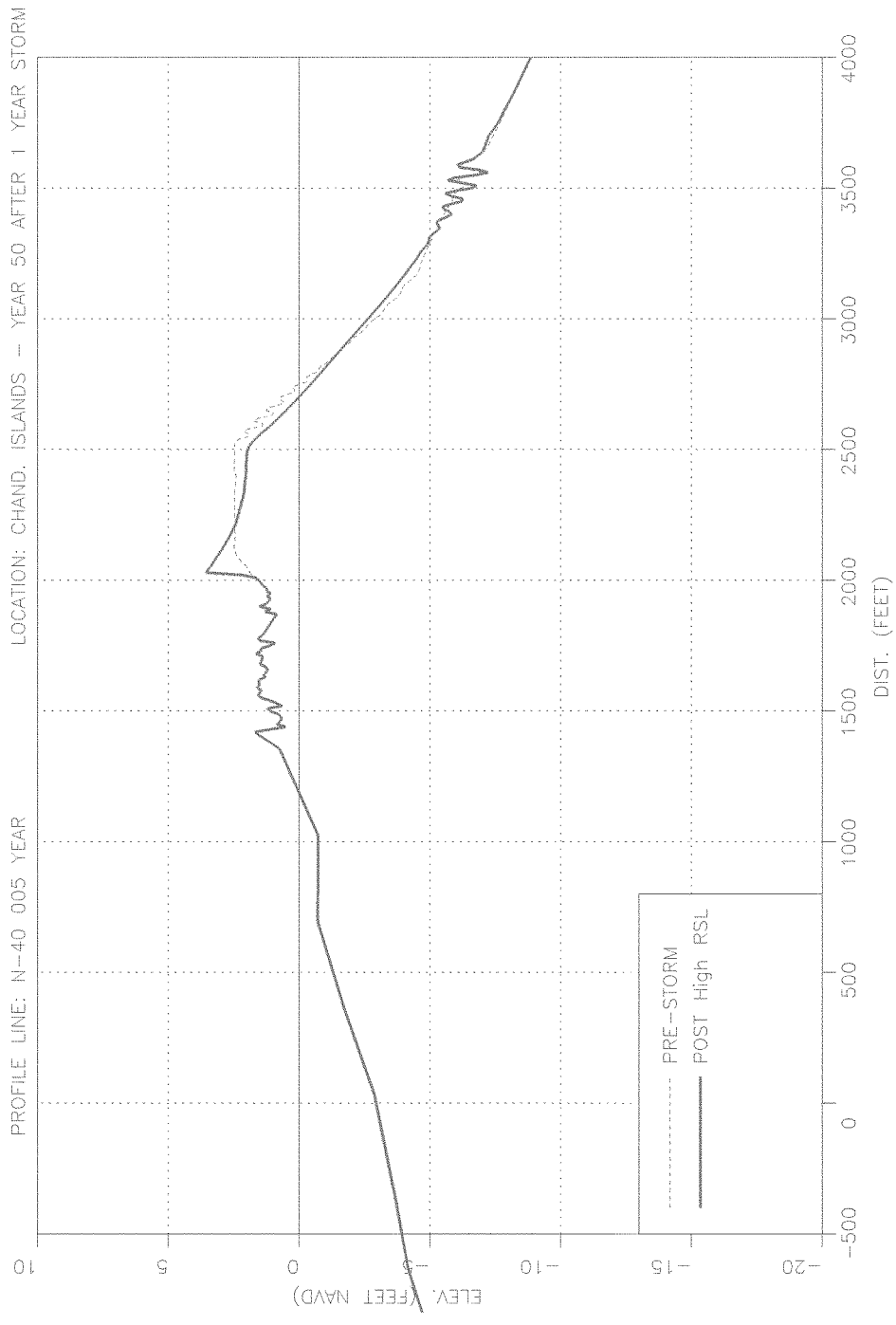

PROFILE LINE: N-40 004 YEAR
LOCATION: CHAND. ISLANDS - YEAR 50 AFTER 1 YEAR STORM
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

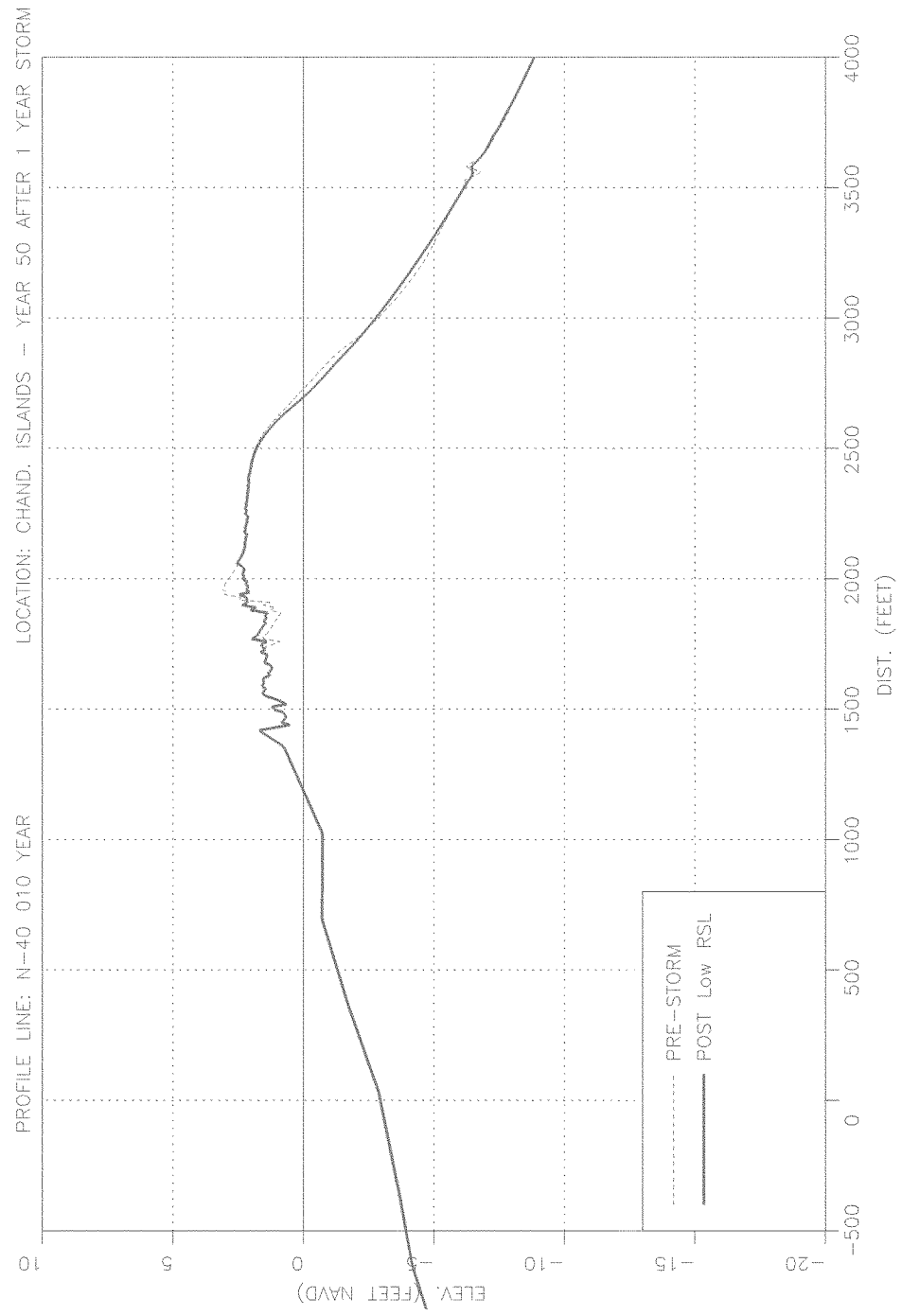

PROFILE LINE: N-40 004 YEAR
LOCATION: CHAND. ISLANDS - YEAR 50 AFTER 1 YEAR STORM
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Med RSL
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

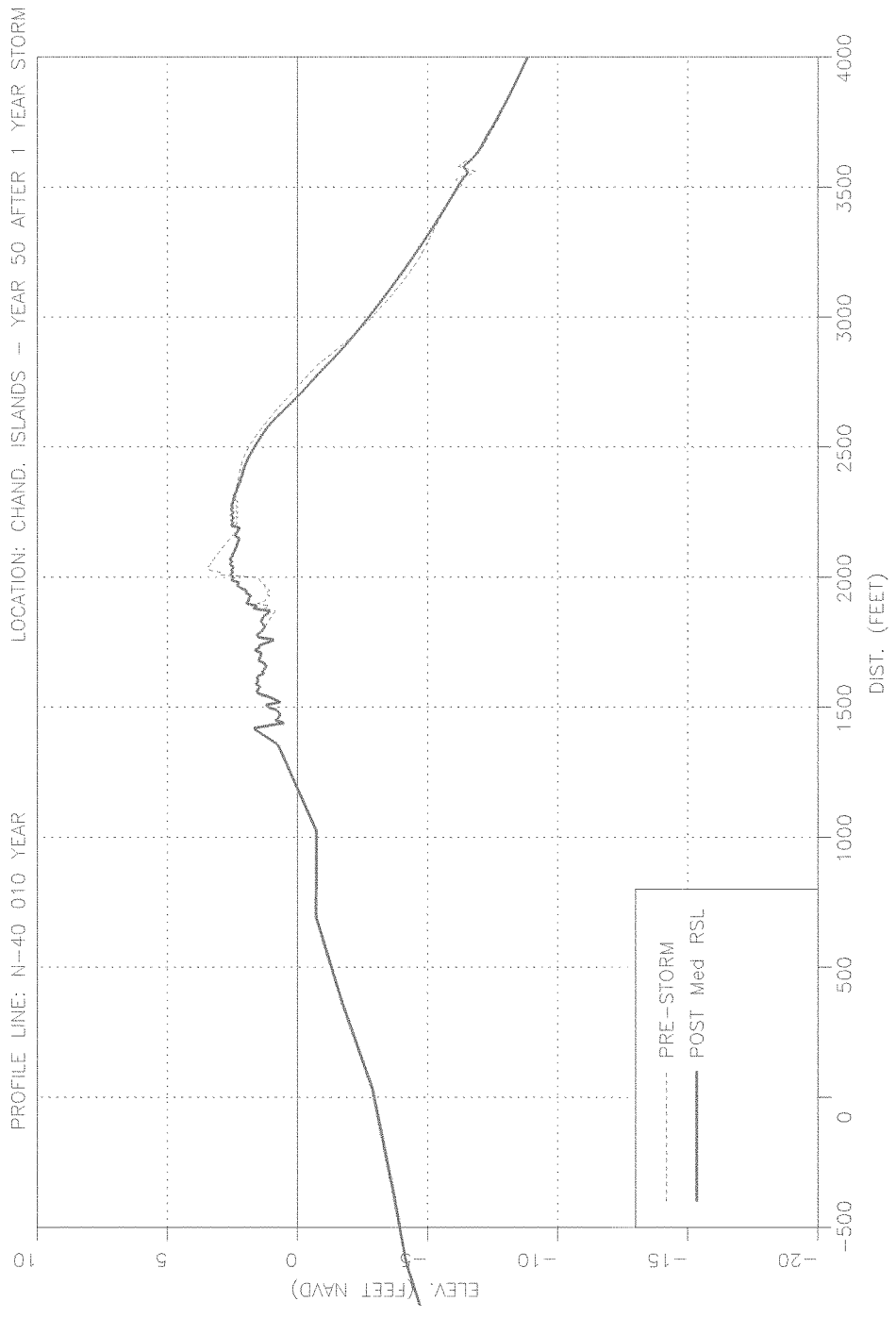

PROFILE LINE: N-40 004 YEAR
LOCATION: CHAND. ISLANDS -- YEAR 50 AFTER 1 YEAR STORM
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST High RSL
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

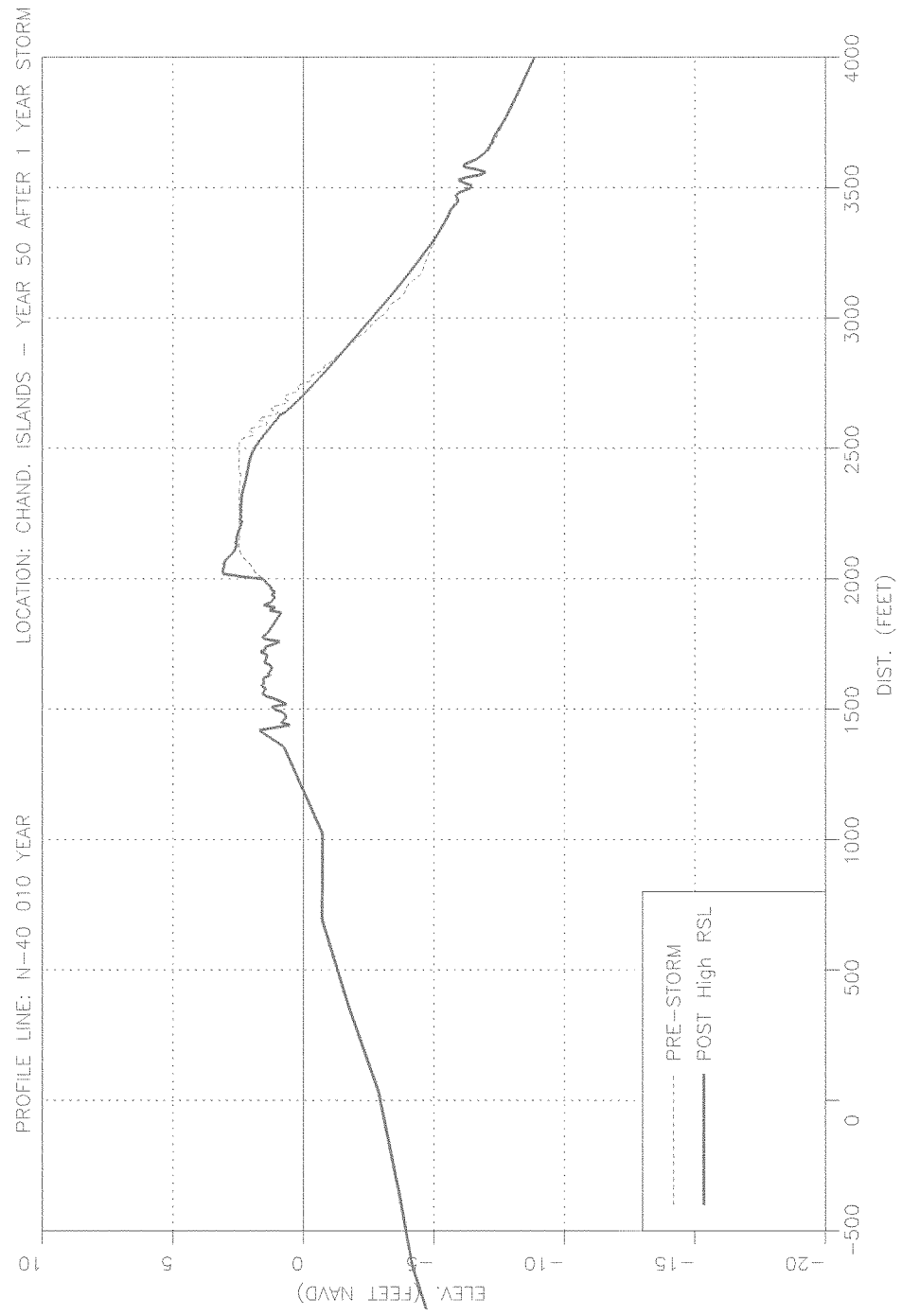

PROFILE LINE: N-40 005 YEAR
LOCATION: CHAND. ISLANDS -- YEAR 50 AFTER 1 YEAR STORM
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

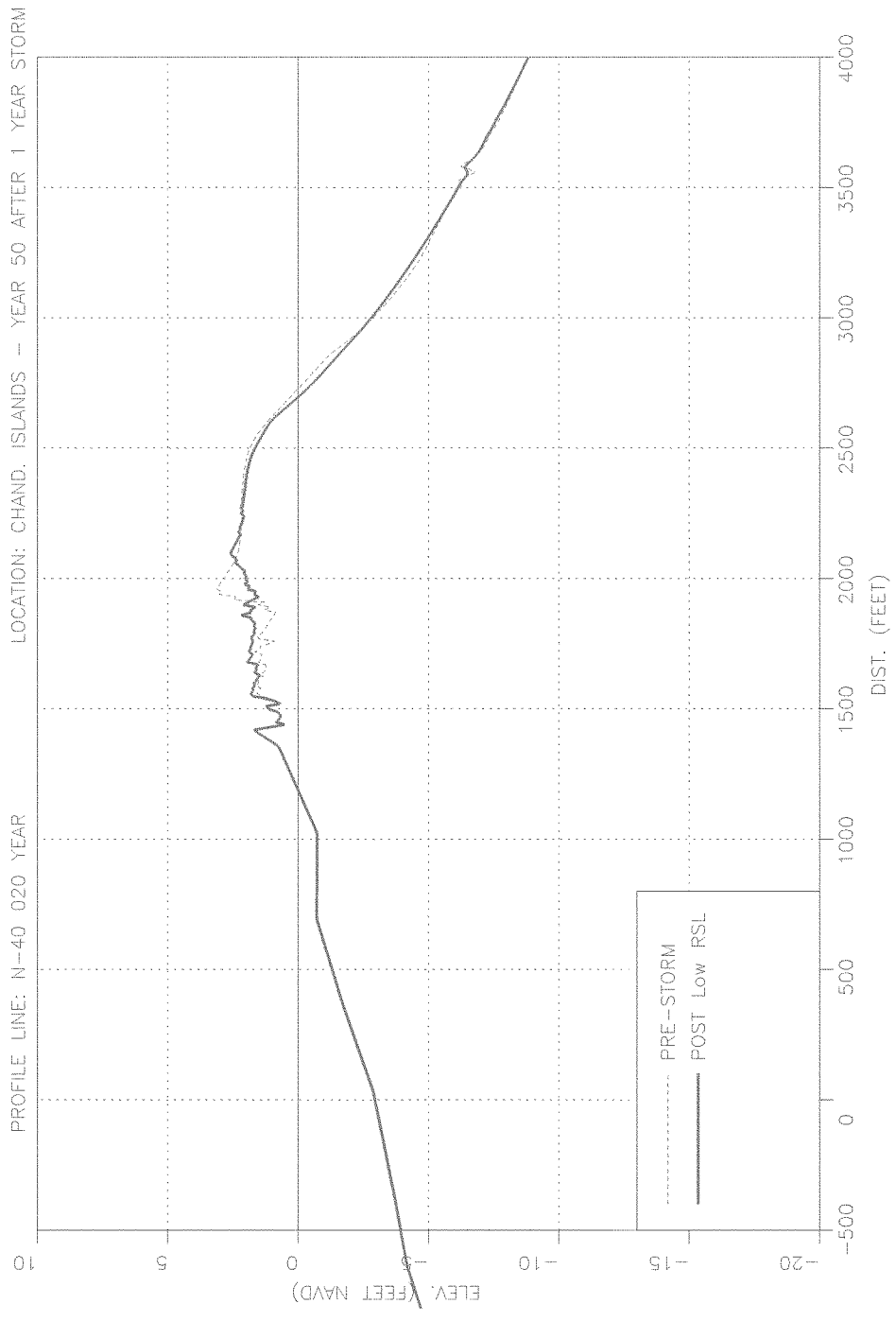

PROFILE LINE: N-40 005 YEAR
LOCATION: CHAND. ISLANDS - YEAR 50 AFTER 1 YEAR STORM
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Med RSL
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

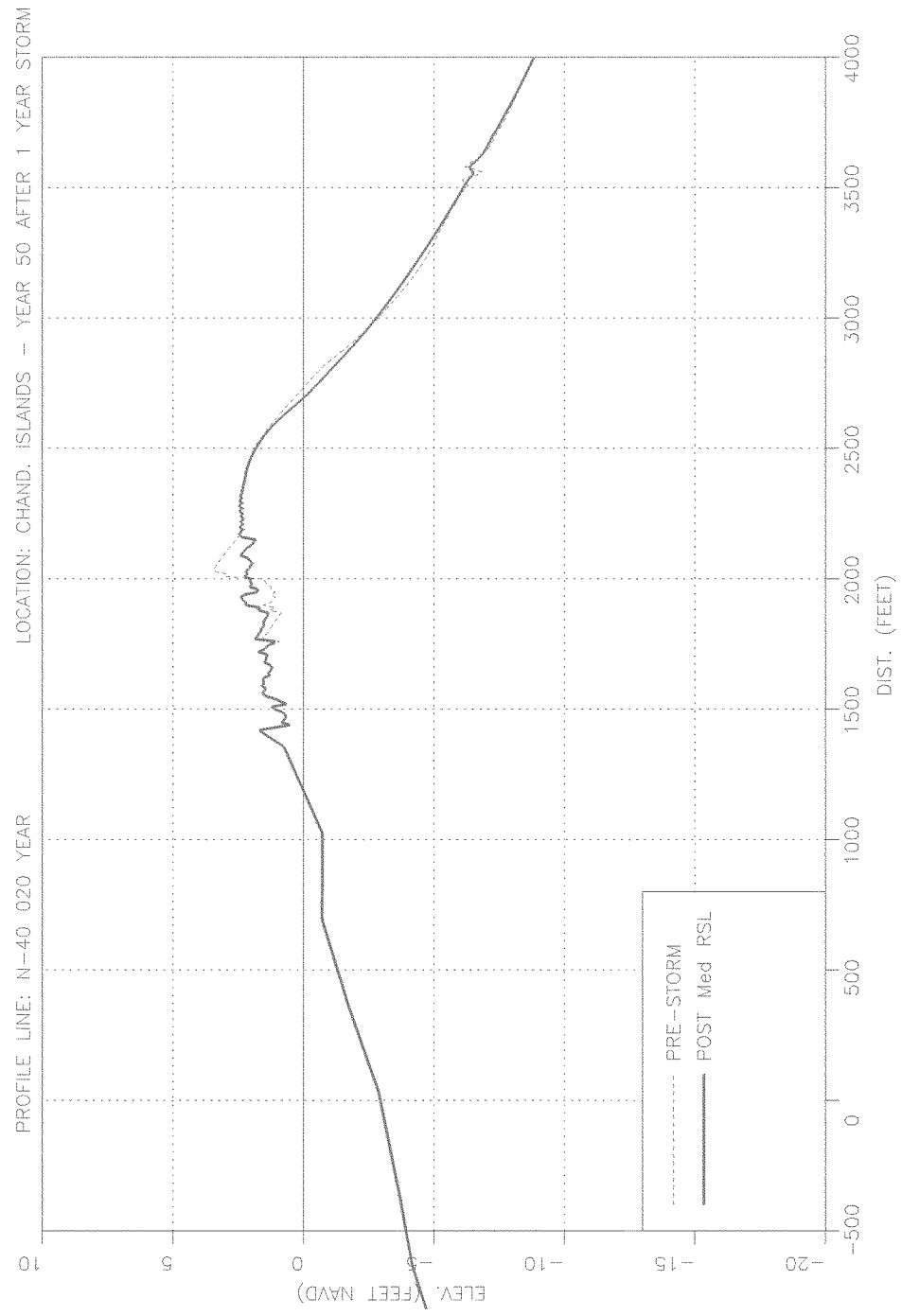

PROFILE LINE: N-40 005 YEAR
LOCATION: CHAND. ISLANDS -- YEAR 50 AFTER 1 YEAR STORM
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST High RSL
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

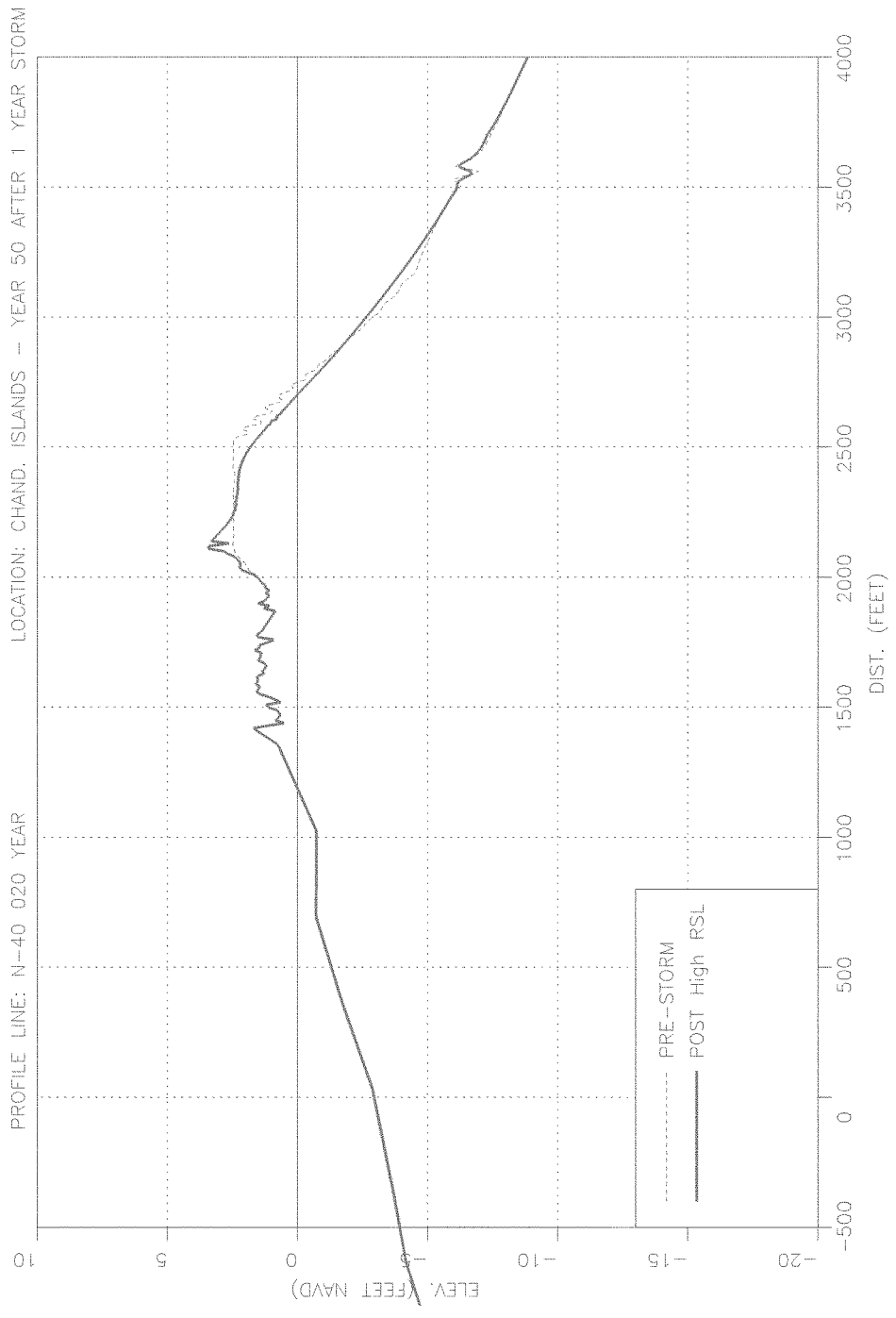

PROFILE LINE: N-40 010 YEAR
LOCATION: CHAND. ISLANDS - YEAR 50 AFTER 1 YEAR STORM
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

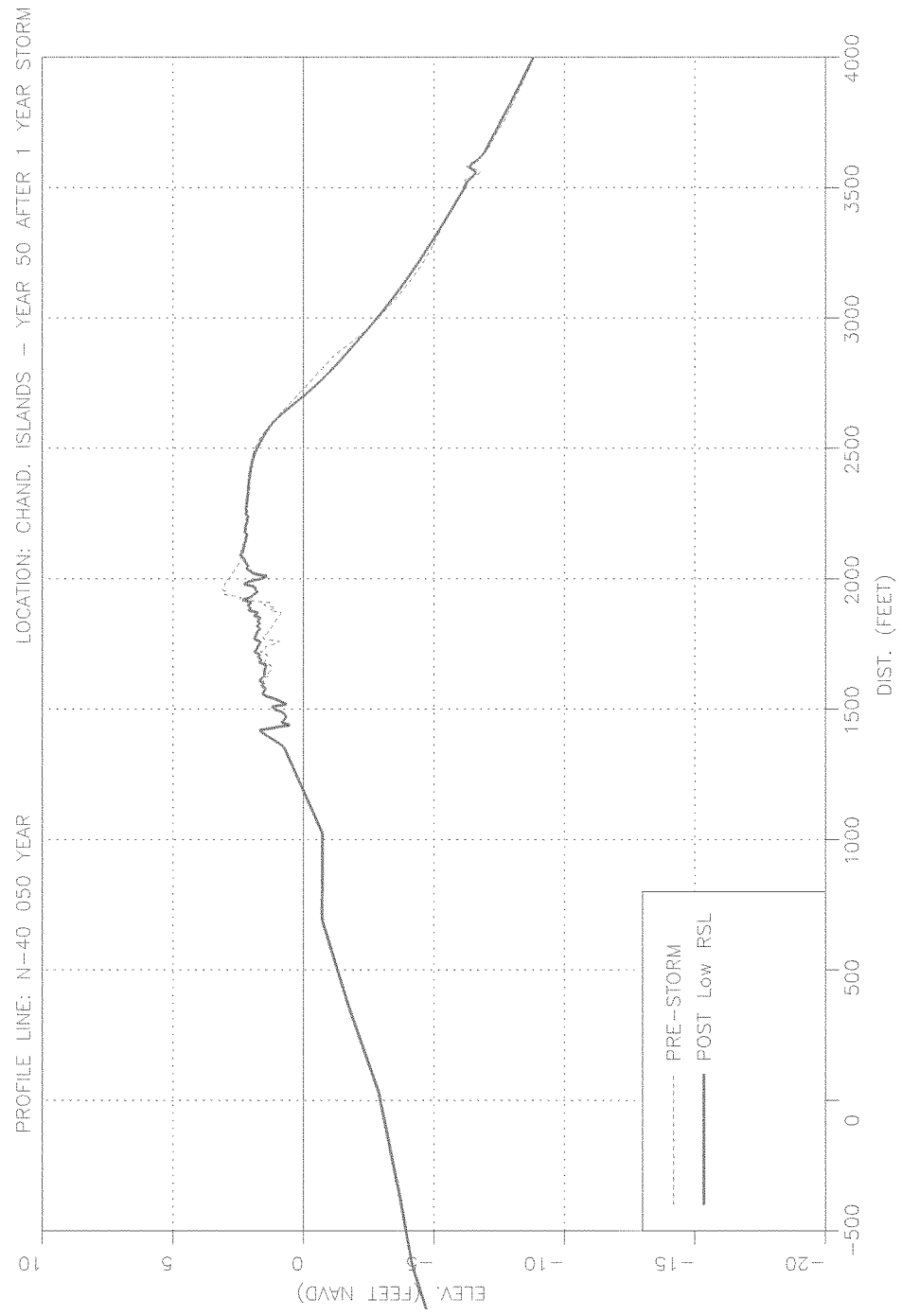

PROFILE LINE: N-40 010 YEAR
LOCATION: CHAND. ISLANDS - YEAR 50 AFTER 1 YEAR STORM
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Med RSL
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

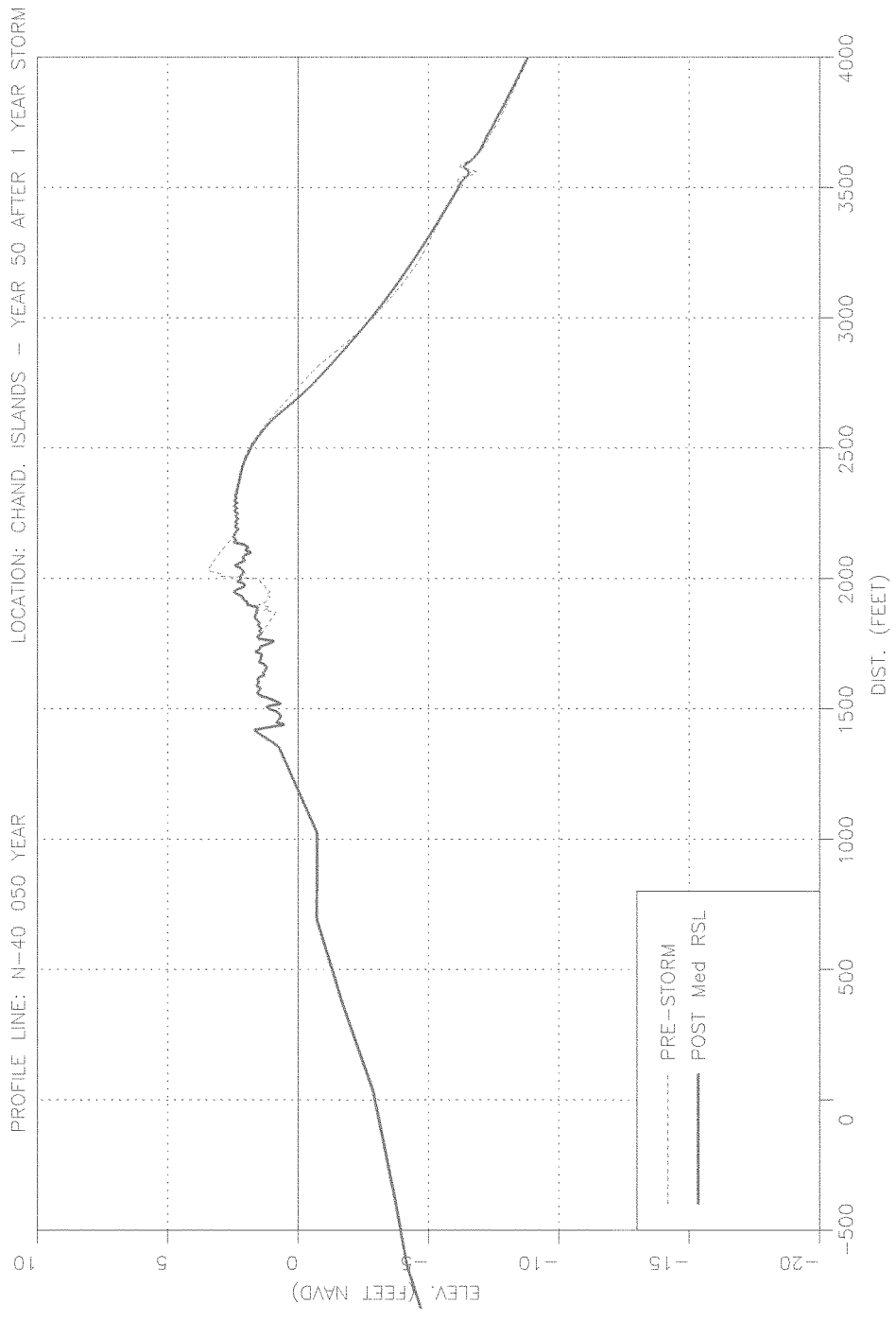

PROFILE LINE: N-40 010 YEAR
LOCATION: CHAND. ISLANDS - YEAR 50 AFTER 1 YEAR STORM
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST High RSL
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

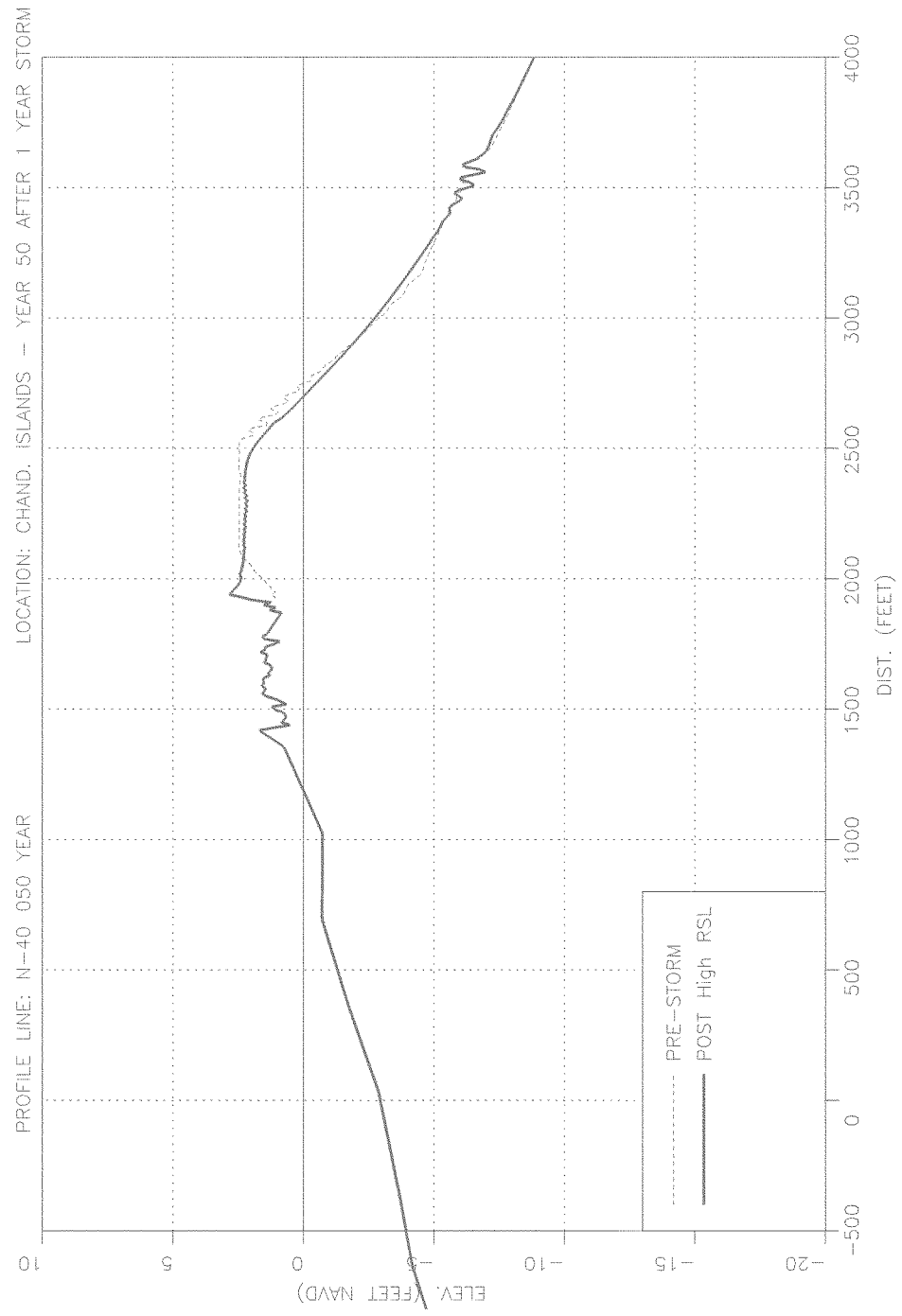

PROFILE LINE: N-40 020 YEAR
LOCATION: CHAND. ISLANDS -- YEAR 50 AFTER 1 YEAR STORM
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

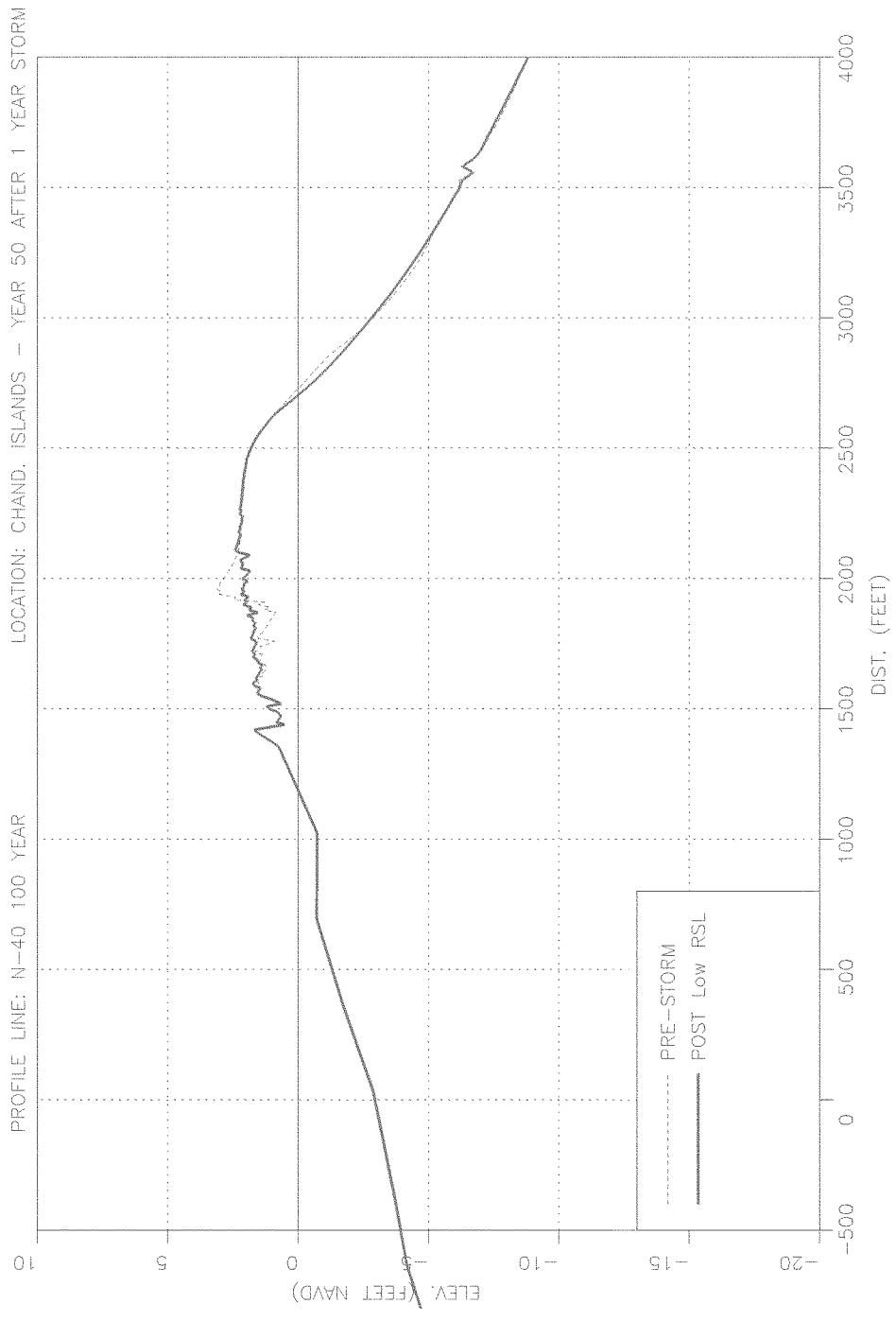

PROFILE LINE: N-40 020 YEAR
LOCATION: CHAND. ISLANDS - YEAR 50 AFTER 1 YEAR STORM
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Med RSL
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

