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FEASIBILITY STUDY OF REAL-TIME REMOTE MONITORING OF STORM AND HURRICANE CONDITIONS AT COASTAL IMPACT

by

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FOREWORD

This work presents an investigation into the basic requirements (e.g., basic equipment and costs) for an array of mobile remote sensing packages which, upon hurricane approach, can be towed to the coast, installed, activated and abandoned in advance of hurricane impact. The remote coastal sensing packages will record hurricane impact forces (i.e., wind, storm surge and waves) and coastal response (i.e., erosion and structural damage) elements.

This report constitutes fulfillment of obligations with the Federal Coastal Zone Management Program (Coastal Zone Management Act of 1972, as amended) through the Florida Office of Coastal Management subject to provisions of contract CM-37 entitled "Hurricane Emergency -- Remote Monitoring Information Tracking (HERMIT)".

A portion of CM-37 was subcontracted (DNR contract C0036) to the Beaches and Shores Resource Center, Institute of Science and Public Affairs, Florida State University, which retained a consultant (Florida Engineering Services Corporation) to conduct the equipment research and provide cost recommendations thereto.

At the time of submission for contractural compliance, James H. Balsillie was the contract manager and Administrator of the Analysis/Research Section, Hal N. Bean was Chief of the Bureau of Coastal Data Acquisition, Deborah E. Flack Director of the Divsion of Beaches and Shores, and Dr. Elton J. Gissendanner the Executive Director of the Florida Department of Natural Resources.

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ABSTRACT

This work presents an investigation into the basic requirements (e.g., equipment and costs) for an array of mobile remote sensing packages which, upon hurricane or storm approach can be towed to the coast, installed, activated and abandoned in advance of impact of the event. These remote coastal sensing packages will record hurricane impact forces (i.e., wind, storm surge and waves) and coastal response (i.e., erosion and structural damage) elements.

INTRODUCTION

Regarding the impact and damage potential of storms and hurricanes, coastal Florida is unique. First, it has by far the longest habitable coastline of any U. S. state. Comparison of the number of barrier islands and ocean-fronting beach lengths for the Atlantic and Gulf states, alone, illustrates the status of Florida's coast (Figure 1).

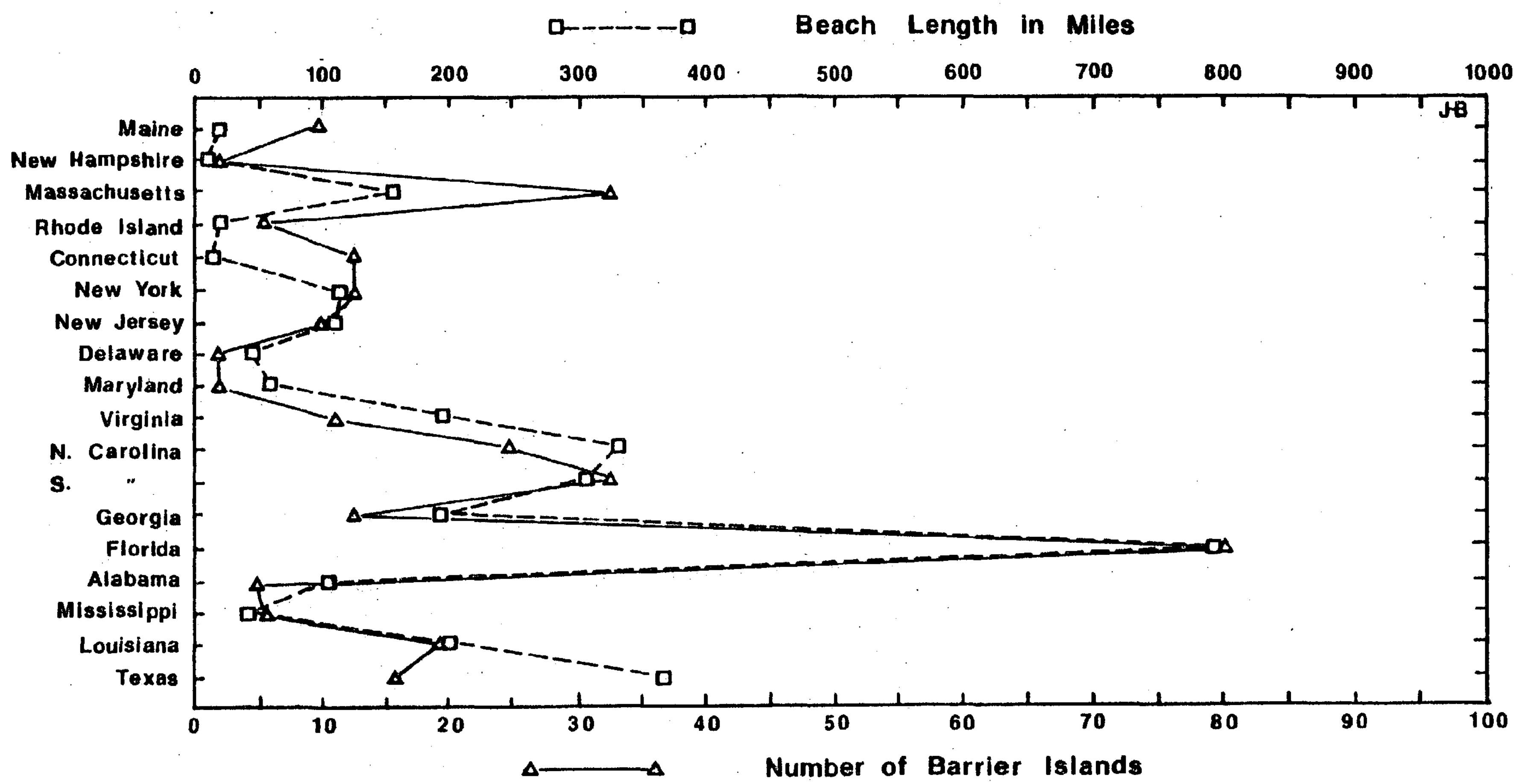


Figure 1. Comparison of beach lengths and number of barrier islands (i.e., coastal barriers) of states on the Atlantic Ocean and Gulf of Mexico (data from the U. S. Department of the Interior, 1979).

Second, its geographic setting and physiography renders Florida particularly susceptable to impact from tropical and subtropical climatological events. Disturbances which are generated in tropical latitudes of the mid-north Atlantic invariably propagate to the west and northwest, those generated in the Caribbean commonly travel to the north, and those generated in the Gulf of Mexico travel, a good share of the time, to the east and northeast (see the cyclone track history compiled by Neumann, et al. 1978). Because of Florida's north-south peninsular and low-lying physiography, these scenarios certainly render Florida vulnerable to extreme climatic conditions.

Historical data (e.g., Bruun, et al. 1962; Dunn, et al. 1967; Ho, Schwert and Goodyear, 1975; Neumann, 1978; Schwert, Ho and Watkins, 1979) indicate that on the average two tropical storms strike coastal Florida each year, with one of the storms reaching hurricane status. Damages from Florida hurricanes assessed in terms of monetary loss and loss of life, are listed in Table 1. It is reported (Rubin, 1979) that "... recent studies ... call attention to the growing potential damage we face from hurricanes, which may soon surpass floods as the greatest hazard in the United States ... destruction of buildings by hurricanes is expected to grow from today's almost $2 billion to about $5 billion constant dollars by year 2000. This is largely due to population growth and movement, coastal development and higher construction values."

There have been many hurricanes which have closely approached coastal Florida but have remained offshore

Table 1. Damage and Fatalities in Florida from Hurricanes.

Year	Fatalities	Dollar Damage
1926	243	115,495,000
1928	1,838	26,235,000
1929	3	821,000
1930	0	75,000
1932	1	150,000
1933	2	4,120,000
1935	405	11,500,000
1936	7	200,000
1937	15	5,000
1939	1	52,000
1941	6	690,000
1944	18	60,000,000
1945	4	54,130,000
1946	0	7,200,000
1947	17	51,900,000
1948	3	17,500,000
1949	2	45,000,000
1950	6	31,600,000
1951	0	2,000,000
1953	0	4,952,000
1956	7	7,299,605
1957	5	75,000
1958	0	(minor)
1959	0	1,656,000
1960	13	305,050,000
1963	1	50,000
1964	11	362,000,000
1965	13	139,300,000
1966	9	15,000,000
1968	9	6,650,000
1972	9	41,000,000
1975	2	100,000,000
1979	3	64,000,000
TOTAL	33	
AVG DAMAGE/EVENT		$44,718,352

Data from Dunn, et al. 1967; U. S. Department of Commerce, 1977; 1979 data are estimates from Daniel Trescott (personal communication, Division of Emergency Management, Florida Department of Community Affairs).

(e.g., Hurricane David of September 1979 along the east coast of Florida) or which have impacted relatively undeveloped coastal areas. If fact, it may be that no truly serious hurricane impact event has occurred since the great hurricane of 1928 which struck Miami, resulting in 1838 fatalities. In 1928, greater Miami had a population of about 120,000. What might one expect if another "1928 hurricane" were to impact Miami today with its population of 1.5 million?

A cumulative frequency plot of hurricanes striking Florida during the period 1885-1983 is given in Figure 2. It appears that from 1885 to about 1950, the data of Figure 2 can be represented by the solid line. Since 1950, it appears that hurricane incidence has substantially declined, as suggested by the dashed line. Based on the longer record one can not, however, assume that such a lull will continue as a new trend. When dealing with the significant population growth in Florida (Figure 3), one feels compelled to anticipate the complacency prevailing among a population of which only a minority has experienced the effects of hurricane impact. Mosely and Davenport (1978) state "... unless human preparation for, and reaction to hurricanes is considered more carefully, and, subsequently, redirected on both government and individual levels, then the catastrophe potential will continue to increase as coastal population grows."

