E C O L O G I C A L   R E V I E W

Rockefeller Refuge Gulf Shoreline Stabilization
CWPPRA Priority Project List 10
(State No. ME-18)

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This document reflects the project design as of the 95% Design Review meeting, incorporates all comments and recommendations received following the meeting, and is current as of October 4, 2005.

ECOLOGICAL REVIEW

Rockefeller Refuge Gulf Shoreline Stabilization

In August 2000, the Louisiana Department of Natural Resources initiated the Ecological Review to improve the likelihood of restoration project success. This is a process whereby each restoration project's biotic benefits, goals, and strategies are evaluated prior to granting construction authorization. This evaluation utilizes monitoring and engineering information, as well as applicable scientific literature, to assess whether or not, and to what degree, the proposed project features will cause the desired ecological response.

I. Introduction

The proposed Rockefeller Refuge Gulf Shoreline Stabilization (ME-18) project is intended to protect a stretch of shoreline along the Rockefeller Wildlife Refuge extending for 9.2 miles from Joseph Harbor to Beach Prong (Figure 1). The Rockefeller Wildlife Refuge, owned by the State of Louisiana and managed by the Louisiana Department of Wildlife and Fisheries, is located in eastern Cameron Parish and western Vermilion Parish and encompasses approximately 76,042 acres. The refuge is bordered on the south by the Gulf of Mexico for 26.5 miles and extends inland toward the Grand Chenier Ridge, a stranded beach ridge, six miles from the Gulf. The Rockefeller Refuge Gulf Shoreline Stabilization project is co-sponsored by the National Marine Fisheries Service (NMFS) and the Louisiana Department of Natural Resources (LDNR). The project would reduce or halt Gulf shoreline retreat and direct marsh loss from Joseph Harbor to Beach Prong, protect saline marsh habitat, and enhance fish and wildlife habitat. Stabilizing the Gulf of Mexico shoreline in the vicinity of Rockefeller Wildlife Refuge was identified by *Coast 2050* as a Region 4 ecosystem strategy which would address the direct loss of coastal wetlands (Louisiana Coastal Wetlands Conservation and Restoration Task Force and the Wetlands Conservation and Restoration Authority 2001).

Shoreline change data for an identified 24.7-mile reach of the Louisiana coast (Rockefeller Refuge: West to East), which encompasses this project area, shows a long-term shoreline change rate of -30.9 feet per year (period of record 1880-1998) and a short-term shoreline change rate of -39.2 feet per year (period of record 1985-1998) (Connor et al. 2004). An analysis of aerial photographs of the project area (March 1998 and July 2002) provides an estimate of the recent short-term average erosion rate of approximately 50 feet per year, which is equivalent to a loss of 57 acres per year over the 9 mile stretch of shoreline (Shiner Moseley and Associates, Inc. 2005). This rate is slightly higher than the previously documented long-term average change rate of -30.9 feet per year due possibly to the effects of Tropical Storm Frances (September 1998); over a four day period there was 60-65 feet of shoreline loss (Tom Hess, Louisiana Department of Wildlife and Fisheries, Personal Communication, May 2002). The highest sub-area erosion rates are near Joseph Harbor inlet with approximately 100 feet per year (Shiner Moseley and Associates, Inc. 2005). The gulf shoreline in this area is composed of whole and crushed clam shell (1.0 to 1.5 feet deep and 50 to 75 feet wide) overlaying an area of previously living, emergent marsh. Wave action dislodges the shell and deposits it over the marsh, exposing the underlying clay marsh soil substrate to erosion.

A geotechnical investigation indicated the presence of very soft clay soils to a depth of about 40 feet in the project area with a bearing capacity insufficient for the construction of a