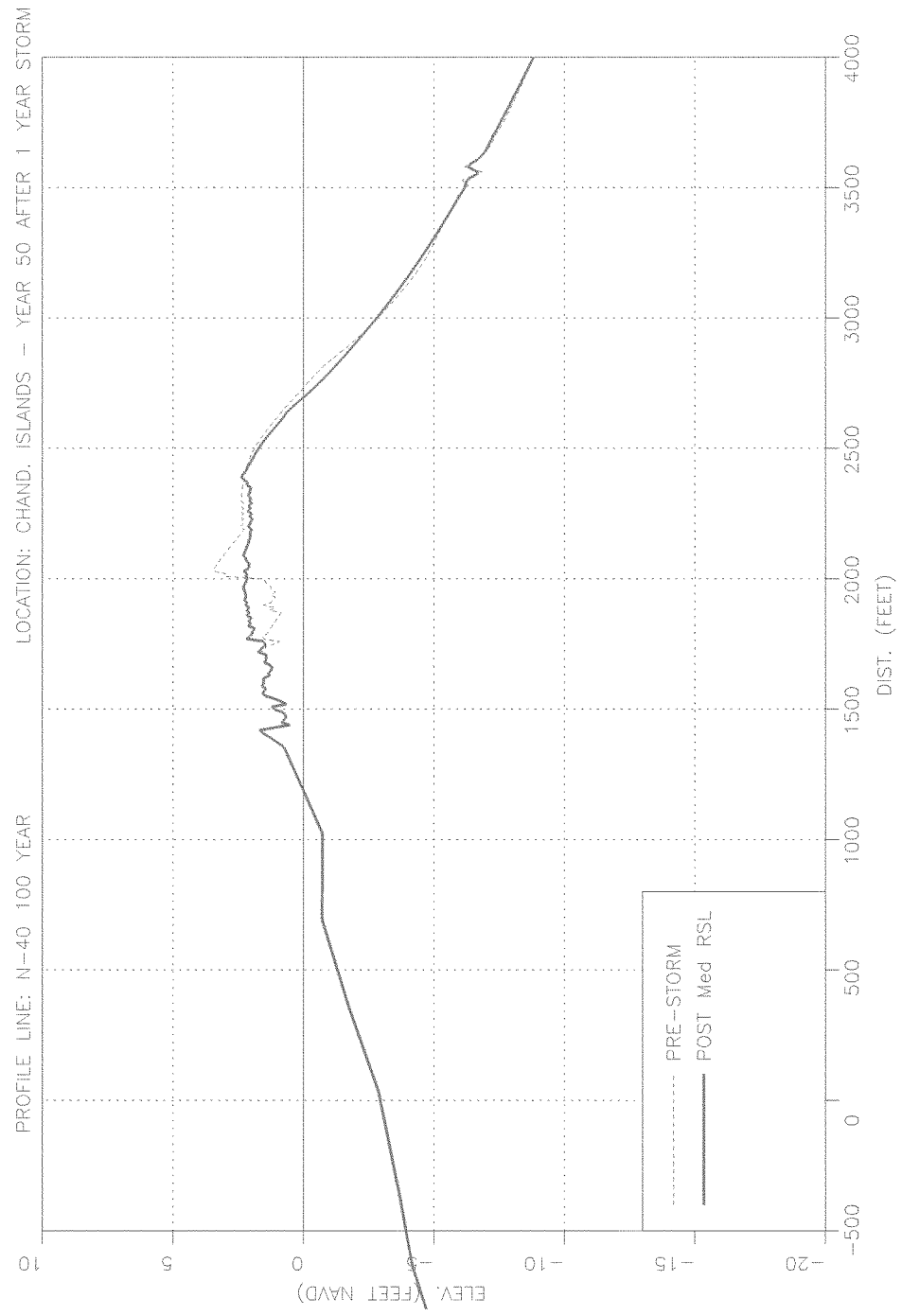

PROFILE LINE: N-40 020 YEAR
LOCATION: CHAND. ISLANDS -- YEAR 50 AFTER 1 YEAR STORM
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST High RSL
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

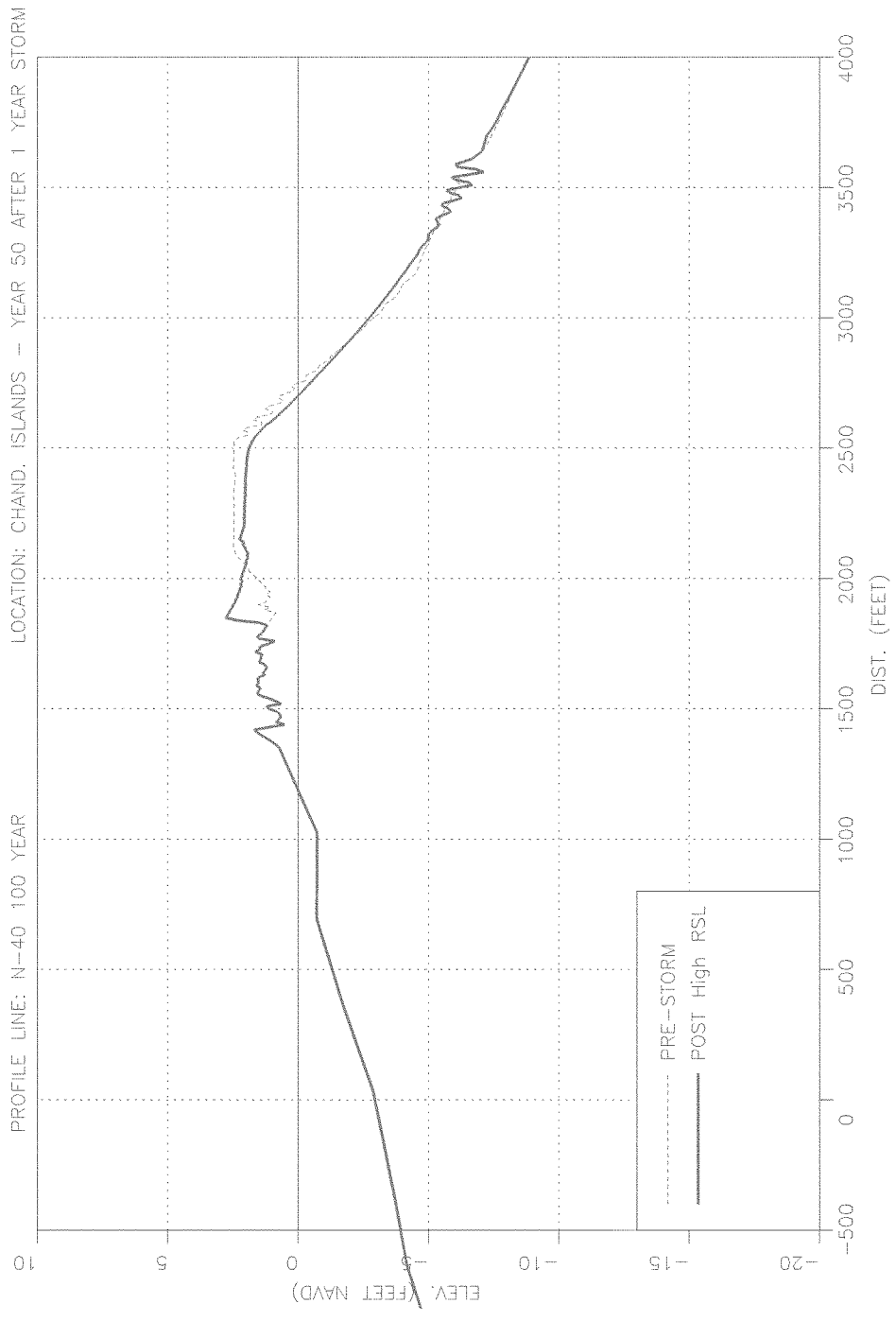

PROFILE LINE: N-40 050 YEAR
LOCATION: CHAND. ISLANDS - YEAR 50 AFTER 1 YEAR STORM
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000


PROFILE LINE: N-40 050 YEAR
LOCATION: CHAND. ISLANDS -- YEAR 50 AFTER 1 YEAR STORM
ELEV. (FEET NAVD)
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000
DIST. (FEET)
PRE-STORM
POST Med RSL


PROFILE LINE: N-40 050 YEAR
LOCATION: CHAND. ISLANDS - YEAR 50 AFTER 1 YEAR STORM
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST High RSL
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

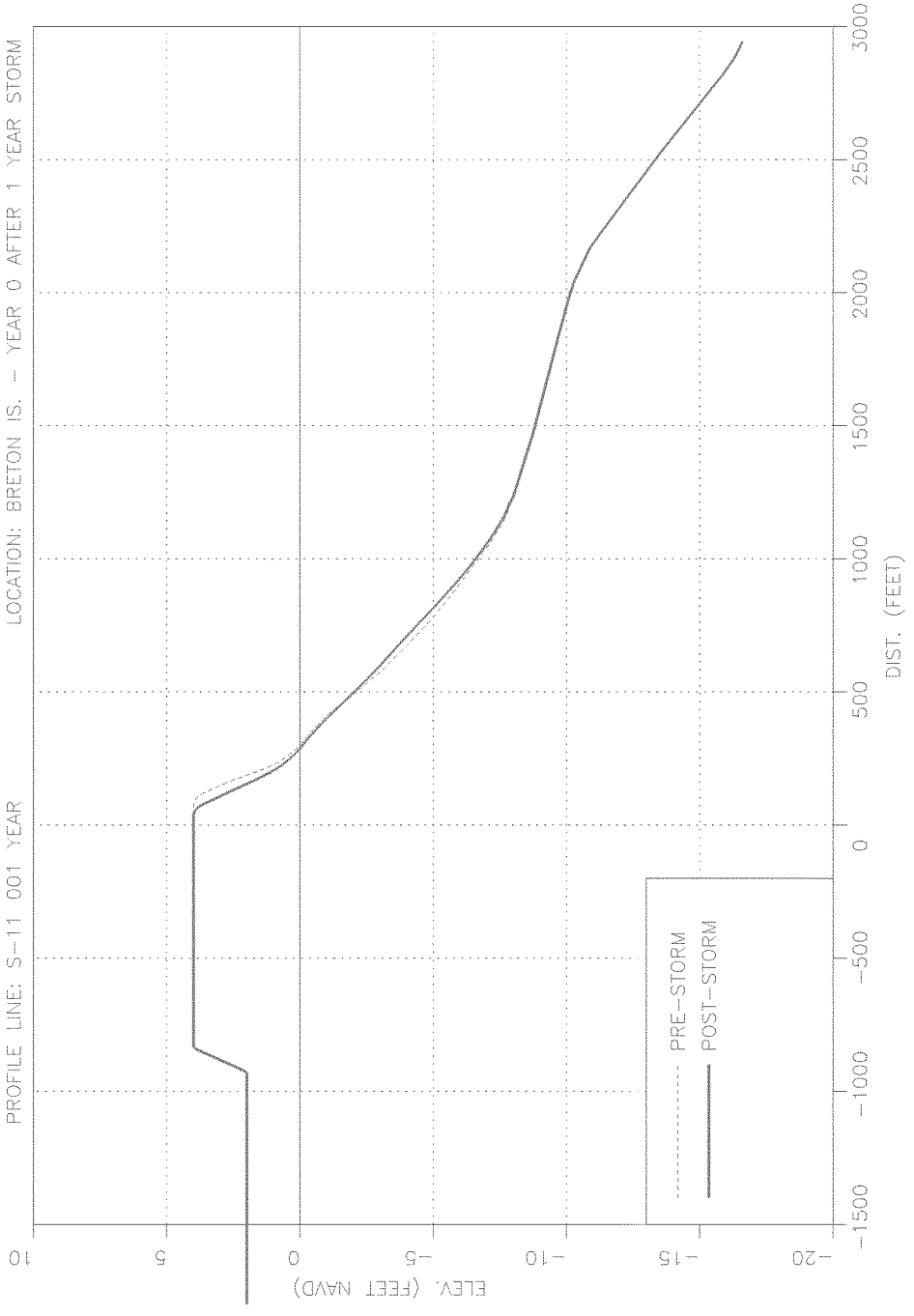

PROFILE LINE: N-40 100 YEAR
LOCATION: CHAND. ISLANDS - YEAR 50 AFTER 1 YEAR STORM
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

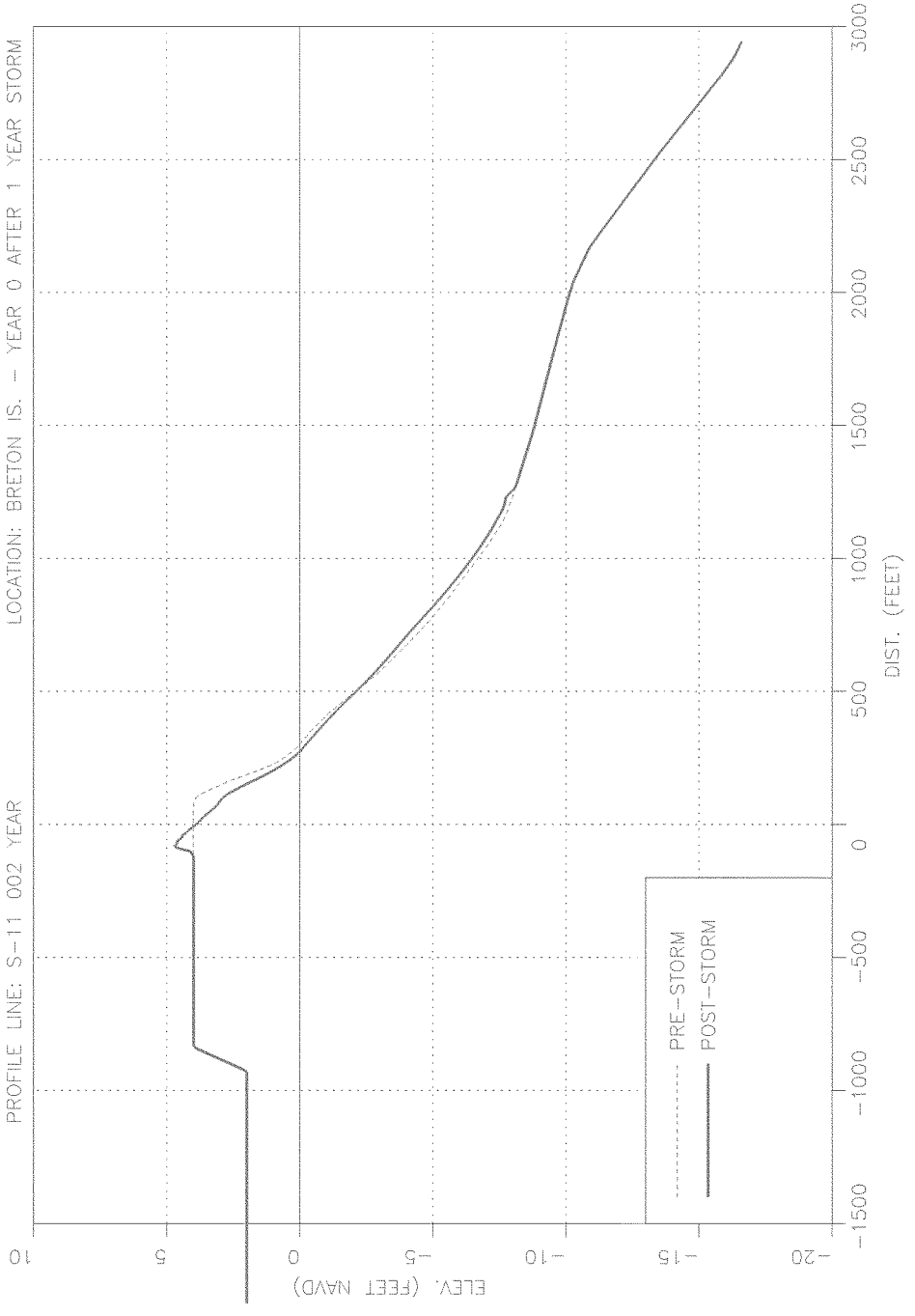

PROFILE LINE: N-40 100 YEAR
LOCATION: CHAND. ISLANDS - YEAR 50 AFTER 1 YEAR STORM
PRE-STORM
POST Med RSL
ELEV. (FEET NAVD)
DIST. (FEET)
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

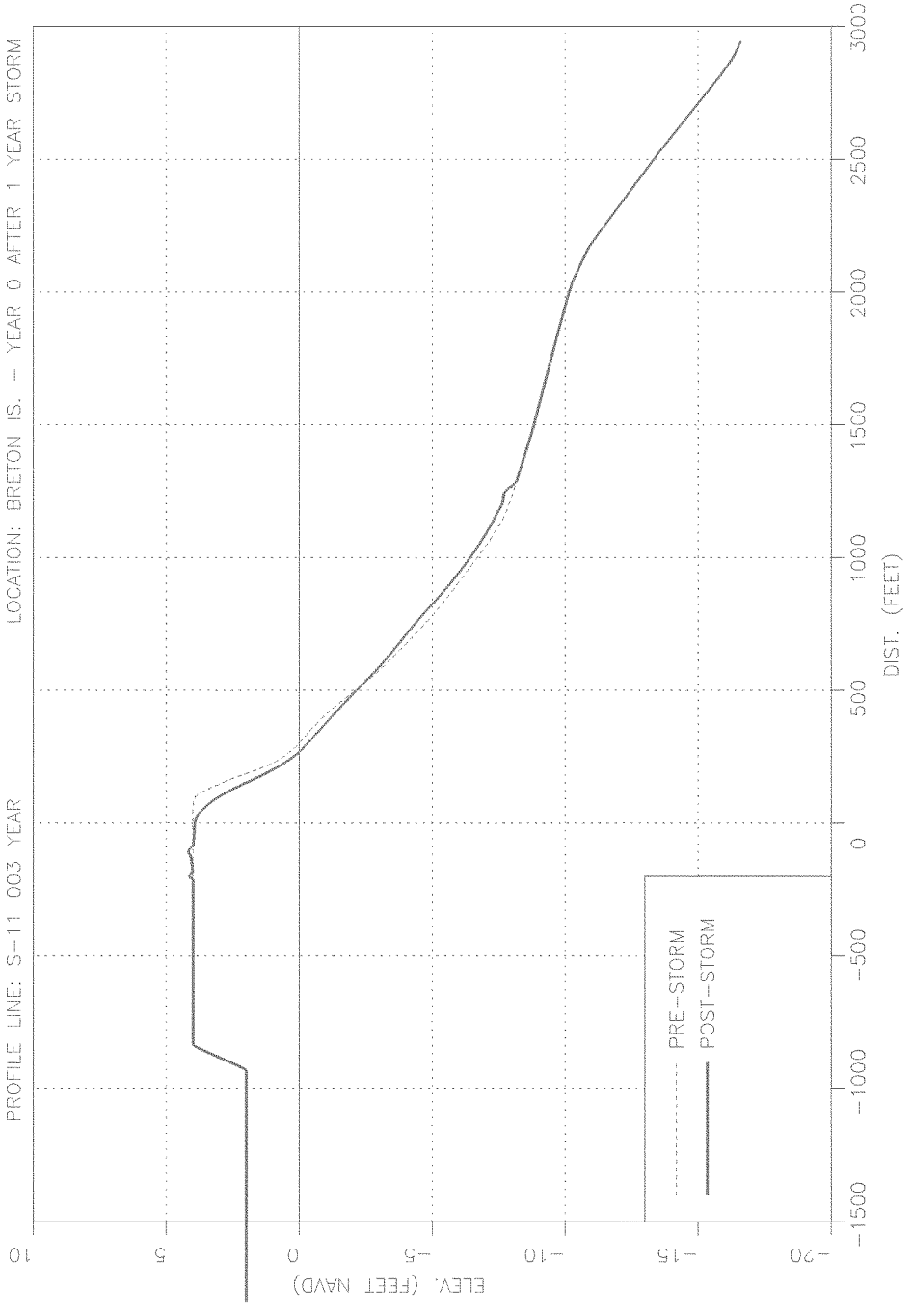

PROFILE LINE: N-40 100 YEAR
LOCATION: CHAND. ISLANDS - YEAR 50 AFTER 1 YEAR STORM
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST High RSL
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000
2500
3000
3500
4000

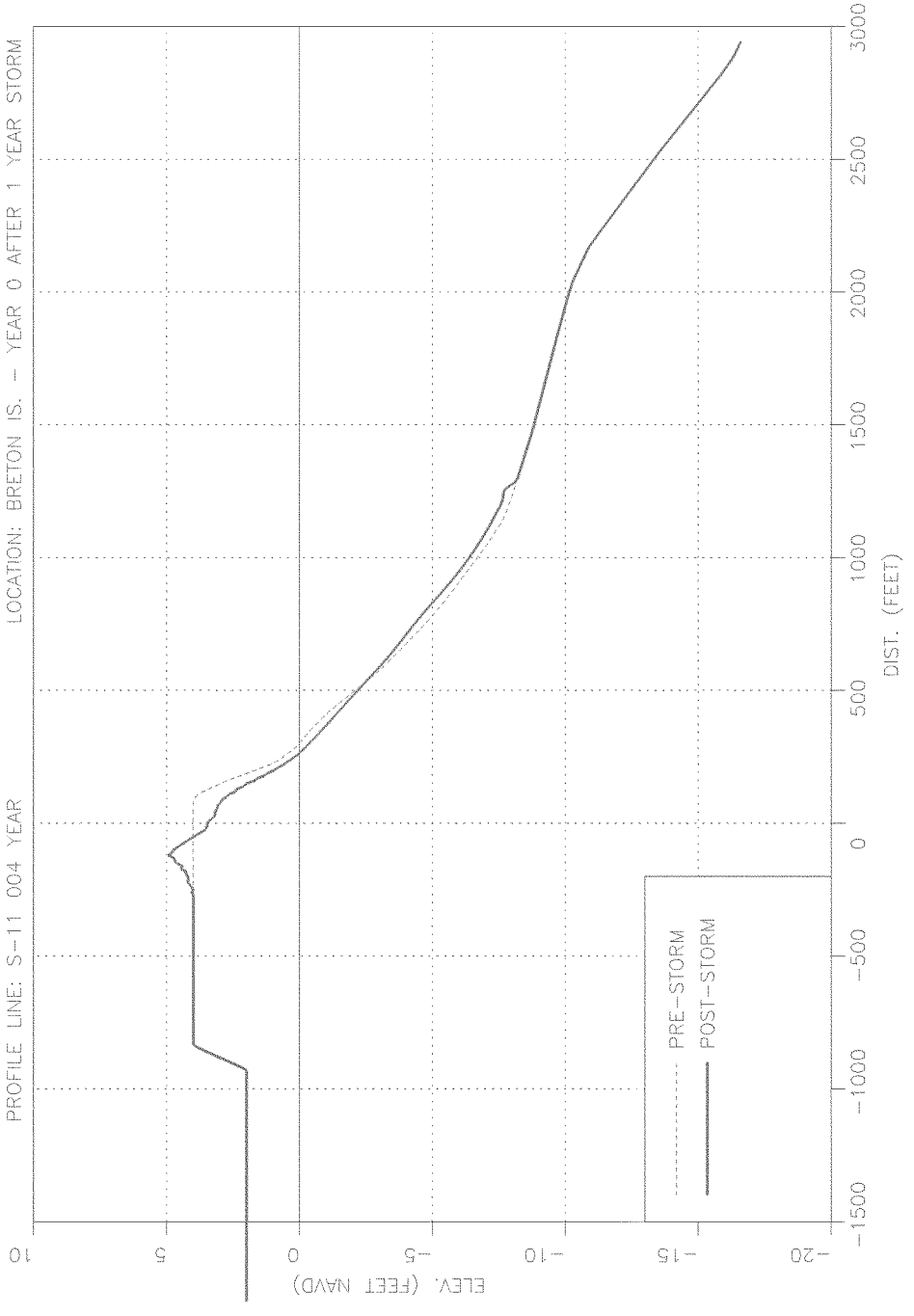
Breton Island Profile S-11

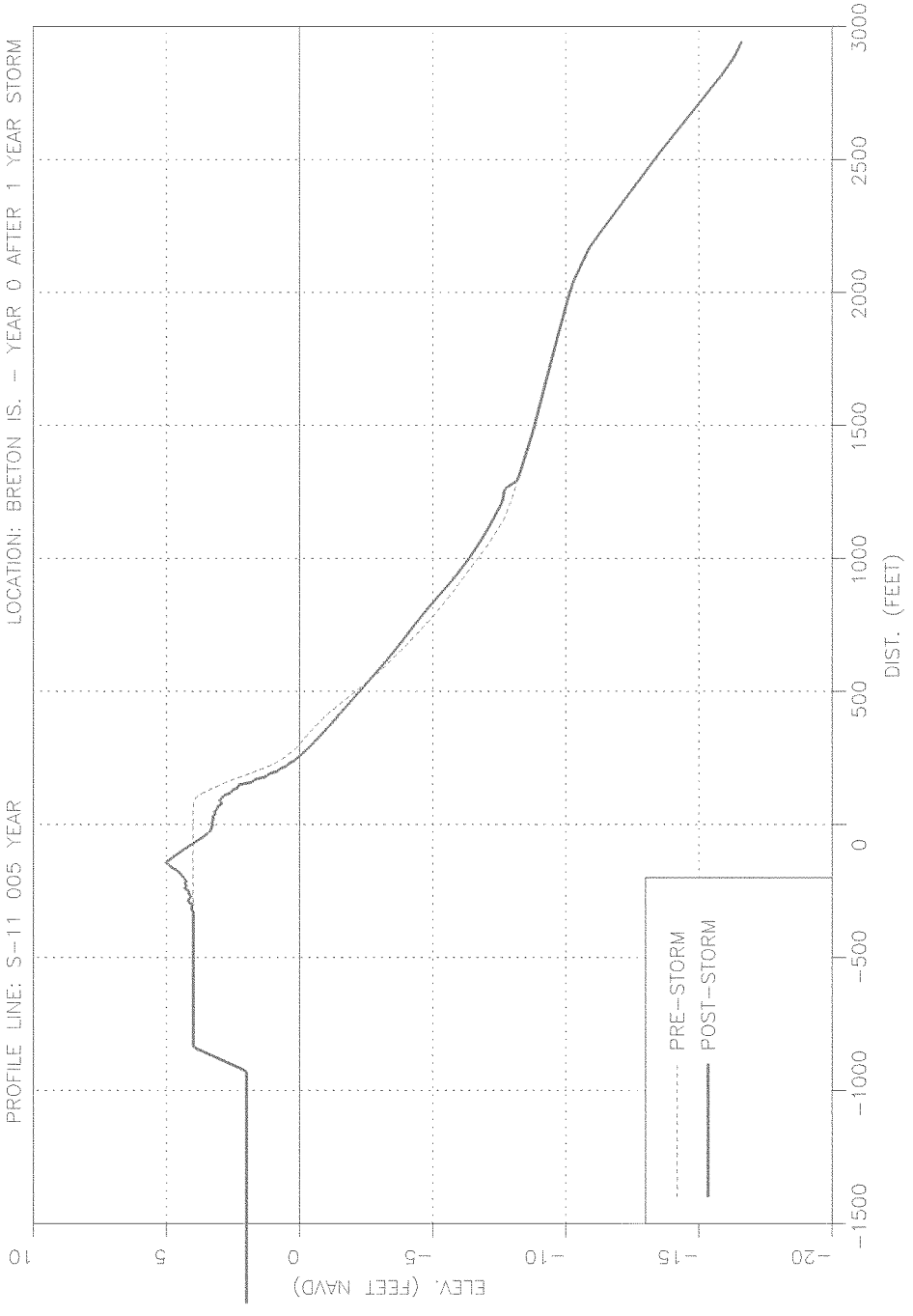
Alternative 1

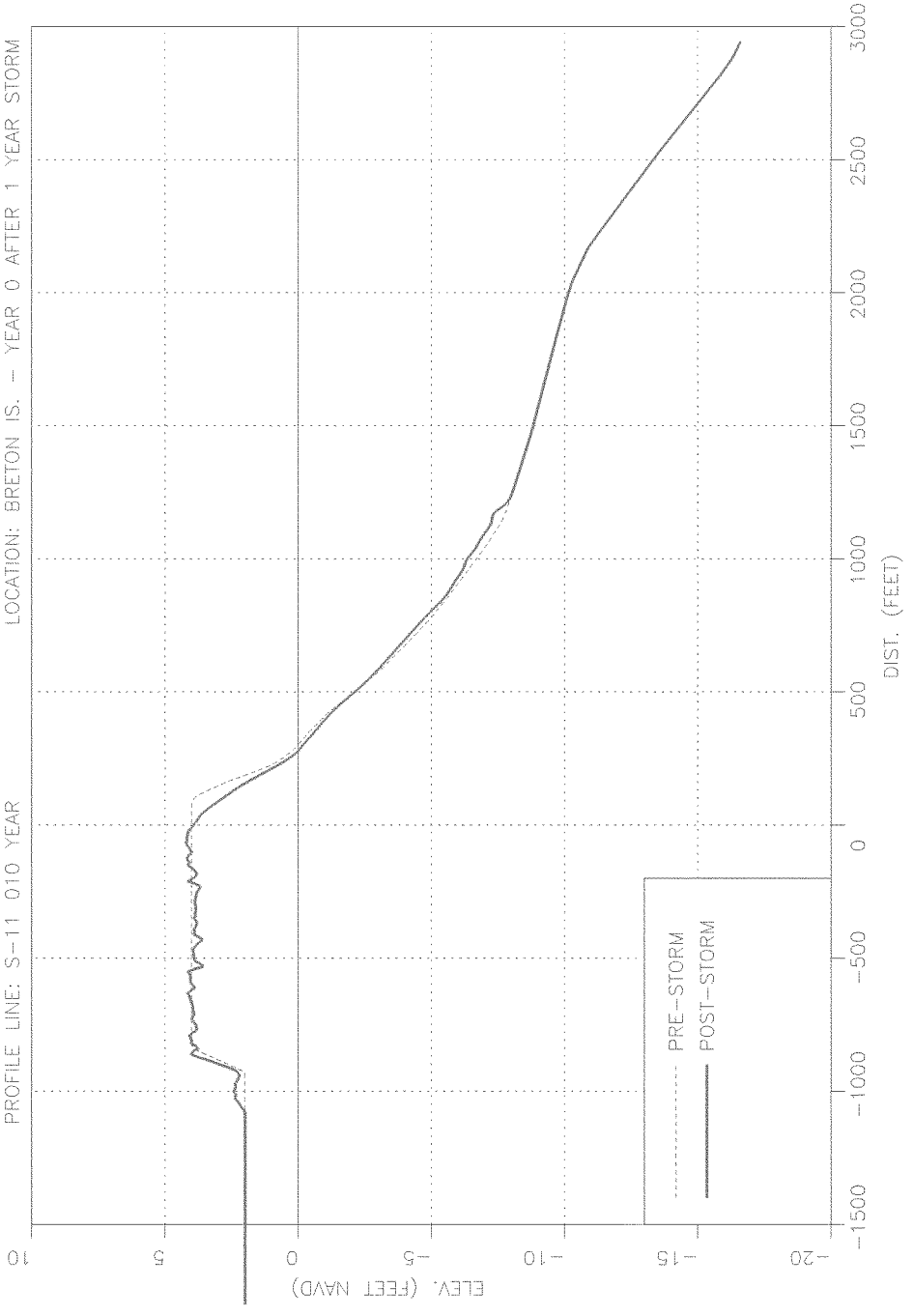

PROFILE LINE: S-11 001 YEAR
LOCATION: BRETON IS. - YEAR 0 AFTER 1 YEAR STORM
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

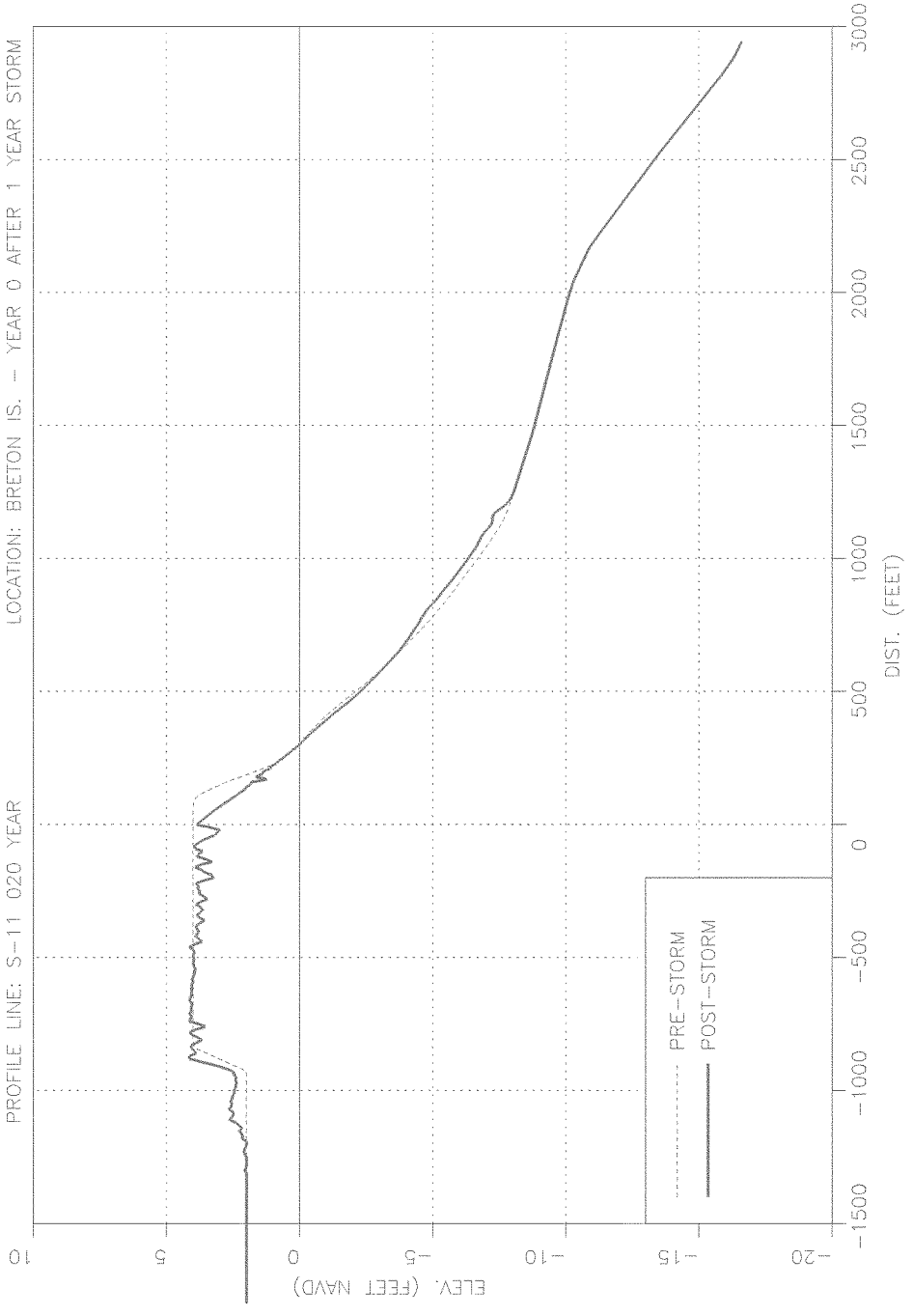

PROFILE LINE: S-11 002 YEAR
LOCATION: BRETON IS. -- YEAR 0 AFTER 1 YEAR STORM
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

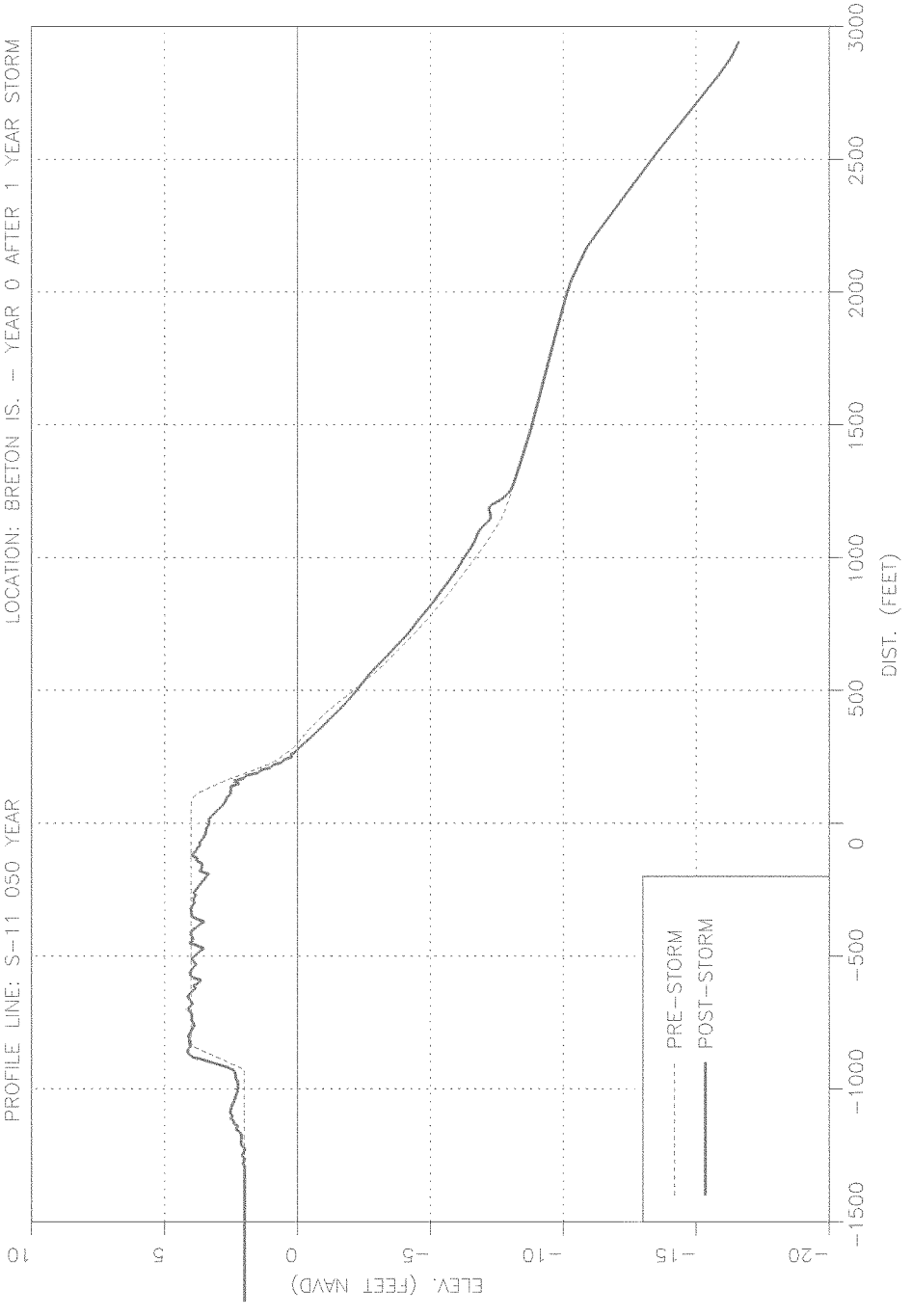

PROFILE LINE: S-11 003 YEAR
LOCATION: BRETON IS. -- YEAR 0 AFTER 1 YEAR STORM
ELEV. (FEET NAVD)
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000
DIST. (FEET)
PRE-STORM
POST-STORM