The hurricane is not the "unheralded killer" it once was due to increased technologies which allow the detection of such events, measurement of their intensity and direction of travel, and the capability to forewarn the public. This is

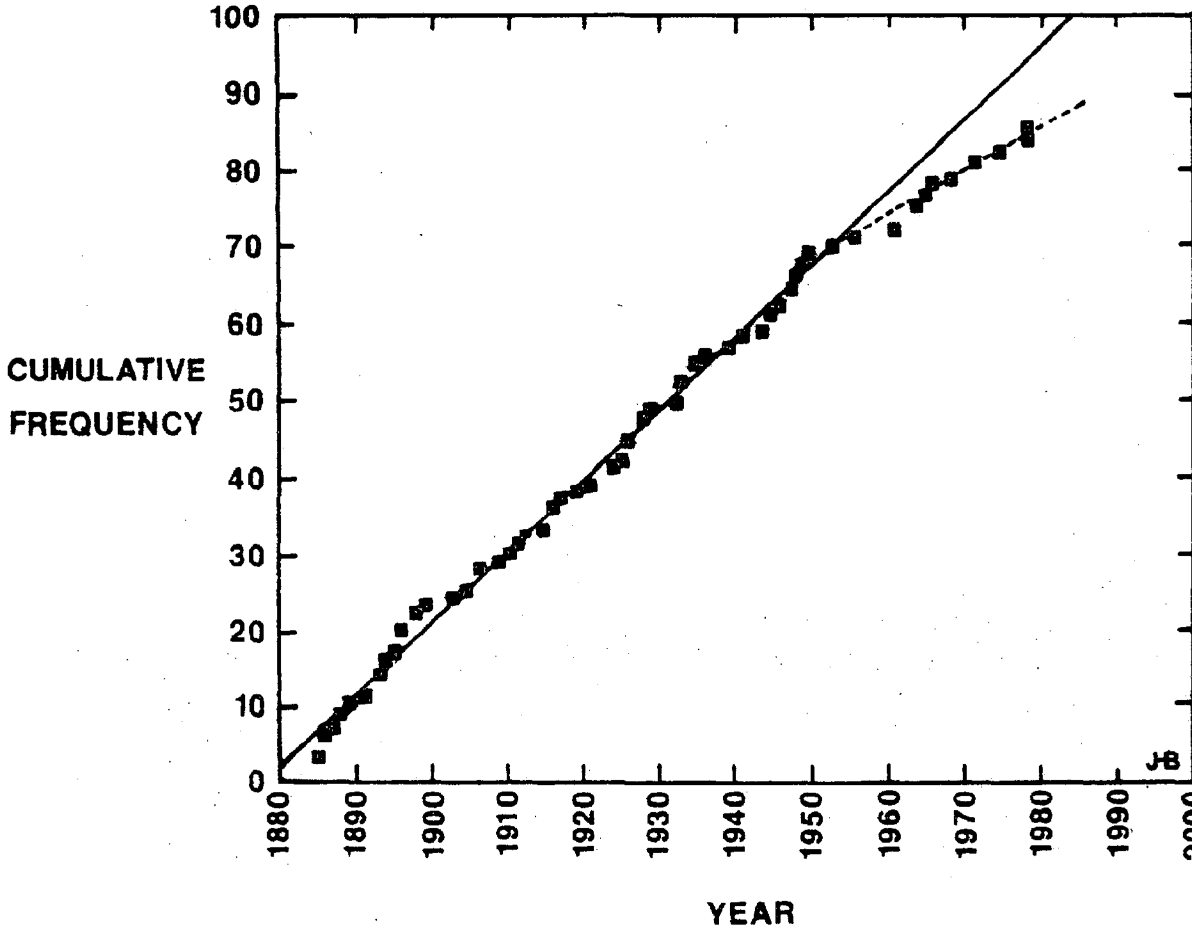


Figure 2. Frequency trend for hurricanes impacting Florida (after Balsillie, 1978).

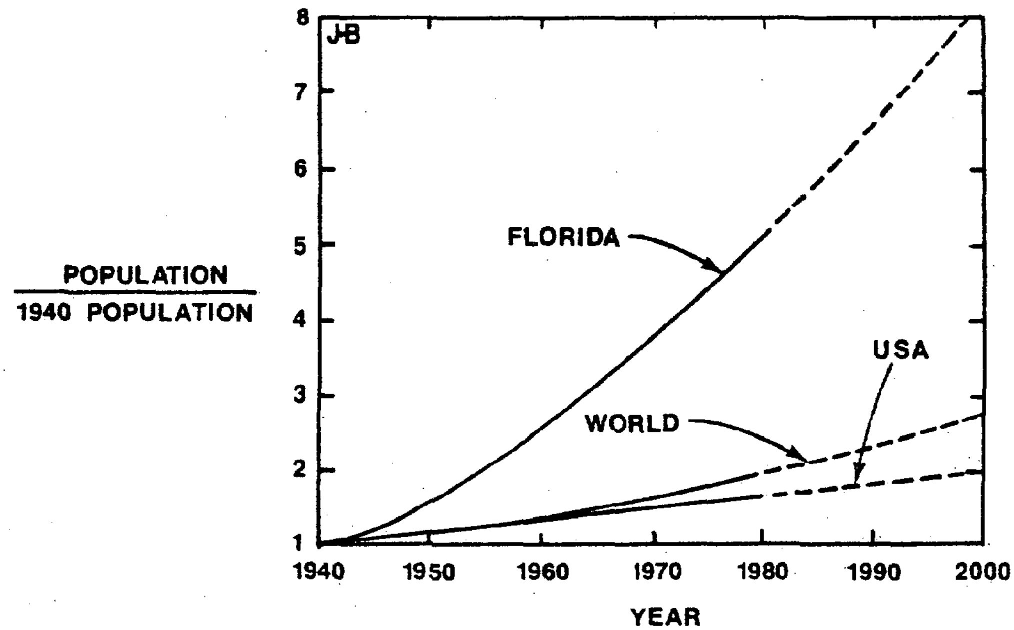


Figure 3. Comparison of Florida, world and U. S. population increases (Florida data from Fernald, 1981; U. S. and world data from Dolmatch, 1979).

not to say, however, that additional work is not needed. For instance, Baker (1980) states:

> Twenty-four hours before expected landfall of a hurricane, approximately 300 miles of coastline will be placed under a warning (the average 24-hour forecast error being 100 miles). Except in very rare storms, the eventual major damage will be confined to an area little more than 50 miles in width. Thus, the imprecision of forecasting technology presents a response problem for the public and for local officials alike.

An underlying theme of many such studies and reports is that we must be able to forecast the behavior of hurricanes as they move from deep water, across the continental shelf, and onto the coast. To a large extent, however, perhaps the basic problem and alternatives toward its solution are being overlooked. THE FUNDAMENTAL ISSUE IS, IN FACT, THAT WE ARE VITALLY INTERESTED IN PREDICTING HOW A HURRICANE WITH GIVEN CHARACTERISTICS WILL, UPON LANDFALL, AFFECT A COAST WITH GIVEN CHARACTERISTICS. The obvious answer is to measure conditions at the coast proper. Force and response elements of extreme event impact at the coast that need to be measured are illustrated in Figure 4. Forces include the wind, storm surge, and waves; responses include vertical and horizontal recession of the nearshore, beach and coast, and structural damages.

Hurricane wind field prediction has been a subject of considerable past research, and is well established. The same has not been true of hydraulic elements. In recent years, however, significant advancements have been made in hydraulic prediction. Storm surge (i.e., the significant rise in the

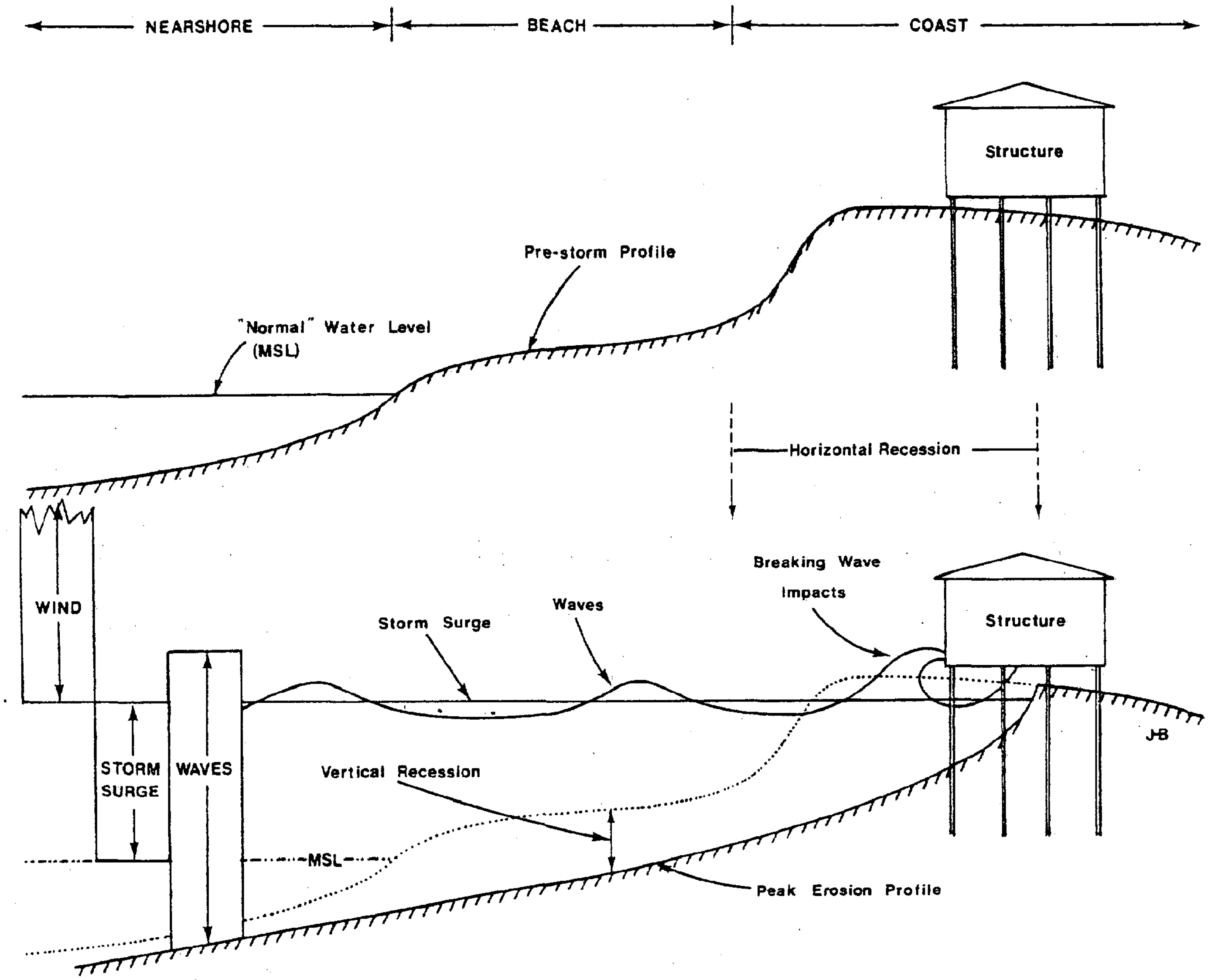


Figure 4. Illustration of forces and response elements due to storm/hurricane coastal impact (after Balsillie, 1978).

water level surface accompanying a storm or hurricane) has been subject to considerable controversy (e.g., U. S. Water Resources Council, 1980; U. S. Army, 1980; National Research Council, 1983). The Florida Department of Natural Resources, Division of Beaches and Shores, however, has adopted a new storm surge numerical computer model (Dean and Chiu, 1981a, 1981b, 1982a, 1982b, 1983, 1984). In addition to flooding, a major importance of the storm surge is that it constitutes a superelevated surface upon which storm-generated waves propagate, allowing the waves to impact the coast at elevations not normally attained. Response of the topography to these forces is erosion. Erosion computer models have been proposed (e.g., Kriebel, 1982, 1984; Dean, 1983; Kriebel and Dean, 1984a, 1984b) which are primarily based on consideration of the storm surge. Incorporating shore-breaking wave dynamics, Balsillie (1984) has developed the Multiple Shore-breaking Wave Transformation model, which not only considers the storm surge but allows for the prediction of coastal wave impacts. While such modeling efforts are based on state-of-the-art information, the best data currently available from which to calibrate models are from actual measurements of pre- and post-storm profile conditions. In fact, the most comprehensive set of data for such calibration has been measured by the Division of Beaches and Shores for Hurricane Eloise which struck the panhandle coast of Florida in September of 1975 (Chiu, 1977; Balsillie, 1983). It is difficult, however, to calibrate a model on a single set of data. Rather, it is desirable that measurements be made for many hurricanes and storms of varying magnitudes and characteristics.