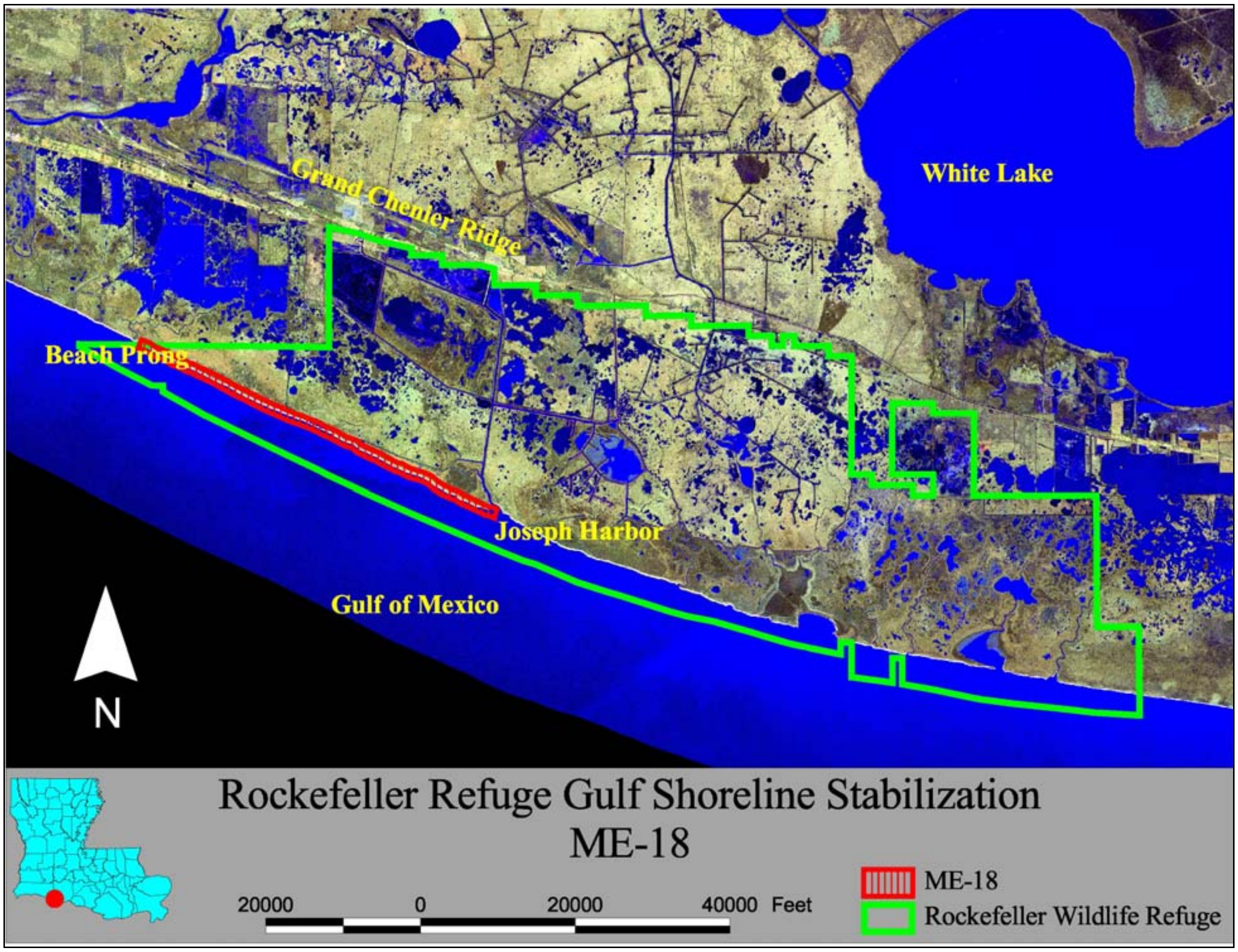

Figure 1. Rockefeller Refuge Gulf Shoreline Stabilization project area.

standard rock breakwater (Shiner Moseley and Associates, Inc. 2005). These soil conditions severely limit the type of shoreline structures that can be constructed to provide the desired level of shoreline protection. To find an acceptable shoreline protection technique, Shiner Moseley and Associates, Inc. (2003) considered over 80 alternatives and variations of alternatives. Most alternatives were determined to be infeasible for one or more of the following reasons (not a comprehensive listing): design parameters, constructability, cost, poor performance, no proven design for Gulf applications, not effective for longer wave periods of open coast, unproven design, subject to debris punctures and deflation, soil load, and reflection over rock. As a result of the initial feasibility study, Shiner Moseley and Associates, Inc. identified and recommended the following two alternatives that could potentially provide the needed protection to the refuge: a reef breakwater with lightweight aggregate core and a concrete panel breakwater. To allow inclusion of a wider array of potential solutions, the design criteria were modified to allow an increase of the construction budget by 50% and a relaxation of the “no erosion under a Category 1 hurricane” requirement resulting in some alternatives being re-considered. The following two additional alternatives were eventually identified and recommended: beach fill with gravel/crushed stone and reef breakwater with sand or gravel/crushed stone beach fill (Shiner Moseley and Associates, Inc. 2004b).