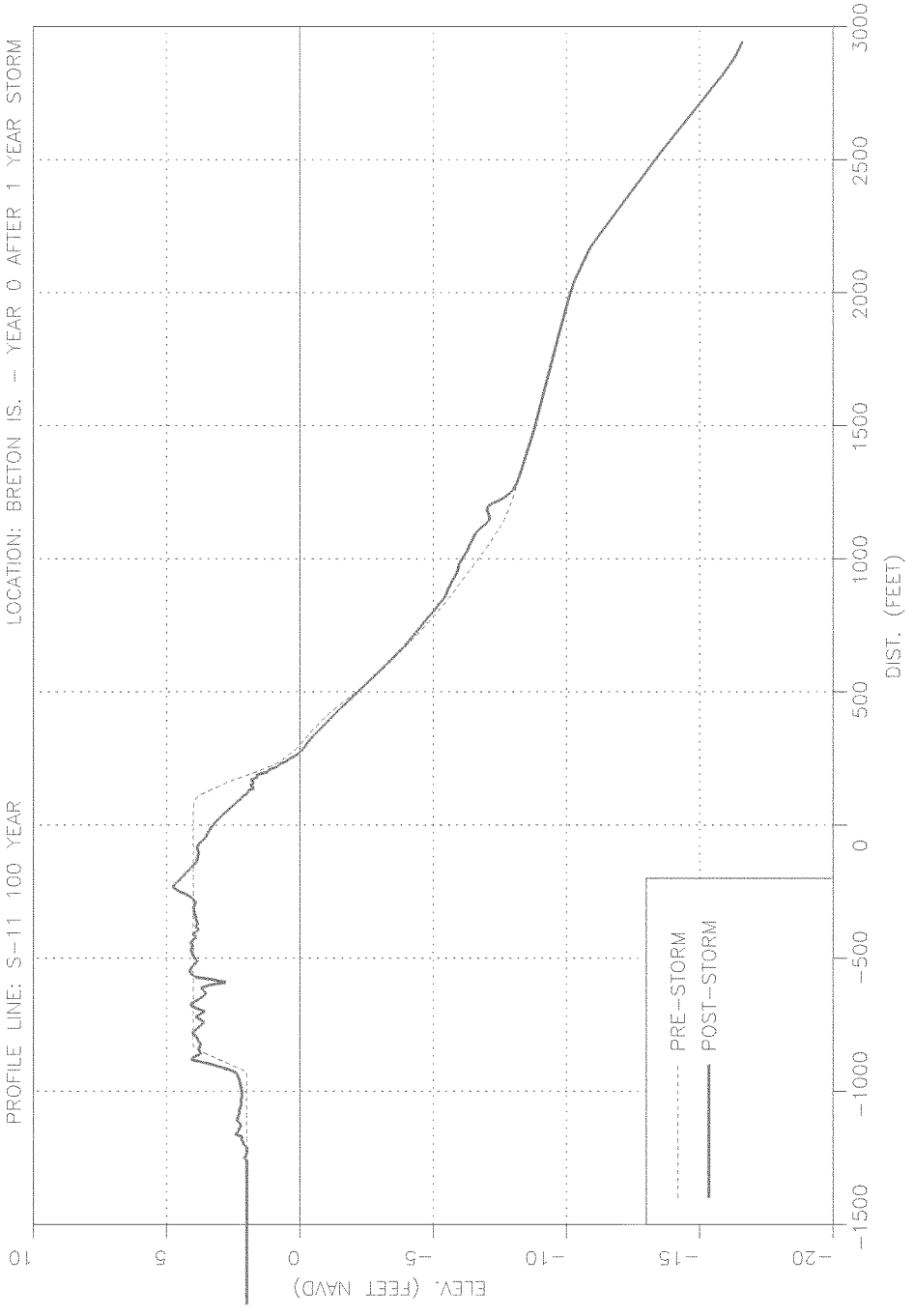

PROFILE LINE: S-11 004 YEAR
LOCATION: BRETON IS. -- YEAR 0 AFTER 1 YEAR STORM
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

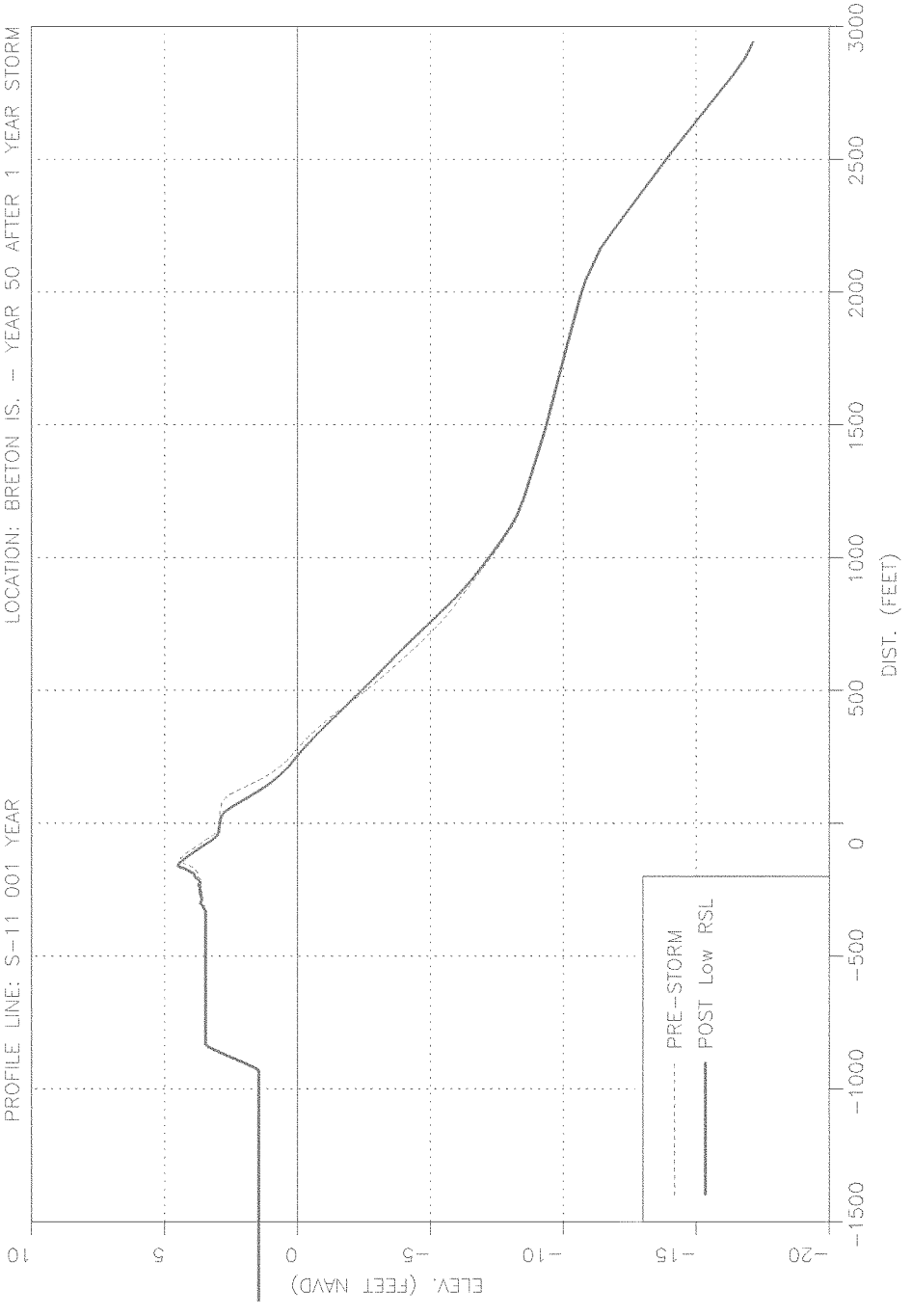

PROFILE LINE: S-11 005 YEAR
LOCATION: BRETON IS. - YEAR 0 AFTER 1 YEAR STORM
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

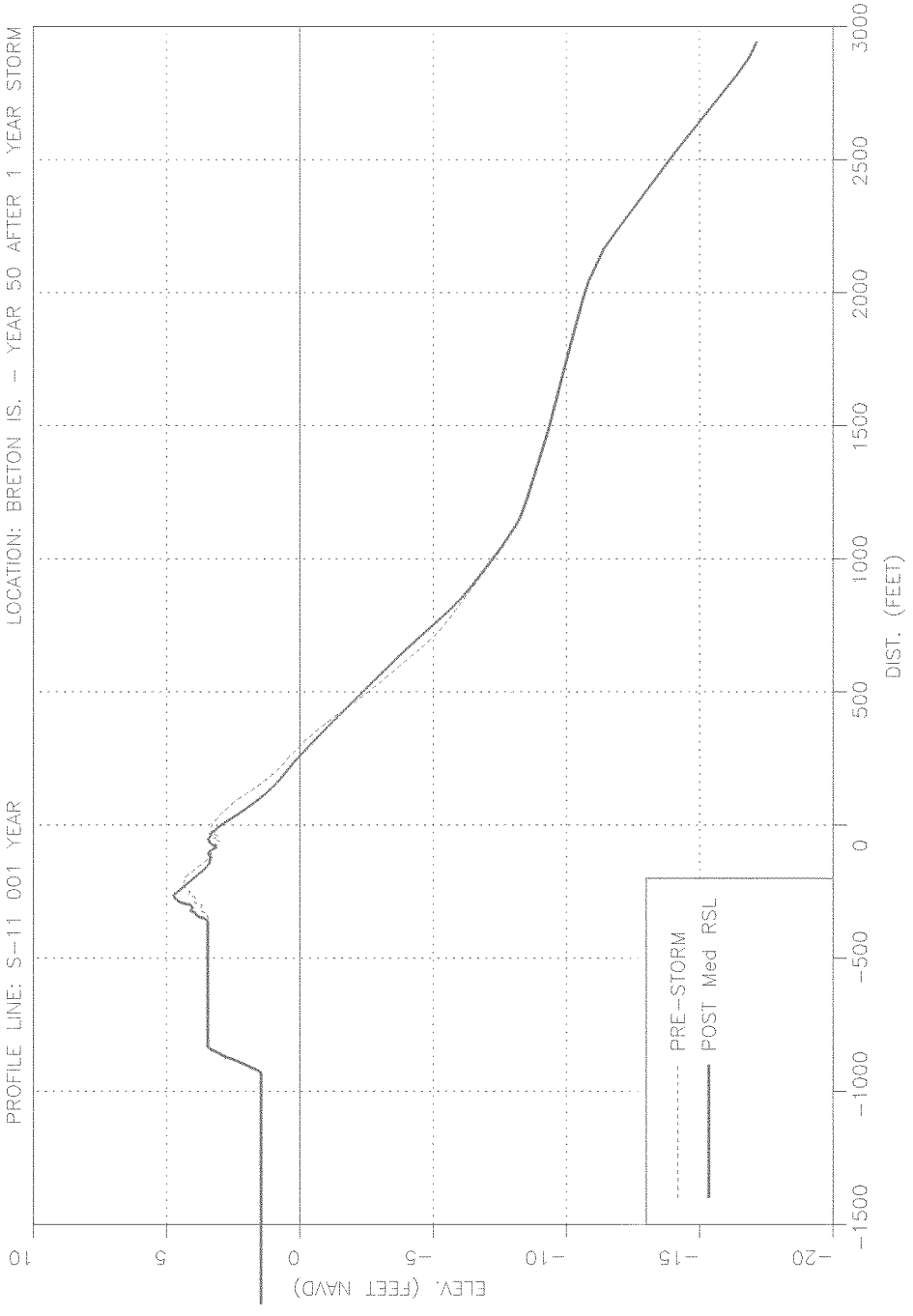

PROFILE LINE: S-11 010 YEAR
LOCATION: BRETON IS. -- YEAR 0 AFTER 1 YEAR STORM
ELEV. (FEET NAVD)
10
5
0
-5
-10
-15
-20
DIST. (FEET)
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000
PRE-STORM
POST-STORM

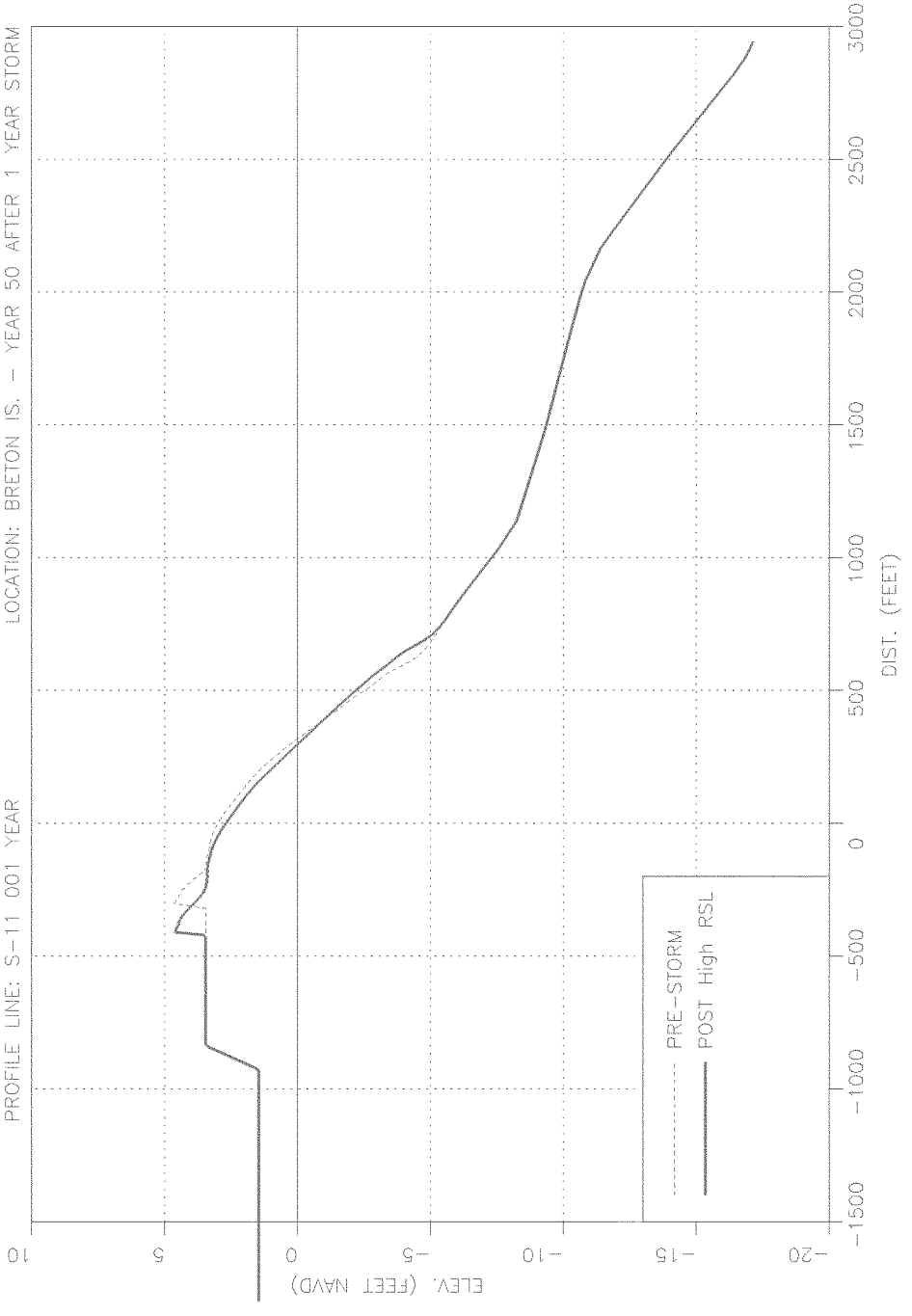

PROFILE LINE: S-11 020 YEAR
LOCATION: BRETON IS. - YEAR 0 AFTER 1 YEAR STORM
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

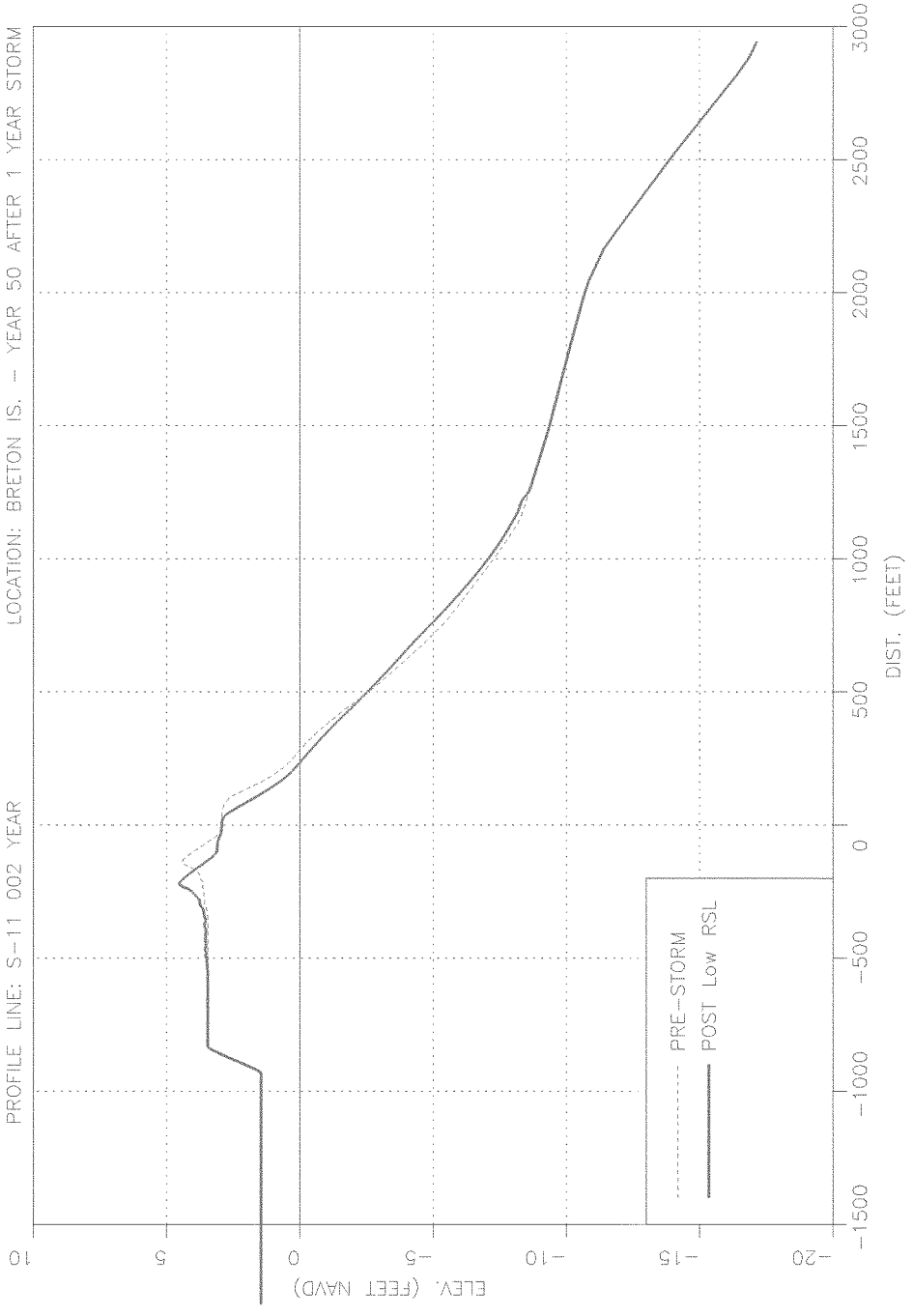

PROFILE LINE: S-11 050 YEAR
LOCATION: BRETON IS. -- YEAR 0 AFTER 1 YEAR STORM
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

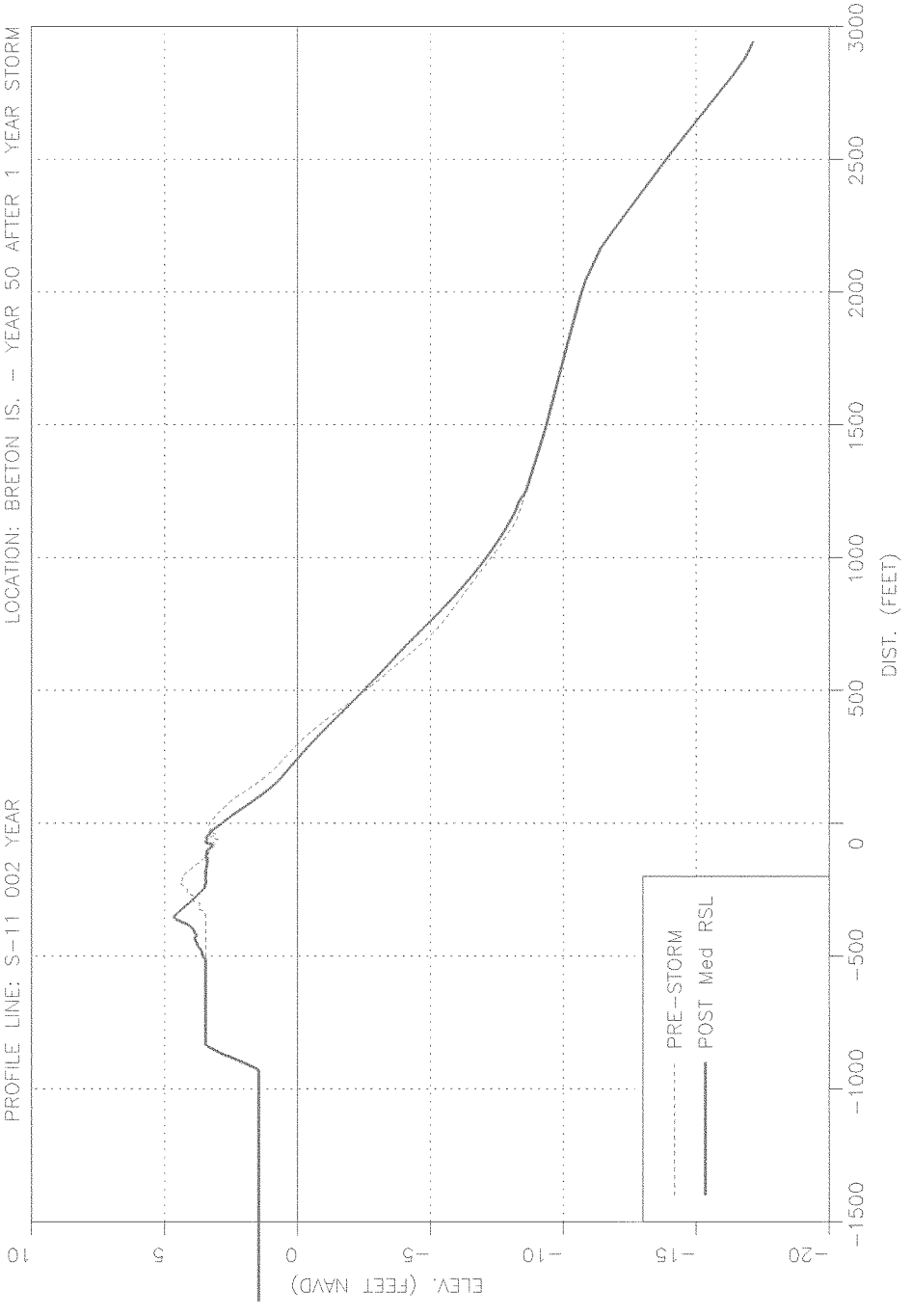

PROFILE LINE: S-11 100 YEAR
LOCATION: BRETON IS. - YEAR 0 AFTER 1 YEAR STORM
ELEV. (FEET NAVD)
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000
DIST. (FEET)
PRE-STORM
POST-STORM

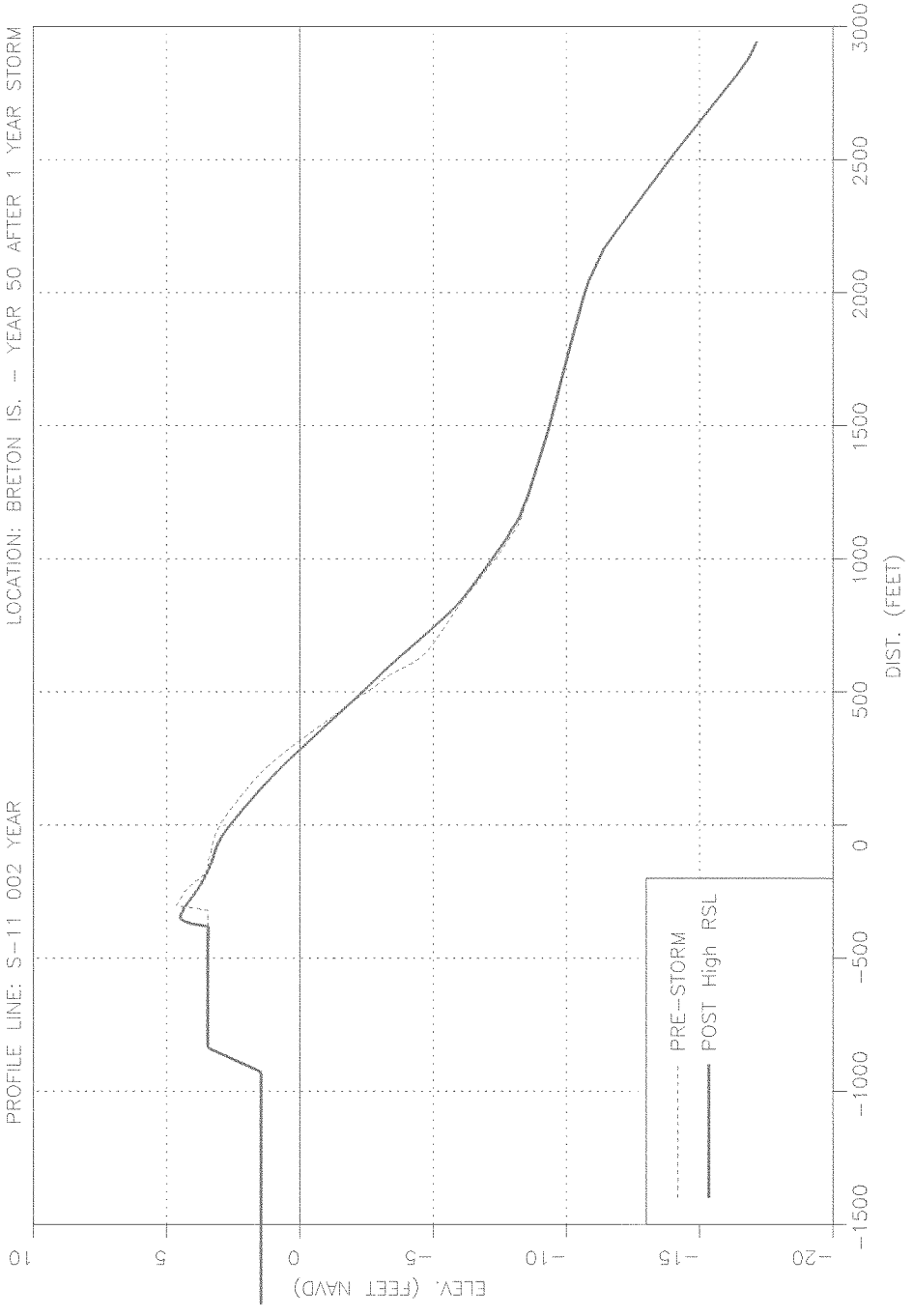

PROFILE LINE: S-11 001 YEAR
LOCATION: BRETON IS. - YEAR 50 AFTER 1 YEAR STORM
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

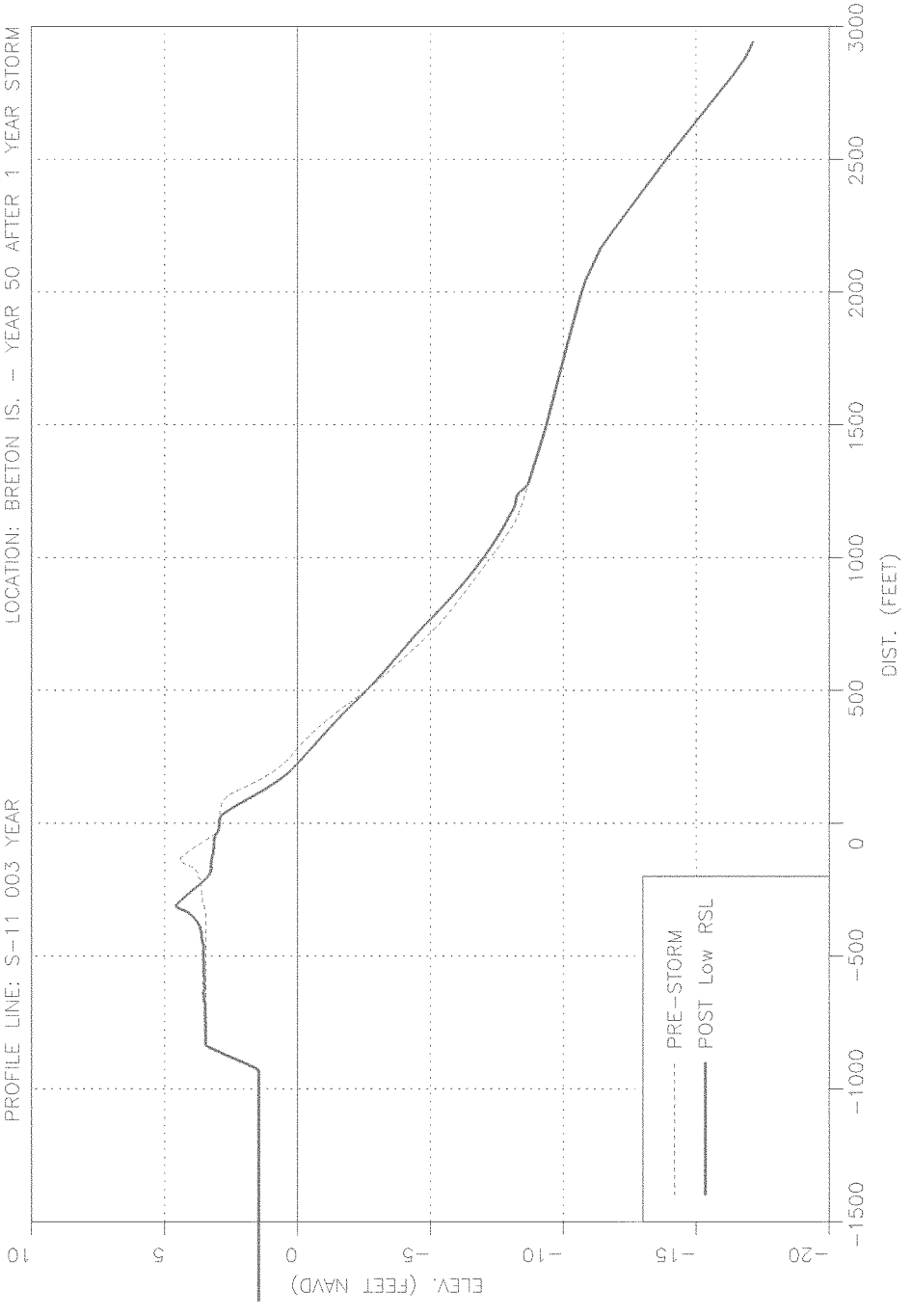

PROFILE LINE: S-11 001 YEAR
LOCATION: BRETON IS. -- YEAR 50 AFTER 1 YEAR STORM
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Med RSL
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

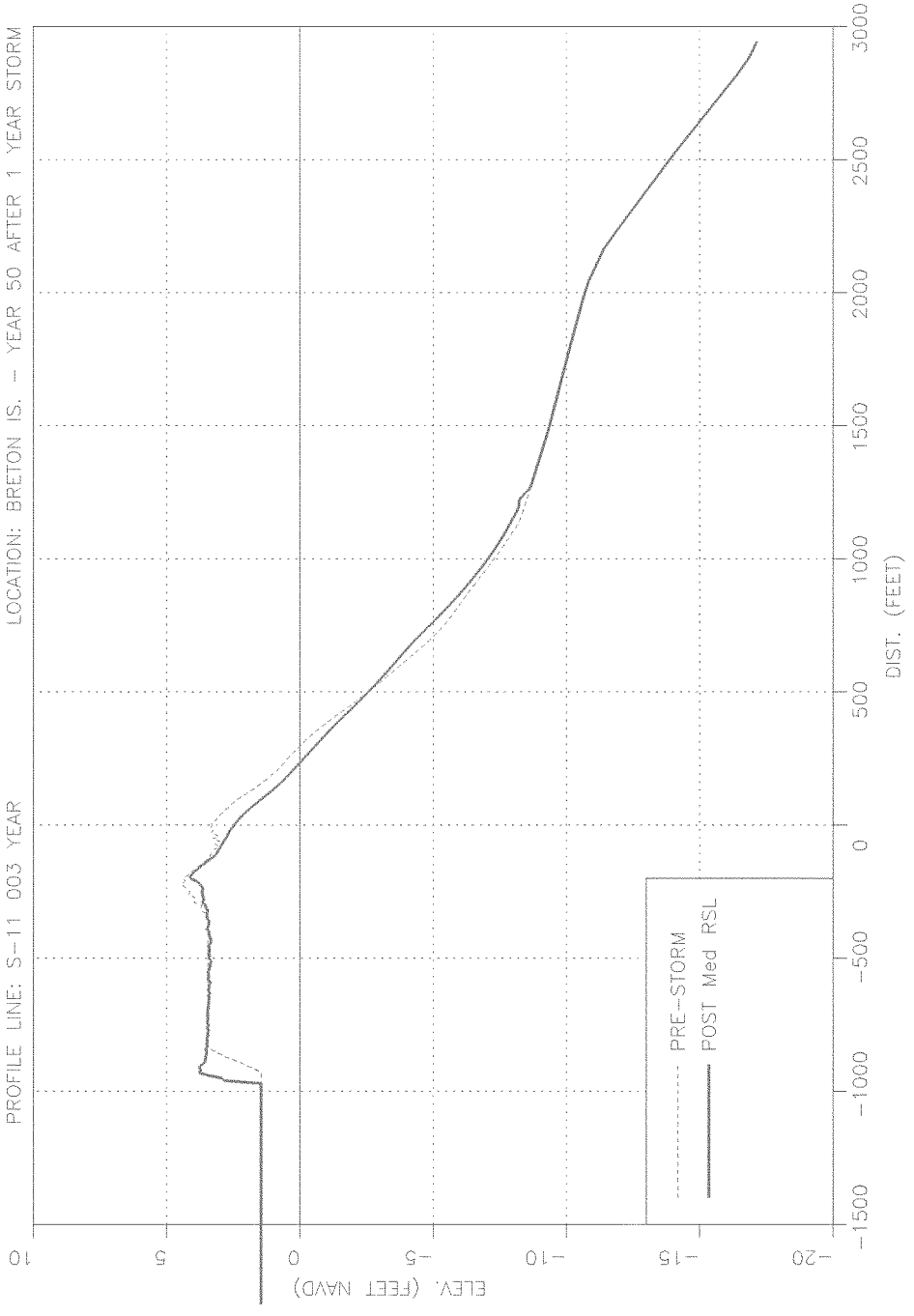

PROFILE LINE: S-11 001 YEAR
LOCATION: BRETON IS. - YEAR 50 AFTER 1 YEAR STORM
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST High RSL
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

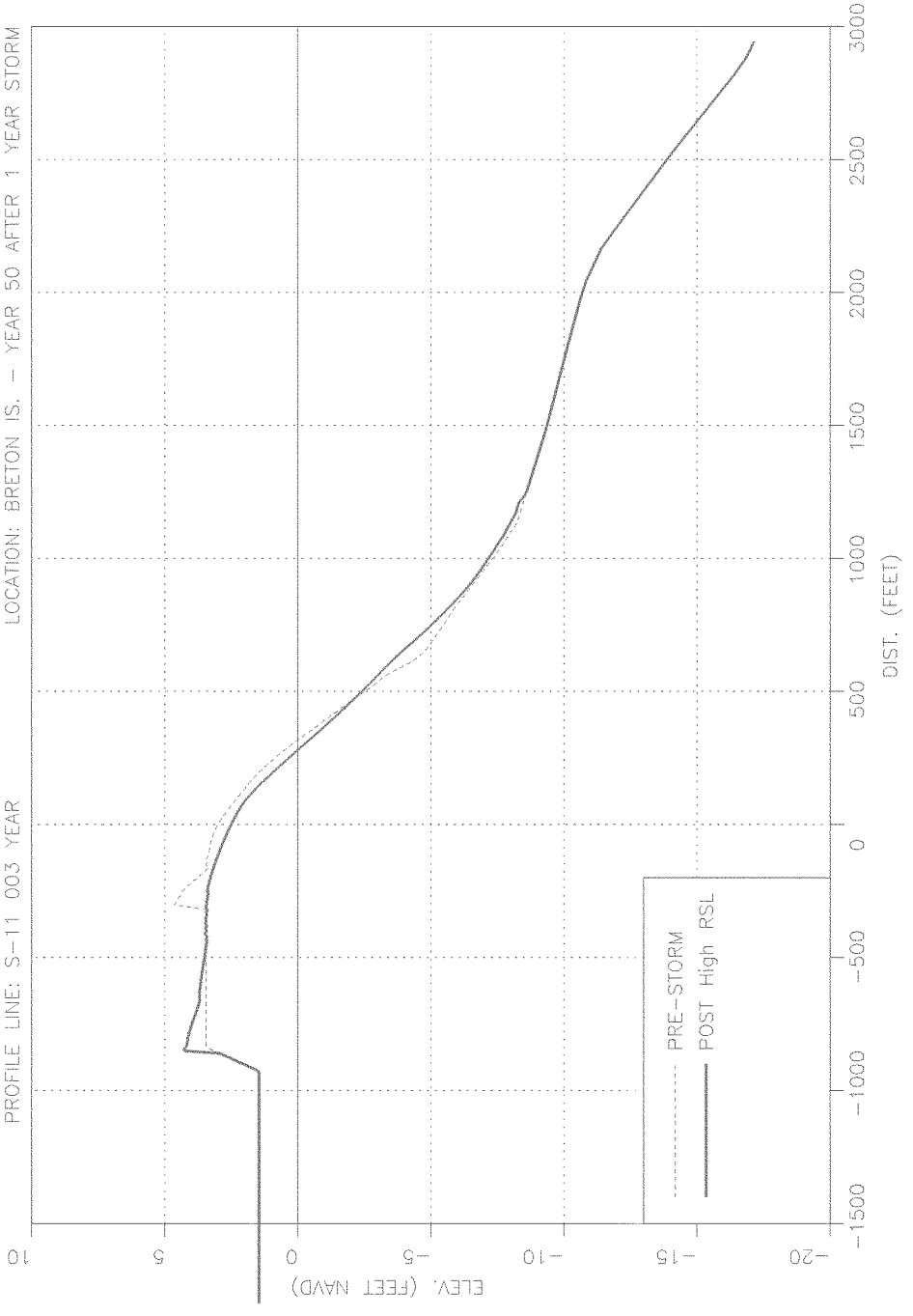

PROFILE LINE: S-11 002 YEAR
LOCATION: BRETON IS. -- YEAR 50 AFTER 1 YEAR STORM
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

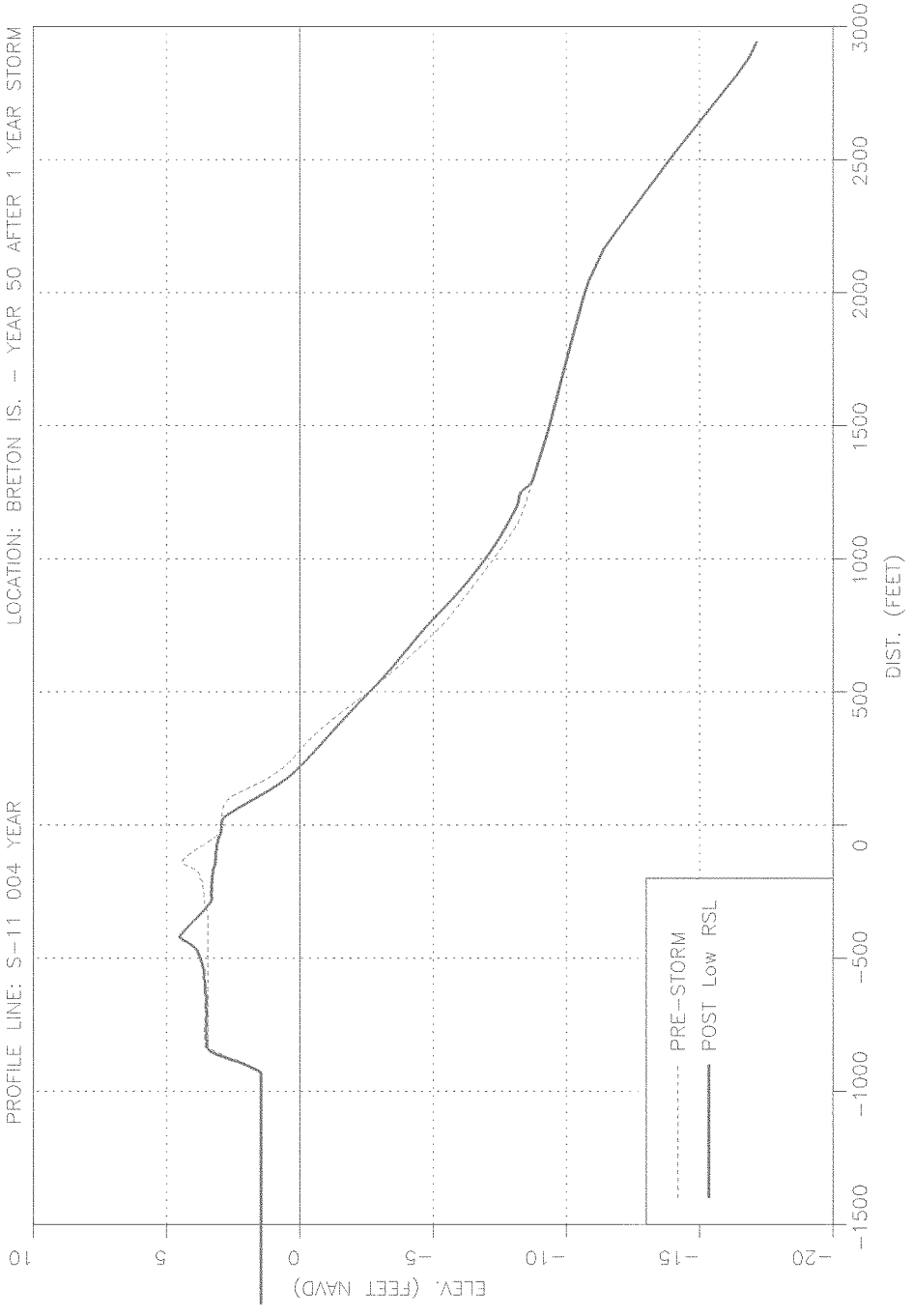

PROFILE LINE: S-11 002 YEAR
LOCATION: BRETON IS. - YEAR 50 AFTER 1 YEAR STORM
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Med RSL
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