An additional, major advantage to direct observation of hurricane and storm impact at the coast is that, if conducted in real time, emergency operations personnel have immediately available information of conditions at the coast. Such information would be a valuable asset in management decision-making processes related to responsibilities of emergency management operations.

The purpose of this work is, therefore, to investigate assembling stand-alone and communcating sensing packages for remote monitoring of beach and coast response to storm and hurricane impact. As a hurricane is tracked, forecasting prognostications can identify the general coastal segment that will be affected by the event (Baker, 1980) 12 to 24 hours in advance of impact. The concept is to construct several mobile packages (i.e., assembled on trailers) which, in advance of impact in accordance with provisions of the Shoreline Emergency Reaction Function (SERF) of the Florida Department of Natural Resources, Division of Beaches and Shores, can be towed to coastal sites, installed and left. The reason for multiple sensing packages is illustrated with the aid of Figure 5. The hurricane or tropical cyclone is circular in shape (inset A of Figure 5). The strength of forces increases from the periphery of the storm toward the eye; inset B of Figure 5 illustrates, for instance, how the wind speed increases. Similar trends are to be expected for the storm surge and the wind-generated waves traveling on top of the surge. In order

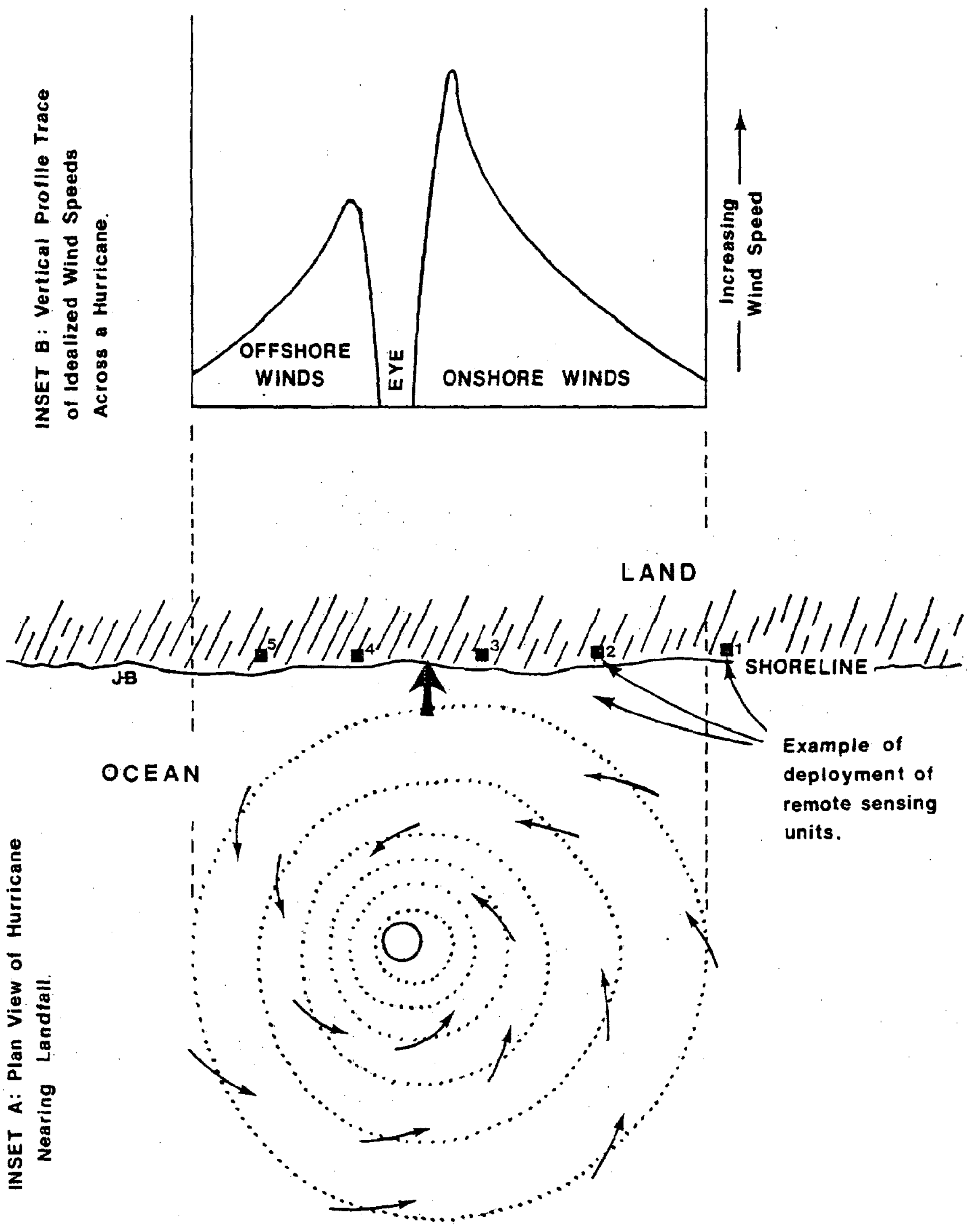


Figure 5. Example of a hurricane approaching landfall in terms of the hurricane wind field (after Balsillie, 1978) and deployment of remote sensing packages. For inset A the bold arrow indicates direction of hurricane travel, small arrow indicate wind direction, dotted lines are lines of equal atmospheric pressure.

to adequately monitor and describe the event, several remote sensing packages would require deployment. An example of such deployment is illustrated in the Figure, in which probable alongshore spacing of the remote packages would be from 15-30 miles. This, then, would allow for obtention of data on forces across the hurricane wind field, which at present are virtually non-existent. Each package should have the capability to be interegated from an inland monitoring site location such as a state emergency operations center (EOC), and to be able to record data on site should communications fail so that data losses are minimized for later analysis. The program must be designed to anticipate that partial equipment loss or damage that might occur, which will affect the feasibility of such a program. Specific tasks of this study are:

1. Survey existing monitoring programs which may augment the existing proposal,
2. Identify equipment requirements, sources and costs for measurement of wind, wave and storm surge forces at remote sites during hurricane impact for real-time transmission to an emergency operations center (EOC).
3. Identify software requirements to support hardware, for realizing data retrieval and analysis, and
4. Prepare a plan of operation.

EXISTING MONITORING PROGRAMS

The National Hurricane Center in Coral Gables, Florida, has for many years been involved with tracking tropical cyclones and hurricanes, through the use of hurricane through-flights and, more recently, using satellite technology. As necessary as this work is, it is considered as a program separate from the goals of the present work since, here, we are interested in impact of the hurricane at the coast proper.

A survey of existing monitoring programs has revealed two systems with possible significant bearing upon the proposal. These are the National Ocean Service's (NOS) primary tide station network and the University of Florida's wave monitoring network.

The first, consists of a series of tide level monitoring stations along the coastal Florida. The location of these stations is illustrated in Figure 6. Each station consists of an analog-to-digital tide gauge which records the water level at six-minute intervals. A backup "bubler" type gauge is also installed at each site. These gauges are installed as "on site" recording stations as opposed to real-time reporting capability. However, one station (Miami Beach) is configured to transmit data at hourly intervals via phone line, to NOS headquarters in Rockville, Maryland. In addition, six of the stations are linked by dedicated phone line to a recorder at the local National Weather Service office.

The second program consists of nine real-time wave recorders operated by the University of Florida, Department of Oceanographic Engineering, called the Florida Coastal Data

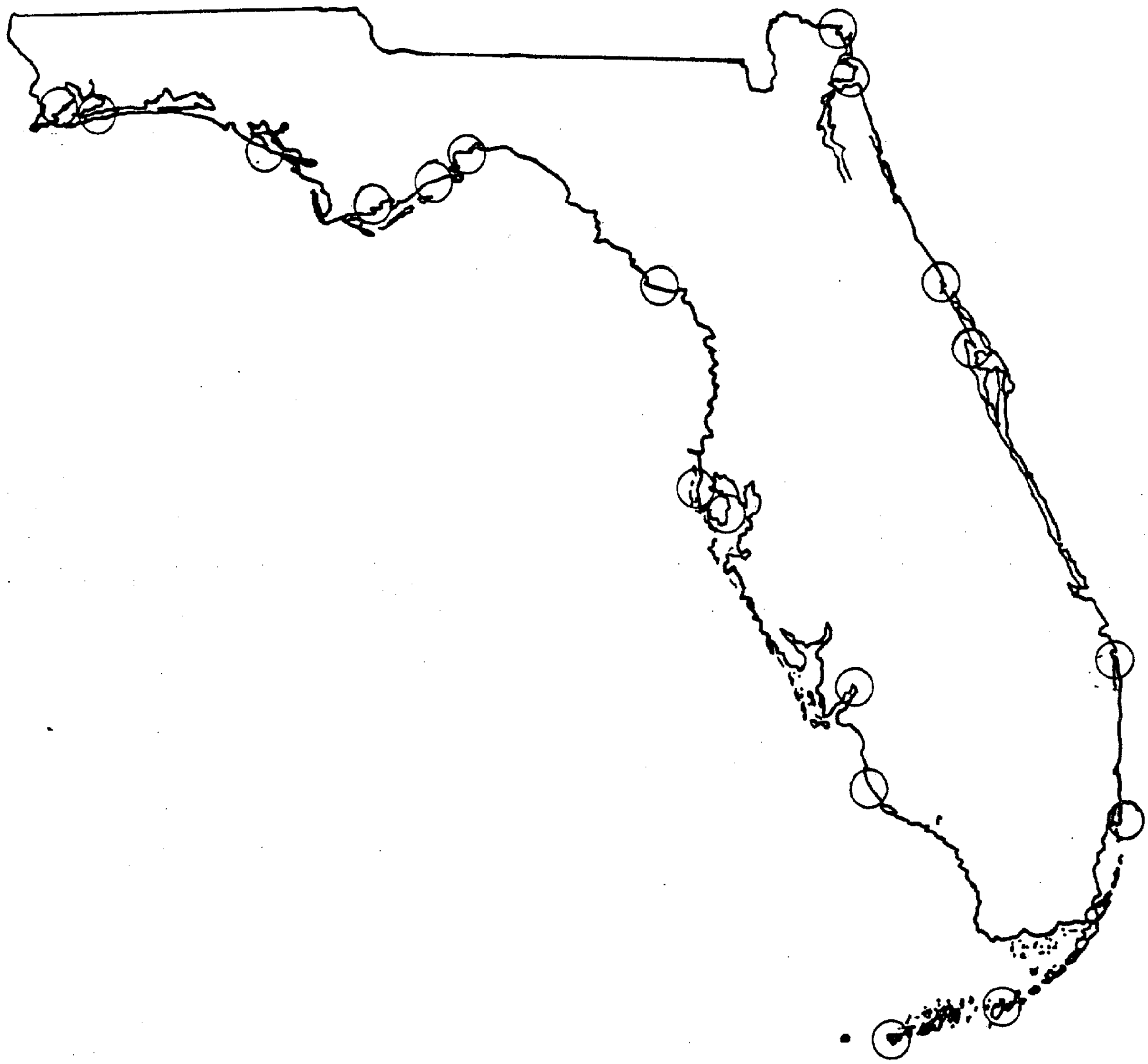


Figure 6. Location of potentially useful National Ocean Service (NOS) tide gauging stations.