Because of uncertainty regarding the constructability, design, and performance of the final four shoreline protection alternatives, they will be evaluated in a small-scale project at Rockefeller Wildlife Refuge, which will help predict their potential success if installed for the full 9.2 mile project. The test installations would allow one year of data accumulation, detailed evaluations, and comparison of each alternative in terms of constructability, ability to withstand soft soils, wave attenuation, shoreline response, maintenance requirements, cost, and aesthetics. The purpose of this stage of the Rockefeller Refuge Gulf Shoreline Stabilization (ME-18) project is to evaluate the efficacy of the four alternative designs of shoreline protection structures, and the soil pre-loading experiment. This Ecological Review focuses exclusively on this test installation stage of the project.

II. Goal Statement

- Test, quantify, and compare the ability of each of four alternative shoreline protection designs to reduce shoreline erosion and withstand the poor soil conditions and harsh environment in the project area.
- Select a design alternative for subsequent construction over the full 9.2 mile project area.

III. Strategy Statement

- Implement a quasi-experimental design that will allow for testing of the achievability of the project goals and selection of a preferred design alternative.

IV. Strategy-Goal Relationship

Project scientists and engineers have ensured that the constructed project design and subsequent one year of data gathering will provide appropriate quantifiable information for evaluating the effectiveness of the alternative shoreline protection techniques in reducing/halting erosion. In addition, structural stability will also be a component in selecting a preferred alternative for field application of the full 9.2 mile project length.

V. Project Feature Evaluation

<u>Geotechnical and Bathymetric Investigation</u>

A geotechnical investigation analyzed by Shiner Moseley and Associates, Inc. (and performed by Fugro South) reports the presence of very soft clay soils to a depth of about 40 feet. The surveys and geotechnical data describe a uniform geography of soft clay soils distributed throughout the project area. These inferior quality soils, which extend to a relatively deep level, represent a poor foundation for construction. Fugro South reported that the allowable bearing pressure on the soil is 250 (with a normal safety factor of 2.0) to 333 pounds per square foot (with a reduced safety factor of 1.5). Standard specifications for a rock breakwater presuppose that such a structure would likely exceed this pressure by three or four times (Shiner Moseley and Associates, Inc. 2005). Surface grab samples (110 obtained) were taken extending out to 2,000 feet from the shore at 2,500 foot intervals along the shoreline. The grab samples show that there is very little sand moving alongshore or across-shore within the littoral system. There does not appear to be any significant source of sand nearshore that could be utilized as borrow areas for beach nourishment (Shiner Moseley and Associates, Inc. 2004a).

John Chance Land Surveyors conducted topographic and bathymetric surveys in June and July 2002. Twenty-two beach profiles were obtained that extended from approximately 600 feet landward to approximately 3,500 feet seaward of the shoreline. The survey results showed that the beach profile shape is relatively uniform alongshore. The consistency in profile shape alongshore suggests that the nearshore bottom contours are parallel to the shoreline. If the beach profile shape and erosion rates remain constant over time, the water depth at the location of the existing beach will be about 5.5 feet in 20 years. Therefore, adequate structure depth and tow protection will be critical to prevent structural failure due to undermining (Shiner Moseley and Associates, Inc. 2004a).

<u>Design Layout</u>

The location of the test program was selected to be at the eastern end of the 9.2 mile project area, a minimum of 2,000 feet from Joseph Harbor. This location was selected to offer Joseph Harbor as a possible offloading point and shelter from waves for construction contractors. A minimum offset of 2,000 feet was selected to minimize the potential influence of the inlet on the test installations. Each of the four chosen shoreline protection treatments will be placed along the shoreline (Figure 2). A 2,000-foot control area will be located 1,350 feet west of the test area. Comparisons of each alternative in terms of constructability, ability to withstand the soft soils, wave attenuation, shoreline response, maintenance requirements, cost, and aesthetics will be made.

Shiner Moseley and Associates, Inc. (2005) calculated the length needed for the breakwater treatments by evaluating the influence of wave diffraction at the breakwater tips. The results suggested that the diffracted waves could influence shoreline response within approximately 150 feet of each end of the breakwaters. Therefore, each breakwater test section was designed with a length of 500 feet, providing approximately 200 feet of protected shoreline that is expected to be beyond significant influence of diffracted waves. Similarly, wave diffraction was also considered for spacing of the breakwater alternatives. Shiner Moseley and Associates, Inc. (2005) estimated that a breakwater spacing that exceeds five times the wavelength will allow the breakwaters to function independently of each other. Following this guidance, for a typical wavelength of 150 feet, the breakwater separation required for discrete evaluation of the alternatives was selected as 750 feet.