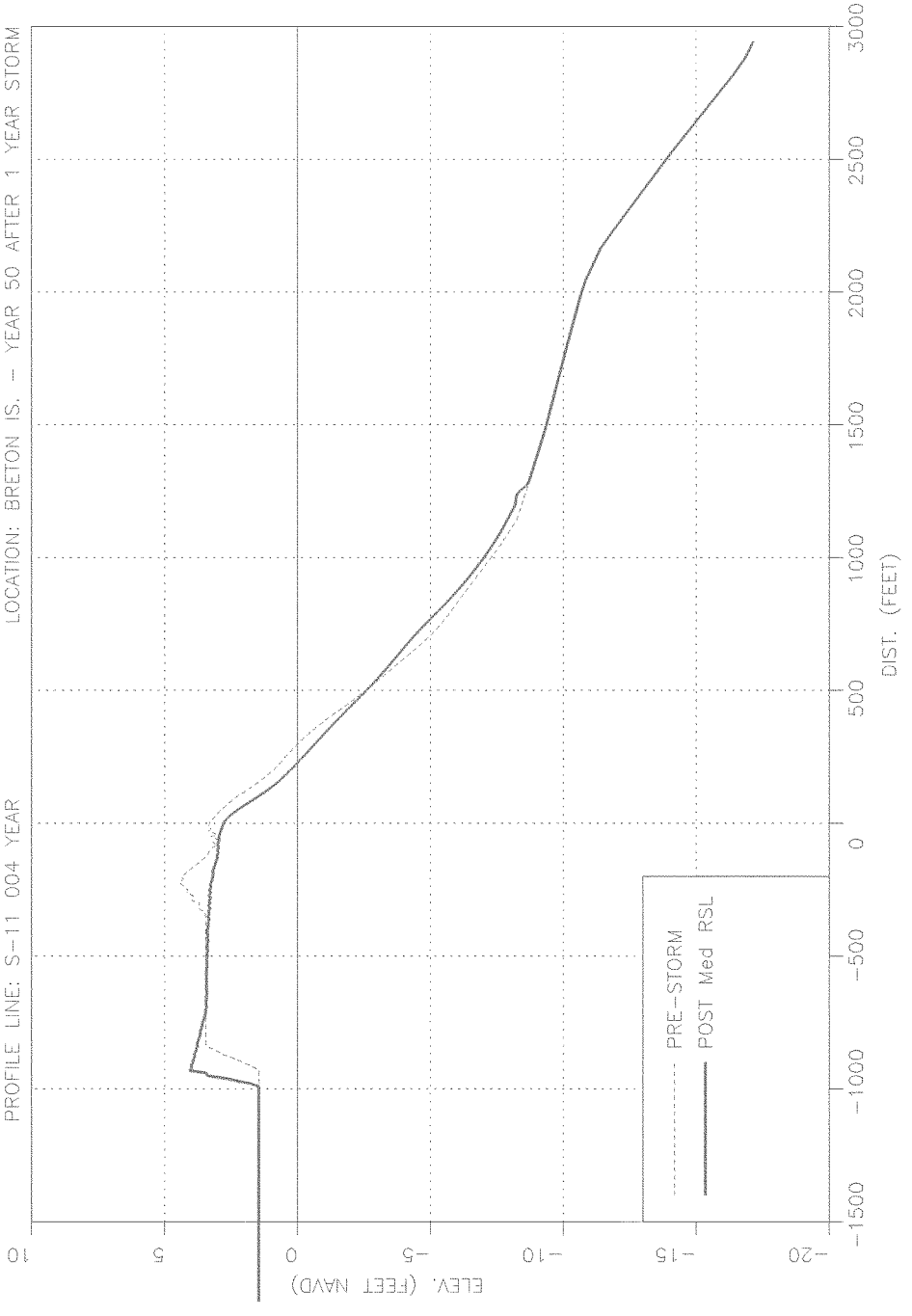

PROFILE LINE: S-11 002 YEAR
LOCATION: BRETON IS. -- YEAR 50 AFTER 1 YEAR STORM
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST High RSL
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

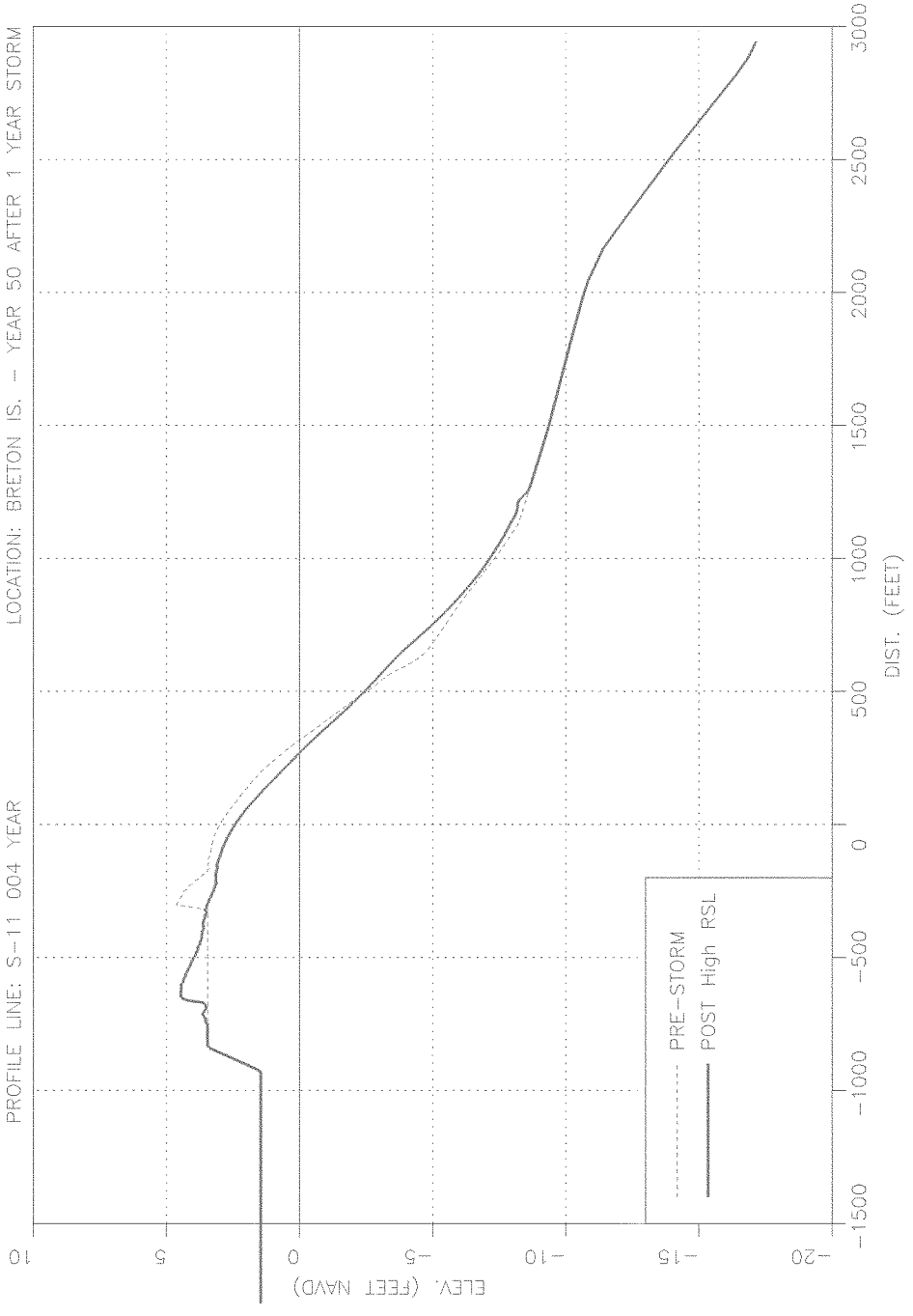

PROFILE LINE: S-11 003 YEAR
LOCATION: BRETON IS. - YEAR 50 AFTER 1 YEAR STORM
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

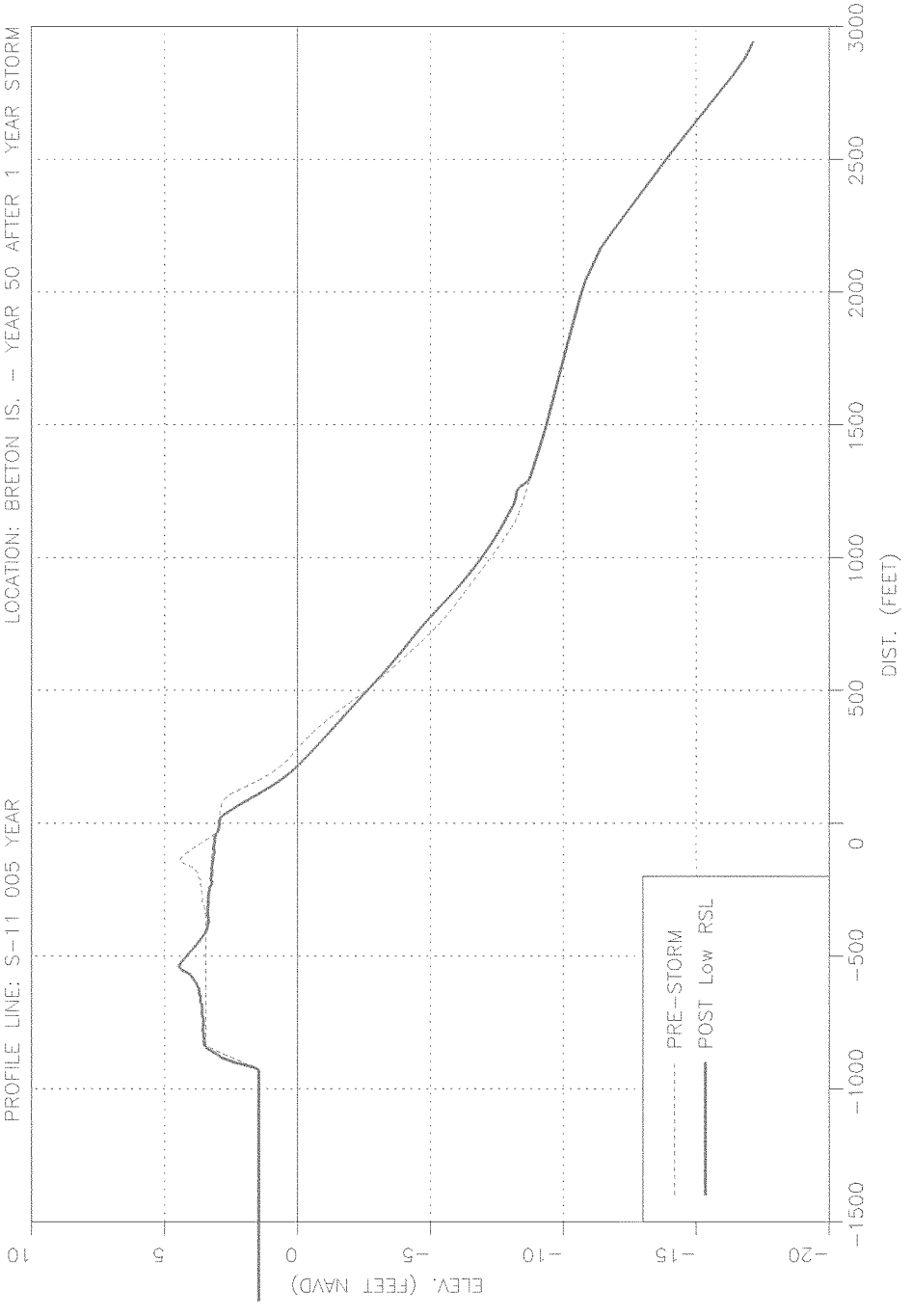

PROFILE LINE: S-11 003 YEAR
LOCATION: BRETON IS. -- YEAR 50 AFTER 1 YEAR STORM
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Med RSL
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

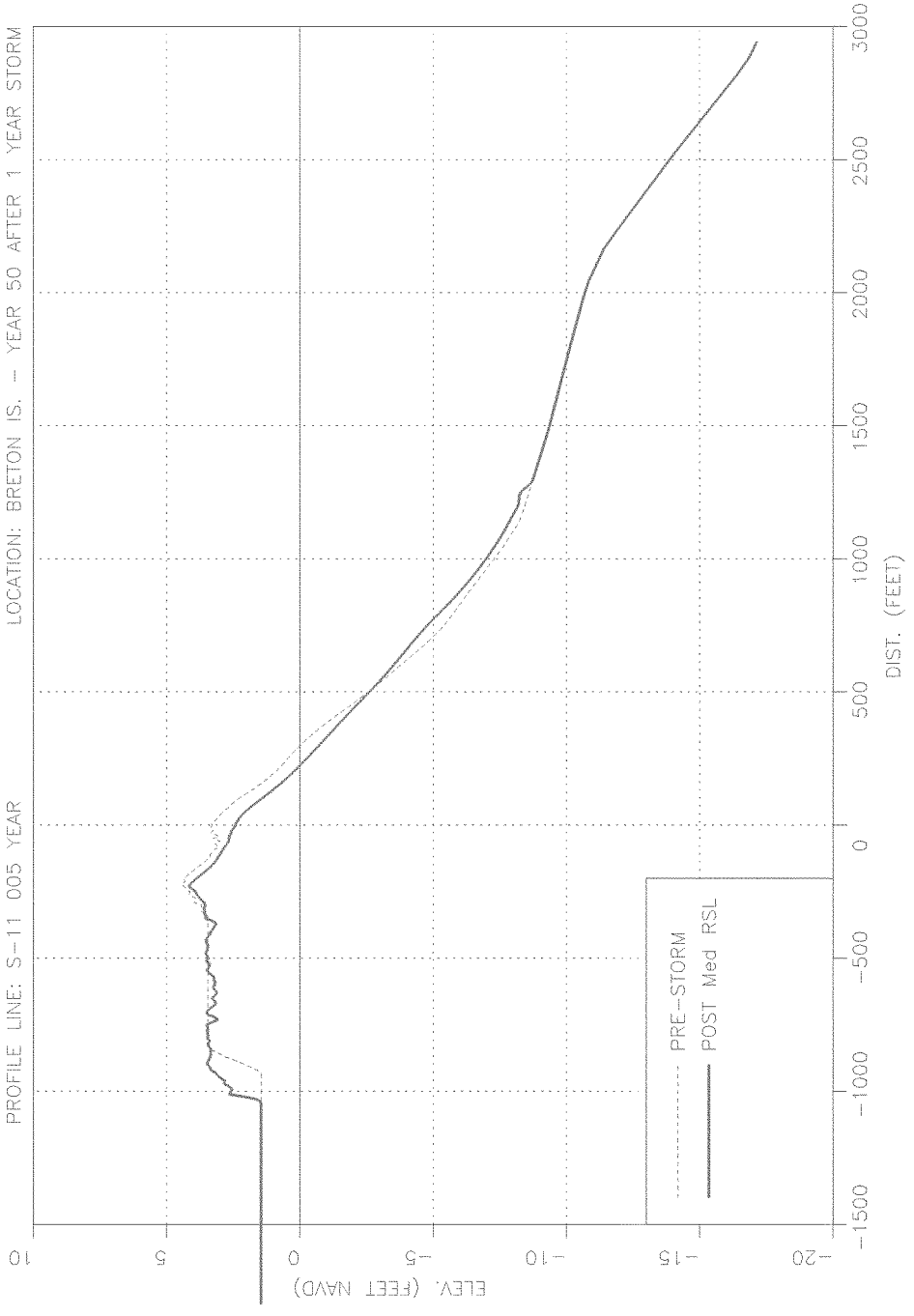

PROFILE LINE: S-11 003 YEAR
LOCATION: BRETON IS. - YEAR 50 AFTER 1 YEAR STORM
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST High RSL
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

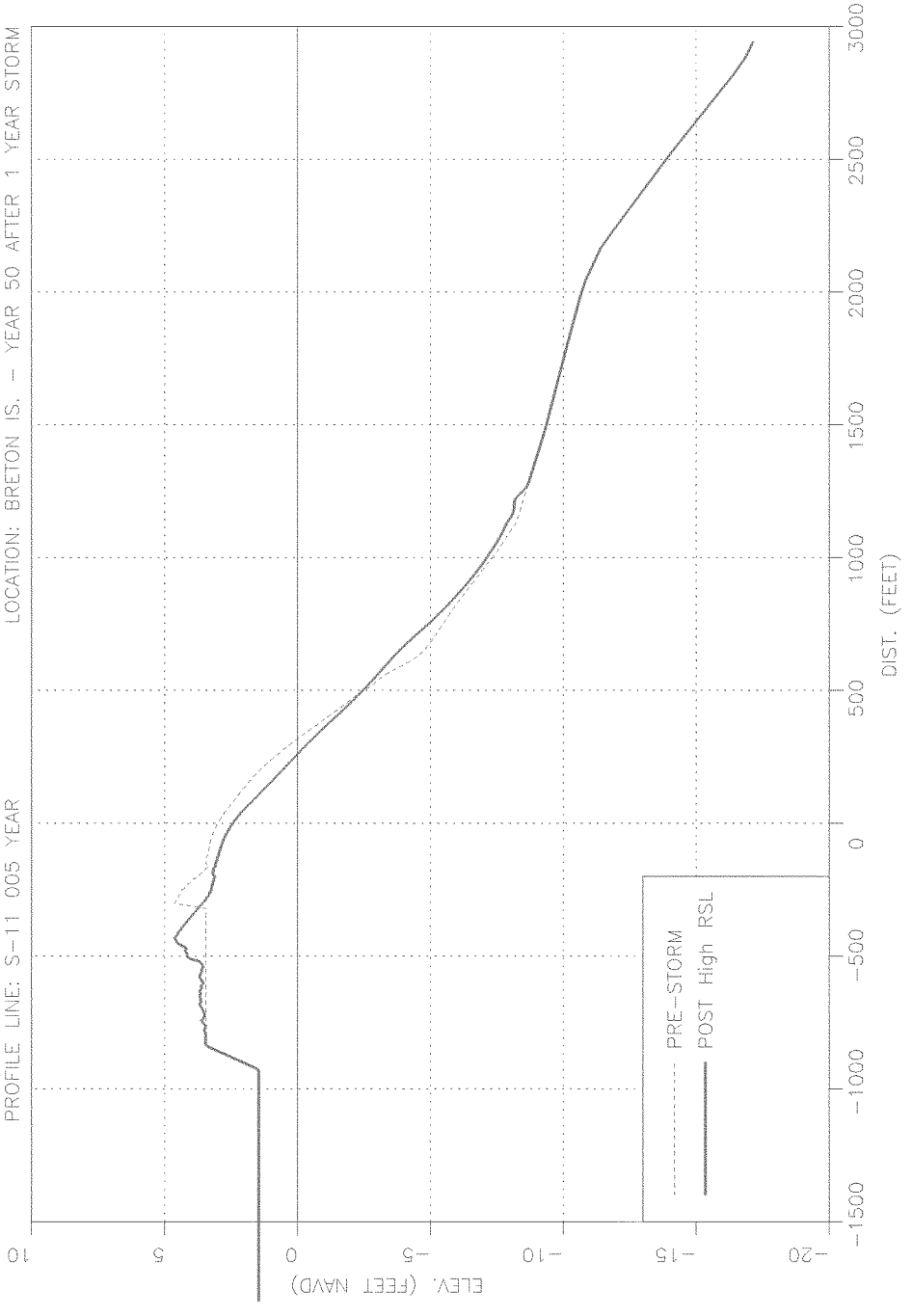

PROFILE LINE: S-11 004 YEAR
LOCATION: BRETON IS. -- YEAR 50 AFTER 1 YEAR STORM
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

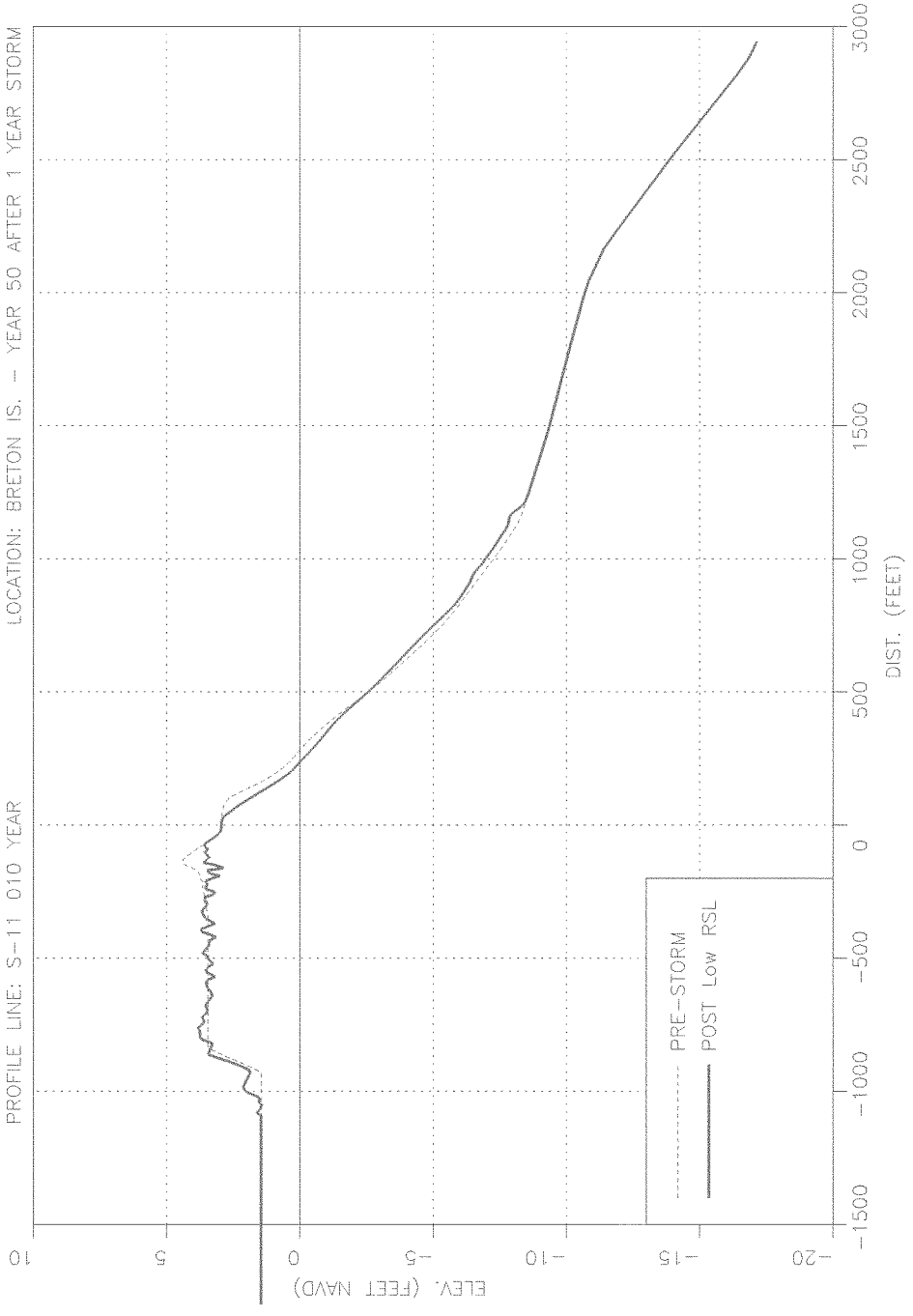

PROFILE LINE: S-11 004 YEAR
LOCATION: BRETON IS. - YEAR 50 AFTER 1 YEAR STORM
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Med RSL
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

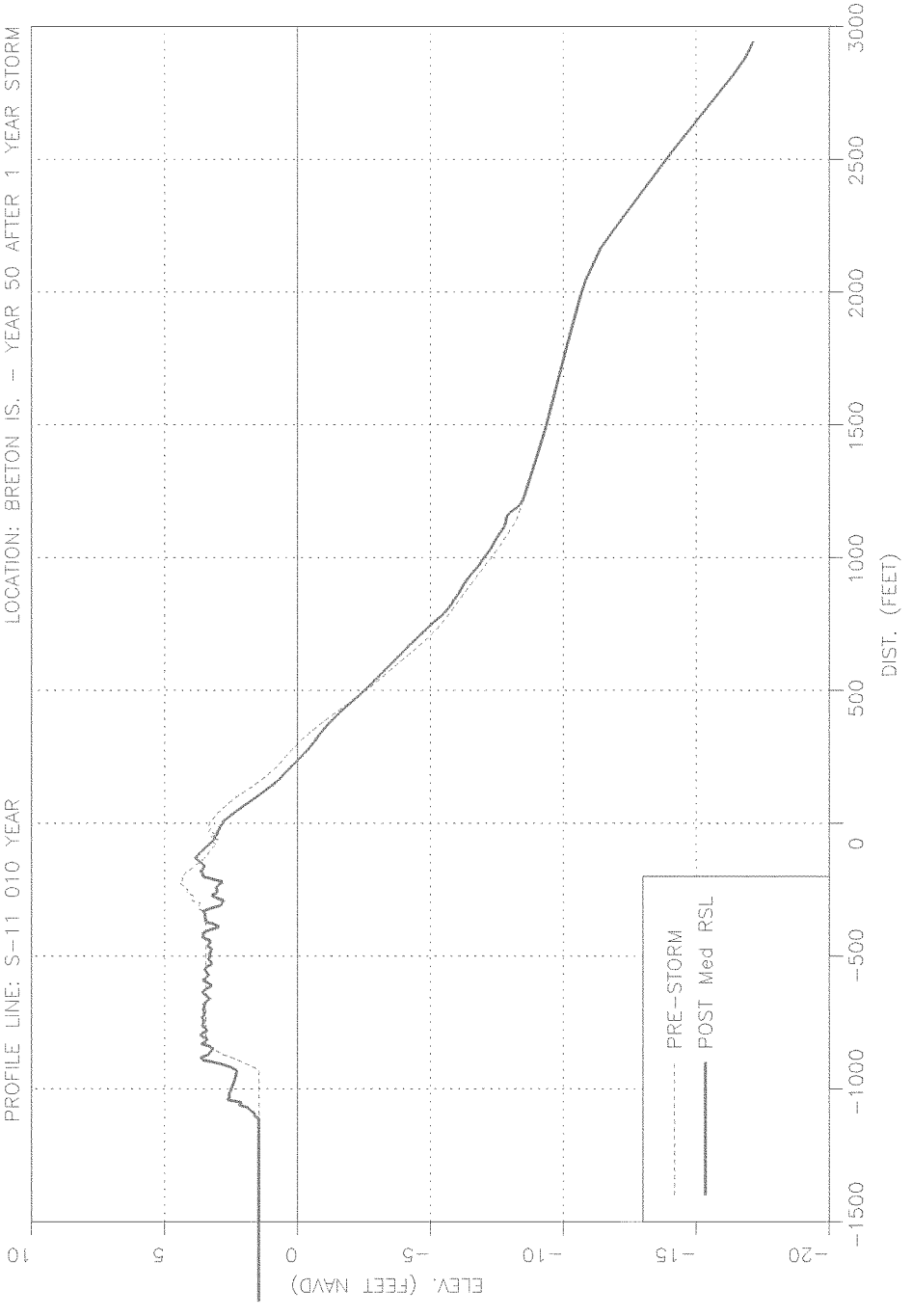

PROFILE LINE: S-11 004 YEAR
LOCATION: BRETON IS. -- YEAR 50 AFTER 1 YEAR STORM
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST High RSL
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

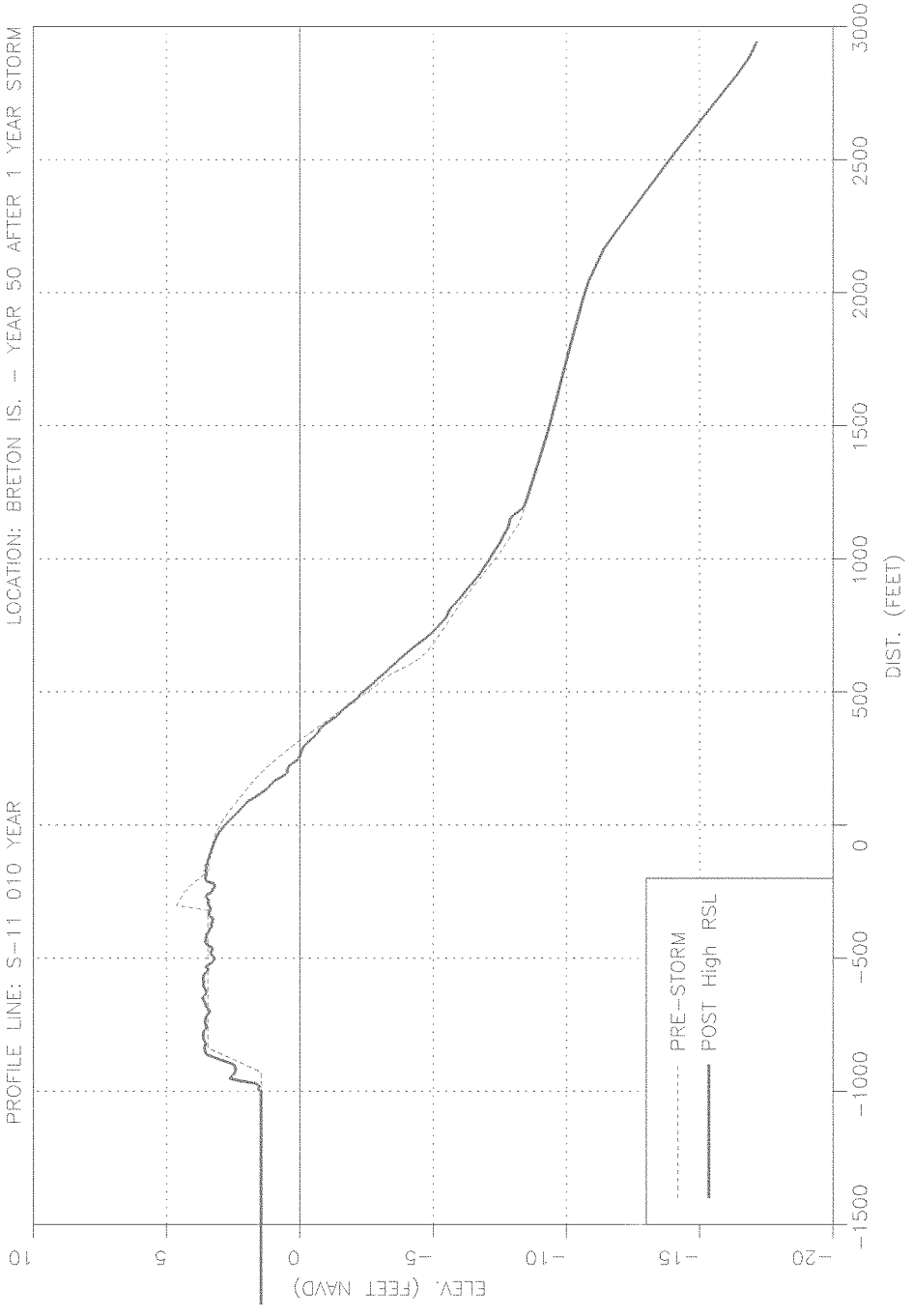

PROFILE LINE: S-11 005 YEAR
LOCATION: BRETON IS. - YEAR 50 AFTER 1 YEAR STORM
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

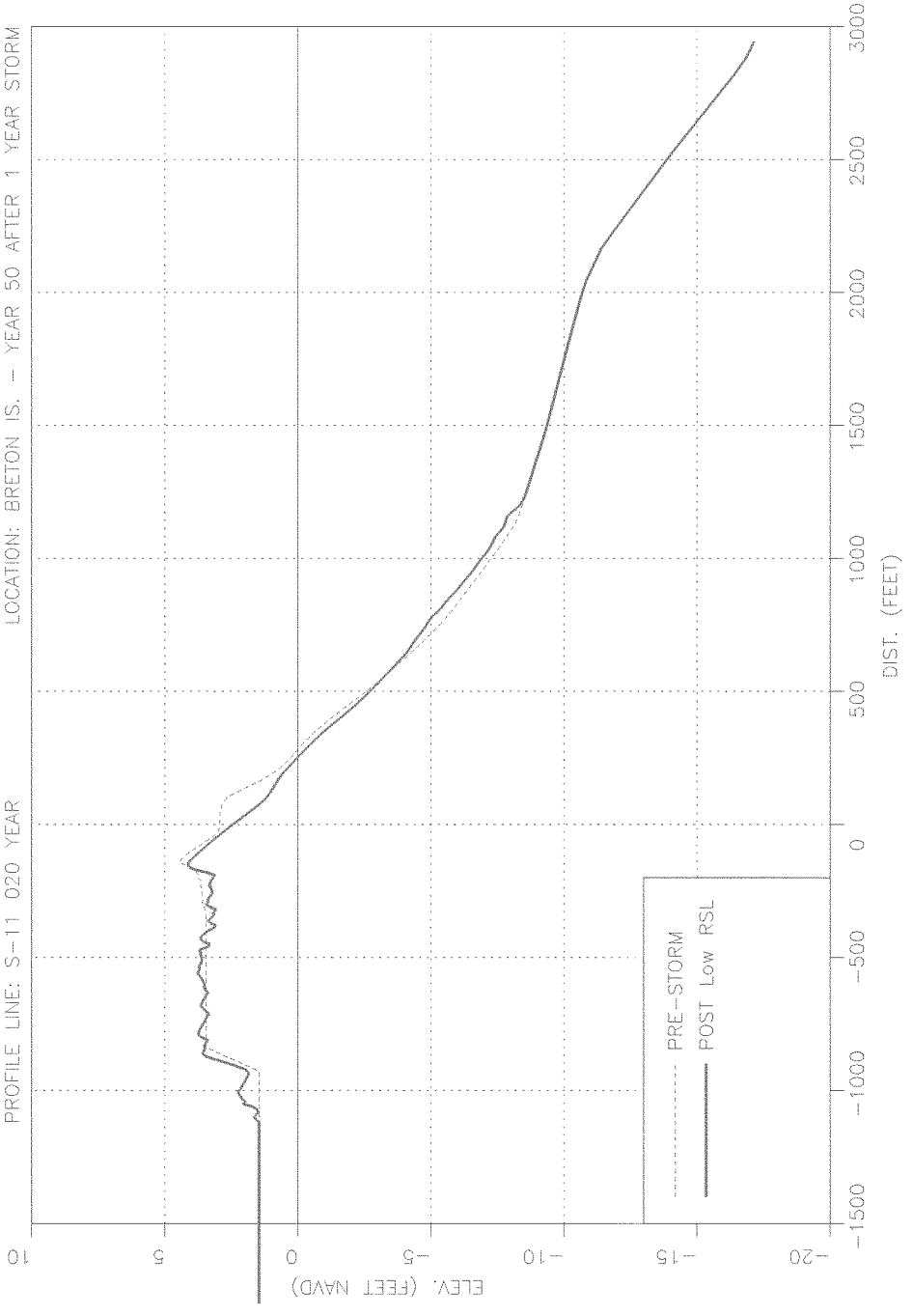

PROFILE LINE: S-11 005 YEAR
LOCATION: BRETON IS. -- YEAR 50 AFTER 1 YEAR STORM
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Med RSL
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

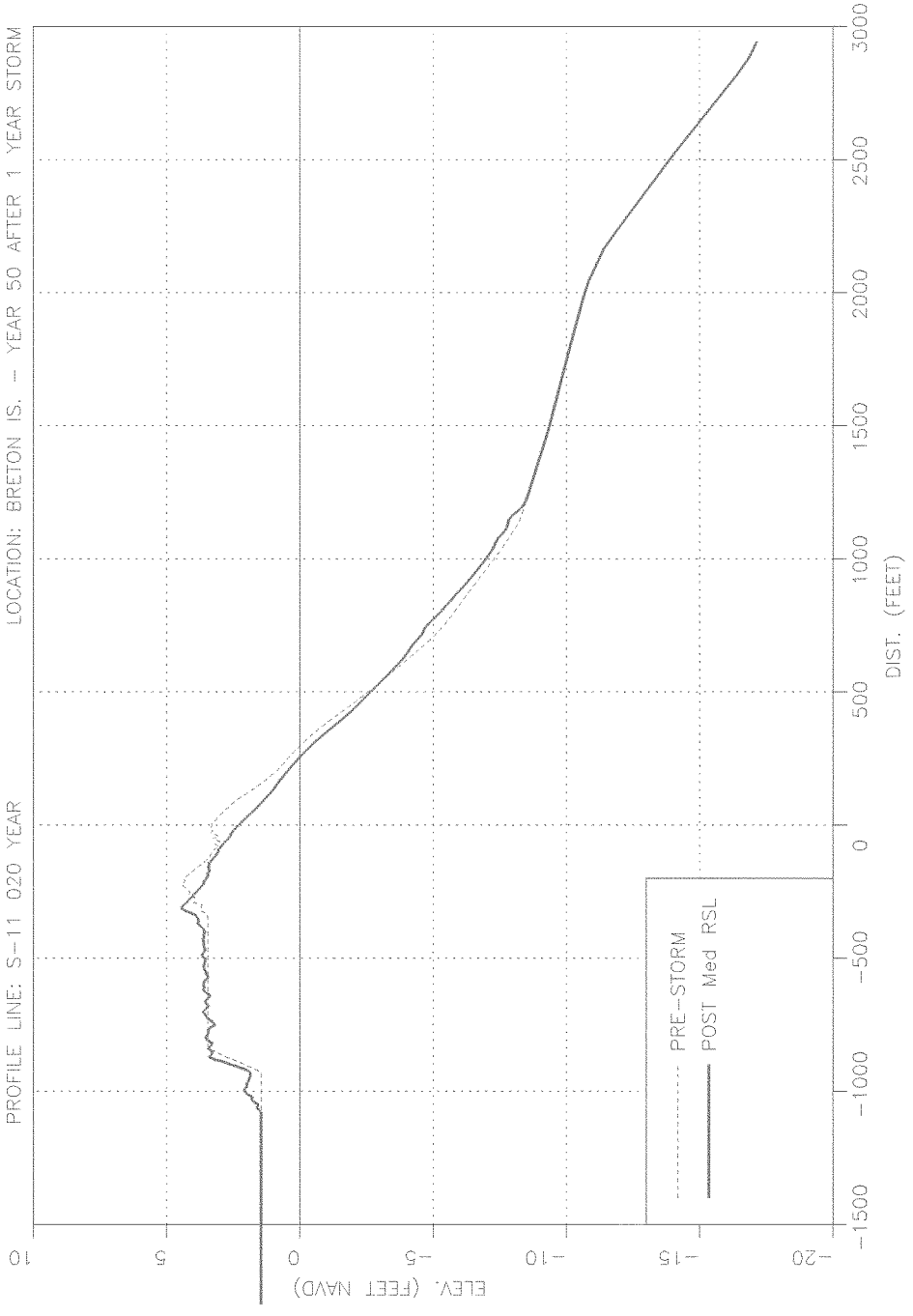

PROFILE LINE: S-11 005 YEAR
LOCATION: BRETON IS. - YEAR 50 AFTER 1 YEAR STORM
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST High RSL
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