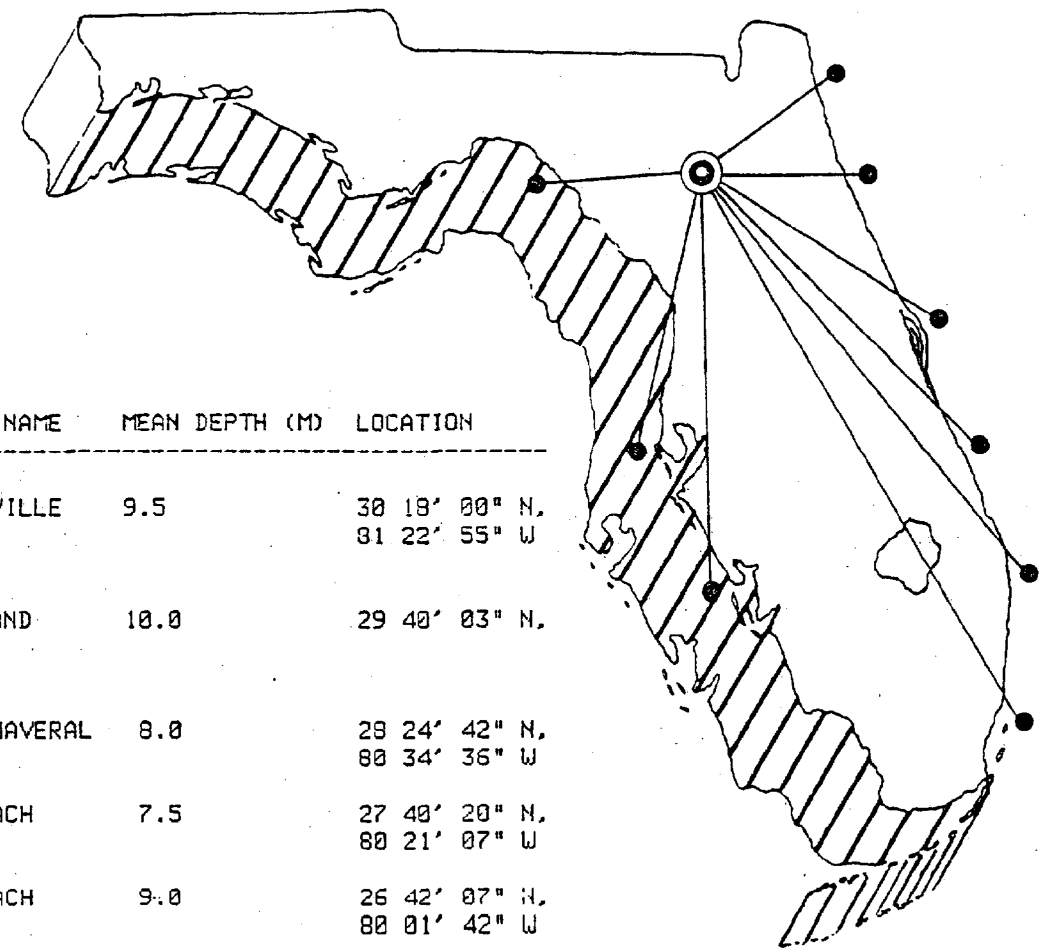
Network (Howell, 1980; Wang, 1982). The location of wave gauges is given in Figure 7.

Neither of these programs will completely satisfy the needs of the coastal impact monitoring system, since the tide gauges monitor only one parameter at fixed locations, and the wave gauges are located offshore (in approximately 30 feet of water) at fixed sites. Therefore, they may not necessarily provide data reflecting impact conditions of a storm. However, both systems offer the potential to provide excellent supplementary information useful towards analyzing storm impact.

For example, consider the six NOS stations with National Weather Service (NWS) hookups. Arrangements could be made with the NWS for calling the appropriate offices at hourly intervals to obtain readings from the meteorlogist on duty. This arrangement would allow real-time monitoring of water levels of the six sites, with a nominal cost outlay.

Data from the NOS telemetry station at Miami Beach may also be easily obtained. Several years ago arrangements were made by G. M. Cole for direct hourly transmission of water level data from the Miami station to the Florida Department of Natural Resources (DNR) in Tallahassee. DNR's Bureau of Survey and Mapping was provided a computer terminal and disk drive utilizing existing NOS software, allowing for data reception. Further, the NOS may be agreeable to the expansion of the system to include other tide stations in Florida..

Similarly, it should be practical to monitor the University of Florida's wave gauge system at nominal cost



STATION NAME	MEAN DEPTH (M)	LOCATION
JACKSONVILLE	9.5	30 18' 00" N. 81 22' 55" W
MARINELAND	10.0	29 40' 03" N.
CAPE CANAVERAL	8.0	28 24' 42" N. 80 34' 36" W
VERO BEACH	7.5	27 40' 20" N. 80 21' 07" W
PALM BEACH	9.0	26 42' 07" N. 80 01' 42" W
MIAMI BEACH	6.5	25 46' 06" N. 80 07' 23" W
CLEARWATER	5.0	27 58' 44" N. 82 51' 00" W
VENICE	7.2	

Figure 7. Location of wave gauges in the Florida Coastal Data Network (after University of Florida, 1984).

(note that telephone enquiry lines have been established). This could be accomplished by arranging to access that option by use of a dial up computer terminal.

Therefore, both systems offer a means of immediately obtaining desirable data with very little cost. Combined with an array of portable monitoring stations deployed along the coast, these existing programs would provide sufficient additional data for determination of detailed parameter profiles across the nearshore zone at various distances from the impact center.

EQUIPMENT SEARCH

Introduction

The following sections report on research conducted to identify equipment sources, requirements and costs for a mobile unit to allow remote monitoring of various environmental parameters during the time of hurricane impact at the coast.

To accomplish this research, contacts were made with federal agencies having contemplated systems requiring similar equipment, and with equipment manufacturers and vendors.

The equipment considerations may be divided into three general categories: 1. the communication link, 2. the sensing equipment, and 3. the receiving equipment. The report is divided to address each category, followed by comments on recommended equipment and deployment procedures.

Communication Link

Three general types of communication links were considered: 1. telephone line, 2. direct radio transmission, and 3. relay through communications satellites.

The direct radio transmission option may not be desirable due to distance constraints. Since a system is desired that can be operated anywhere in the state with real-time monitoring in Tallahassee, many areas would be beyond the limit of readily available data transmitters.

The telephone link was found to be unsatisfactory due to the possibility of loss of such communications during hurricanes, and because of problems involved in establishing a telephone hookup in the short time span available when attempting to rapidly facilitate deployment and operation.

Therefore, all equipment considered involved the use of Geostationary Operational Environmental Satellites (GOES). There is a wide range of equipment available for GOES communication linkage, with established procedures for the use of the satellites and/or the use of "down linkage" through the Wallops Island, Virginia and Suitland, Maryland facilities. The use of GOES may be arranged by formal application to the National Environmental Satellite Service. "Currently, there are two GOES satellites plus a spare in orbit at an altitude of approximately 23,000 miles. The two primary satellites provide data-collection capability for essentially all of the Western Hemisphere, excluding the polar regions. Platforms in North, Central, and South Americas; New Zealand, Australia and parts of Africa; and substantial areas of the Atlantic and Pacific Oceans can relay data through one of the two GOES satellites ... Presently, there is no charge to the user for the relay of data and its dissemination from Suitland, Maryland. Users are responsible for all data-collection hardware, communication hardware, and line costs required to retrieve data from this governmentally controlled point." (Synergetics, 1982)

To use such a system would require a data collection platform (DCP) at the remote site plus a computer terminal at the Tallahassee receiving end. The DCP collects and transmits data from various sensors.

Information was collected from three manufacturers of suitable DCPs for GOES communication. DCP prices may vary considerably depending on the various options selected. However, for estimation purposes, typical prices are given in Table 2.

Table 2. Available Data Collection Platforms (DCPs) for GOES Communication.

Description	Approx. Cost
Harder	$5,100
Suitron	$5,500
Synergetics International ...	$4,000

In addition to a purchase of a DCP, consideration may be given to the possibility of the use of one currently owned by the federal government for field evaluation of the proposed monitoring system. For example, NOAA currently has three DCPs not in use and has, unofficially, expressed a willingness to loan such equipment.

Sensing Equipment

The monitoring of at least four parameters are addressed in this project. These include water stage, wind direction and speed, and wave height and period.

Water Level Sensors

Three types of water stage sensors are available with the accuracy and resolution desired for the project. They are: 1. analog-to-digital float type gauges, 2. acoustical water level measuring devices, and 3. pressure-type sensors. Because of the possibility of inaccuracies due to extremes in atmospheric pressure and water characteristics associated with hurricanes, pressure sensor gauges are not considered for this project.

Both the float and acoustic types require the installation of a stilling well to dampen short period wave action. This is somewhat of a constraint due to the problems involved in installing a well that will withstand hurricane force wave action. The acoustic type, however, requires only a 1/2-inch diameter well and no float, and is therefore less of a problem.

Water level recorders and costs for consideration are given in Table 3.

Table 3. Available Water Level Sensors and Costs.

Description	Approx. Cost
Acoustic Type: Aquatrak (Sutron Model 1000)	$1,600
Float Type: Leupold & Stevens (Model 7001 with adapter to electronic output)	$2,600

It is noted that the Department of Natural Resources already has a considerable number of float type gauges in its inventory which may be available for such a project. For use of those gauges, only an adapter (costing approximately $600) would be required.

Wave Sensors

Three basic wave sensors for measuring wave height and period are avialable for consideration: 1. the tethered bouy, 2. the subsurface pressure sensor, and 3. the so-called "wave staff" gauge. There are certain advantages and disadvantages of each.

The buoy type is accurate because it measures at the water surface. However, it generally requires an extra radio transmission system to send data from the buoy. There is also some question as to the ability of a buoy to withstand the full impact of a hurricane.

The subsurface pressure sensor is installed on the ocean bottom away from the surf and wind, and is easily adapted to allow a cable to transmit the data to DCP. However, pressure-sensitive devices of this type cannot measure short period waves. They are sensitive to water depth changes which must be compensated, and any subsurface currents which cannot be compensated. Analysis of the pressure data can also require considerable processor resources.

The wave staff is a cable, installed vertically on a pier or piling, which detects changes in water height due to changes in the resistance of the staff. This sensor would be the easiest to install for the present application.

Units for consideration are listed in Table 4.

Table 4. Available Wave Sensors and Costs.

Description	Approx. Cost
Buoy type:	
Endeco - Type 956	$22,500
NBA - Wave Crest	$8,500
Subsurface Pressure Type:	
Endeco - Type 1002	$10,500
Sea Data - 635-11	$10,000
Grundy - Model 4600 with signal processor	$8,500
Wave Staff Type:	
Grundy - Model 9611	$8,500

Wind Sensors

A number of sensors are available for monitoring wind direction and speed. However, with one exception the investigated wind sensors are limited to wind speeds of less than approximately 50 meters per second (i.e., 97 knots or 112 mph). The exception uses a static tube device instead of the traditional cup type anemometer and can withstand speeds in excess of 103 meters per second (i.e., 200 knots or 230 mph).

Possible sensors for consideration are listed in Table 5.

Table 5. Available Wind Speed Sensors and Costs.