<u>Shoreline Protection Alternatives</u>

Specifications for the construction and monitoring of each of the test parameters are given below:

Alternative 1: Beach fill with gravel/crushed stone (Figure 3)

This test section will be 700 feet in length and will be contiguous to the next test section to the east. For this stand-alone beach fill Shiner Moseley and Associates, Inc. (2005) recommended gravel or crushed stone (G/CS) rather than sand because of the gravel or crushed stone's higher stability under wave action. For the given project budget, sand is not expected to provide adequate storm protection unless applied in combination with retention structures. This alternative will be constructed with material having a median particle size of approximately one inch. Terminal groins will be constructed at each end of the beach fill to reduce spreading alongshore and to reduce the influence of end effects (Shiner Moseley and Associates, Inc. 2005). This will mimic the effects of a longer reach of fill, and allow for a shorter test section.

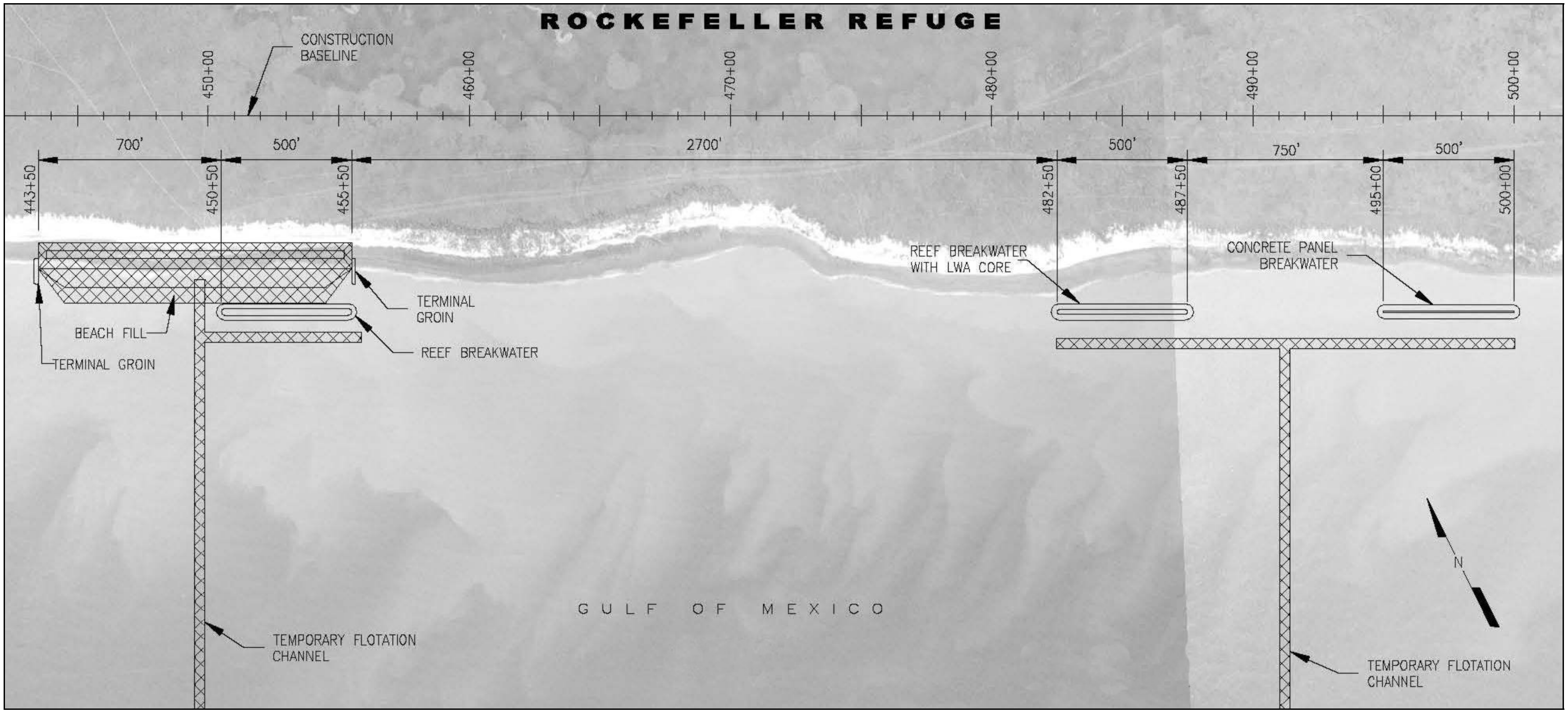

Figure 2. Design layout for test sections (Shiner Moseley and Associates, Inc. 2005).