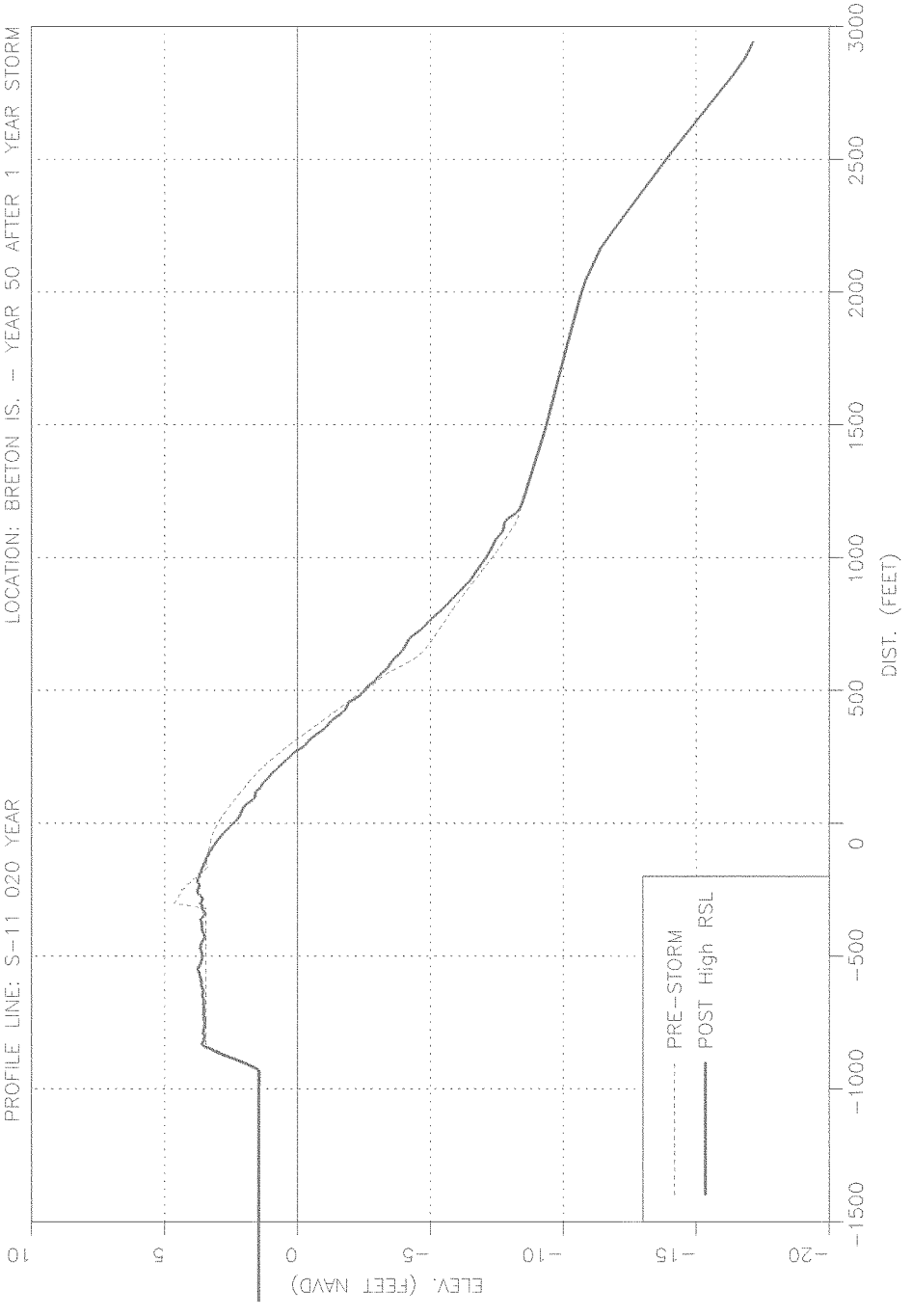

PROFILE LINE: S-11 010 YEAR
LOCATION: BRETON IS. -- YEAR 50 AFTER 1 YEAR STORM
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

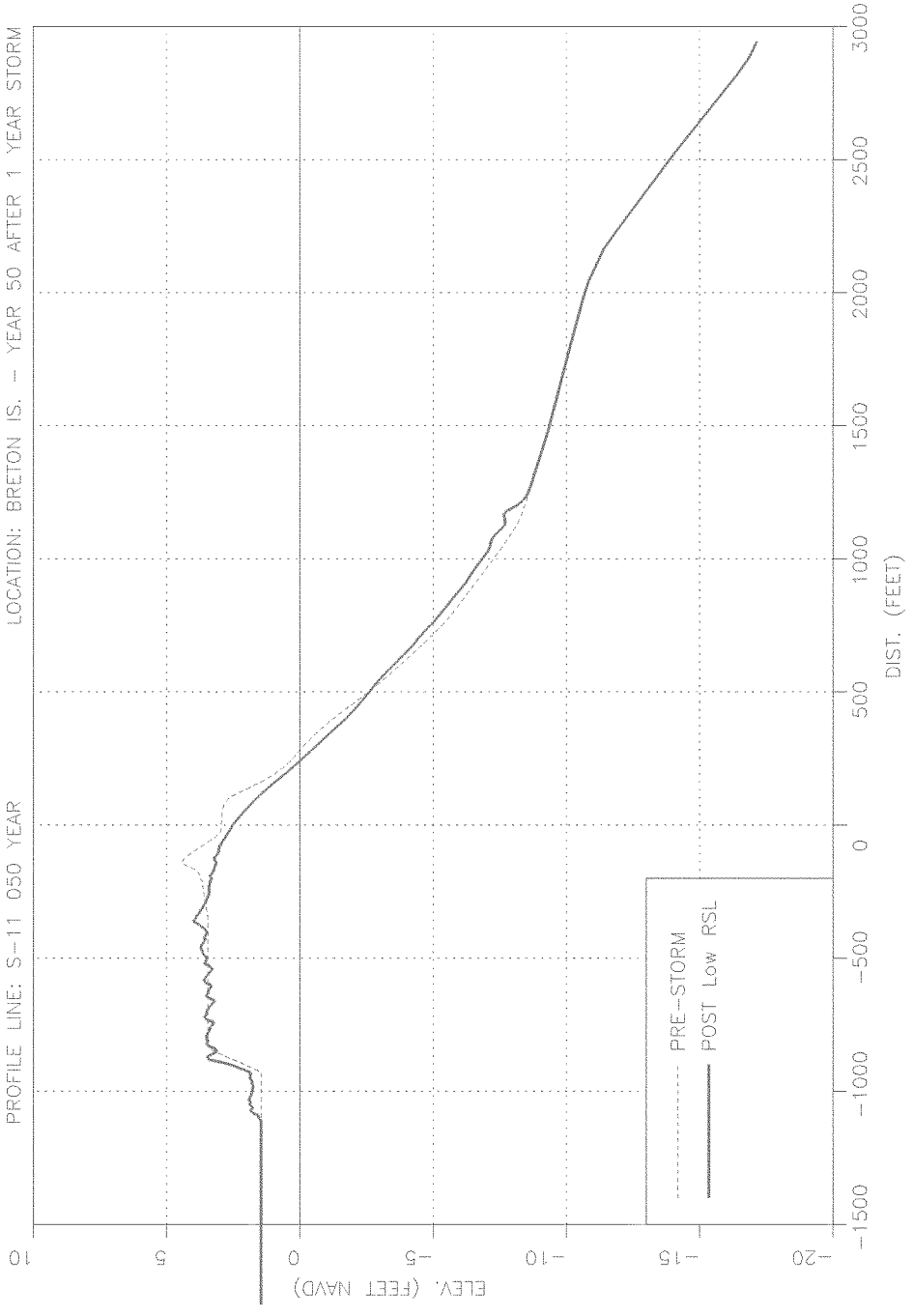

PROFILE LINE: S-11 010 YEAR
LOCATION: BRETON IS. - YEAR 50 AFTER 1 YEAR STORM
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Med RSL
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

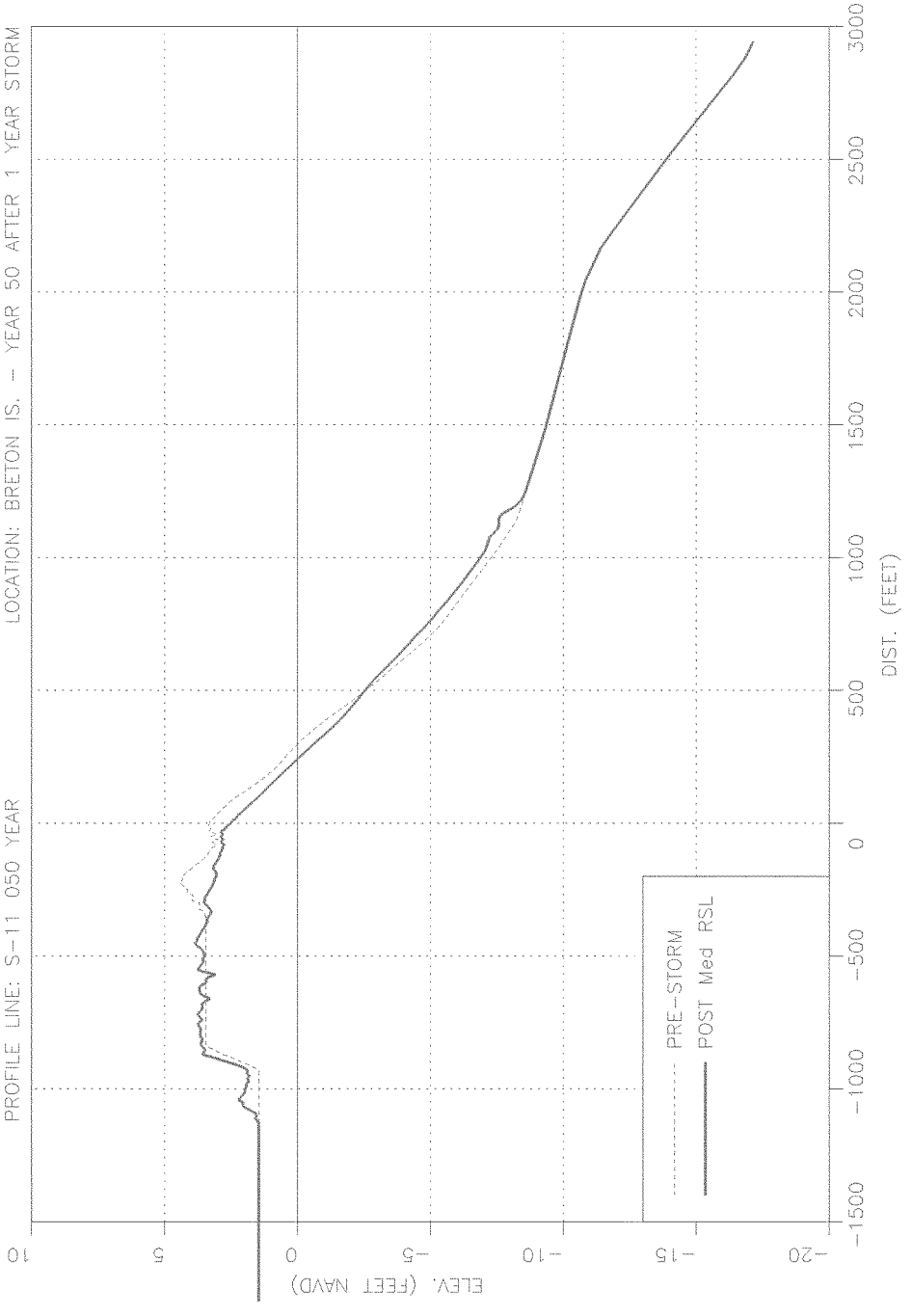

PROFILE LINE: S-11 010 YEAR
LOCATION: BRETON IS. -- YEAR 50 AFTER 1 YEAR STORM
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST High RSL
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

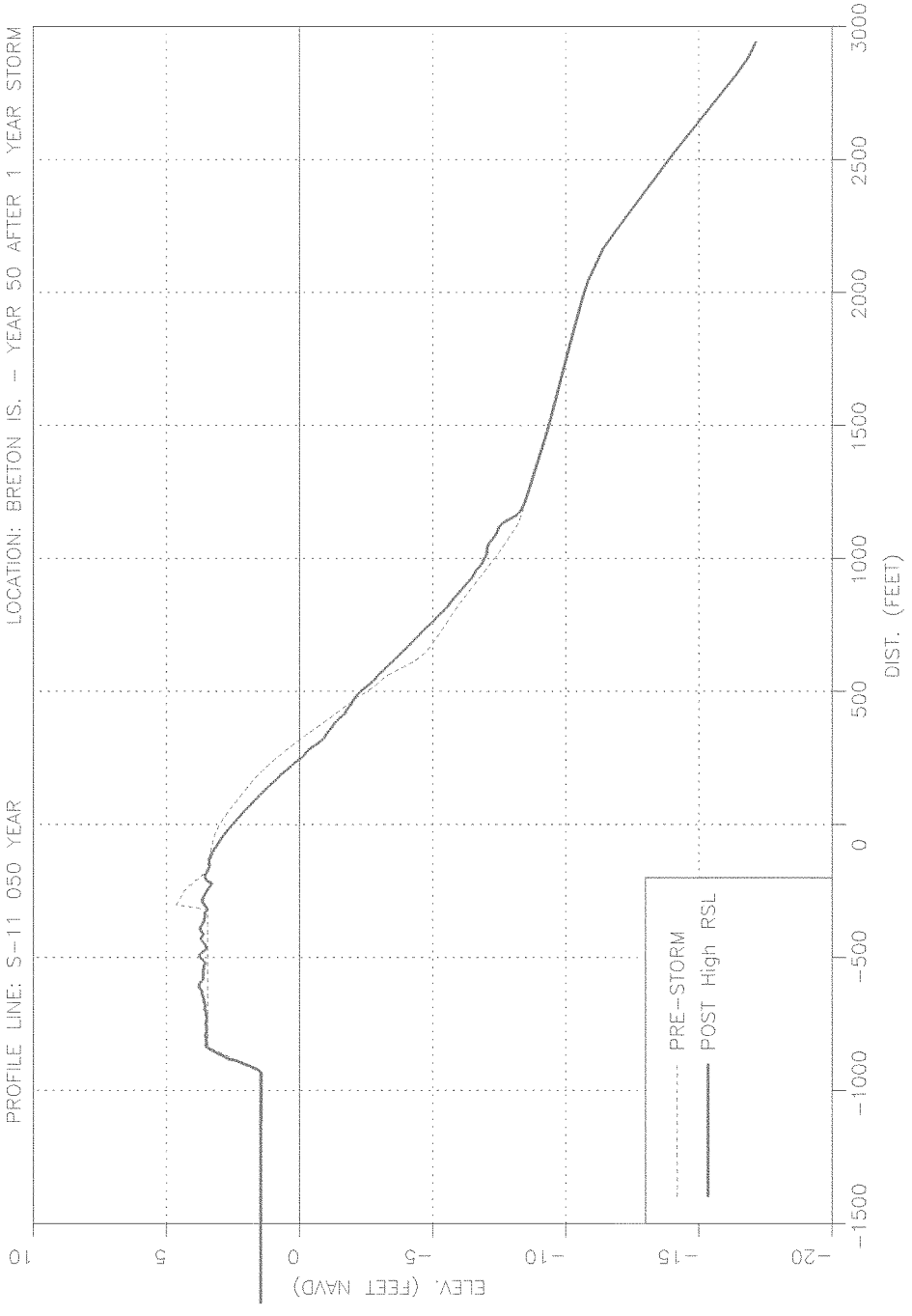

PROFILE LINE: S-11 020 YEAR
LOCATION: BRETON IS. - YEAR 50 AFTER 1 YEAR STORM
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

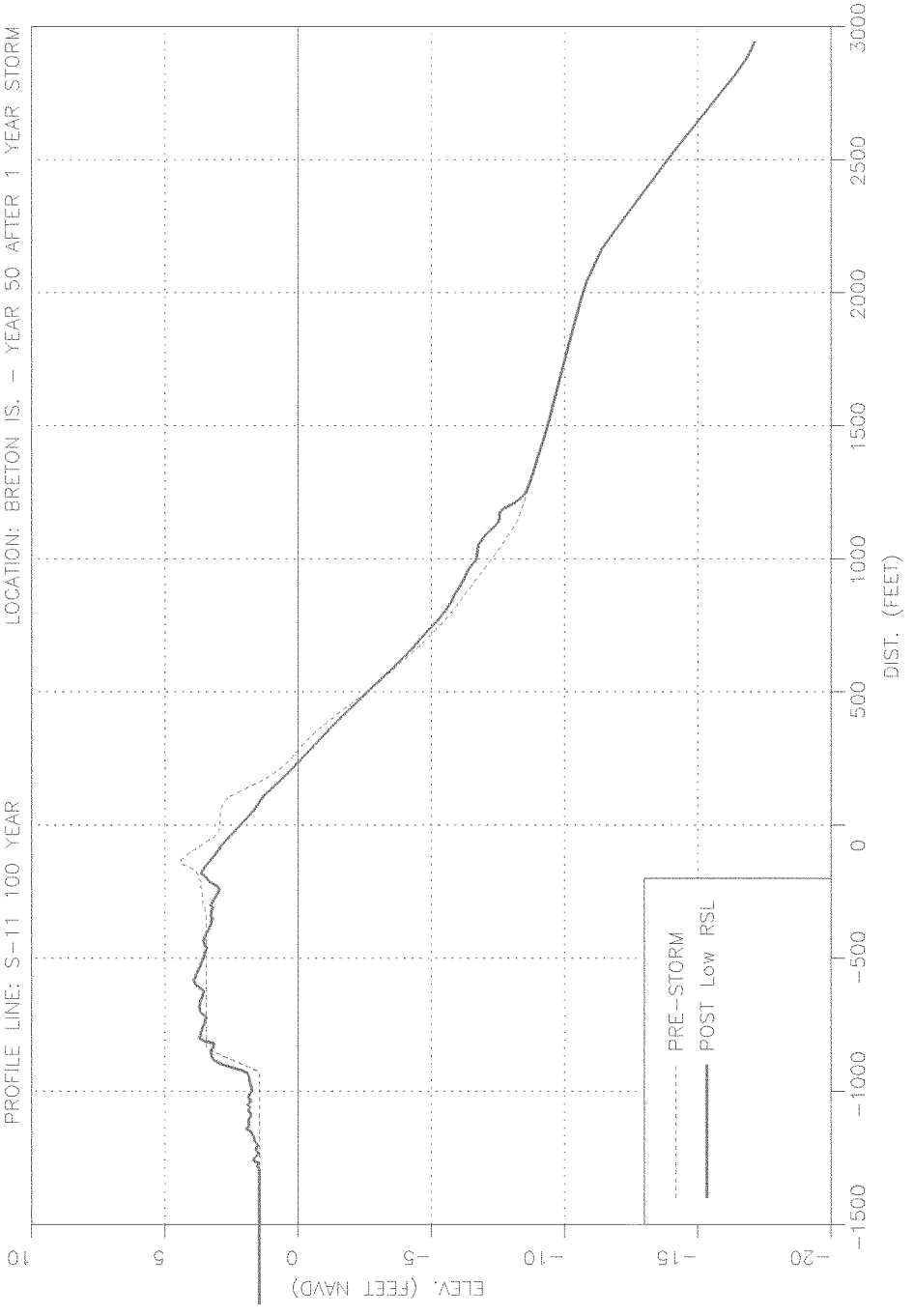

PROFILE LINE: S-11 020 YEAR
LOCATION: BRETON IS. -- YEAR 50 AFTER 1 YEAR STORM
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Med RSL
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

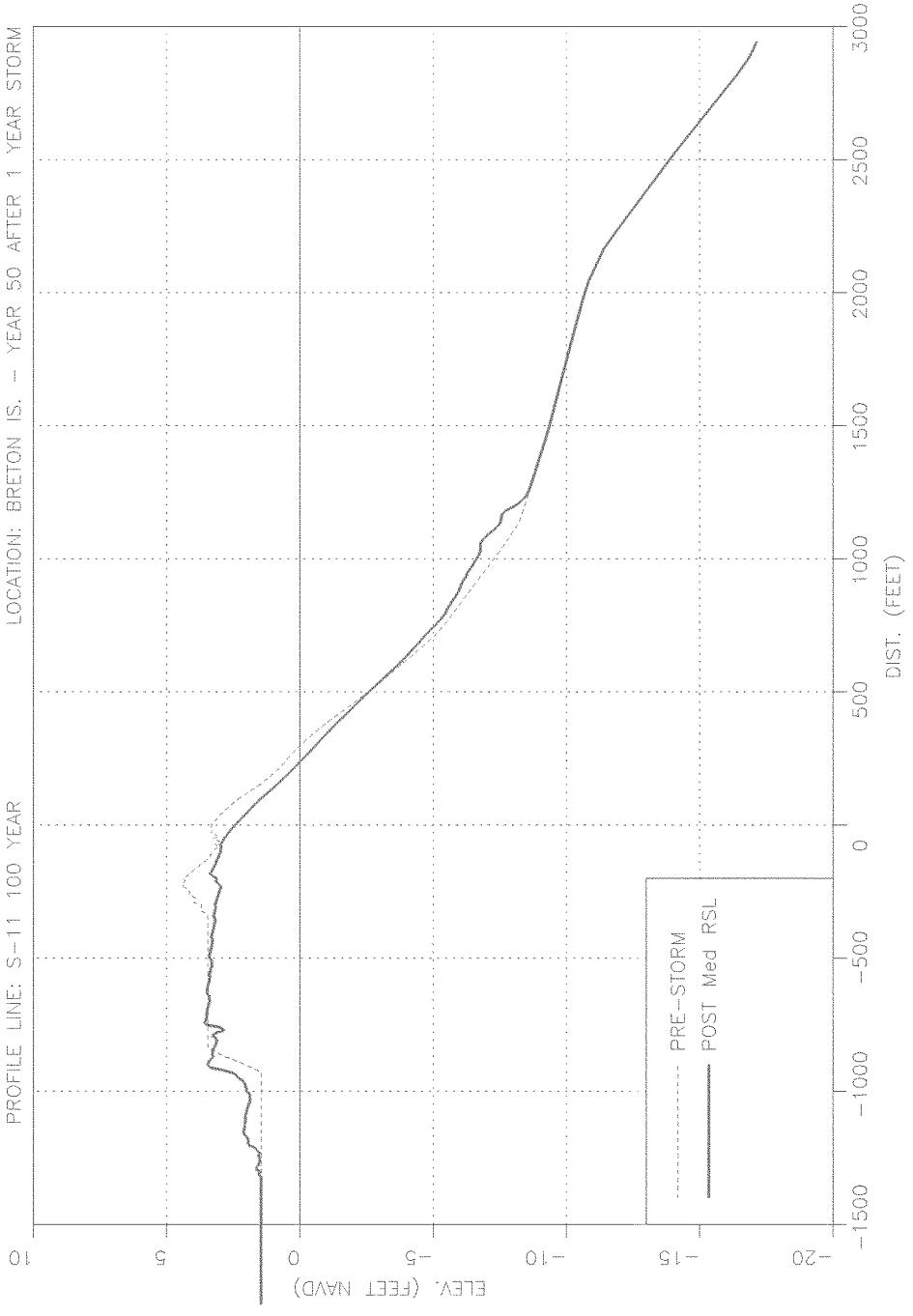

PROFILE LINE: S-11 020 YEAR
LOCATION: BRETON IS. - YEAR 50 AFTER 1 YEAR STORM
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST High RSL
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

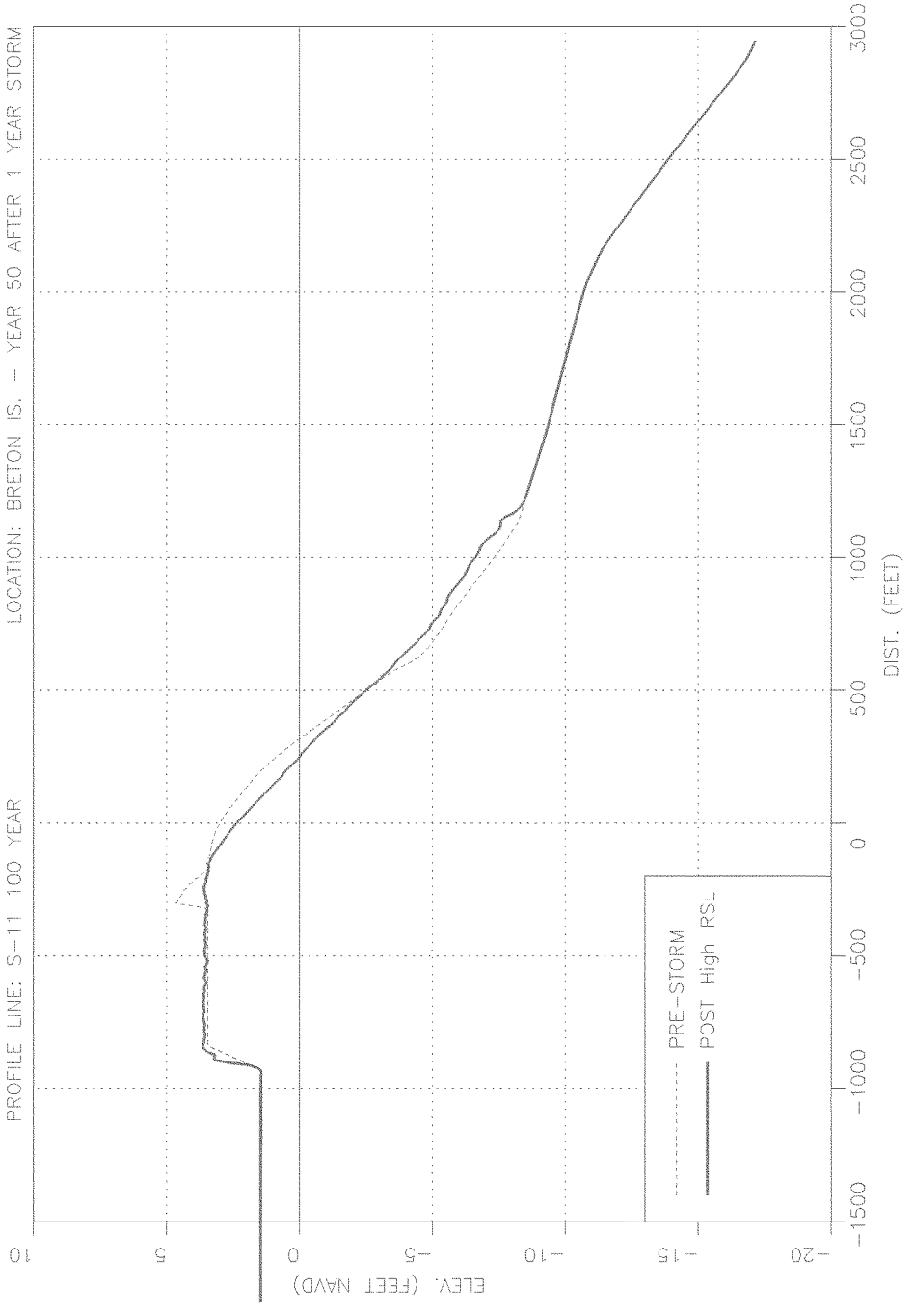

PROFILE LINE: S-11 050 YEAR
LOCATION: BRETON IS. -- YEAR 50 AFTER 1 YEAR STORM
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000


PROFILE LINE: S-11 050 YEAR
LOCATION: BRETON IS. - YEAR 50 AFTER 1 YEAR STORM
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Med RSL
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000


PROFILE LINE: S-11 050 YEAR
LOCATION: BRETON IS. -- YEAR 50 AFTER 1 YEAR STORM
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST High RSL
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

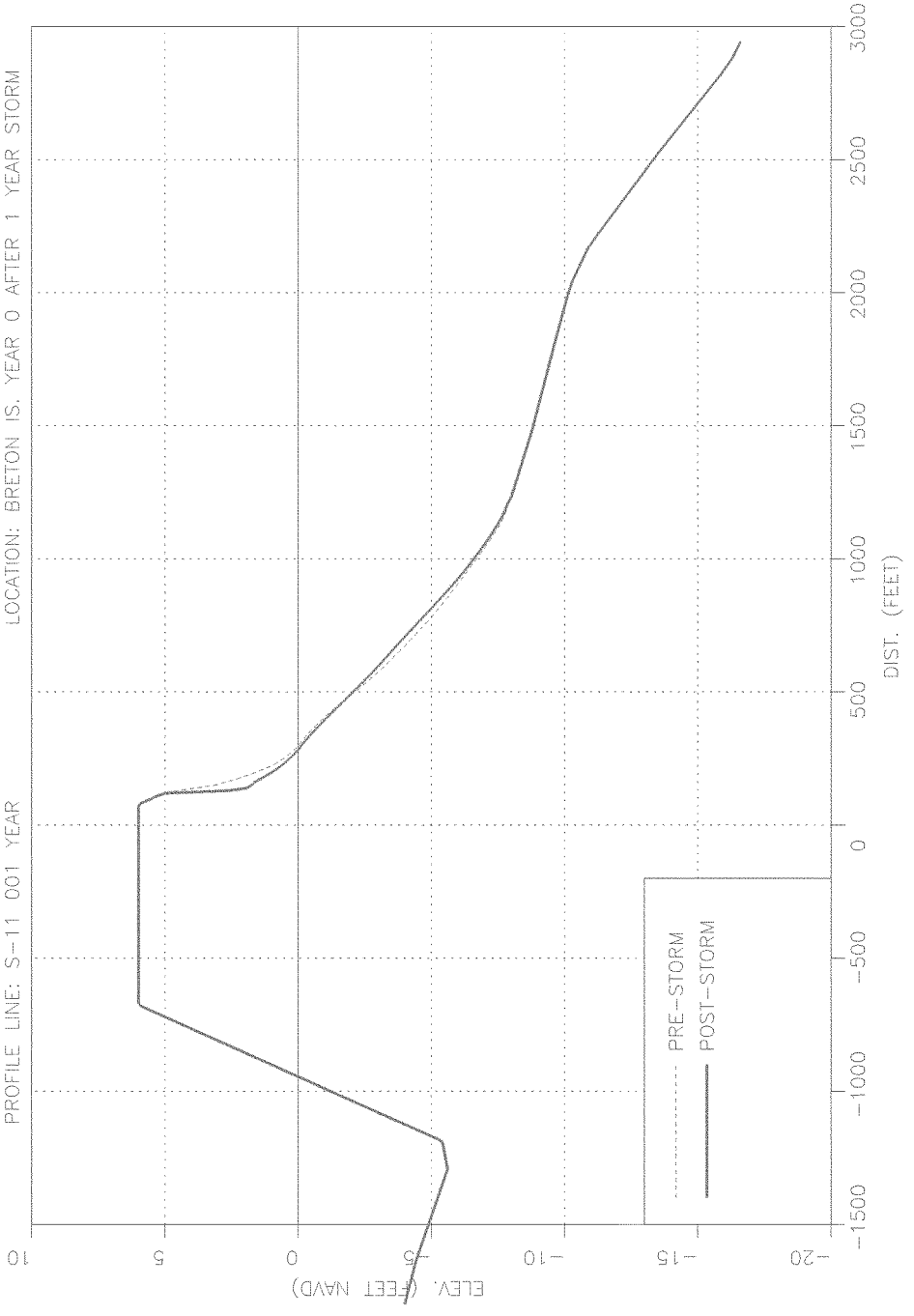

PROFILE LINE: S-11 100 YEAR
LOCATION: BRETON IS. - YEAR 50 AFTER 1 YEAR STORM
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

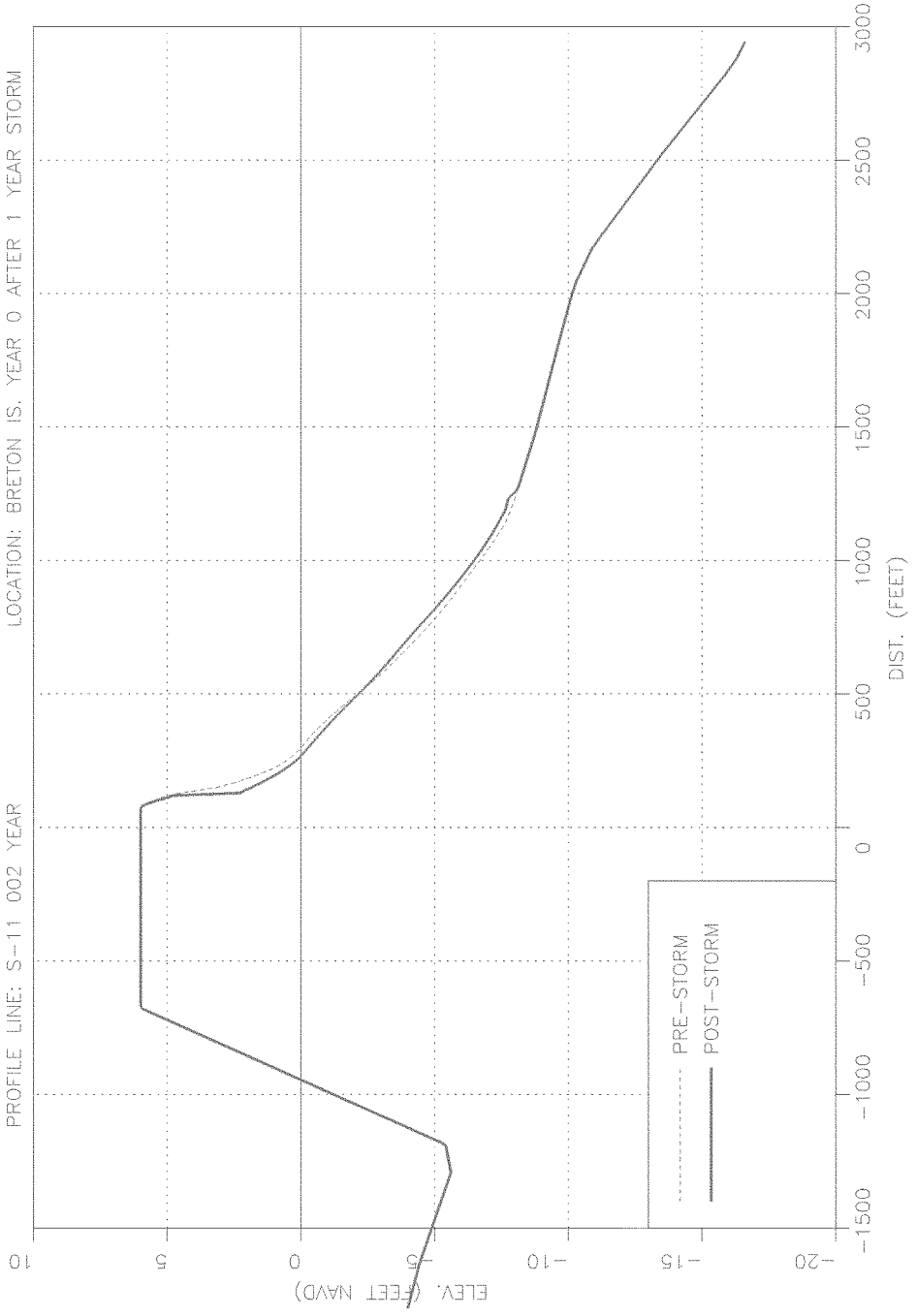

PROFILE LINE: S-11 100 YEAR
LOCATION: BRETON IS. -- YEAR 50 AFTER 1 YEAR STORM
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Med RSL
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

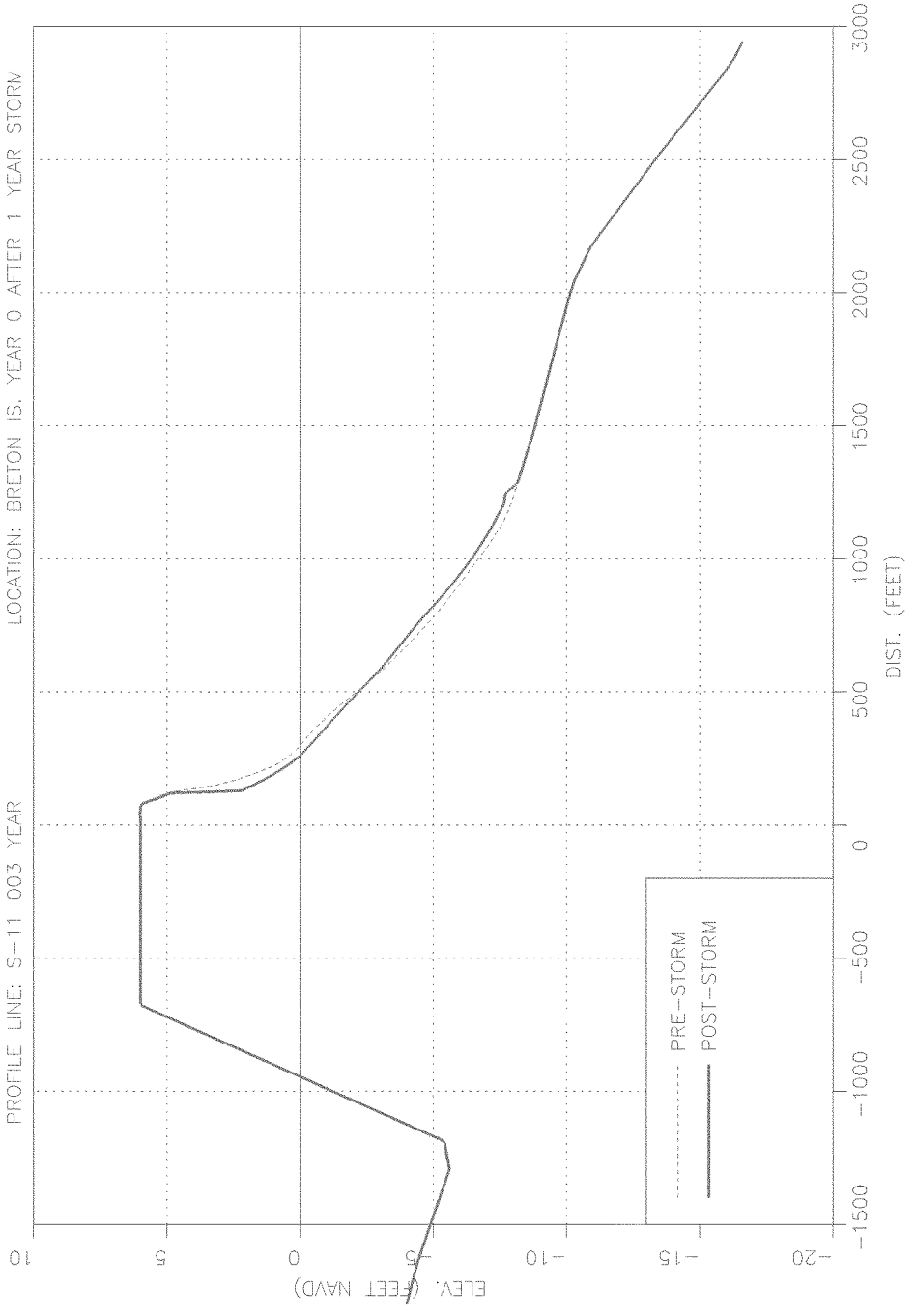

PROFILE LINE: S-11 100 YEAR
LOCATION: BRETON IS. - YEAR 50 AFTER 1 YEAR STORM
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST High RSL
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