Description	Approx. Cost
Cup Type Anemometer:	
Aanaderra Instruments - Models 2740/2750 ...	$1,200
Grundy - Models WD717/WS717	$900
Bendix - Aerovane	$2,000
Static Tube Type:	
Rosemont	$5,000

Onsite Recording

There is envisioned the possibility of telecommunications failure between the field sensing stations and the remote monitoring station. There is, therefore, a need to be able to record data from each sensor, either simulataneously or sequentially. Based on a preliminary investigation (Table 6) such capability would involve about a $2,000 equipment outlay. Using a 3600-foot 4-track tape at a recording speed of 15/32 inches per second would provide 102.4 hours of continuous recording, or 25.6 hours of continuous 4-head recording.

Recording capability will require an additional power supply, assuming that public utilities service may not be assured. Stand-alone generator costs are also approximated in Table 6.

Table 6. Representative Cost for Onsite Recording.

Description	Approx. Cost
Tandberg TD20A-L Logging Recorder (4-track, 10.5" reel, 15/16" or 15/32" ips	$1,995
Onan K450 (450 watts, electronic starter) Gas Generator	$340

Receiving Equipment

Requirements of equipment to receive the monitoring data are nominal. They can include a micro-computer equipped with terminal emulation software, a telephone modem, some type of output device such as a printer (with plotting capability), and a disk drive or tape drive. With the current proliferation of small computers, the selection of equipment meeting these requirements is, for practical purposes, almost limitless.

Typical equipment available include the following (Table 7):

Table 7. Typical Terminal Stations and Costs.

Description	Approx. Cost
Texas Instrument Silent 700	$4,000
Hewlett Packard 85	$4,000
IBM 3279 Graphics Terminal	$3,700

It is noted that the Department of Natural Resources currently has a number of terminals suitable for use for this project.

Video Monitoring

Recent advances in video camera technology have led to discussion and consideration of installing on-site video capability. A desirable configuration would be for remotely controlled scanning of an 180-degree arc. Representative costs for video capability are listed in Table 9.

Table 9. Representative Video Equipment Costs.

Description*	Approx. Cost
Color and/or B/W Video Camera (WV-3040)	$670
AC Adapter (WV-3203)	$44
Auto Scanner, 20 - 325 (WV-7203B)	$161
Mounting Bracket (WV-7030)	$48
Remote Controlling Unit (WV-7320)	$118
1/2" Time Lapse Recorder	$2,432
Time-Date Generator	$283
TOTAL APPROXIMATE COST	$3,756

*All items are from Panasonic.

The usefulness of video monitoring and real-time recording at the coastal site will be for obtaining data on wave activity (i.e., breaker episodes, wave period and shore-breaker heights) using existing methodology (e.g,. Berg and Hawley, 1972) and determination of erosion rates (e.g., dune/bluff erosion, scour) and sediment transport behavior (e.g., overwash processes).

The camera will need to be enclosed within the water-tight remote sensing package in a manner which reduces any background reflection, but which allows for scanning capability up- and down-coast.

The capability to transmit images back to the monitoring site (i.e., state EOC) in real-time has been investigated, since such capability would have great value in the emergency management decision-making process. However, given the large amounts of information that needs to be transmitted, problems arise. The option of slow scan video teleconferencing is available (i.e., transmission and receipt of images once every 8 to 256 seconds, depending on transmission band width). About this Southworth (1978) states:

> Unfortunately, user experience, to date, is largely limited to a relatively small group which includes IBM, Satellite Business Systems, Bell Canada, NASA, the U. S. Office of Telecommunications, and a number of other government agencies. The transmission economies of still frame television make usage likely to expand rapidly in the near future, particularly as more high quality audio channels become available through satellite transmission.

While the state-of-the-art knowledge has increased since

1978 (e.g., as evidenced by the recent affordable availability of television satellite communications), experienced expertise related to the realization of such capability for the proposed system is apparently confined to a small group of technicians. From recent discussion with state officials (e.g., Messrs. Tom Brooks and Charles Townsend of the Division of Communications, Florida Department of General Services) who outlined the variety of transmitting options and technical requirements for each, it quickly became apparent that, given the present state-of-the-art, to specify a given configuration was beyond the scope of this study. Even so, it is recommended that the consideration and investigation of video image transmission not be eliminated during the design phase of an implemented project. Unfortunately, for purposes of this report it is not at this time possible to propose a general configuration and cost outlay. However, onsite video monitoring remains as a viable, recommended capability.

Recommended Equipment

Based on the preliminary analysis allowed under the scope of this study, a recommended equipme... combination is given in Table 8. It is noted that the selection of recommended equipment is somewhat subjective with the wide variety of combinations of equipment available.

Such equipment would use a GOES satellite and the National Environmental Satellite Service (NESS) down-link facilities. Data would be transmitted from the NESS Suitland, Maryland, facility to Tallahassee by dial-up telephone line link. The anticipated configuration is illustrated on Figure 8.

The total hardware cost for such a system, including waterproof packaging, masts, connecting cables (and allowing a percentage for unforeseen connections and interface costs), would range between $40,000 and $45,000.

Table 8. Approximate Cost for a Single Remote Sensing Unit.

Description	Approx. Cost
DATA SENSORS	
Water Level - Aquatrak Acoustic gauge	$1,600
Wave Height - Grundy Model 9611 wave staff	$8,500
Wind - Rosemont	$5,000
DATA COLLECTION PLATFORM	
Synergetics International	$4,000
ONSITE RECORDING	$2,000
VIDEO MONITORING	$3,756
POWER SUPPLY	$340
Approximate Total Cost	$25,196

*Receiving equipment not included ... see discussion in the section on "Plan of Operation".

Equipment Integration

At the time of implementation of this study, there was an identified need to specify how receiving equipment and computer hardware were to be interfaced. In the interim period, however, advancements have reached proportions

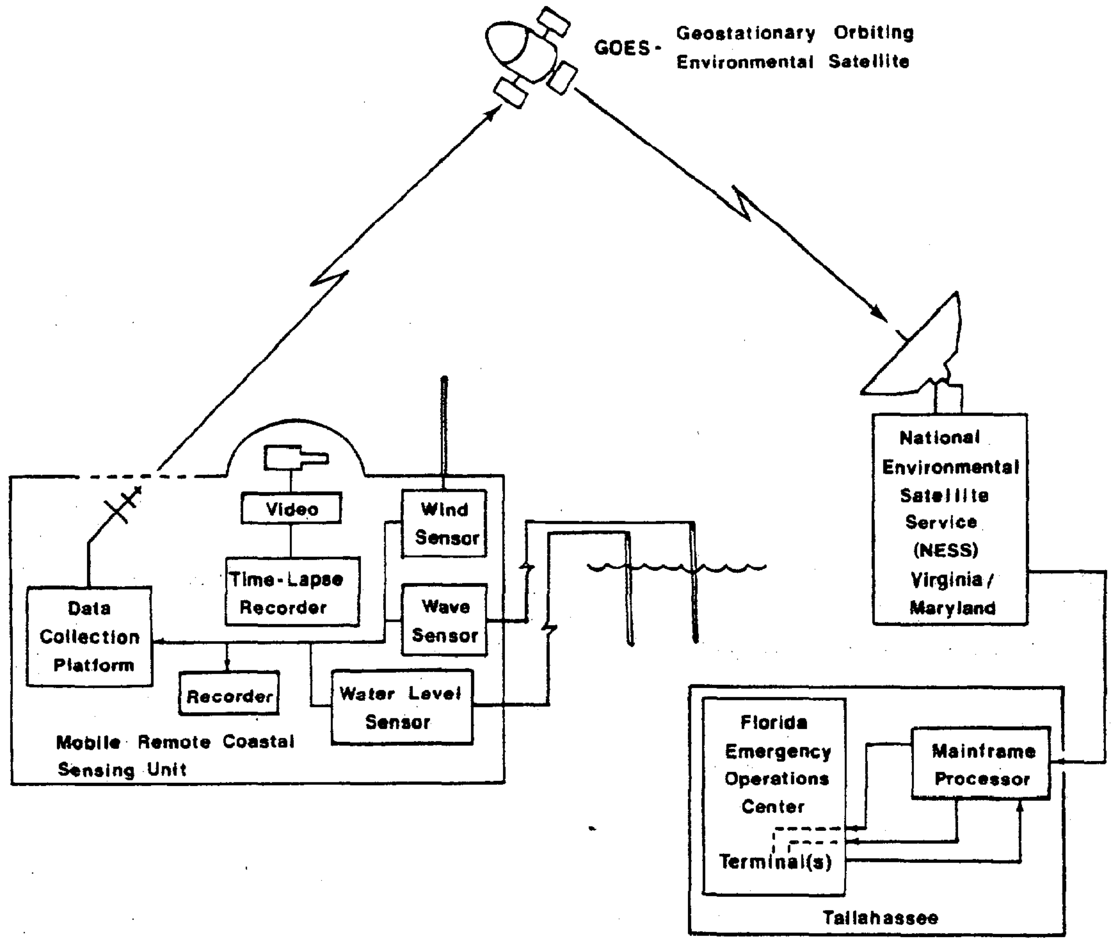


Figure 8. Proposed remote sensing unit configuration.

(e.g., note the current status of the personal computer industry) such that there would be little accomplished in such a search. Principally, with the prolific vendor-sources of hardware, firmware and software that have been developed in the past 24 months and attendant advancements, virtually any component regardless of the manufacturer can now be interfaced in some way. Further, from reports of new advancements in the making (e.g., IBM "mega-chip" research and development) there may be available, by the time the recommendations of this study are implemented, new technology significantly modifying any configuration that might currently be considered.

SOFTWARE NEEDS

Software needs for the proposed system may be categorically approached as:

1. data retrieval,
2. data reduction,
3. coastal processes simulation, and
4. records listing and graphical display.

Data Retrieval

Software needed for the retrieval of data from the remote data collection sites is standard "off-the-shelf" communications programming available at minimal cost. This software facilitates down-loading of data transmitted through the National Environmental Satellite Service (NESS) Center to the Florida terminal location. It may also be used to assimilate data from the University of Florida's wave gauging program.

Data Reduction

Retrieved raw wind, tide and wave data may all, to some extent, require reduction and additional treatment. For example, for wave data such methodology is standardized (e.g., Harris, 1972, 1974; Thompson, 1977, 1980; Howell, 1980; Wang, 1982) with software available from public domain sources (e.g., the U. S. Army Coastal Engineering Research Center, and the University of Florida). Reduction methods for tide data are available from a variety of sources (Cole, 1983).

Coastal Processes Simulation

It is suggested here that, eventually, it would be desirable to be able to predict, for a real event, probable storm surge, wind and wave impacts and coastal erosion well in advance of actual landfall of the hurricane. Such an approach would require numerical computer modeling techniques, and would serve toward calibrating numerical modeling approaches that when perfected would provide a valuable decision making tool. Input information for numerical computer simulation are characteristics of the event from through-flight and satellite monitoring by the National Hurricane Center and data collected from NWS tide gauges, CDN offshore wave gauges and the remote coastal sensing packages of this study.