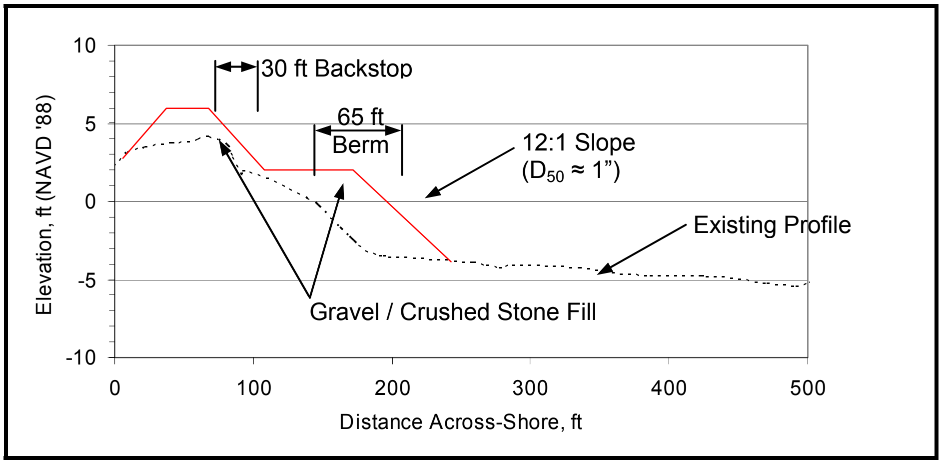

Figure 3. Alternative 1: Beach fill with gravel/crushed stone (Shiner Moseley and Associates, Inc. 2005).

Alternative 2: Reef breakwater with sand or gravel/crushed stone (G/CS) beach fill (Figure 4)

This test section will be 500 feet in length, contiguous to the test section to the west and 2,700 feet from the test section to the east. Shiner Moseley and Associates, Inc. (2005) recommended that to maximize protection during storms, the breakwaters should be aligned parallel to the shore. Furthermore, to prevent any potential wave regeneration between the breakwater and the shoreline, a fetch of 200 feet or less would effectively limit the erosive waves that could harm an un-vegetated shoreline. It is generally understood that a 4 to 5 foot water depth is the minimum required for barged-based operations. Therefore, a water depth of approximately 5 feet, corresponding to a bottom depth of -4.0 feet NAVD-88, was determined to be the appropriate distance offshore to set the breakwaters. The -4 foot contour is located approximately 150 feet from the shoreline (Shiner Moseley and Associates, Inc. 2005). For this alternative, gravel/crushed stone was recommended over sand due to its greater stability; in addition, the relatively flat profile that would have been required for sand could potentially bury the breakwater (Shiner Moseley and Associates, Inc. 2005). Terminal groins will be constructed at each end of the beach fill to reduce spreading alongshore and to reduce the influence of end effects (Shiner Moseley and Associates, Inc. 2005). This will mimic the effects of a longer reach of fill, and allow for a shorter test section.