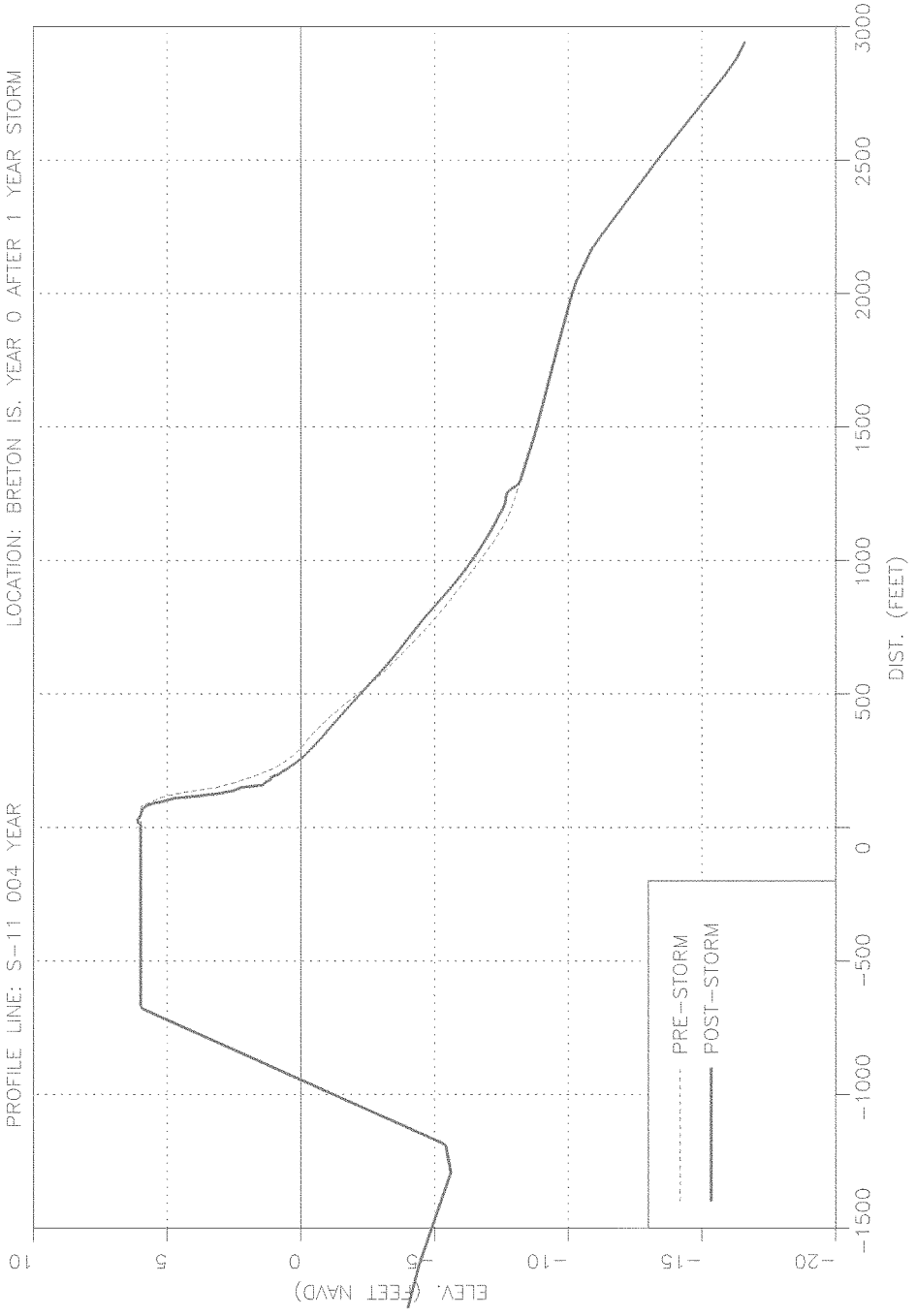
Breton Island Profile S-11

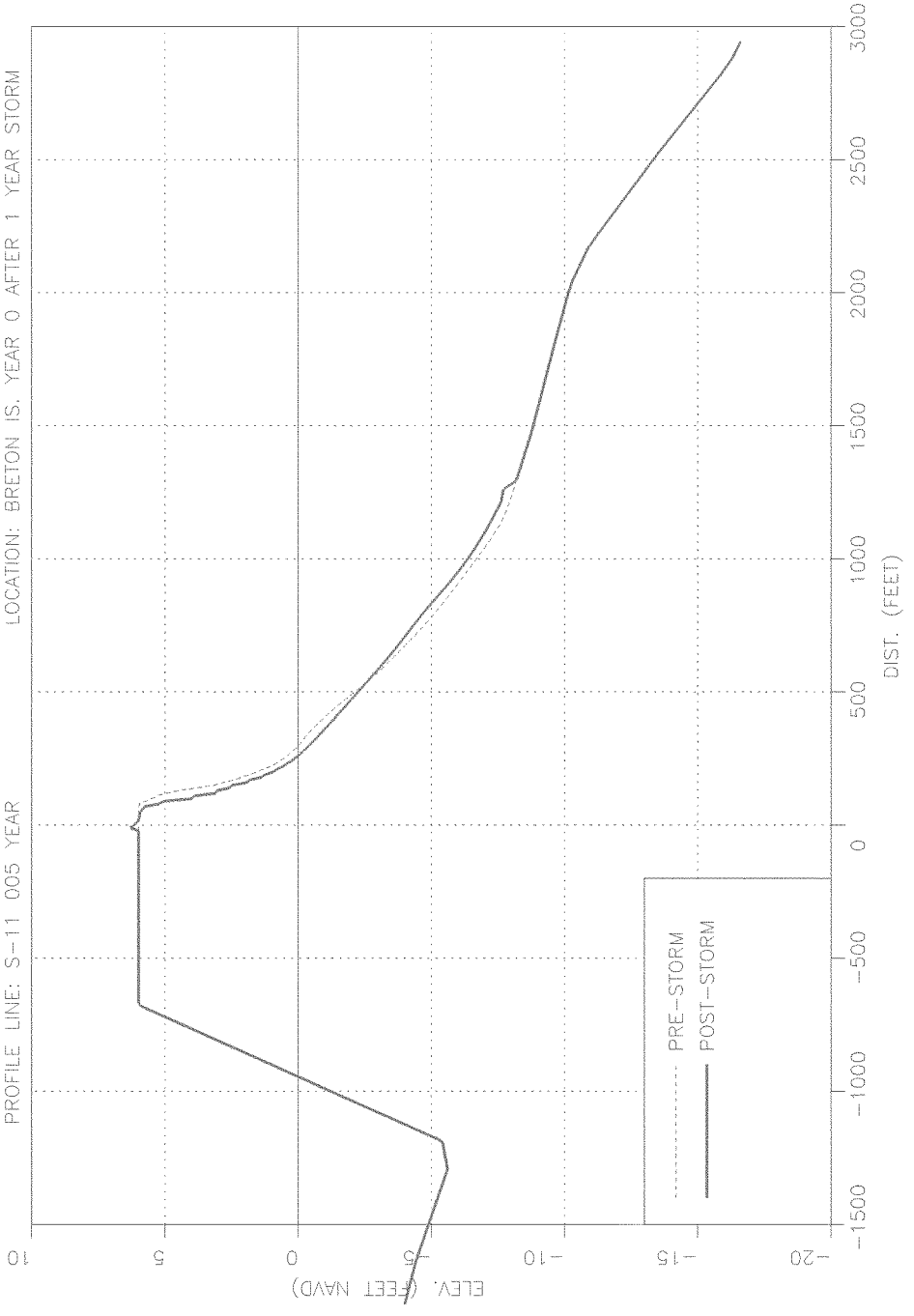
Alternative 2

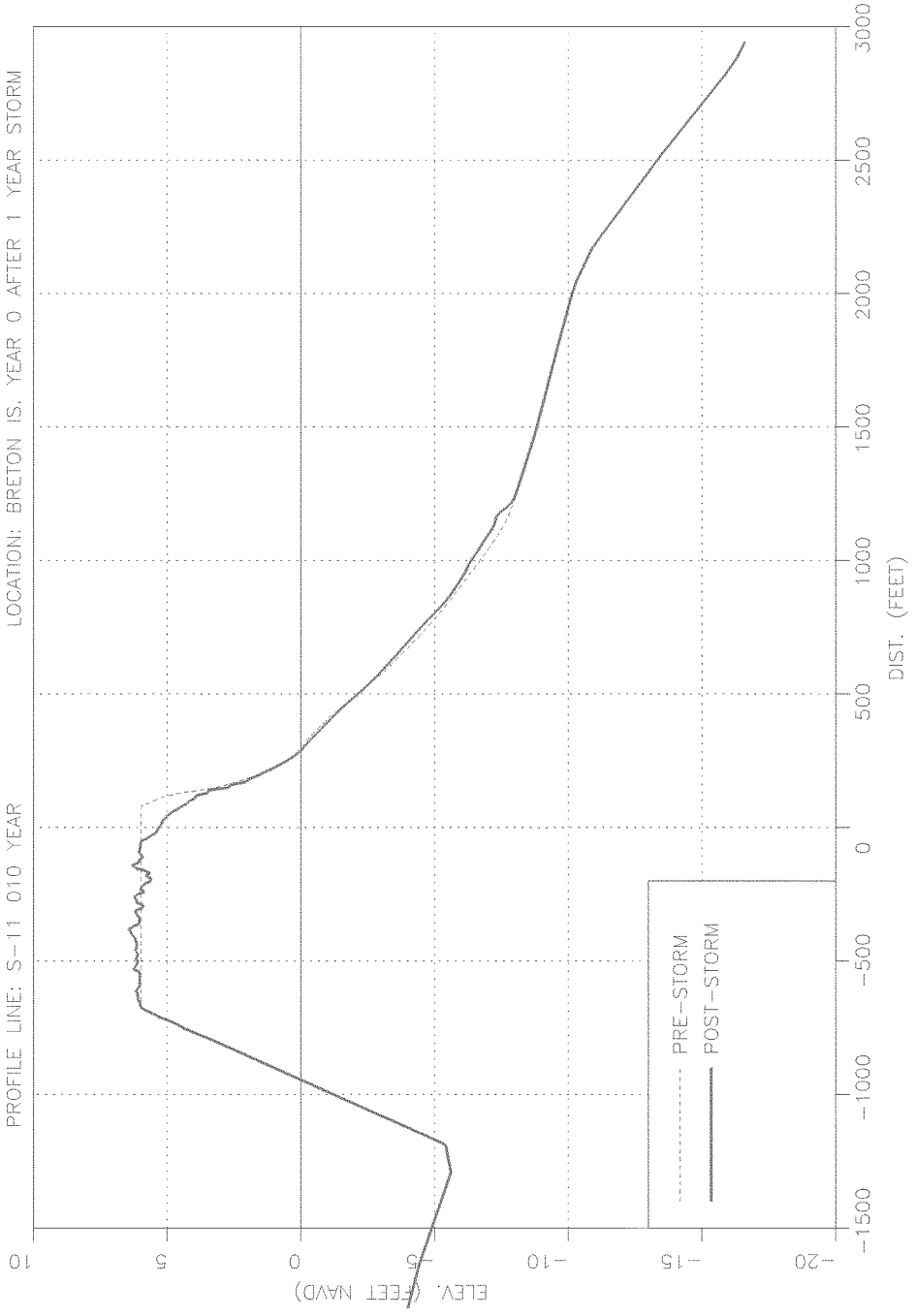

PROFILE LINE: S-11 001 YEAR
LOCATION: BRETON IS. YEAR 0 AFTER 1 YEAR STORM
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

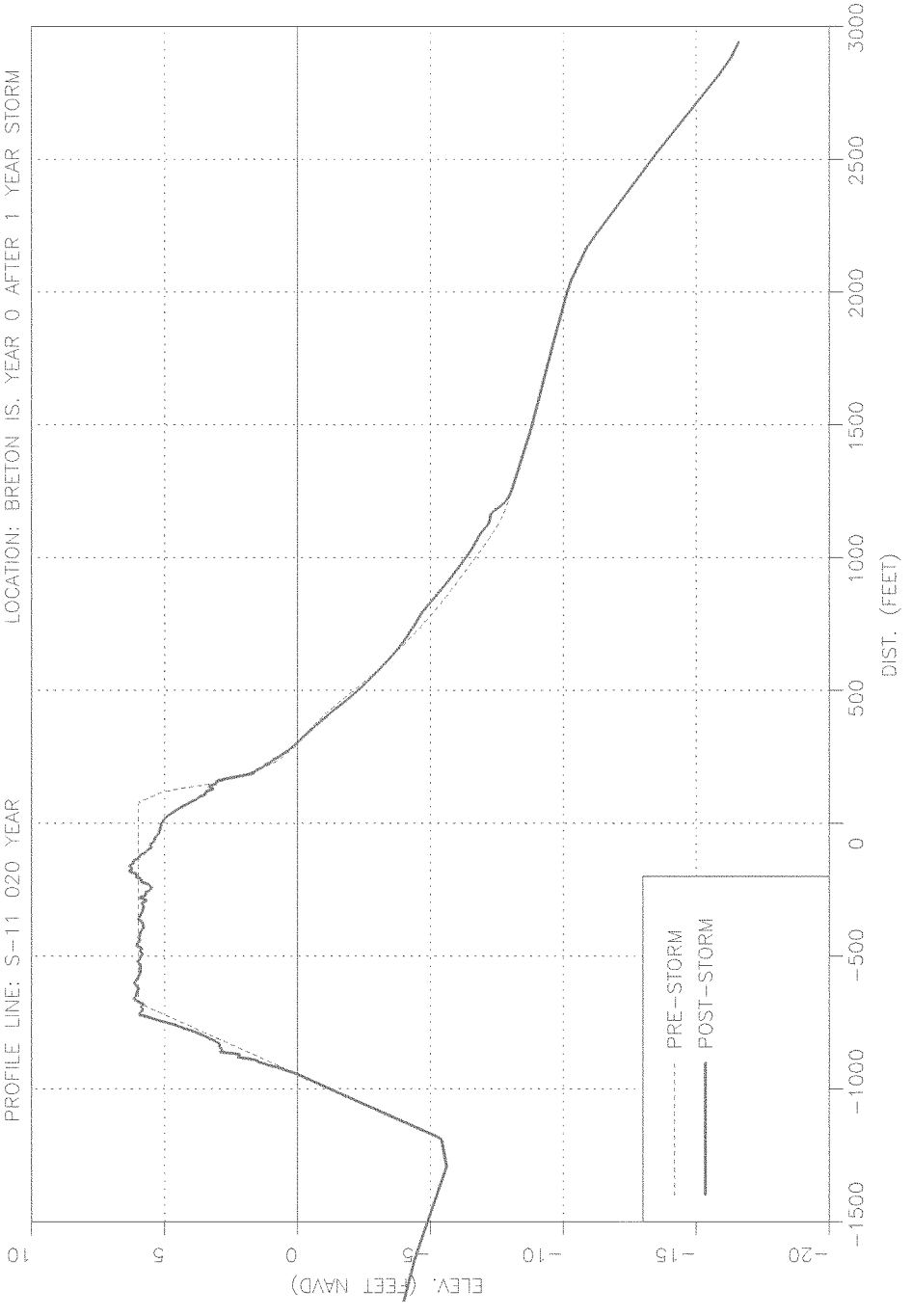

PROFILE LINE: S-11 002 YEAR
LOCATION: BRETON IS. YEAR 0 AFTER 1 YEAR STORM
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

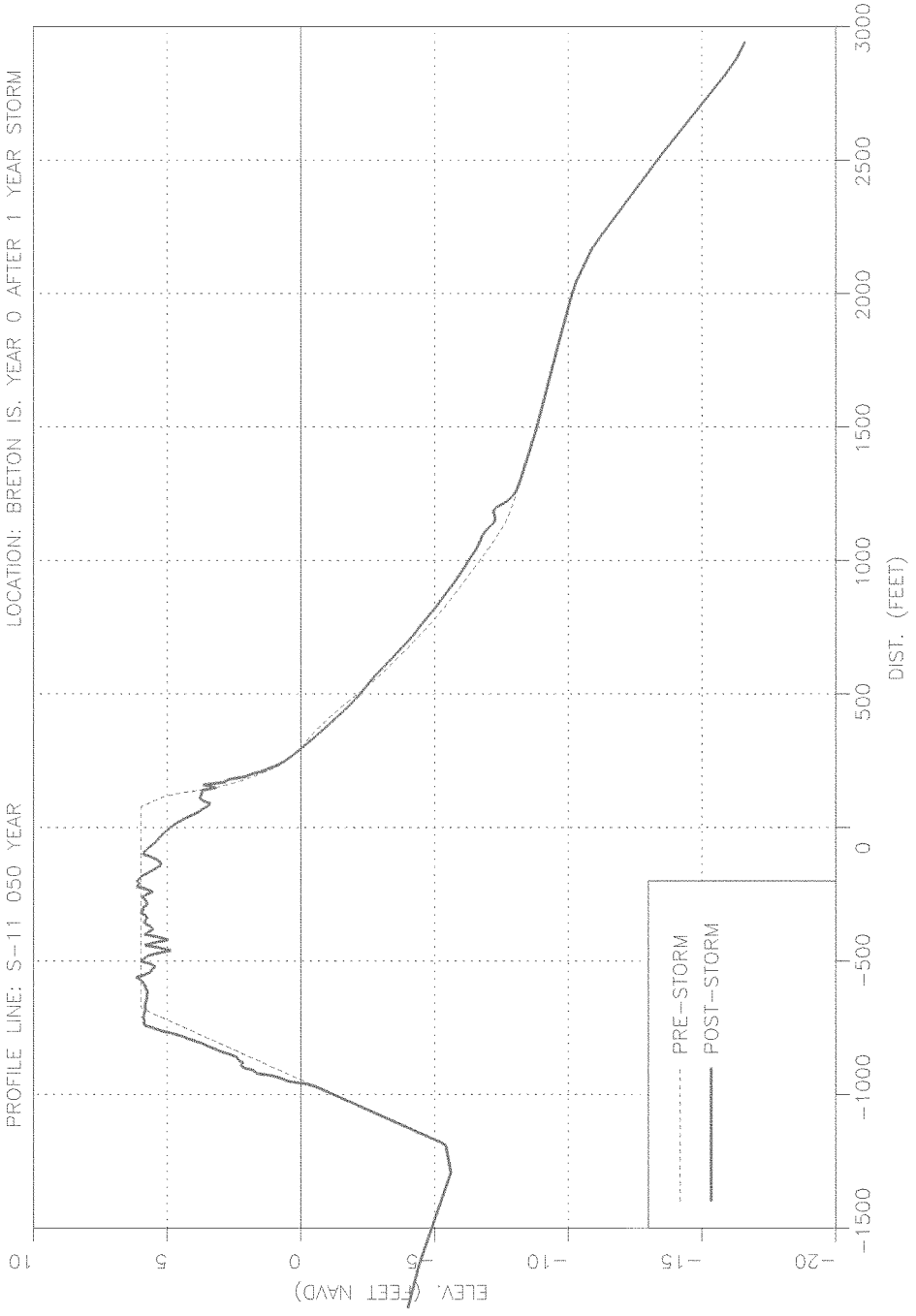

PROFILE LINE: S-11 003 YEAR
LOCATION: BRETON IS. YEAR 0 AFTER 1 YEAR STORM
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

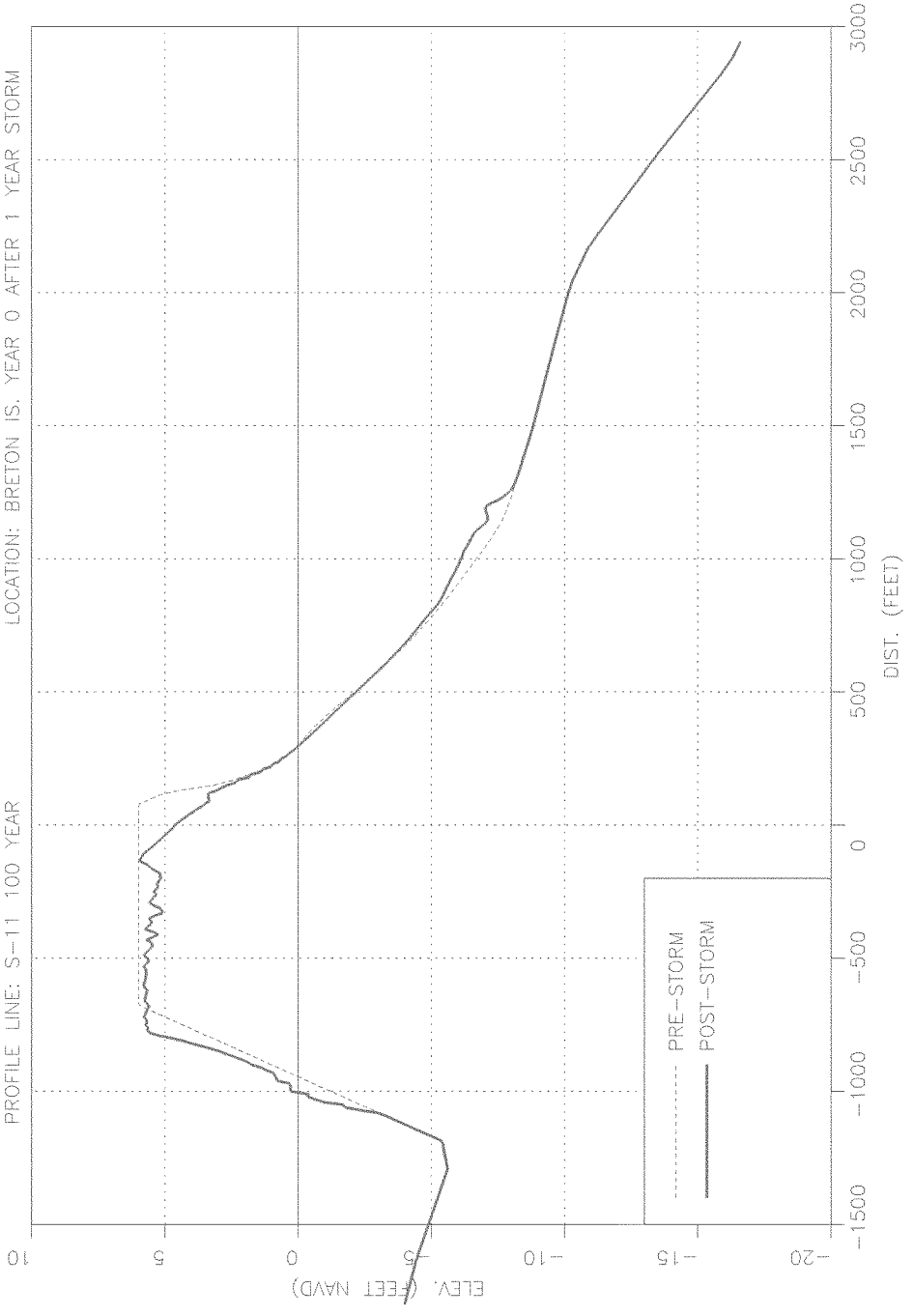

PROFILE LINE: S-11 004 YEAR
LOCATION: BRETON IS. YEAR 0 AFTER 1 YEAR STORM
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

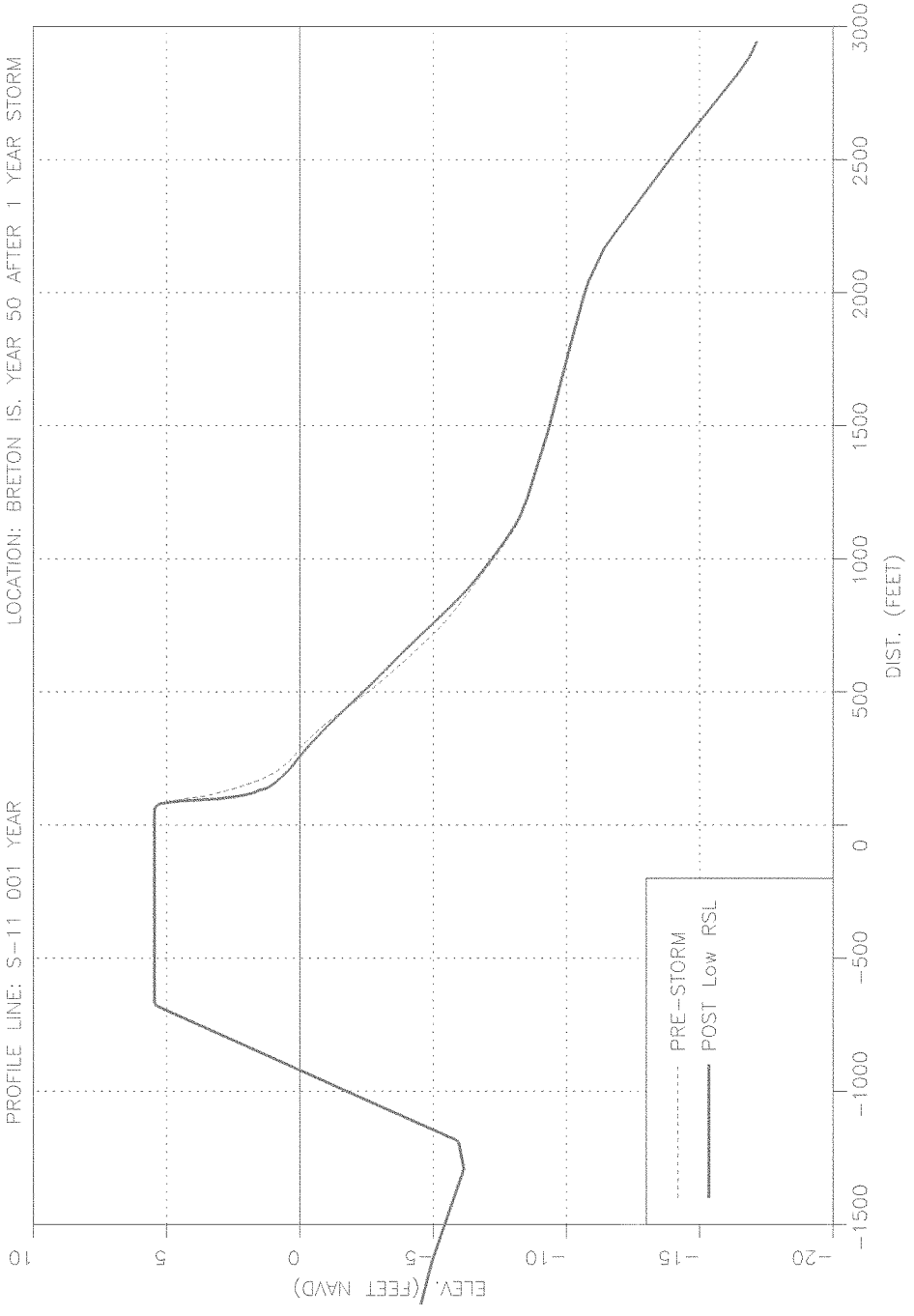

PROFILE LINE: S-11 005 YEAR
LOCATION: BRETON IS. YEAR 0 AFTER 1 YEAR STORM
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

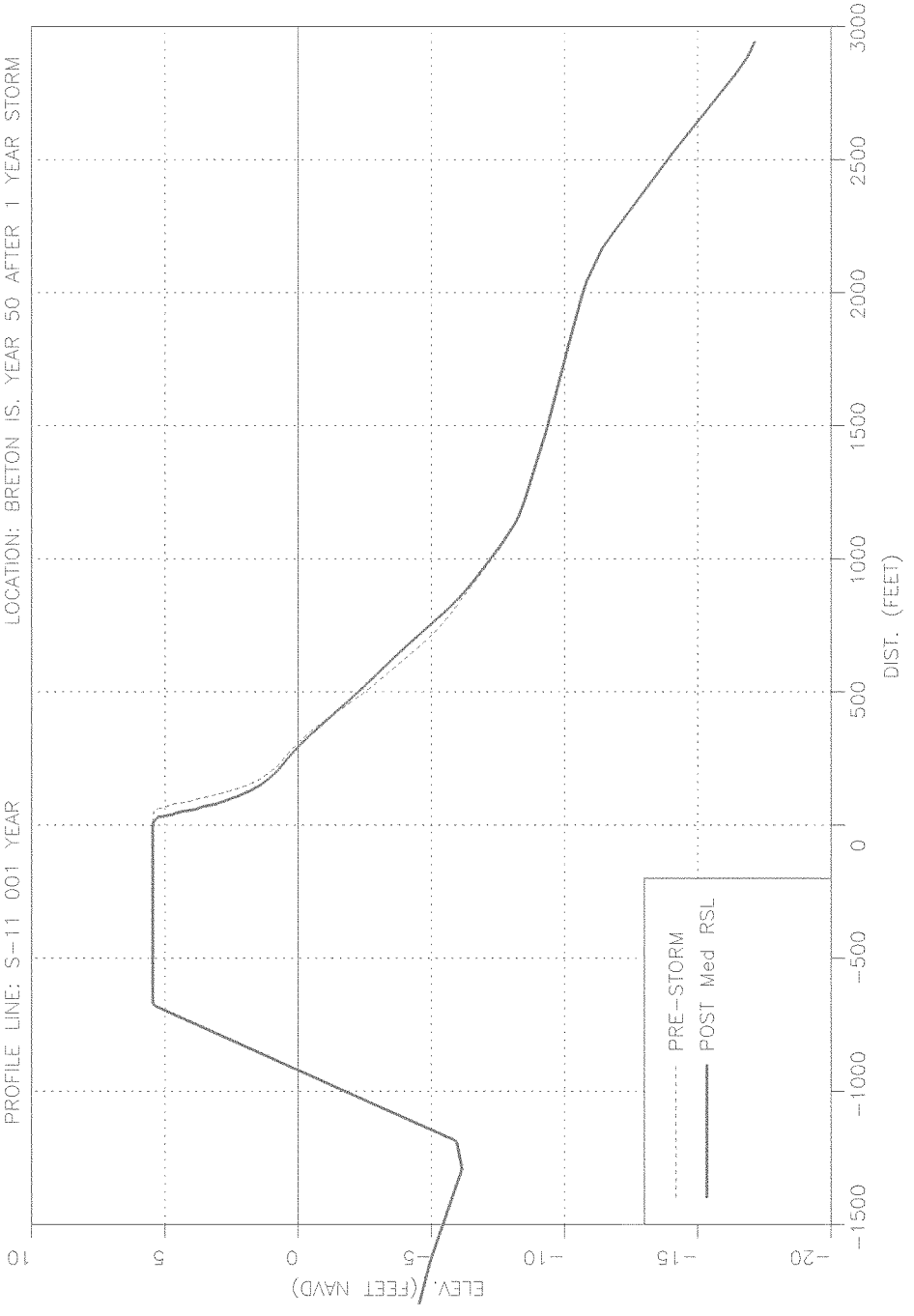

PROFILE LINE: S-11 010 YEAR
LOCATION: BRETON IS. YEAR 0 AFTER 1 YEAR STORM
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

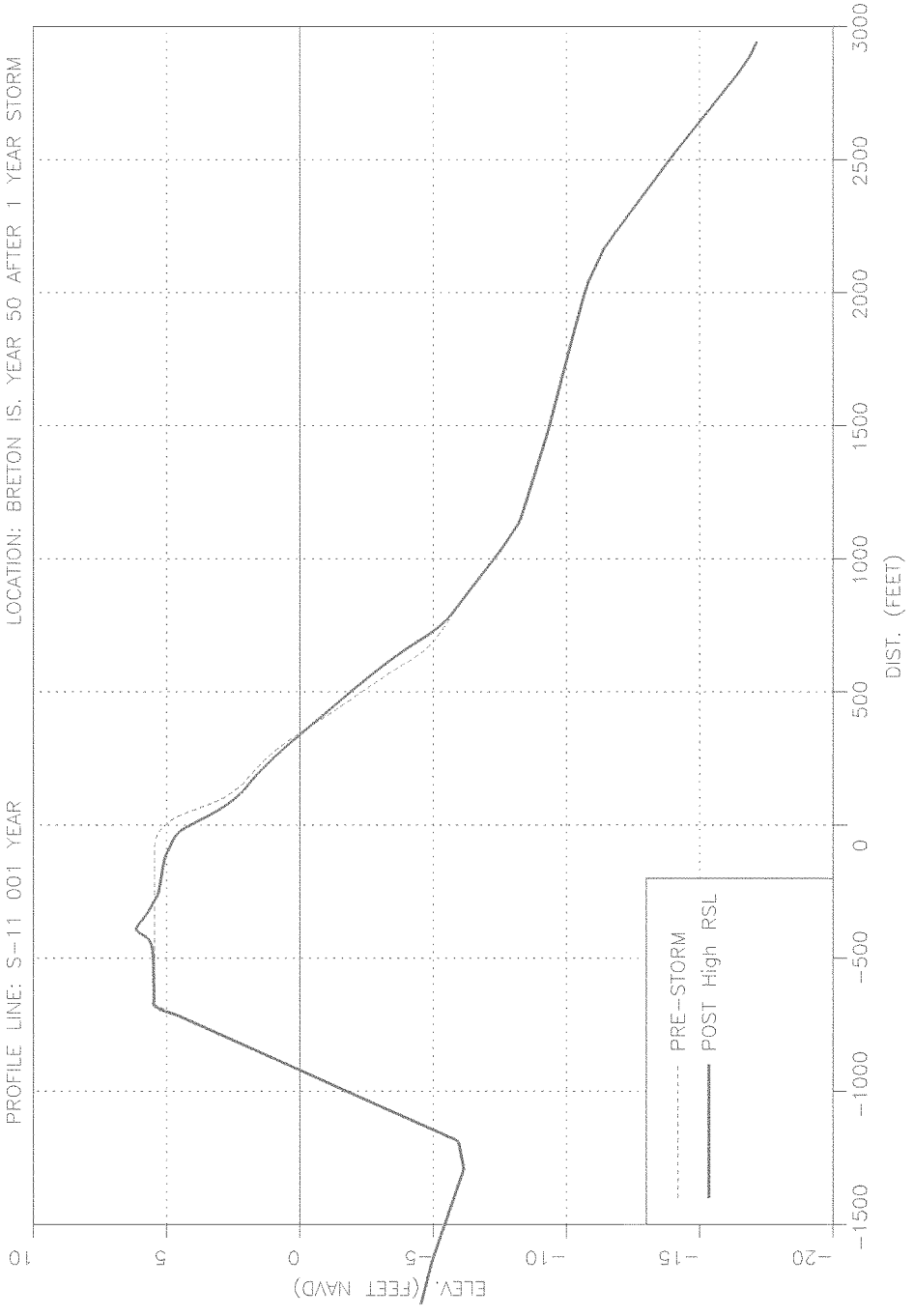

PROFILE LINE: S-11 020 YEAR
LOCATION: BRETON IS. YEAR 0 AFTER 1 YEAR STORM
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

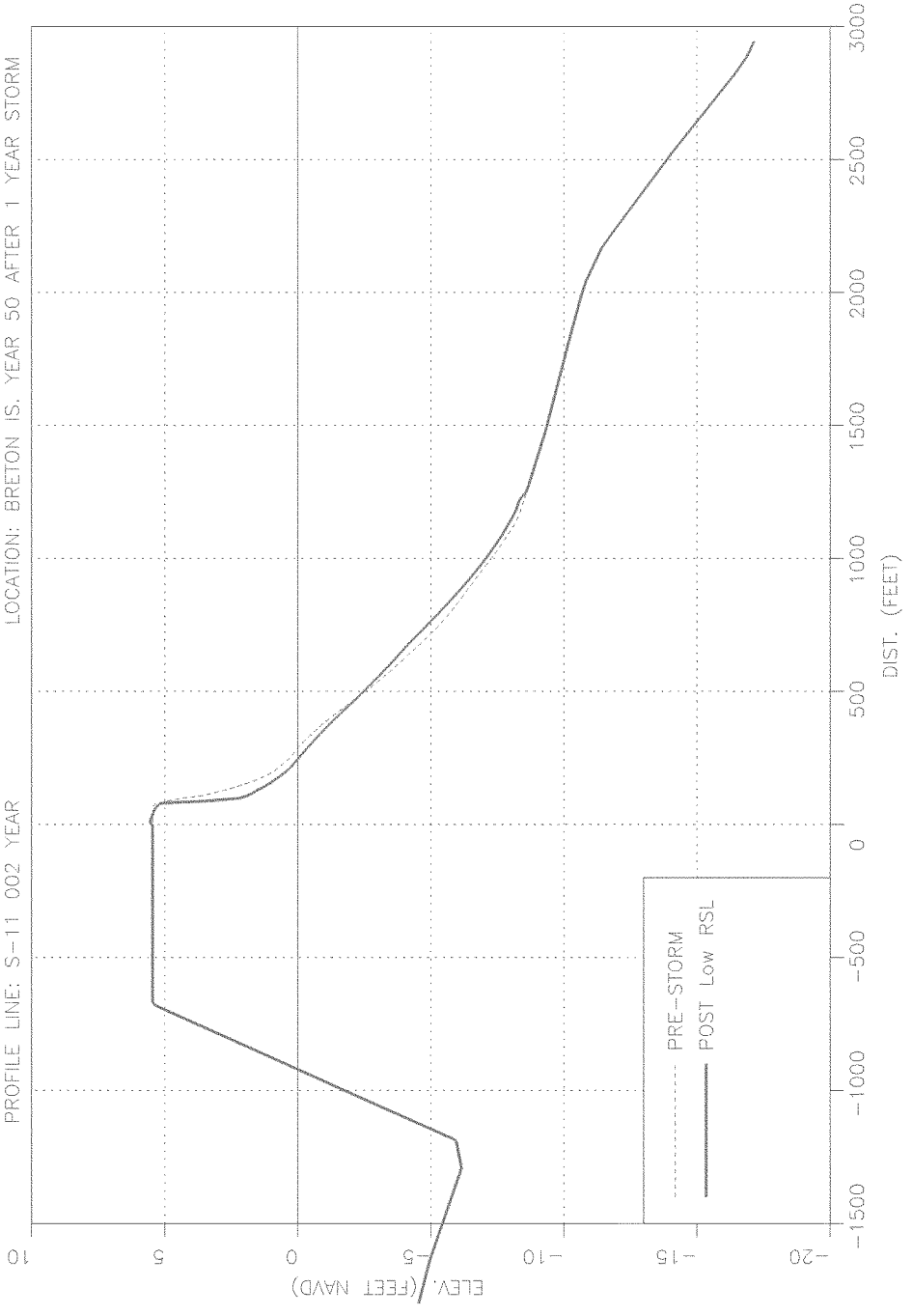

PROFILE LINE: S-11 050 YEAR
LOCATION: BRETON IS. YEAR 0 AFTER 1 YEAR STORM
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST-STORM
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

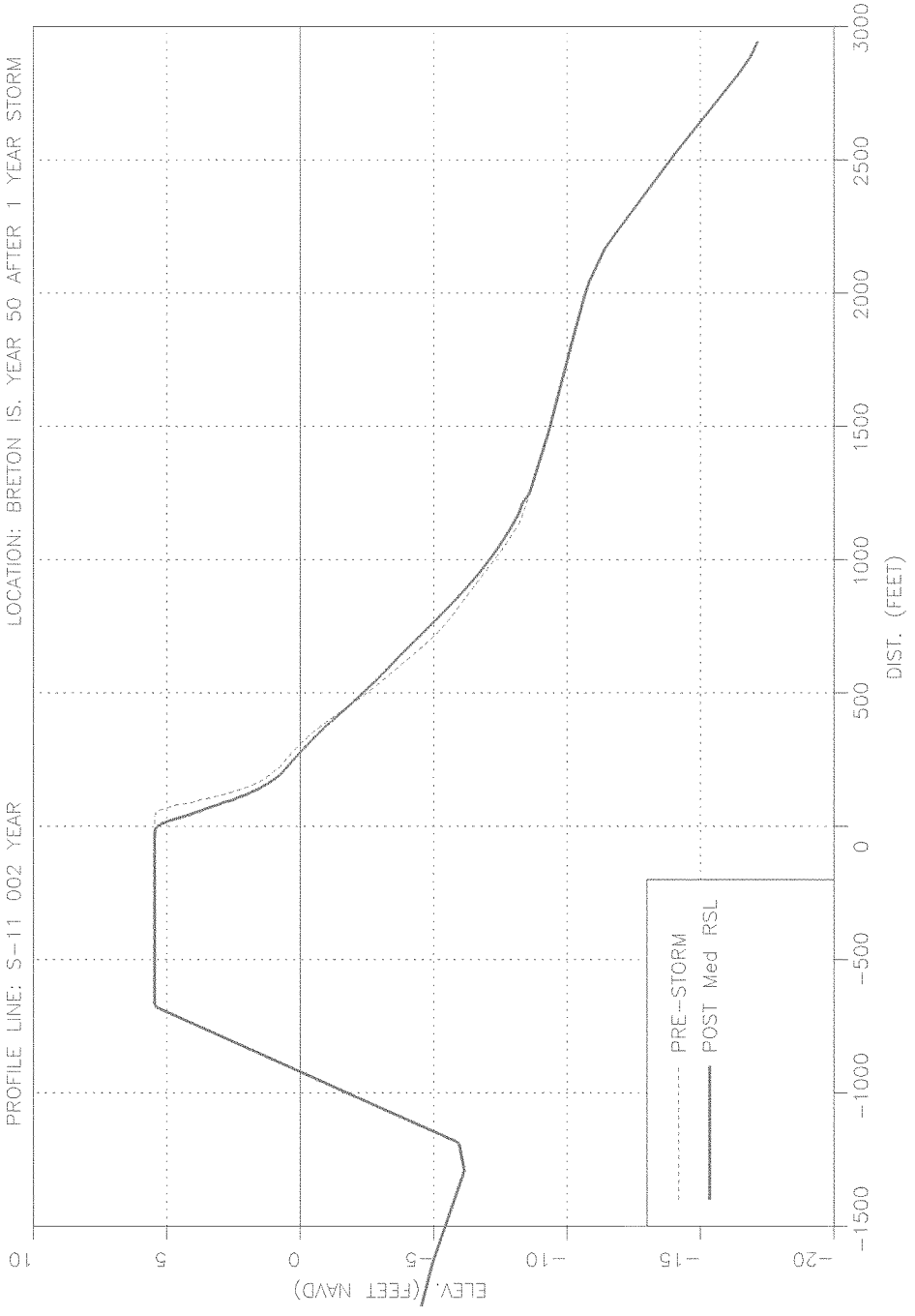

PROFILE LINE: S-11 100 YEAR
LOCATION: BRETON IS. YEAR 0 AFTER 1 YEAR STORM
ELEV. (FEET NAVD)
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000
DIST. (FEET)
PRE-STORM
POST-STORM