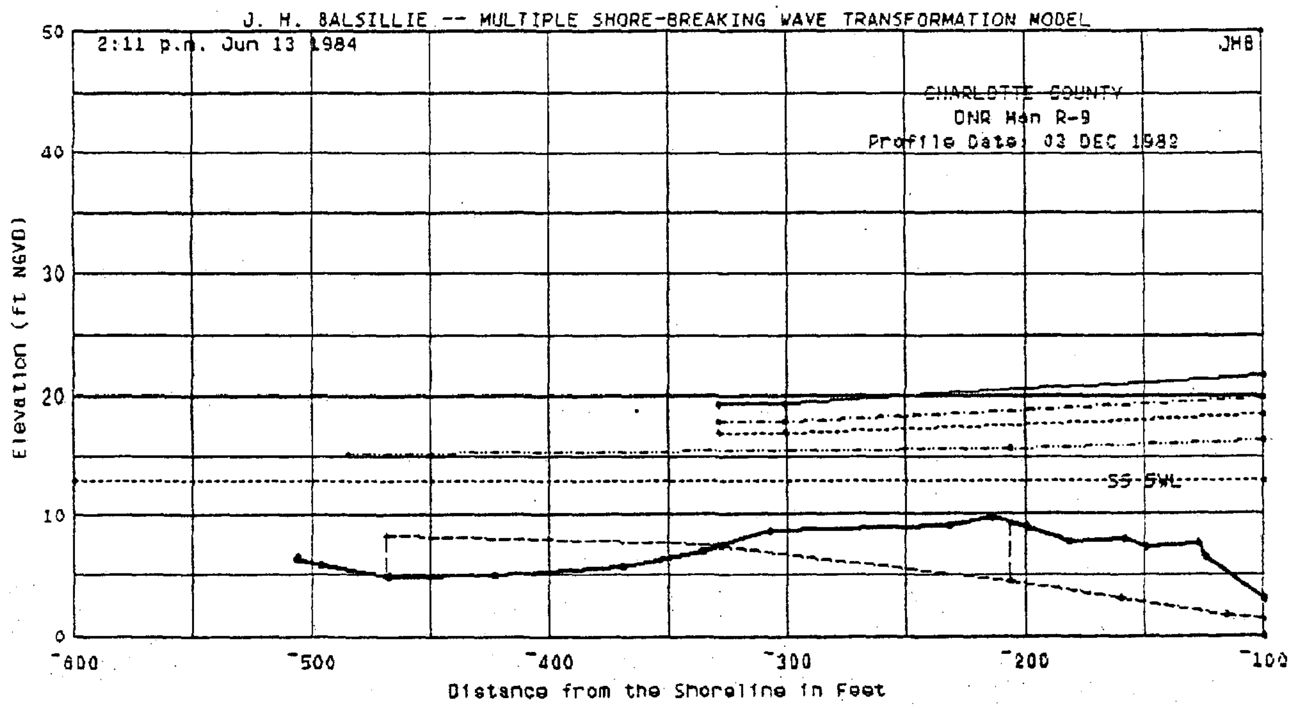
Prediction of the behavior of the coast due to storm/hurricane impact will require specialized software.

A major, necessary parameter is the storm surge. Storm surge numerical computer modeling (Dean and Chiu, 1981a, 1981b, 1982a, 1982b, 1983, 1984) now operating on DNRs NRMSS IBM 4341, requires considerable time and resources. Discussions have been held with Dr. R. G. Dean (author of the software) in which he has given assurances that it would be possible to modify the existing one-dimensional model (i.e., the simplest model) to produce more timely results. A major difficulty in using the model is the accession of bathymetric and topographic data. While the data exists on the NRMSS computer system (Beaches and Shores Data Bank), the files need to be reformatted to accomodate accessibility. Then efficient search software could be developed to rapidly obtain the needed bathymetric and topographic information for the predicted path of the storm event.

Response of the coast to storm-generated wind, wave and surge forces may be predicted using several methods (e.g., Dean, 1983; Kriebel, 1982, 1984; Balsillie, 1984). Responses include erosion (i.e., horizontal and vertical recession of the coastal topography) and potential wave impacts. Results of one of these methods are illustrated in Figure 9 (see Figure 9c for explanation of the symbols). Such software could be easily incorporated.

Records Listing and Graphical Display

Software requirements for display results are minimal. As for data retrieval, software for this function is available "off-the-shelf" or may be written by a programmer experienced in plotting (e.g., Figure 9) routines. An additional example of the type of computer generated plots



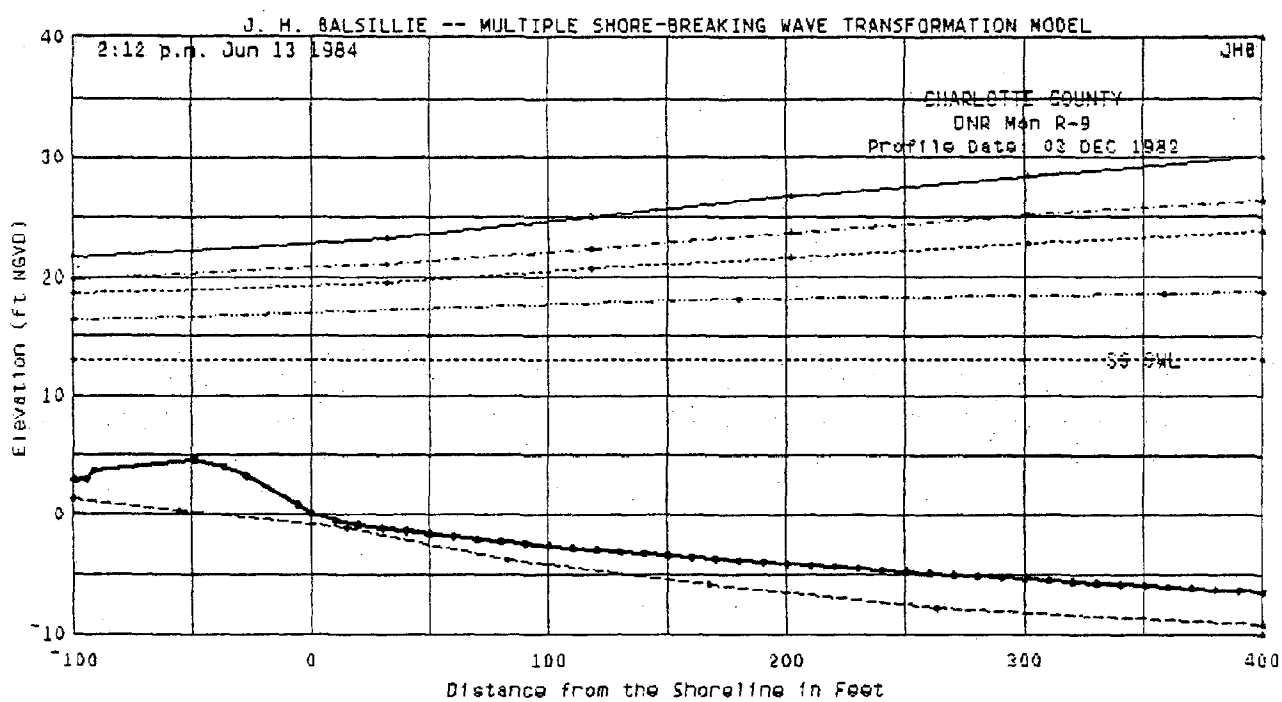
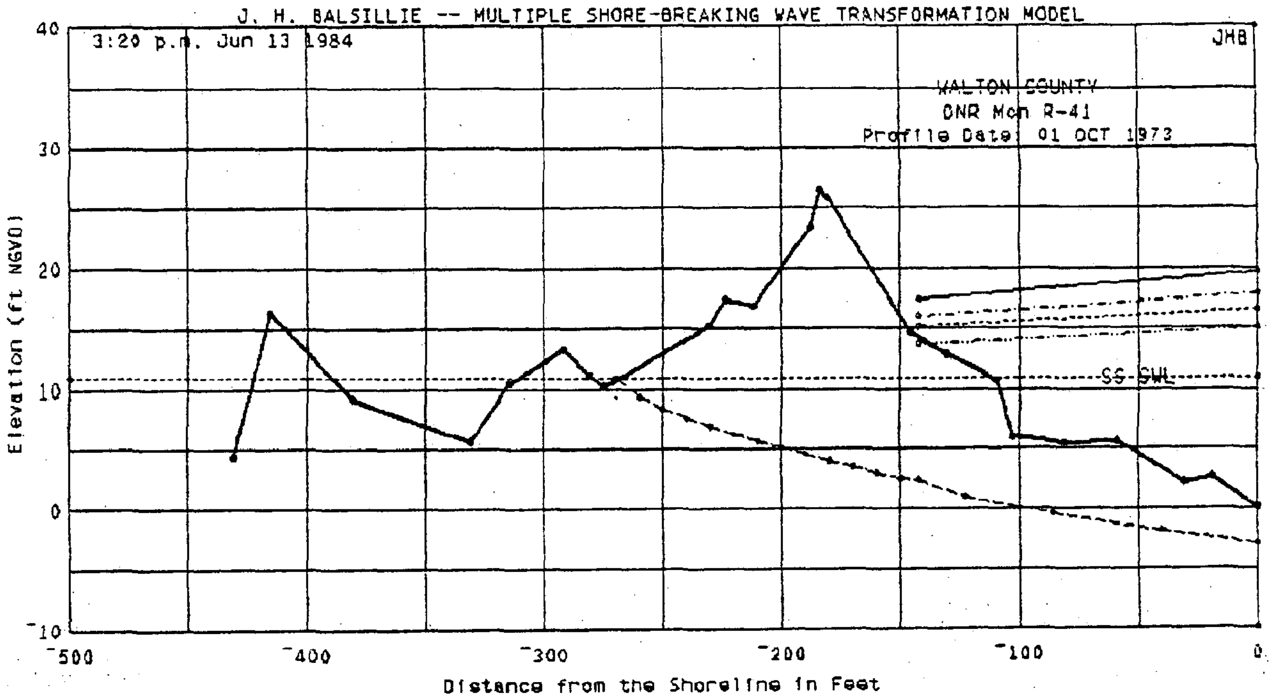


Figure 9a. Example of predicted erosion and wave impacts due to hurricane impact for a flooded profile in Charlotte County, FL from the MSBWT Computer Model (from Balsillie, 1984). Symbols are explained in Figure 9c.