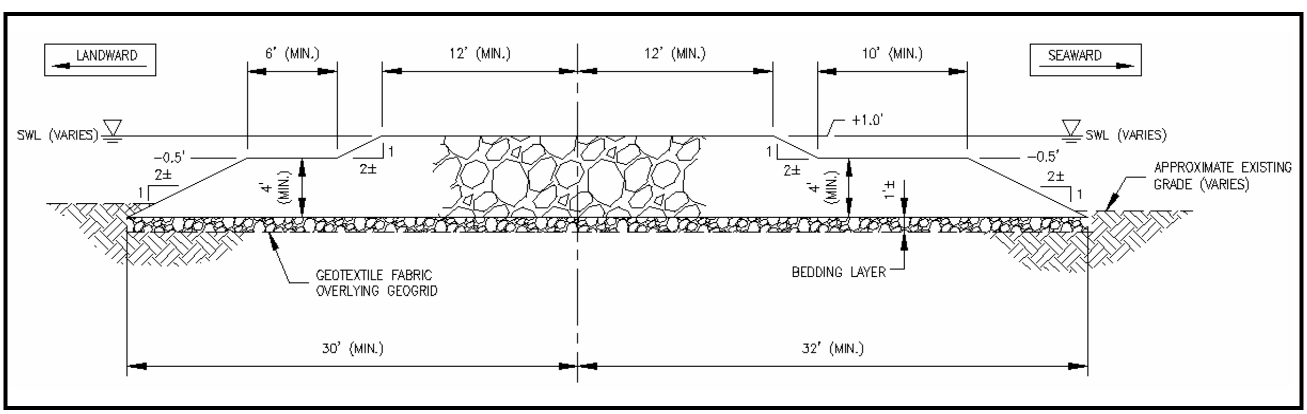

Figure 4. Reef breakwater concept for Alternative 2 (Shiner Moseley and Associates, Inc. 2005).

Alternative 3: Reef breakwater with lightweight aggregate (LWA) core (Figure 5)

This test section will be 500 feet in length and will be 750 feet from the next test section to the east. The breakwater will be constructed parallel to the shore, at the -4.0 feet NAVD-88 contour (approximately 150 feet from shore). The current design calls for approximately 3.75 feet of lightweight aggregate covered by 4 feet of armor stone, resulting in an initial crest elevation of +3.25 feet NAVD-88.). Fugro South has estimated that structure settlement will lower the crest elevation to approximately +1.9 feet NAVD-88 over a time period of several decades (Shiner Moseley and Associates, Inc. 2005). The structure would have a crest width of 18 feet. It should be noted that the less-permeable core and approximate 2.25 feet greater crest elevation of the reef breakwater with LWA core will result in less stability than the Alternative 2 reef breakwater (Shiner Moseley and Associates, Inc. 2005).

The typically constructed solid rock reef breakwater may be deemed to be too heavy for the very soft soils in this project area; therefore, the design was modified by using lightweight aggregate for the core of the breakwater. The submerged weight of the aggregate is approximately 9 pounds per cubic foot versus the 91 pounds per cubic foot for conventional stone thereby greatly reducing the bearing pressure (Shiner Moseley and Associates, Inc. 2004a).

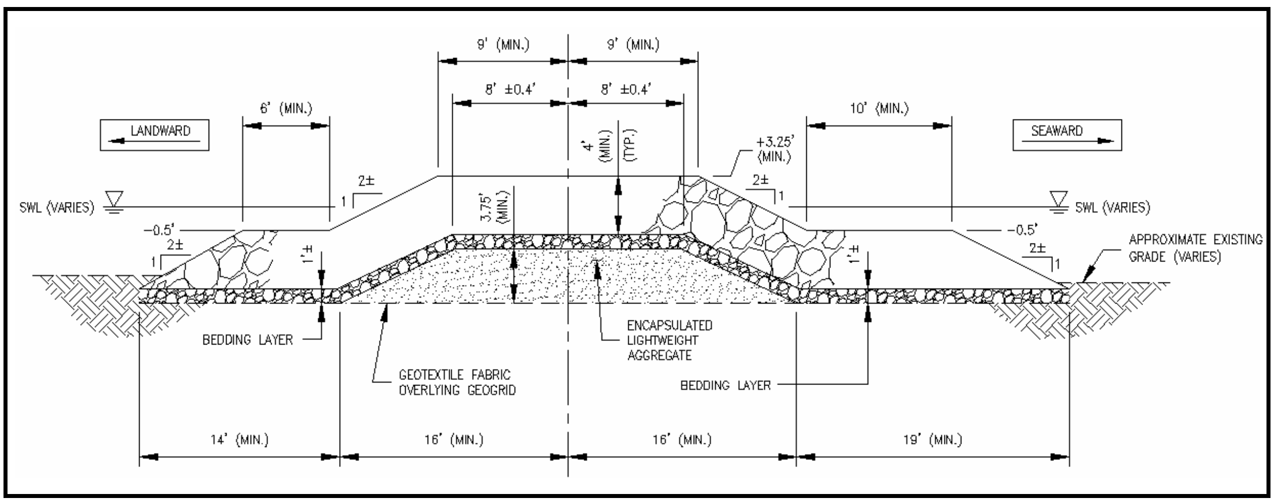

Figure 5. Alternative 3: Reef breakwater with lightweight aggregate core (Shiner Moseley and Associates, Inc. 2005).