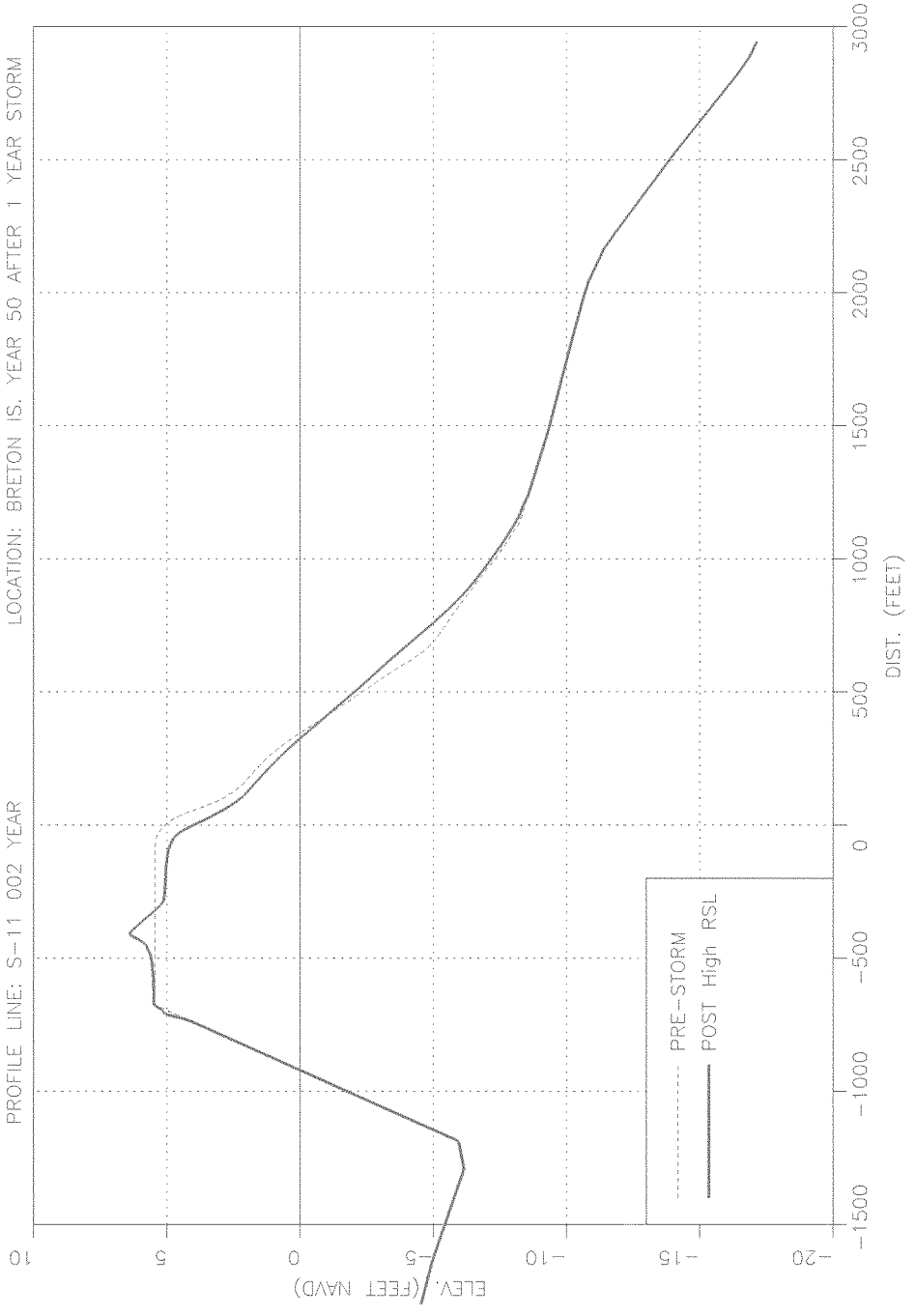

PROFILE LINE: S-11 001 YEAR
LOCATION: BRETON IS. YEAR 50 AFTER 1 YEAR STORM
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

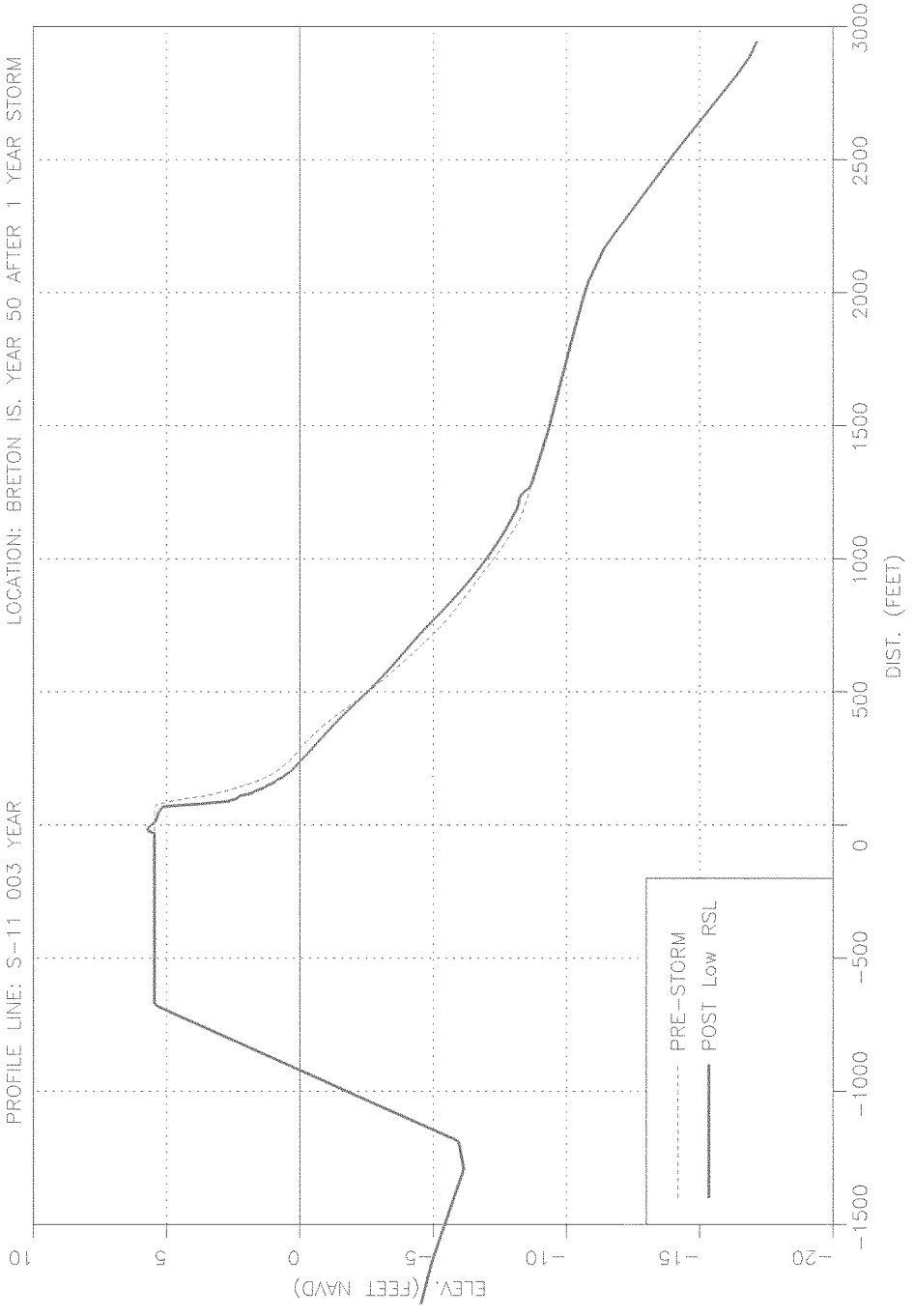

PROFILE LINE: S-11 001 YEAR
LOCATION: BRETON IS. YEAR 50 AFTER 1 YEAR STORM
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Med RSL
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

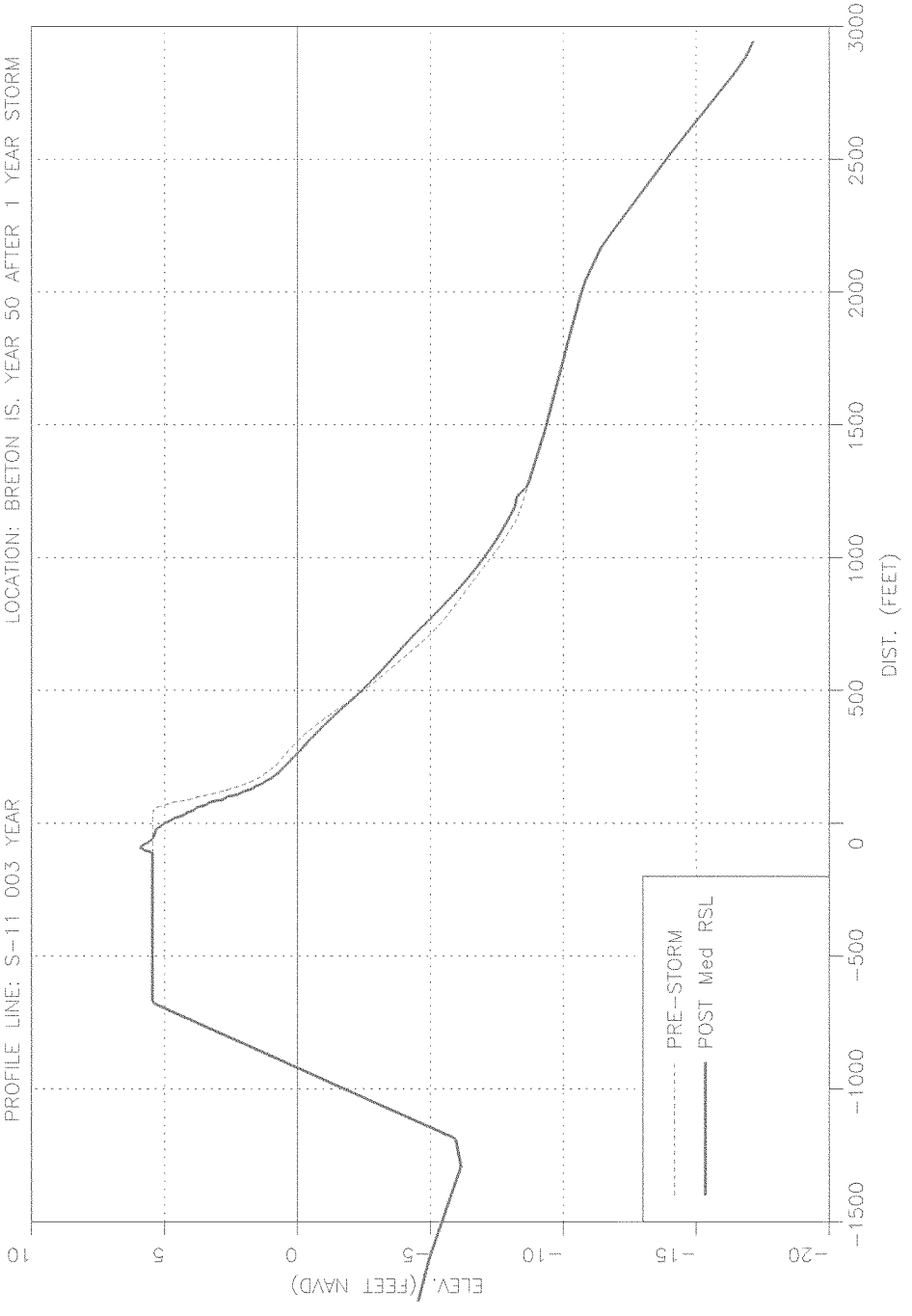

PROFILE LINE: S-11 001 YEAR
LOCATION: BRETON IS. YEAR 50 AFTER 1 YEAR STORM
ELEV. (FEET NAVD)
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000
DIST. (FEET)
PRE-STORM
POST High RSL

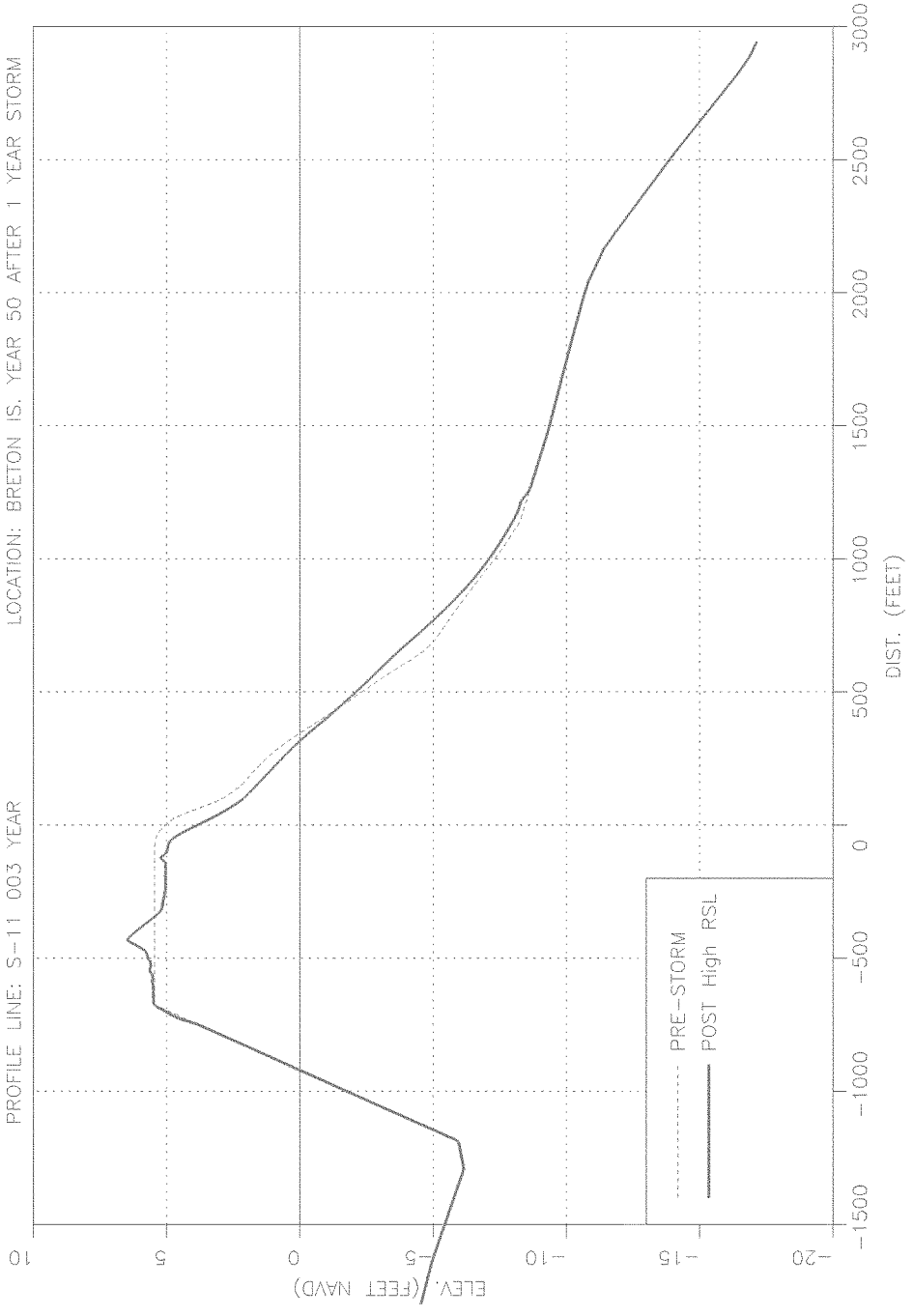

PROFILE LINE: S-11 002 YEAR
LOCATION: BRETON IS. YEAR 50 AFTER 1 YEAR STORM
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

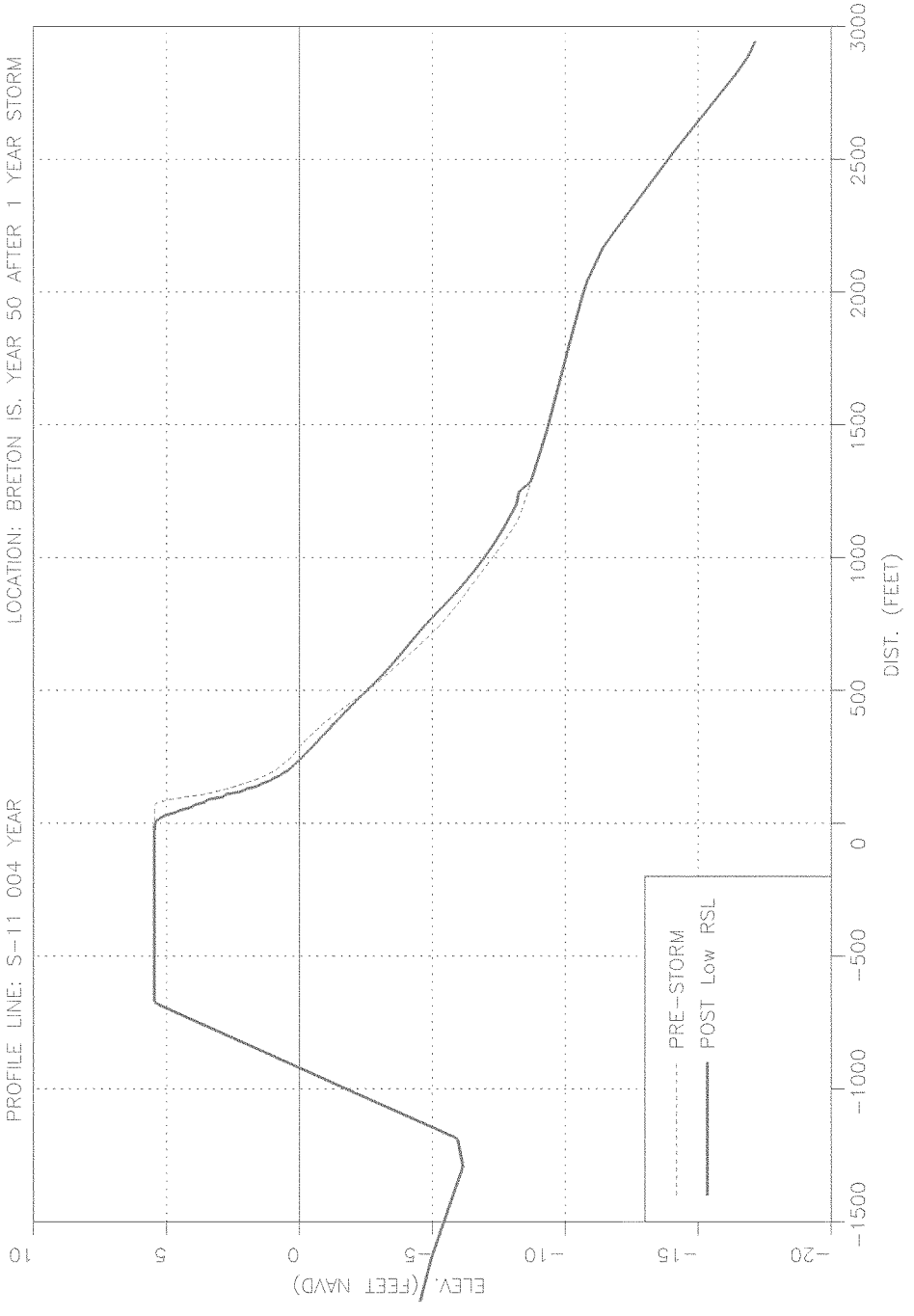

PROFILE LINE: S-11 002 YEAR
LOCATION: BRETON IS. YEAR 50 AFTER 1 YEAR STORM
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Med RSL
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

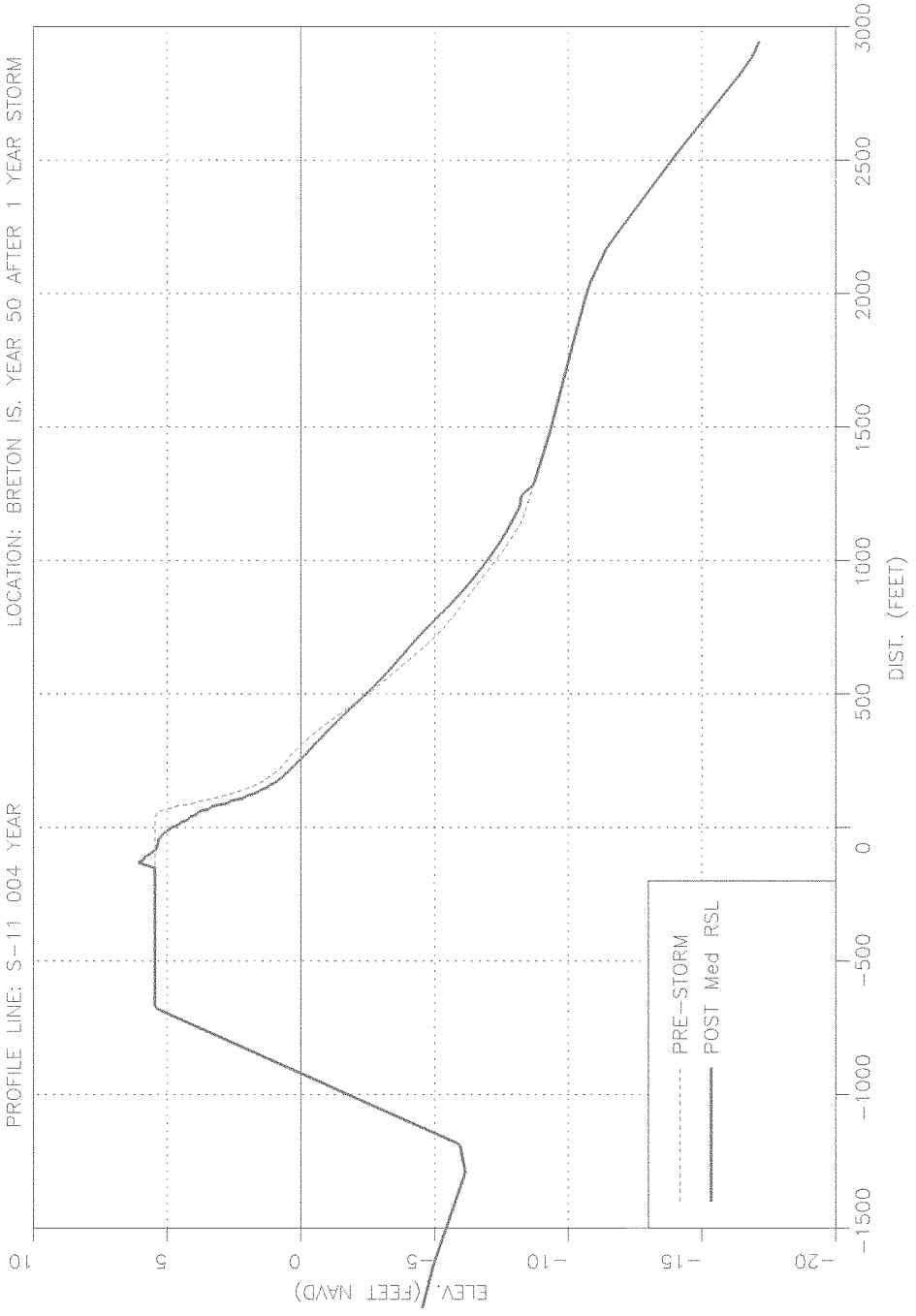

PROFILE LINE: S-11 002 YEAR
LOCATION: BRETON IS. YEAR 50 AFTER 1 YEAR STORM
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST High RSL
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

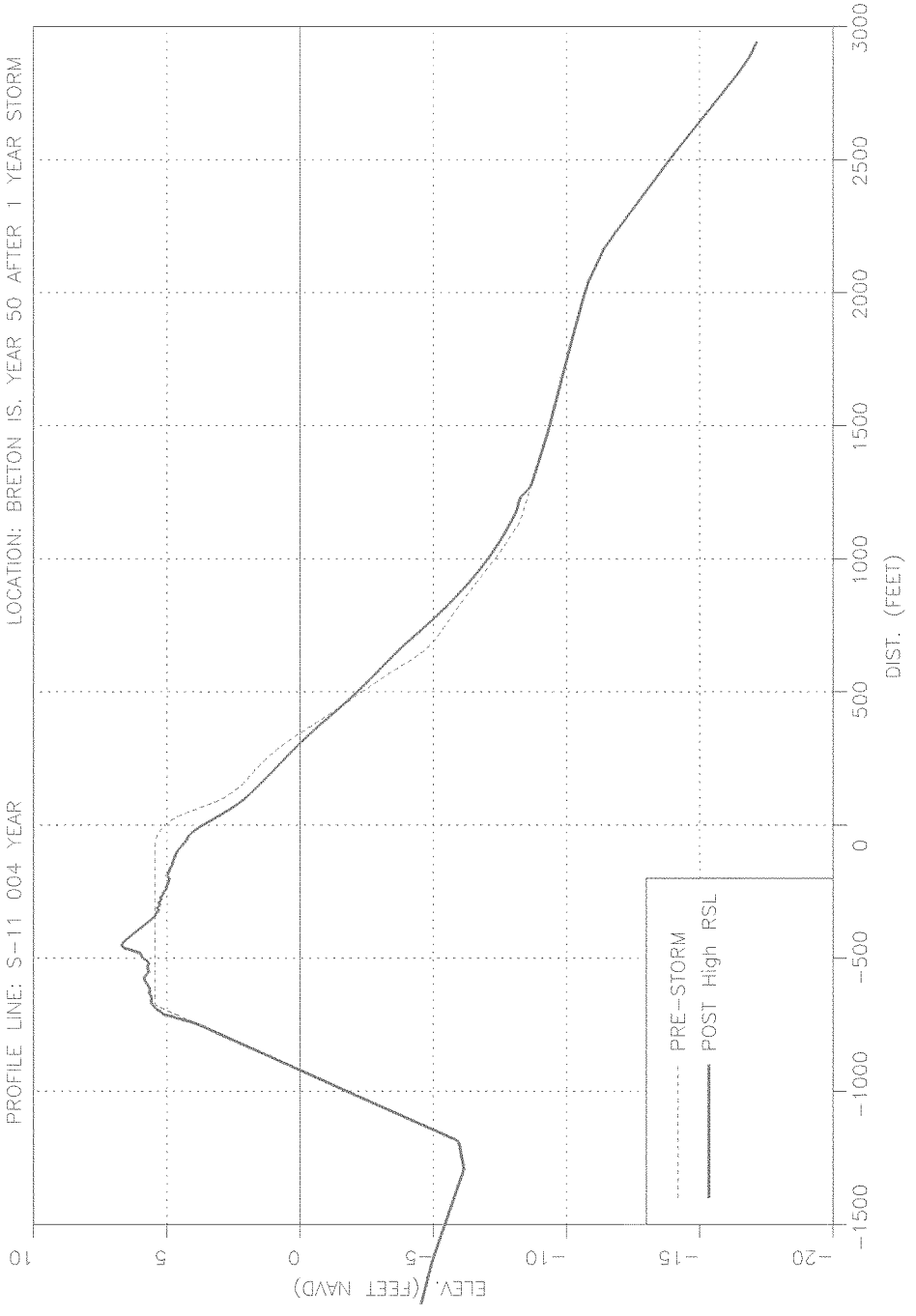

PROFILE LINE: S-11 003 YEAR
LOCATION: BRETON IS. YEAR 50 AFTER 1 YEAR STORM
PRE-STORM
POST Low RSL
ELEV. (FEET NAVD)
DIST. (FEET)
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

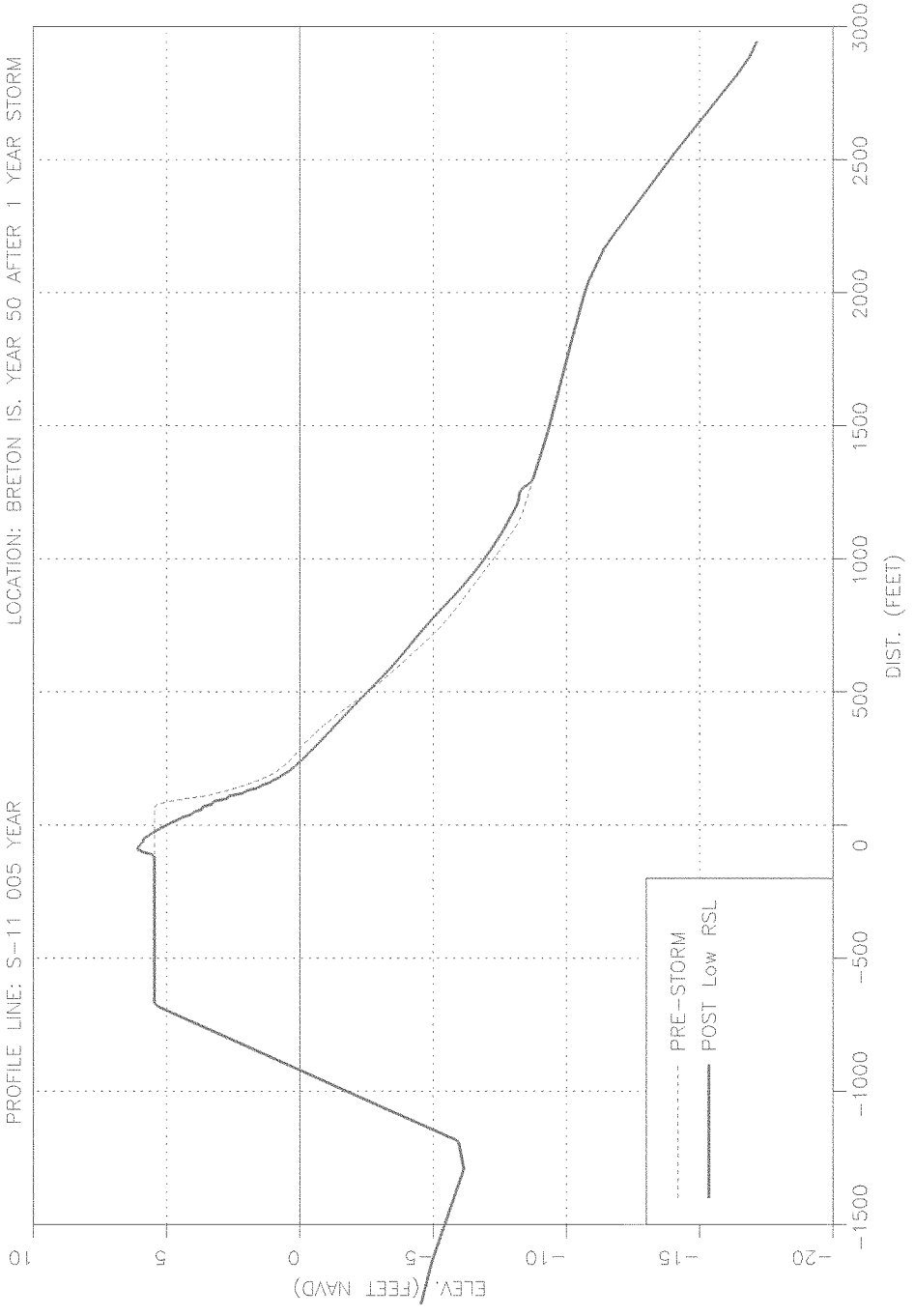

PROFILE LINE: S-11 003 YEAR
LOCATION: BRETON IS. YEAR 50 AFTER 1 YEAR STORM
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Med RSL
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

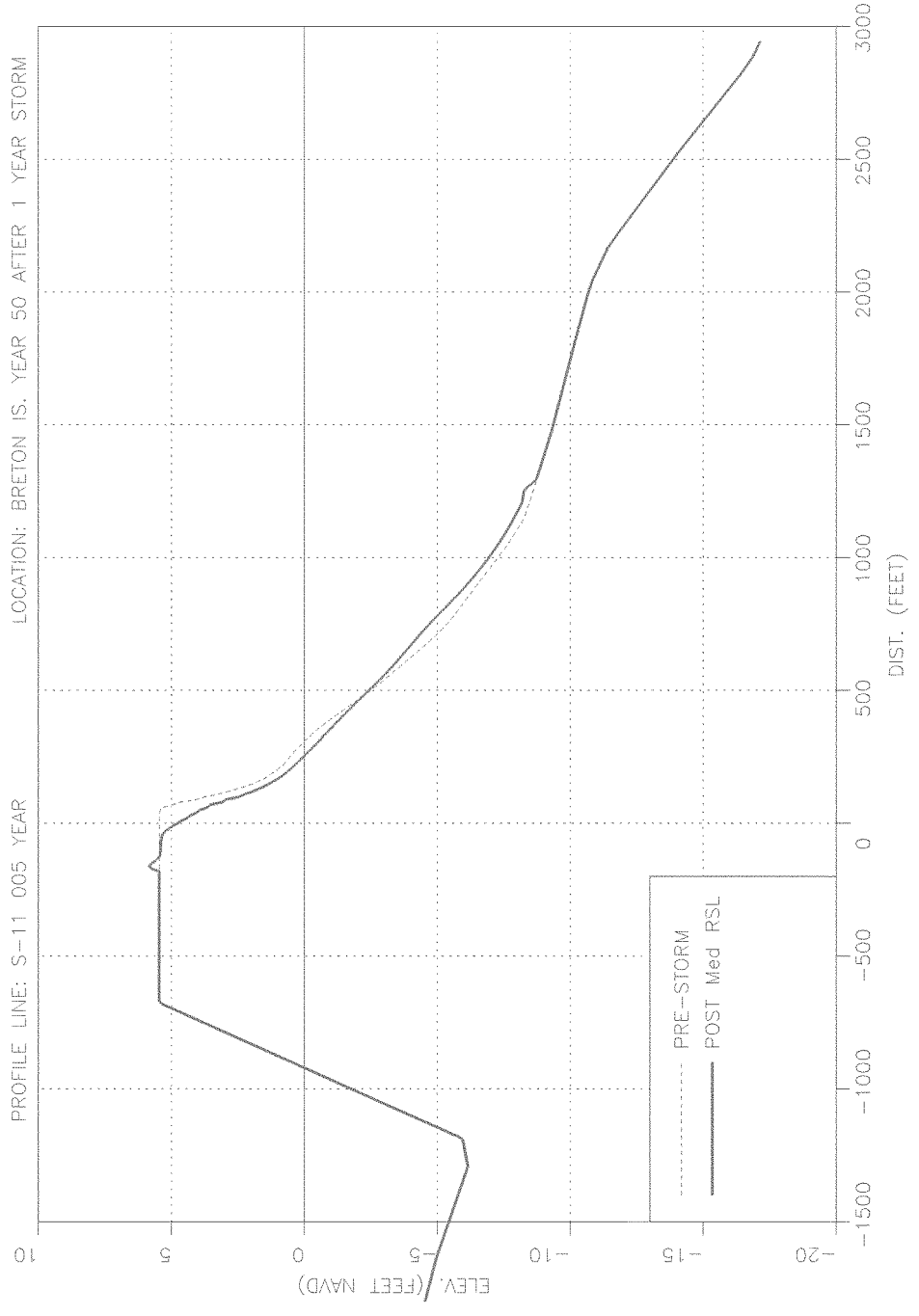

PROFILE LINE: S-11 003 YEAR
LOCATION: BRETON IS. YEAR 50 AFTER 1 YEAR STORM
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST High RSL
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

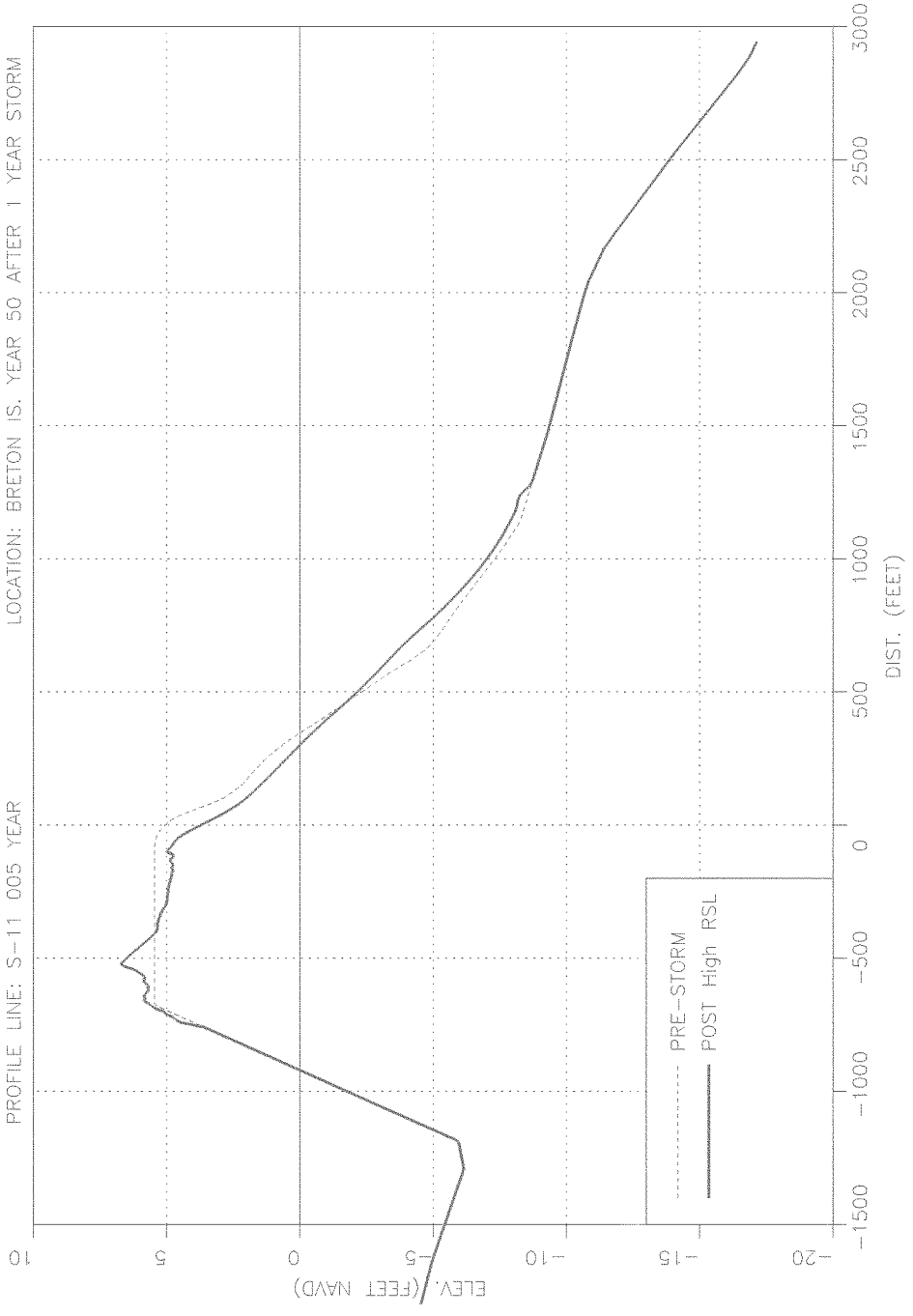

PROFILE LINE: S-11 004 YEAR
LOCATION: BRETON IS. YEAR 50 AFTER 1 YEAR STORM
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

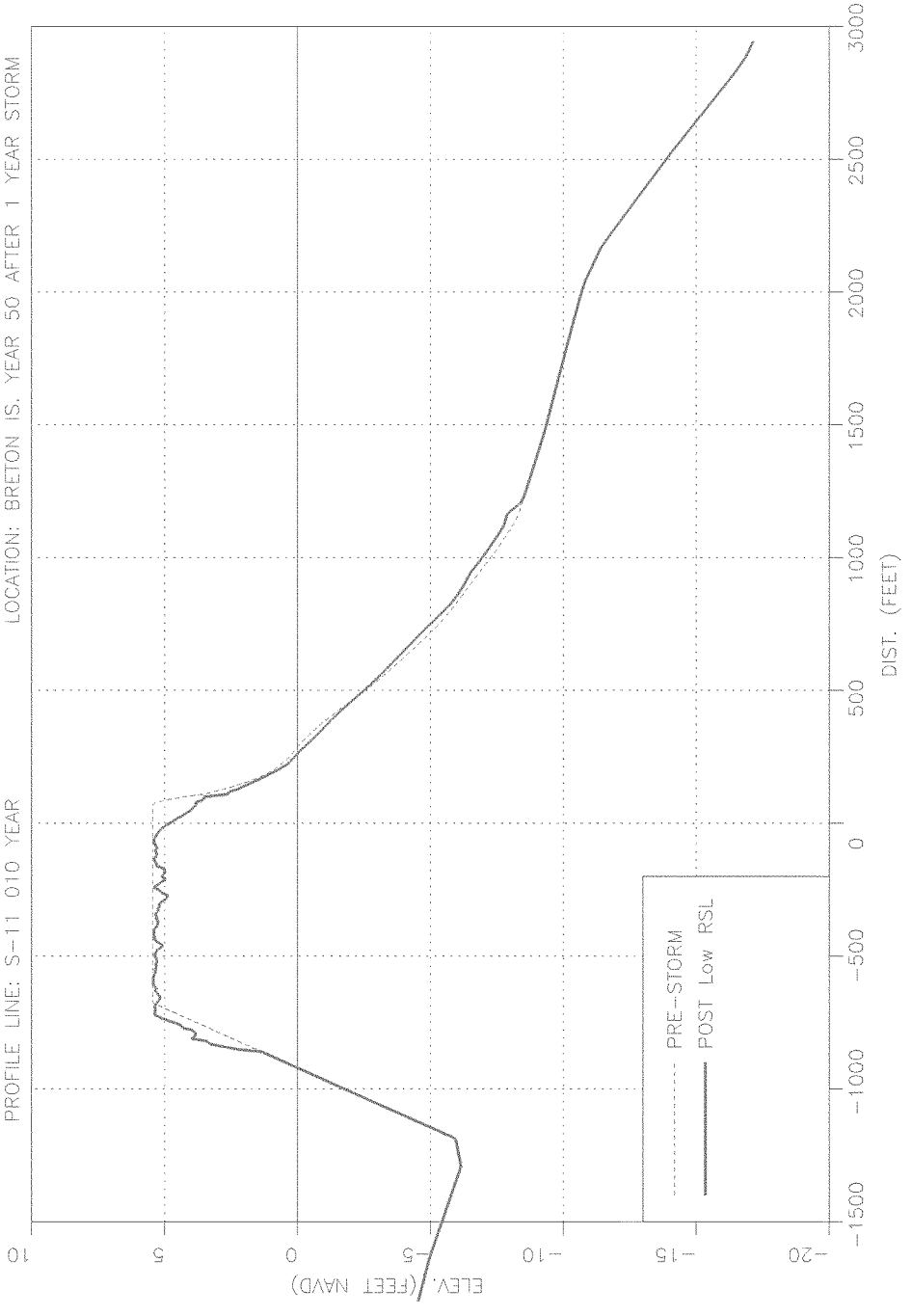

PROFILE LINE: S-11 004 YEAR
LOCATION: BRETON IS. YEAR 50 AFTER 1 YEAR STORM
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Med RSL
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