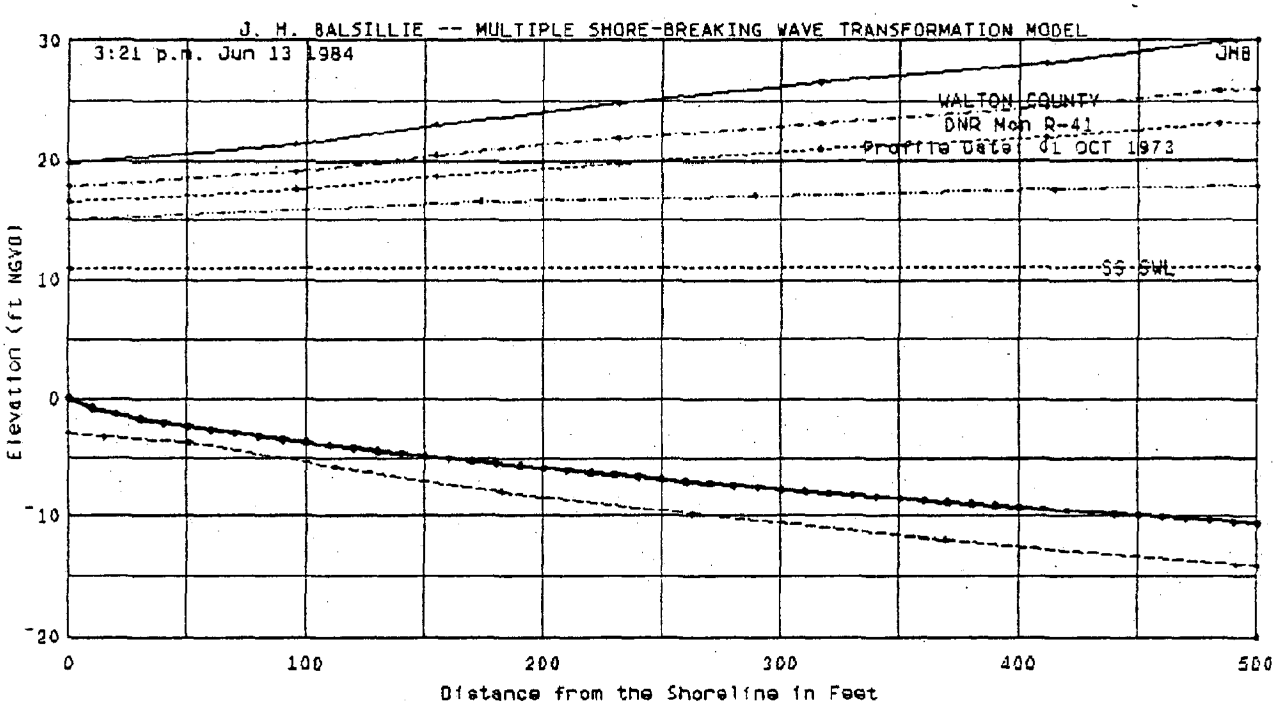


Figure 9b. Example of predicted erosion and wave impacts due to hurricane impact for a non-flooded profile in Walton County, FL from the MSBWT Computer Model (from Balsillie, 1984). Symbols are explained in Figure 9c.

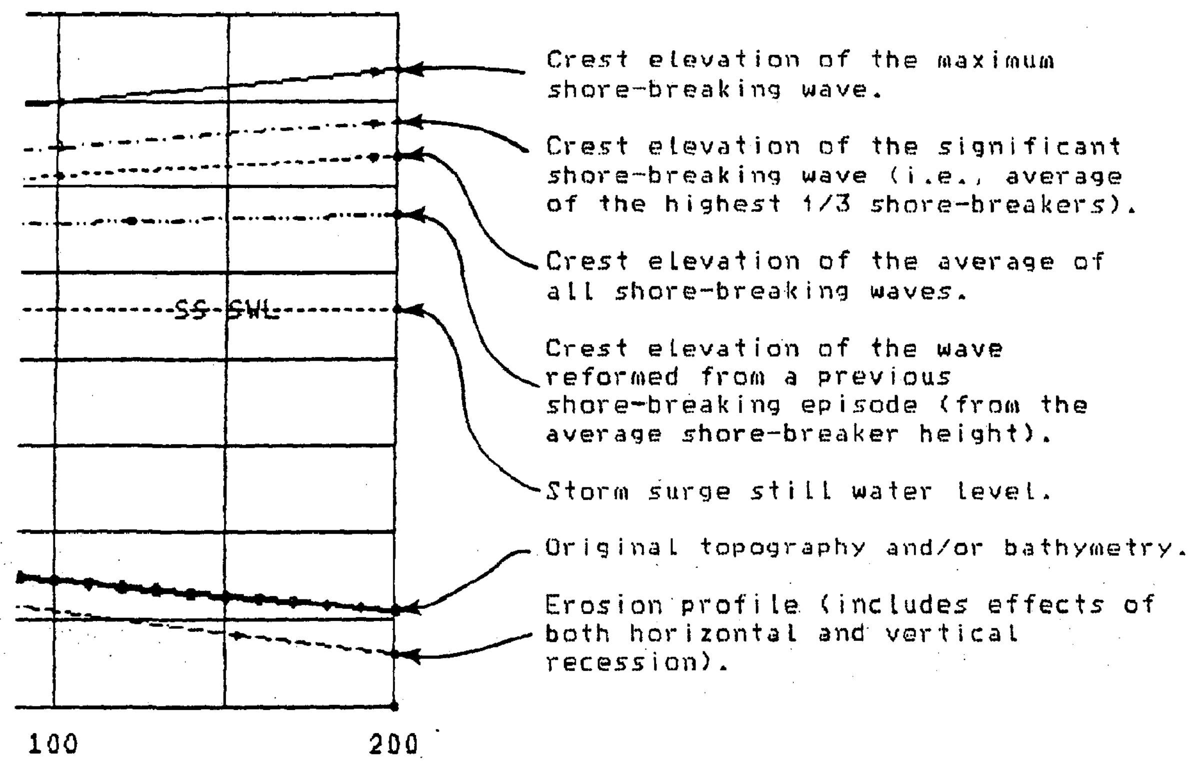


Figure 9c. Explanation of symbols used in Figures 9a and 9b.

additional example of the type of computer generated plots detailing the storm-generated forces, is illustrated in Figure 10.

PLAN OF OPERATION

The proposed plan of operation involves real-time field monitoring from three sources: 1. the proposed portable remote monitoring system of this work, 2. tide gauges of the National Ocean Service, and 3. wave gauges of the University of Florida, which would provide information on the forces and responses of a hurricane at coastal impact. A fourth source ... the National Hurricane Center ... provides information about the character of the storm (e.g., central pressure, pressure deficit, size, direction of travel, forward speed). Although this later information is important as input for eventual numerical computer simulation of impending coastal impact of a hurricane, it is extraneous to the monitoring goals of this study.

The intent of the mobile remote coastal sensing packages is to facilitate installation. The packages are to be mounted on trailers in sealed, weather-proof containers. Once the "probable" landfall coordinates are evident ... i.e., 12 to 24 hours in advance to landfall ... the packages can be towed to the coast (i.e., to sites with piers so that the water level and wave sensor probes can be installed), secured using screw-anchors, activated, and abandoned until the event passes. A special feature to such an approach is that with 5 sensing packages, a significant length of coastline

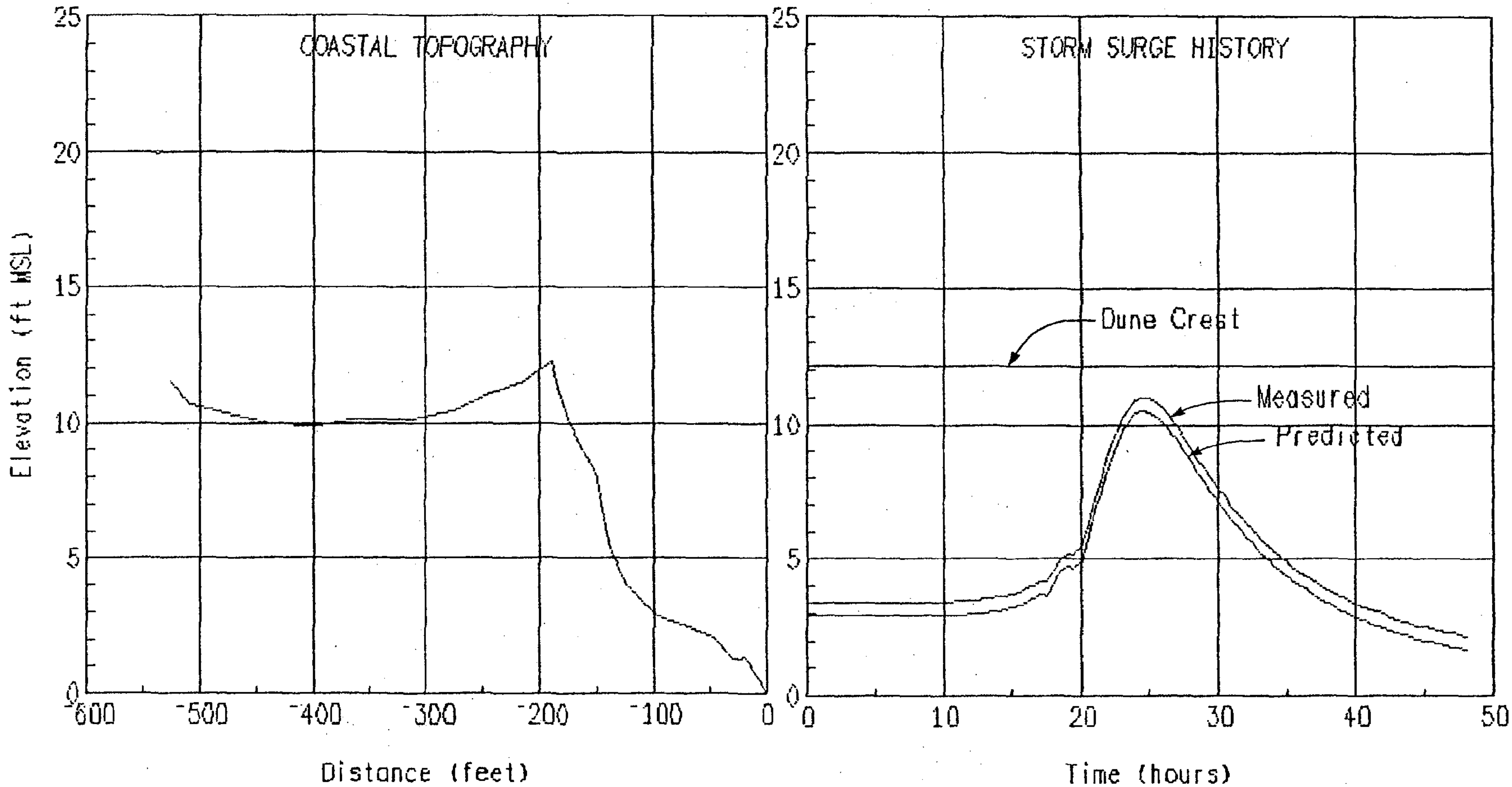


Figure 10. Computer generated plot for an idealized storm surge history for a specific DNR coastal profile, illustrating how force information can be plotted.

can be instrumented, thereby increasing assurance that most of the packages will be within the hurricane wind field. The Division of Beaches and Shores, Bureau of Coastal Data Acquisition has an experienced field staff involved in littoral data collection (Sensabaugh, Balsillie and Bean, 1977) who have also been involved in pre- and post-storm data collection. Hence, the experienced staff is available for installing the proposed packages.

Monitoring (i.e., computer terminals) and display (i.e., printer-plotter capability) equipment for the interegation, receipt and processing at an inland site (e.g., the Division of Emergency Management's EOC, or the Division of Beaches and Shores Analysis/Research Section) of the remotely collected coastal impact data, has not been included in the cost study for the remote sensing field packages. This omission is not an oversight, because: 1. compatible equipment already exists within state government, although logistics associated with relocation and installation at a central site would require attention, or 2. if additional equipment were obtained to be used for hurricane monitoring, it would not be cost-effective for the equipment to sit idle except for emergency conditions but would require additional justification based on current or needed programmatic responsibilities.