Alternative 4: Concrete panel breakwater (Figure 6)

This test section will be 500 feet in length and will be 750 feet from the test section to the west. The concrete panel breakwater resulted from the Shiner Moseley and Associates, Inc. review of non-standard structures, and involves contiguous 40-foot long pre-cast concrete cap with wall panels and steel sheet piles. Each forty-foot cap consists of three 10-foot long panels and two 5-foot gaps. With this methodology, as compared to a solid wall, there is a resultant lower wave force on the wall and consequently a lower construction cost, as compared to a solid wall. With less wave force, the structure can be lighter and require less material. The 10-foot sections would reduce wave energy to an acceptable level (Shiner Moseley and Associates, Inc. 2005). The concrete panel breakwater will be constructed parallel to the shore, at the -4 feet NAVD-88 contour (approximately 150 feet from shore). The upper soft clays at the site will be removed to -9 feet NAVD-88 and replaced with sand to improve soil strength and allow the cantilevered wall to resist wave force. The sand, which will be protected by armor rock, will provide lateral resistance that the soft clays cannot. These panels and cap will be pre-cast and set on two concrete piles that are driven into deeper firm clays to prevent settlement of the panels (Shiner Moseley and Associates, Inc. 2005).

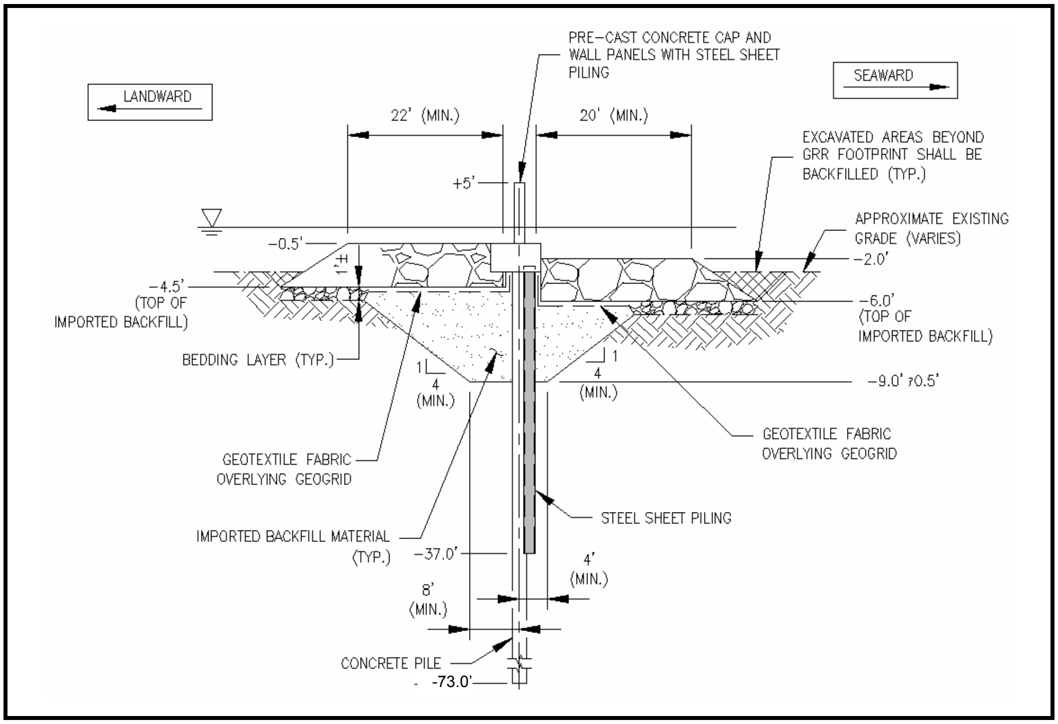

Figure 6. Alternative 4: Concrete panel breakwater (Shiner Moseley and Associates, Inc. 2005).

<u>Monitoring Plan</u>

The objectives of the monitoring plan are (1) to collect data that will allow for design optimization of each section and (2) to determine performance characteristics of each alternative tested. The monitoring plan will consist of land-based and aerial photography, wave and tide gauging, bathymetric and topographical surveying, and measurement of structure settlement with settlement plates (Shiner Moseley and Associates, Inc. 2005). Monitoring will begin during construction of the test sections and last for one year. In accordance with scientific experimental protocol, a control section has been identified that is outside of the influence of the test sections (see Figure 7).