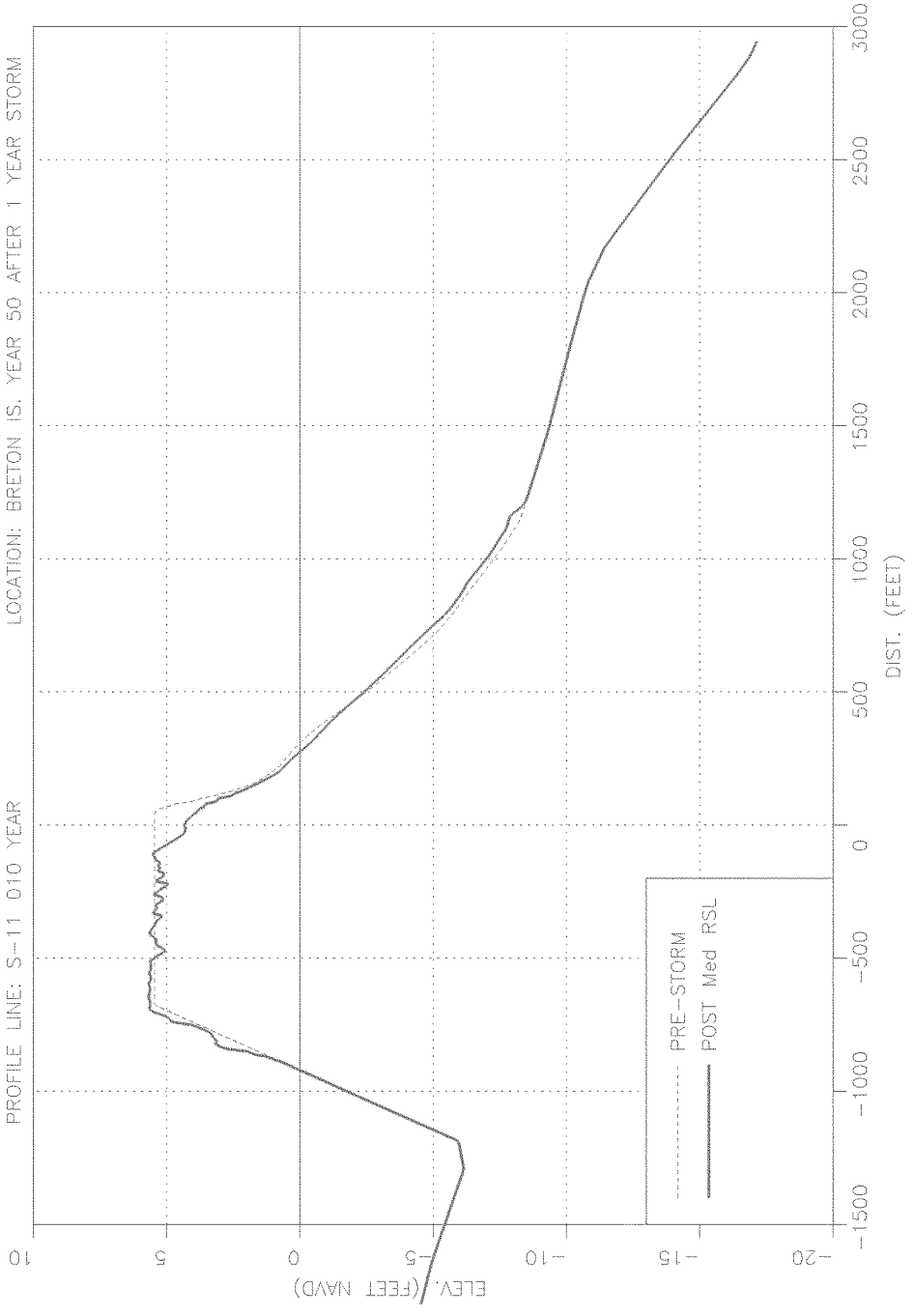

PROFILE LINE: S-11 004 YEAR
LOCATION: BRETON IS. YEAR 50 AFTER 1 YEAR STORM
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST High RSL
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

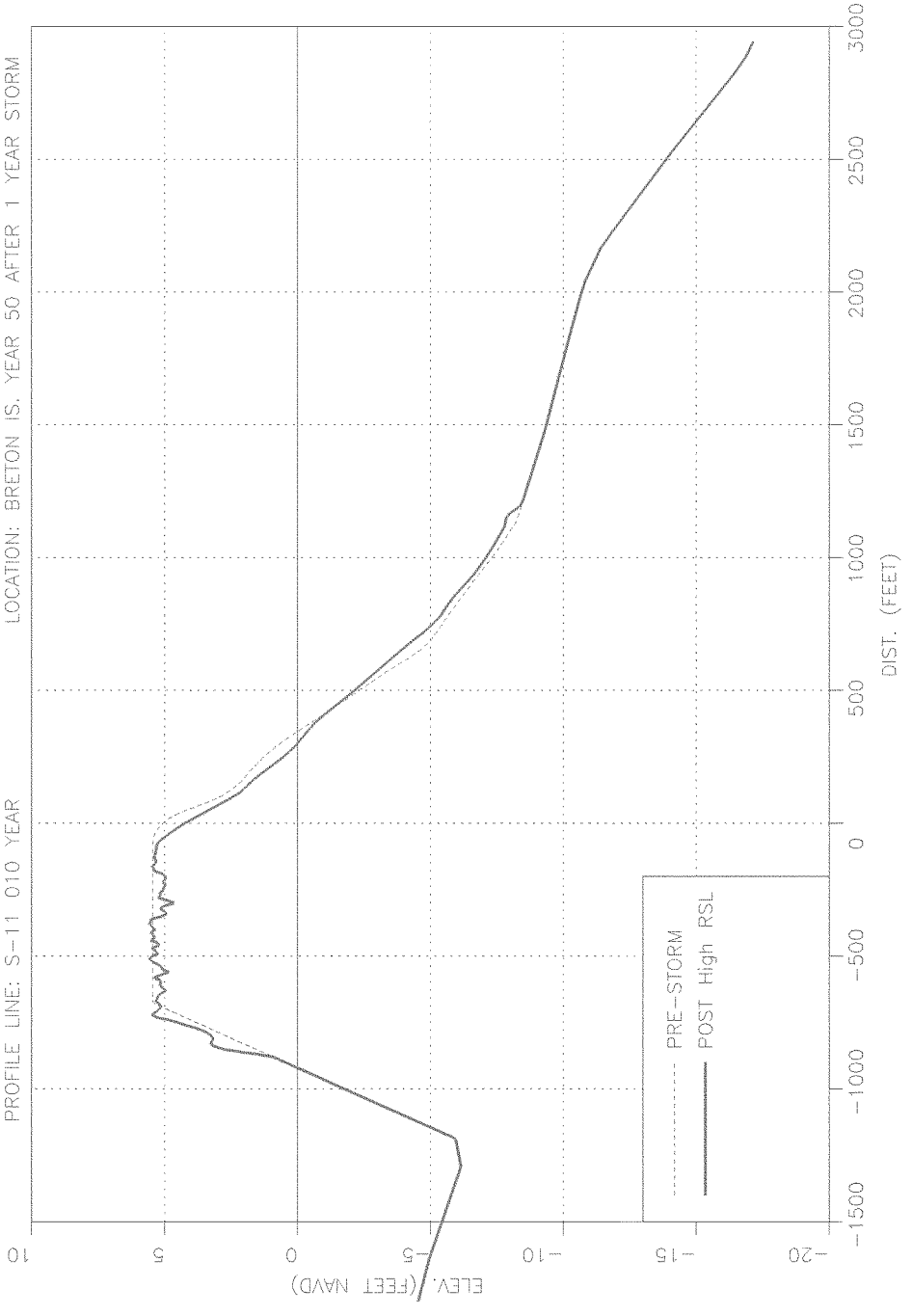

PROFILE LINE: S-11 005 YEAR
LOCATION: BRETON IS. YEAR 50 AFTER 1 YEAR STORM
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

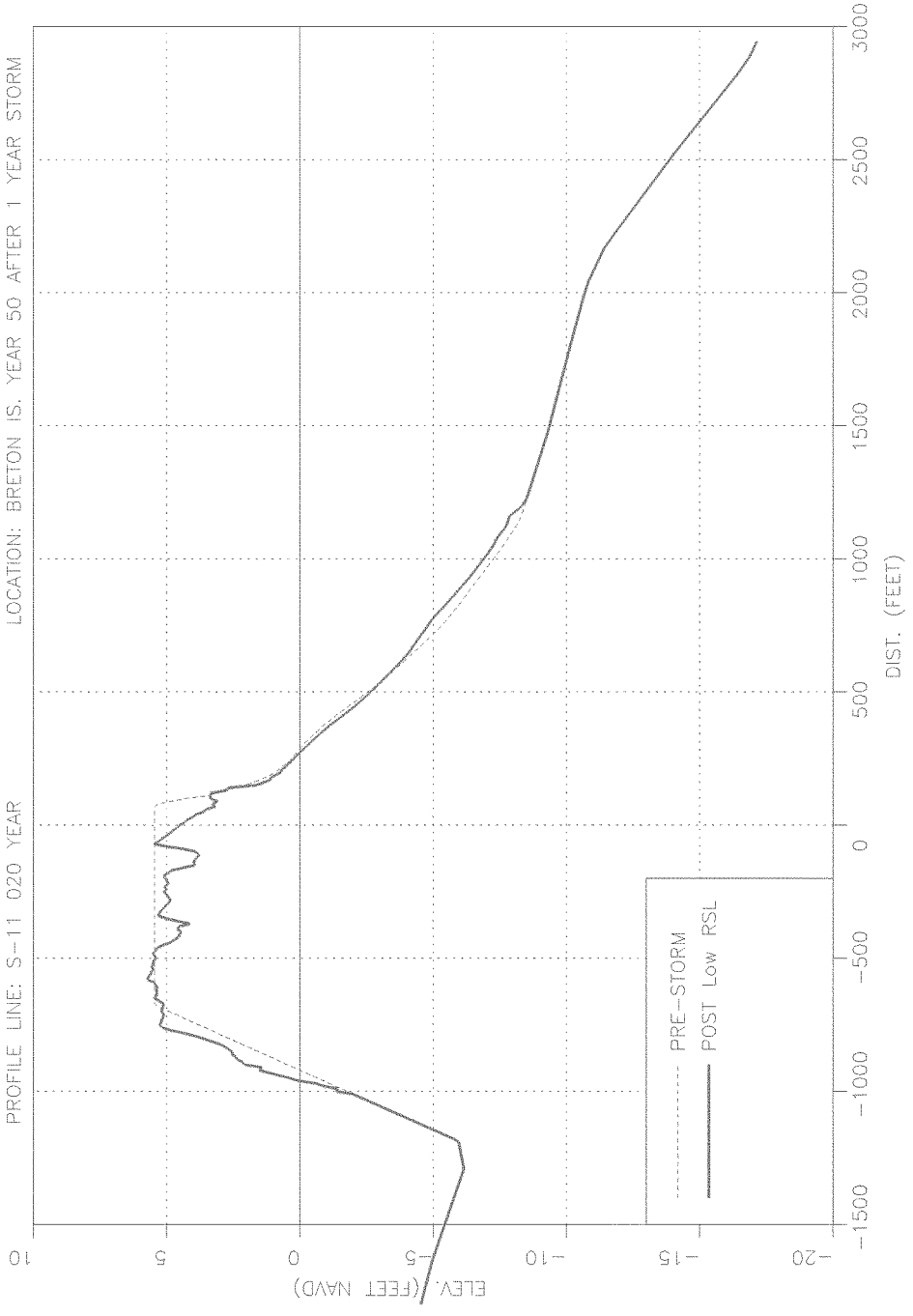

PROFILE LINE: S-11 005 YEAR
LOCATION: BRETON IS. YEAR 50 AFTER 1 YEAR STORM
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Med RSL
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

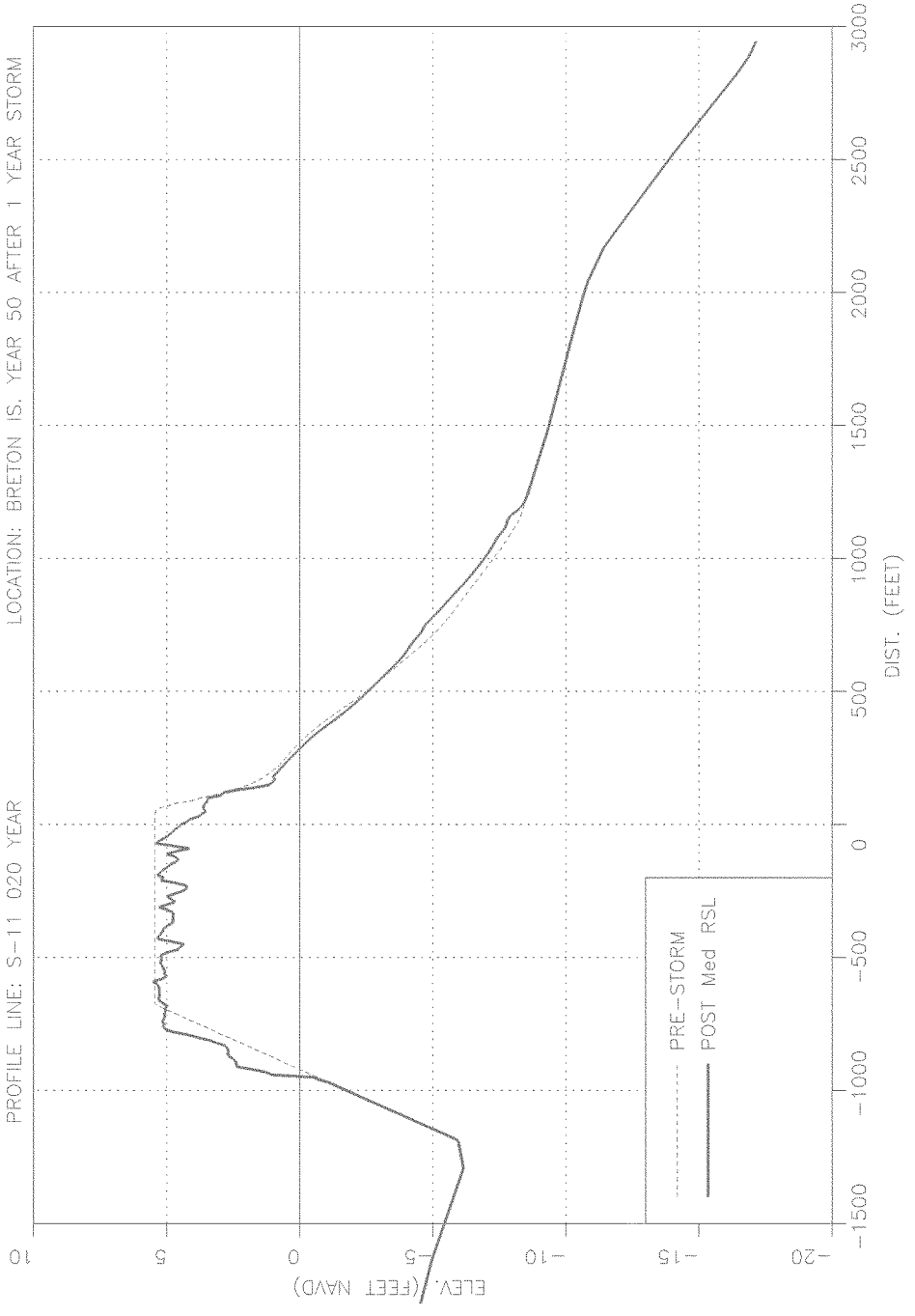

PROFILE LINE: S-11 005 YEAR
LOCATION: BRETON IS. YEAR 50 AFTER 1 YEAR STORM
PRE-STORM
POST High RSL
ELEV. (FEET NAVD)
DIST. (FEET)
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

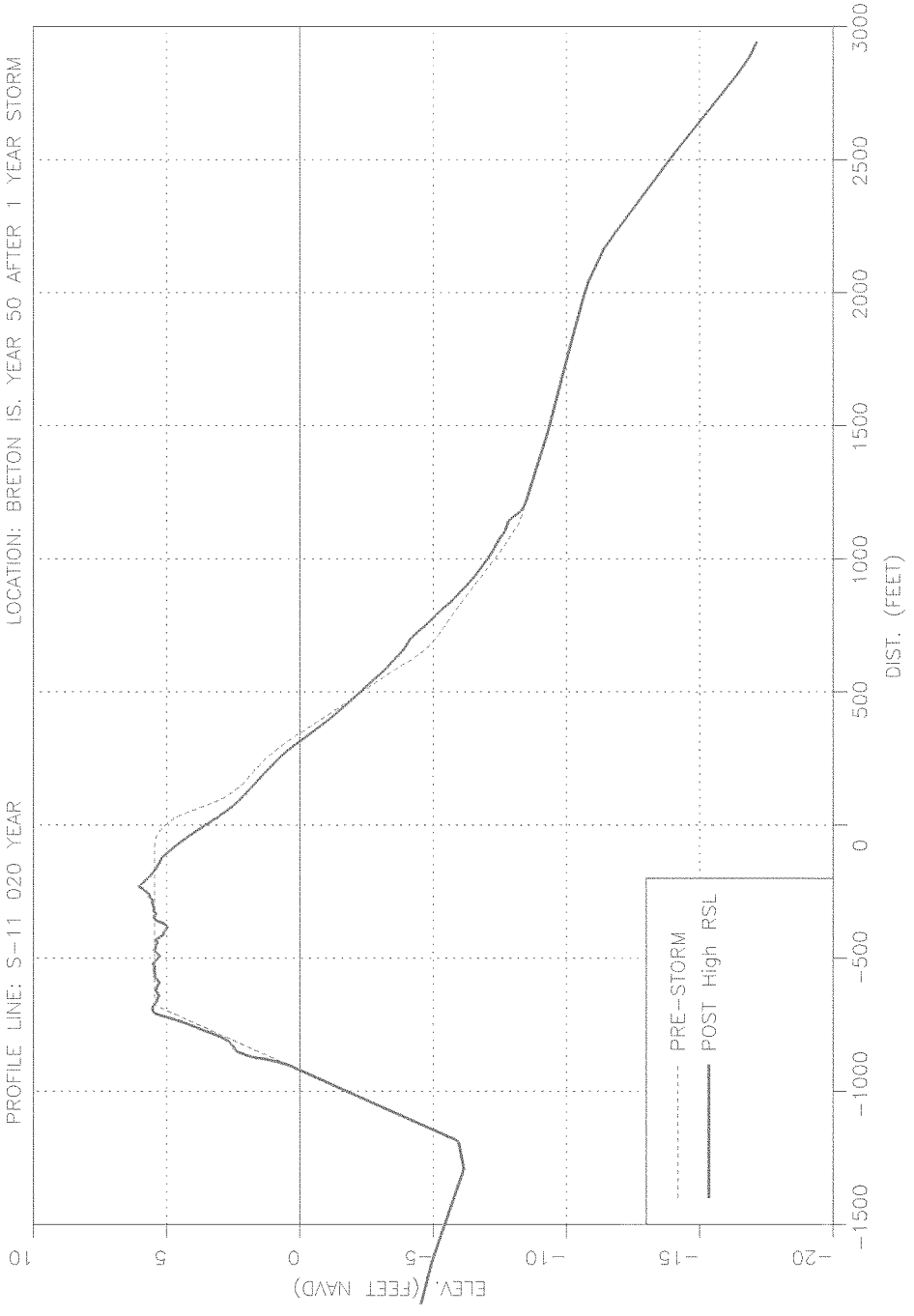

PROFILE LINE: S-11 010 YEAR
LOCATION: BRETON IS. YEAR 50 AFTER 1 YEAR STORM
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

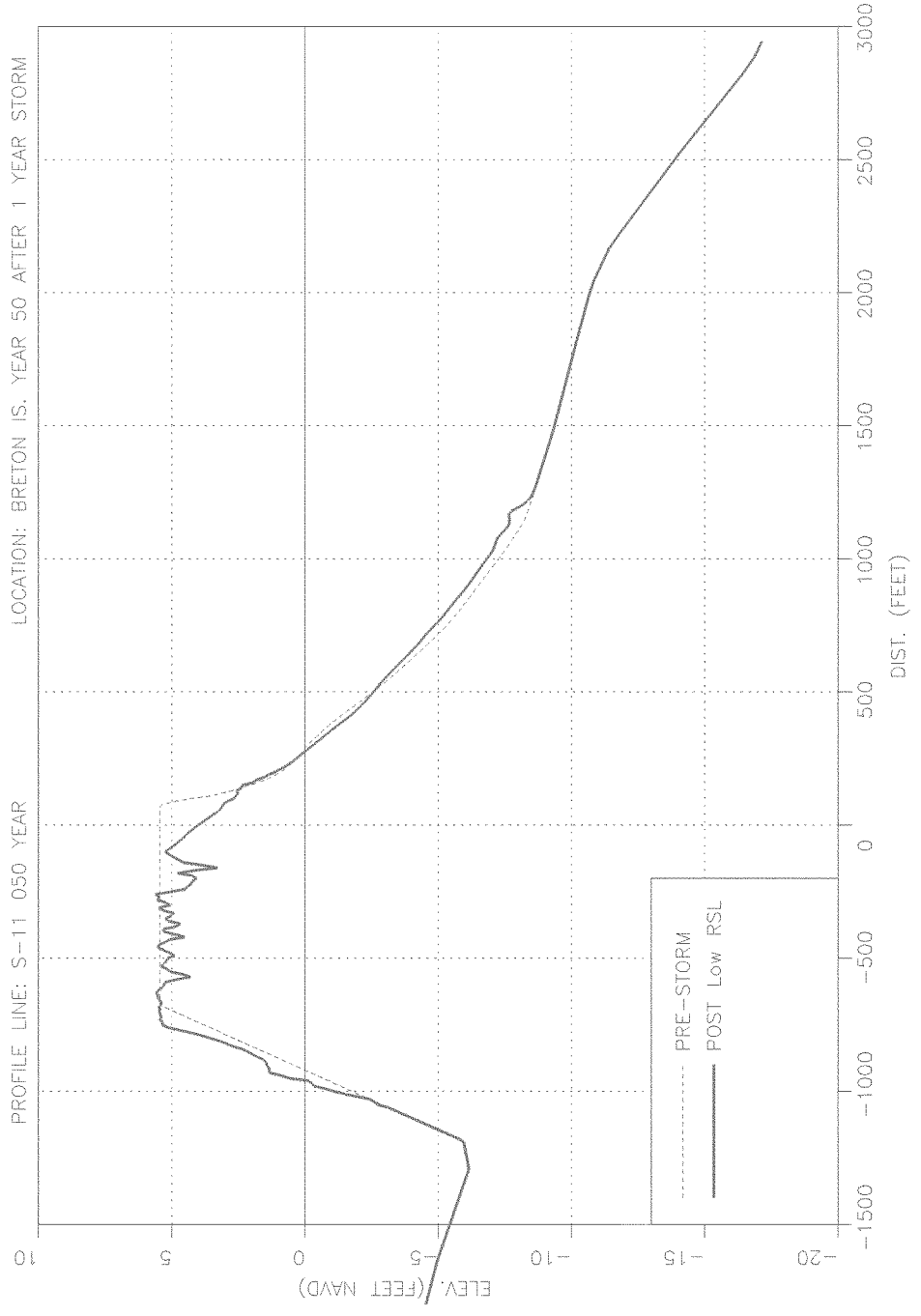

PROFILE LINE: S-11 010 YEAR
LOCATION: BRETON IS. YEAR 50 AFTER 1 YEAR STORM
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Med RSL
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

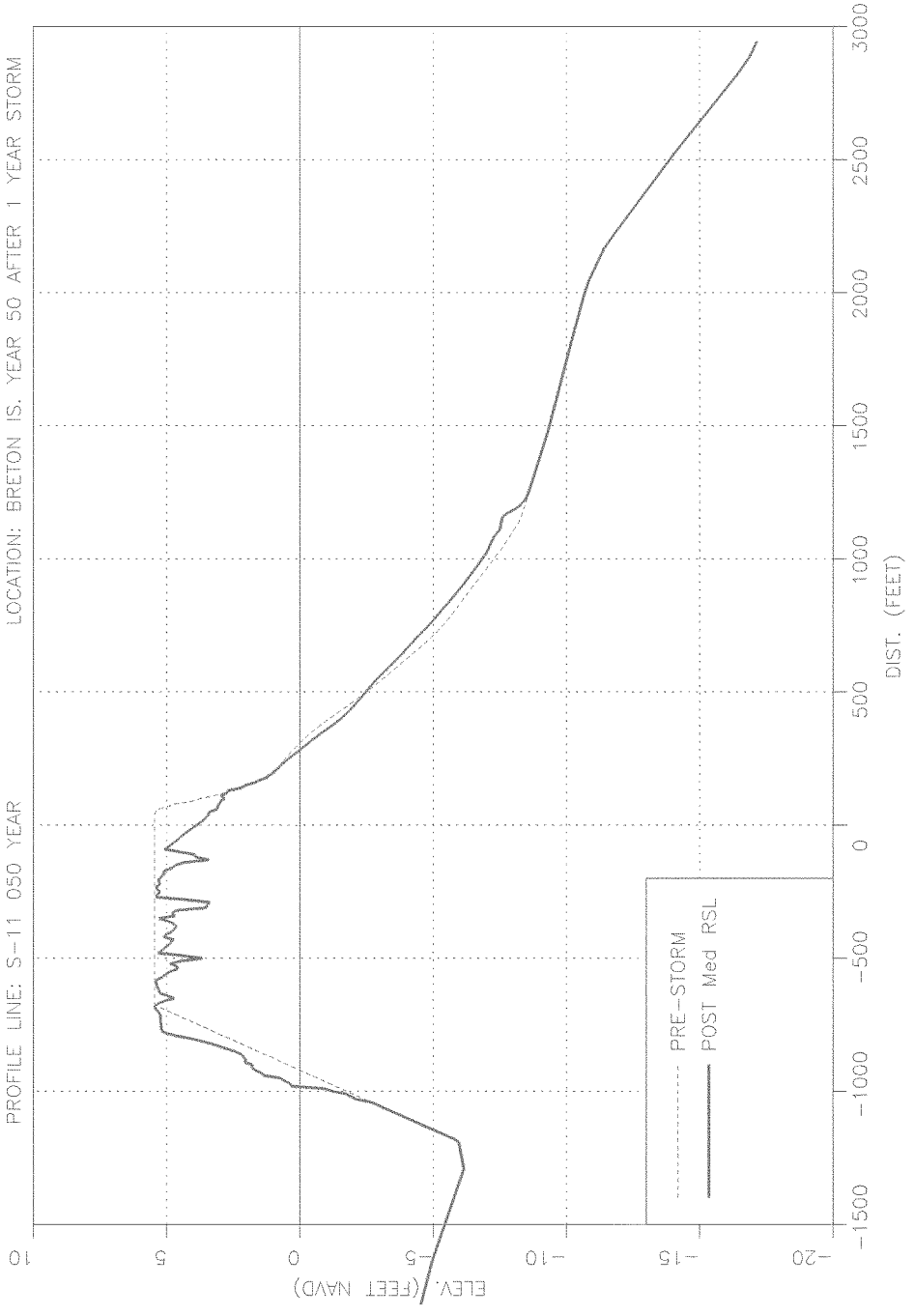

PROFILE LINE: S-11 010 YEAR
LOCATION: BRETON IS. YEAR 50 AFTER 1 YEAR STORM
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST High RSL
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

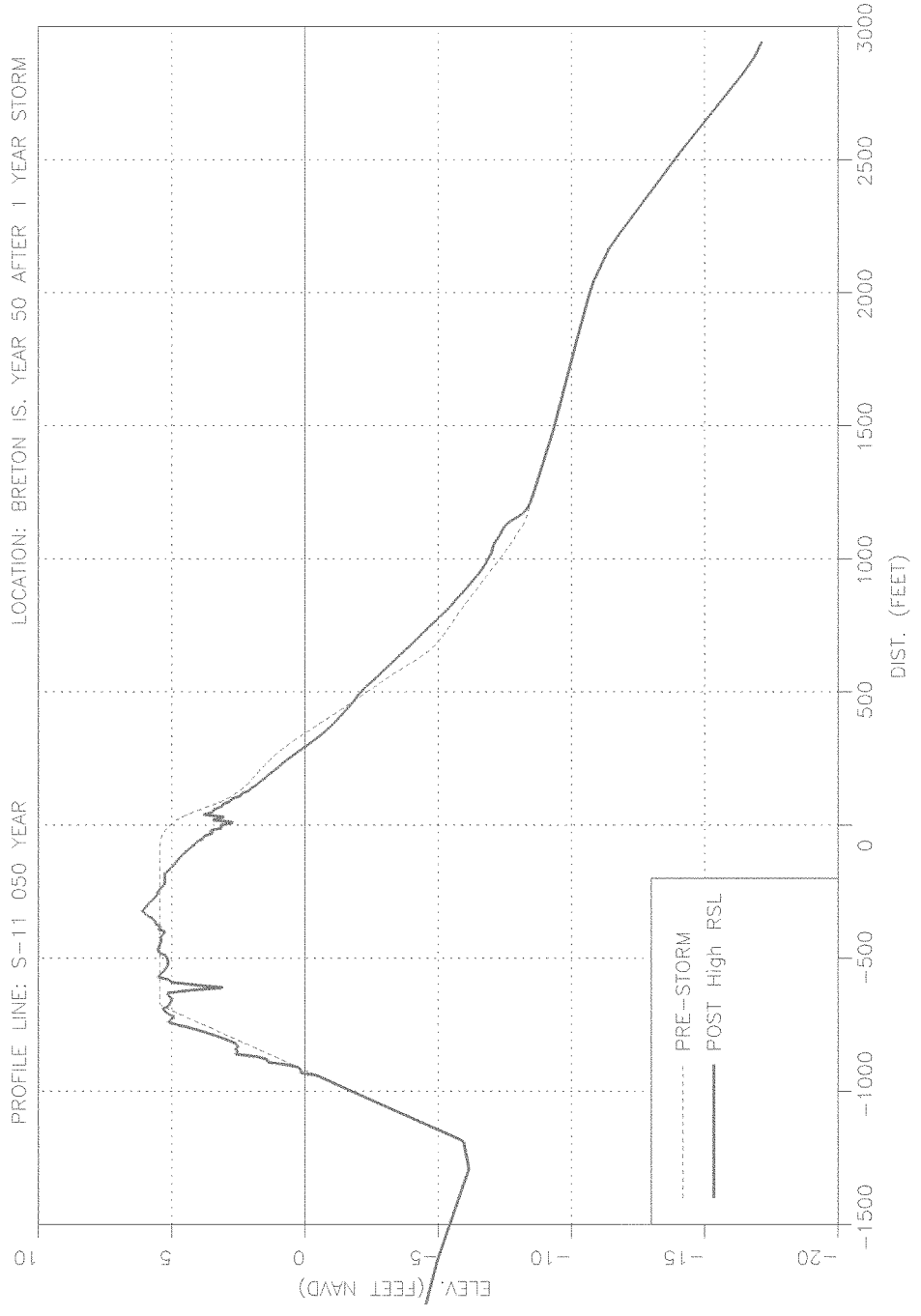

PROFILE LINE: S-11 020 YEAR
LOCATION: BRETON IS. YEAR 50 AFTER 1 YEAR STORM
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

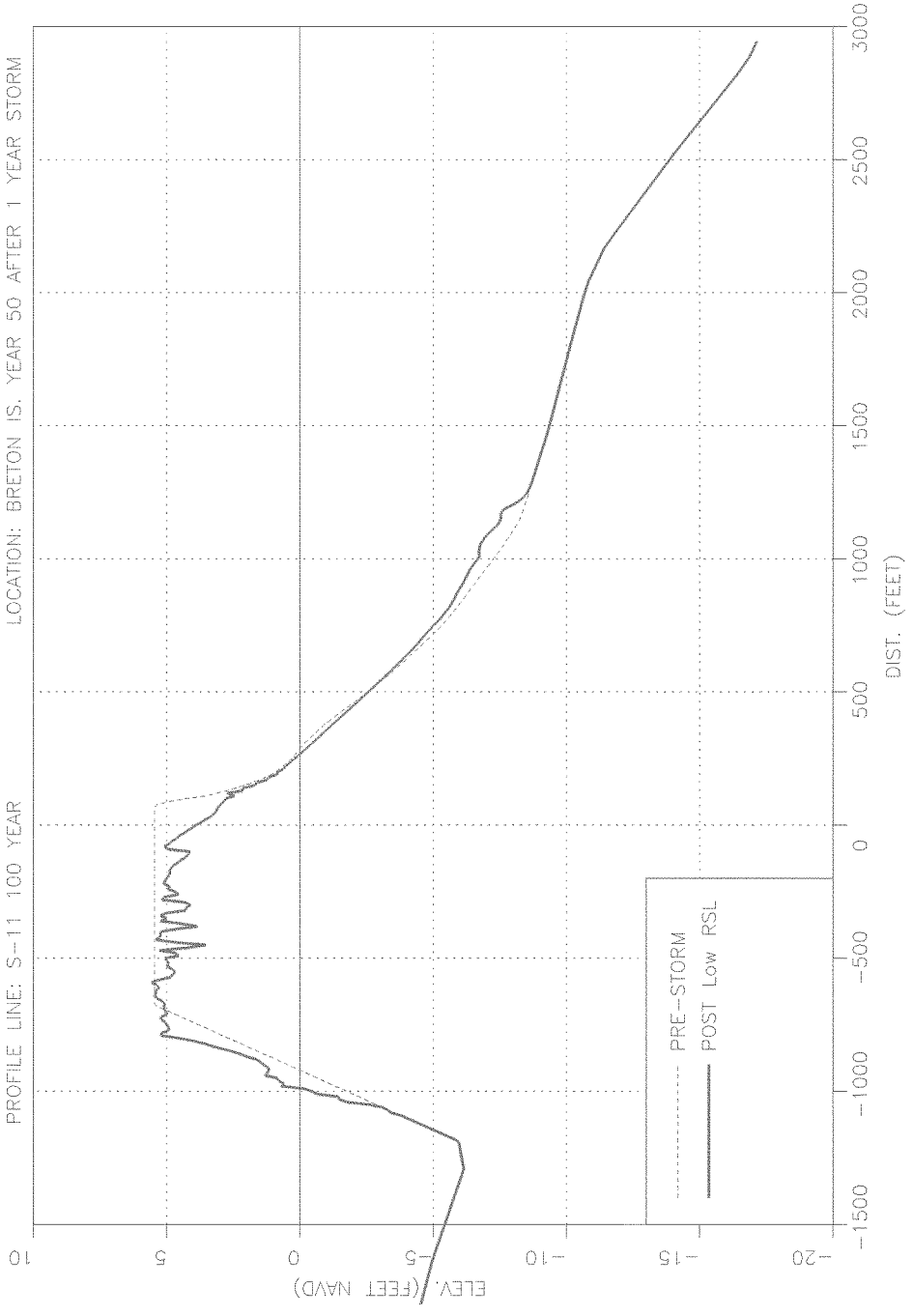

PROFILE LINE: S-11 020 YEAR
LOCATION: BRETON IS. YEAR 50 AFTER 1 YEAR STORM
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Med RSL
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

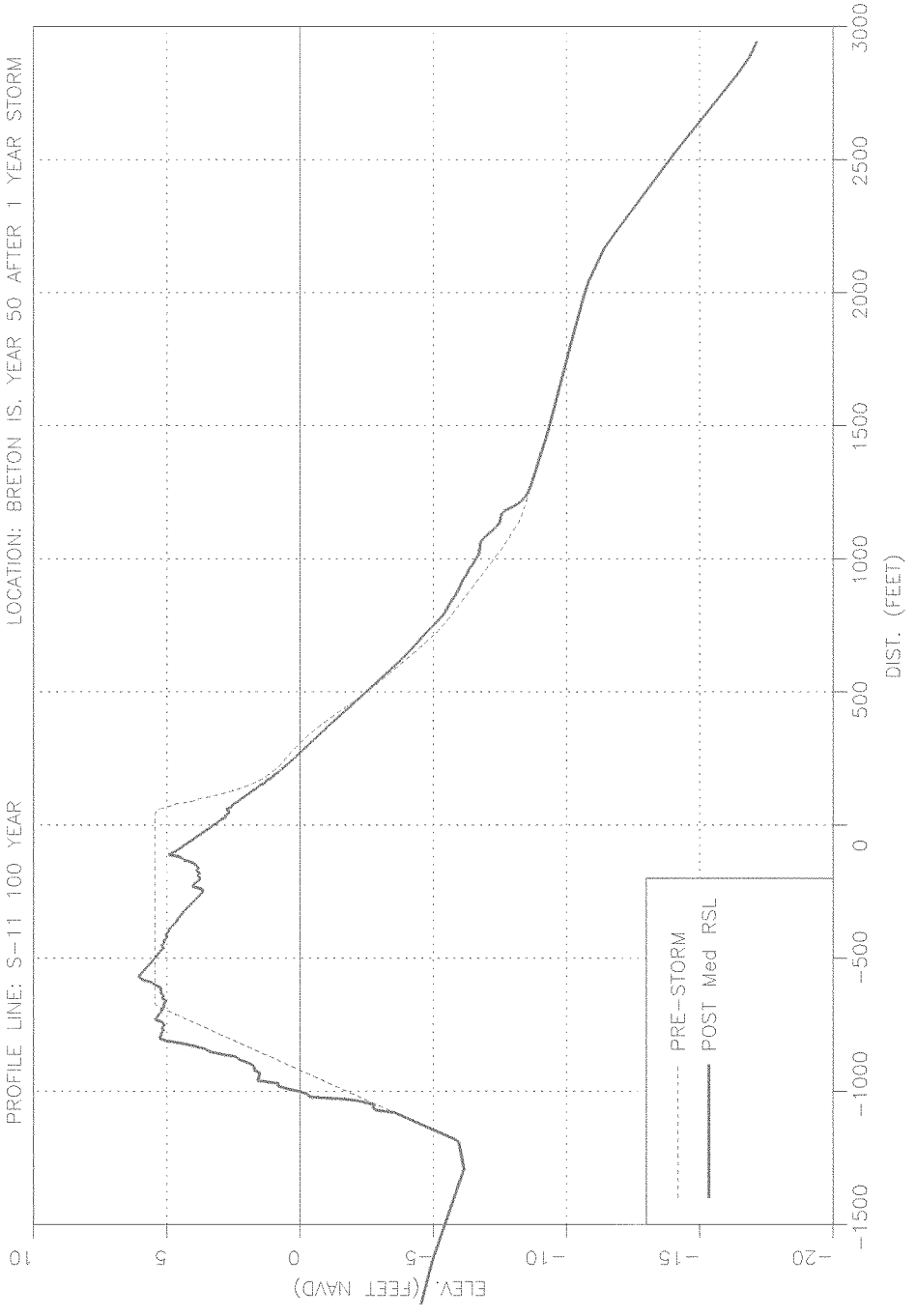

PROFILE LINE: S-11 020 YEAR
LOCATION: BRETON IS. YEAR 50 AFTER 1 YEAR STORM
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST High RSL
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000


PROFILE LINE: S-11 050 YEAR
LOCATION: BRETON IS. YEAR 50 AFTER 1 YEAR STORM
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000


PROFILE LINE: S-11 050 YEAR
LOCATION: BRETON IS. YEAR 50 AFTER 1 YEAR STORM
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Med RSL
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000


PROFILE LINE: S-11 050 YEAR
LOCATION: BRETON IS. YEAR 50 AFTER 1 YEAR STORM
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST High RSL
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000


PROFILE LINE: S-11 100 YEAR
LOCATION: BRETON IS. YEAR 50 AFTER 1 YEAR STORM
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Low RSL
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000


PROFILE LINE: S-11 100 YEAR
LOCATION: BRETON IS. YEAR 50 AFTER 1 YEAR STORM
ELEV. (FEET NAVD)
DIST. (FEET)
PRE-STORM
POST Med RSL
10
5
0
-5
-10
-15
-20
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000

FOR CONTINUATION OF HOUSE DOCUMENT 113-78

MRGO ECOSYSTEM RESTORATION PLAN
FEASIBILITY STUDY

SEE PART 4