The above configuration would require mainframe support resources of a larger computer system. Because of requirements for management of geographic data bases, simulation software, large storage capacity, telecommunications needs, and the obvious desirability of a Tallahassee location, two systems may at this time be considered for use.

The first is located at the Florida Department of Natural Resources' Natural Resources Management Systems and Services Data Center. The center operates an IBM 4341 Model Group II processor with 8 megabytes of real and 8 megabytes of virtual memory. Advantages to this processor source is that it now drives storm surge and coastal processes software in support of responsibilities of the Division of Beaches and Shores, and has an array of computer hardware (e.g, terminals, printer-plotter, electrostatic plotter, digitizer) and support firmware and software. If the central monitoring site were to be located other than in the Douglas Building, then in addition to the terminal hardware (see Table 7), printer-plotter and communications and control devices would be needed. Equipment identification and associated costs for these latter items are given in Table 9.

Table 9. Additional Communications and Printer-Plotter Equipment Costs.

Description	Approx. Cost
IBM 3274 Controller (16-ports)	$5,000
Modem	$1,450
IBM 3287 Printer-Plotter	$6,350

The second system is located on the Florida State University campus at the Florida Resources and Environmental Analysis Center (FREAC). FREAC is currently in the process of developing a Land Boundary Information System (LABINS) which would provide a compatible environment for storage and processing of monitored hurricane information. An advantage to this processor source may be the availability of larger computer processing resources and telecommuncications capability.

The command center would receive data for the portable monitoring system by telephone line with the National Environmental Satellite Service computer which in turn receives data via satellite relay. Data from the University of Florida's wave gauge program would be linked by telephone line to access wave data. Data from the NOS tide stations would be obtained by calling the National Weather Service office near each gauge. They could provide data by scaling hourly values from the remote recorders in their offices. The operational aspects of the effort are conceptually illustrated in Figure 11. It is noted from Figure 11 that telephone line communication to obtain wave and tide data from the NOS and CDN programs is vulnerable to disruption or loss due to storm conditions. A strong point in favor of the coastal remote sensing packages is telecommuncations capability with onsite recording as a back-up. The telephone line link between NESS (Maryland/Virginia) would be fairly secure since most hurricanes will strike Florida south of Tallahassee (an alternative arrangement may be possible), as would any required dedicated line in Tallahassee to a local mainframe computer processor.

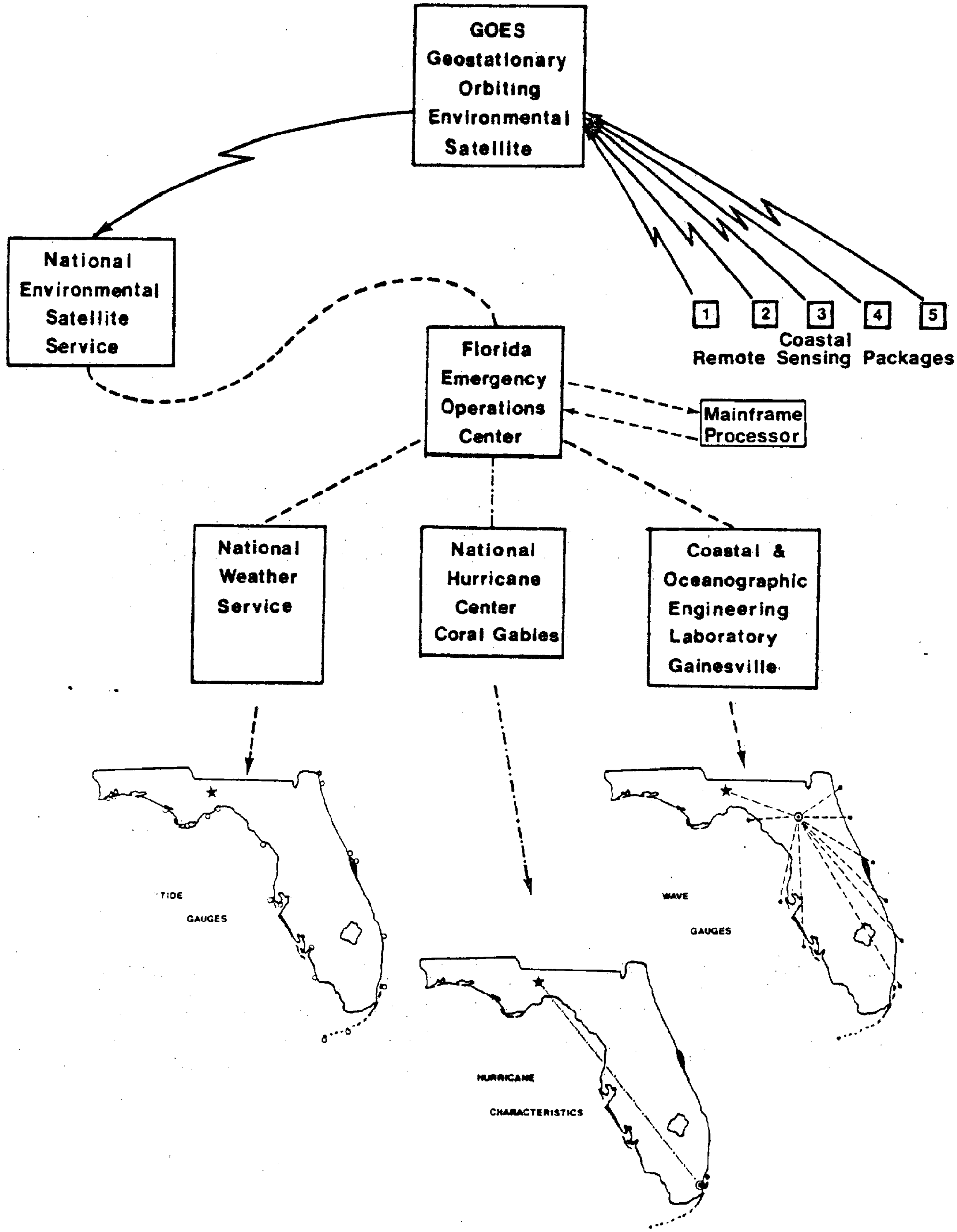


Figure 11. Conceptual illustration of data retrieval (solid lines indicate telecommunications, dashed lines dedicated telephone communications, dash-dot-dash lines unknown but existing communications).

FEASIBILITY ANALYSIS

The systematic approach investigated in this work will involve the expenditure of about $250,000 for the communications, computer needs and construction of 5 mobile sensor packages. Such a sum is not inconsequential, and there is a need to "put into perspective" the anticipated capital outlay.

Of Florida's approximately 1,200 miles of tidal shoreline, about 660 miles are actual moderate to high energy beaches of which about 275 miles are designated recreational beaches (Fernald, 1981). Studies conducted by Curtis, Shows and Spence (1980) and Curtis and Shows (1982) indicate that use of designated recreational beaches currently earns the State of Florida about $1,250,000 annually per mile of shoreline. This usage includes beach user and camping fees, concession earnings, road and bridge tolls, etc. At Ft. Desota National Memorial in Pinellas County, Curtis, Shows and Spence (1980) found that beach usage costs an average of $6.50 per day per user (includes in-state and out-of-state users). Park-type beach use is, therefore, very inexpensive. Commercially developed coasts (e.g., with hotels, restaurants, etc.) realize much higher earnings. For example, in a study of the Delray Beach nourishment project, Curtis and Shows (1982) found an average expenditure of $43.90 per day per visitor, for out-of-state tourists only. This suggests beach-related earnings of $8,470,000 annually per mile of shoreline. This figure does not include benefits due to existence and maintenance of a beach affording storm protection. In view of these estimates, the cost of the proposed system would be only from 3% to 20% (a weighted average of 5%) of the annual earnings from a single mile of Florida beach!

If one compares the cost of the proposed system to the average dollar damage for a hurricane (see Table 1, noting that the damages are not in constant dollars), the cost of the approach is only 0.6% of an expected, average dollar loss.

In fact, it is the belief of the authors that with the current technological state-of-the-art and the economics associated with hurricane and storm damage, such a systematic approach is inevitable. The question that remains is when? At the very least, the concept addressed in this work has "come-of-age".

RECOMMENDATIONS

Based on the results of this study, it is recommended that a technical task force be established to deliberate on various identified issues. The task force should be composed of individuals with demonstrated technical experience in coastal data collection and processing, storm surge and coastal processes and simulation, storm-hurricane mechanics, electronics and communications engineering, or hazards management. The issues are:

1. Design of the mobile (i.e., trailorable) remote coastal monitoring package to include:
   a. consideration and identification of existing (e.g., piers, groins) or natural features

(e.g., rock outcrops) for installation of wave and water level sensors.

b. package design such that it may be used for "normal" littoral survey work (e.g., as established in Florida and described by Sensabaugh, Balsillie and Bean, 1977), which will serve to maximize service and increase economic justification of the approach.

2. Develop the capability for assured, real-time obtention of data from existing monitoring programs. This includes data sources from the wave gauge program at the University of Florida, National Weather Service tide gauging stations, and storm/hurricane characteristics from the National Hurricane Center. The major issues here are the development of secure data transmission capability and, where possible, timely pre-processing of data (e.g., spectral analysis of wave gauge data ... e.g., Thompson, 1980) to increase efficiency of transmission, rather than to transmit raw or partly analyzed data.

3. Implement the plan of operation regarding the centralized monitoring center in Tallahassee, including equipment needs, justification and request to the Information Resource Commission, and/or identification of existing equipment and time-related logistics for equipment transfer and installation.

4. Development of real-time storm surge prediction

capability. This includes modification of existing software for timely surge prediction, identification of topographic/bathymetric base data requirements and development of management software, specification of systems resource requirements, and hardware for realization of results.

5. Actively investigate existing equipment sources. It would seem entirely possible that federal defense agencies have equipment (retired or active) which might be procured for constructing the remote packages; trailers and sealed containers come to mind as an example, which would require only modification. This approach would greatly defray costs.

An initial role of the task force may be to review these issues, identify any others which may have bearing on the proposed concept, and prepare a resolution as to realization of the goals. For instance, final issues may be assigned to particular state government agencies as tasks, others may be treated as items requiring research proposals. The task force would then serve as a review and coordinating body.

SPECIAL NOTE: This report provides trade names of various commercial products in order to determine expected costs. Any name, however, is listed as a benchmark only with the caveate assumption that such commercial products are competitively priced. Therefore, the citation of trade names in this document does not constitute an official

Florida Department of Natural Resources endorsement or approval of the use of such commerical products.

ACKNOWLEDGEMENTS

During early to mid-developmental phases of this project, many individuals were instrumental in providing knowledgable influence, direction and support of its goals. Acknowledgment of the contributions of all individuals involved would require far more space than can be allotted here. Among the more notable contributors are Dennis W. Berg, Chief of the Division of Technical Information, Coastal Engineering Research Center; Richard Hess and Rear Admiral Wesley V. Hull, National Oceanic and Atmospheric Administration; Robert S. Wilkerson, Director of the Division of Public Safety and Planning, Florida Department of Community Affairs (currently Chief of the Technological Hazards Division, State and Local Programs and Support, Federal Emergency Management Agency); John D. Wilson, Bureau of Disaster Preparedness, Florida Department of Community Affairs (currently Project Manager, Tri-State Study, Federal Emergency Management Agency).

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