The following monitoring components will be utilized to collect data during the one-year monitoring period (Shiner Moseley and Associates, Inc. 2005):

- ***Surveying:*** Locations for survey transects are shown in Figure 8. Transects shown are spaced 100 feet along the test section for Alternative 1 and 50 feet along test sections for Alternatives 2, 3, and 4 and should be surveyed pre-construction, post-construction, and quarterly for one year for a total of five surveys. Additional transects should be surveyed at 100 feet, 300 feet, and 500 feet beyond each test alternative to evaluate updrift and downdrift impacts. A 2,000 foot control area will be located 1,350 feet west of the test area, as shown in Figure 7. Transect spacing within the control area will be 200 feet.

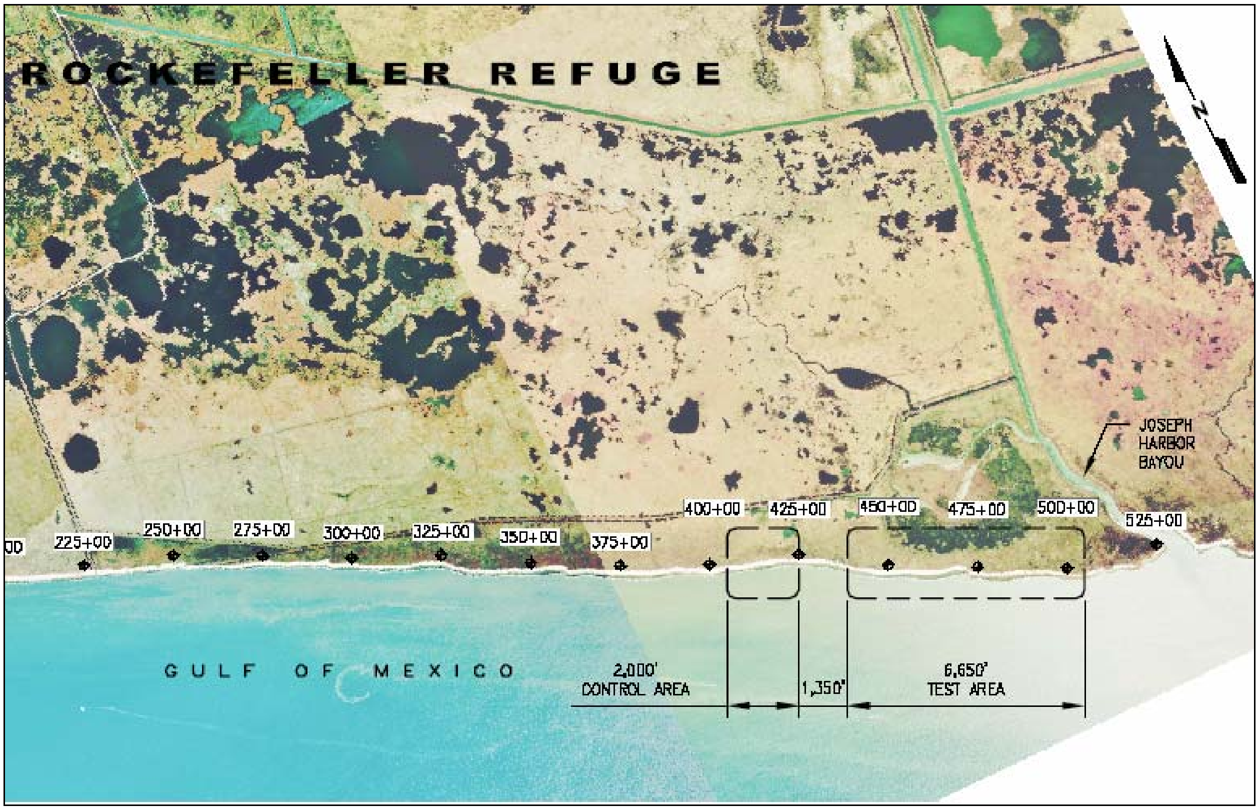

Figure 7. Location of test and control areas (Shiner Moseley and Associates, Inc. 2005).

At a minimum, transects should be 600 feet long, extending 400 feet offshore. The initial survey of the control site will coincide with the completion of the test sections.

Surveying profiles will be used to determine the effectiveness of each alternative in reducing shoreline erosion and their effect on the adjacent shoreline. Structure surveys will be used to determine settlement, scour, and structure stability. The surveys provide a direct comparison between each alternative and the control section to determine the effectiveness of each alternative and its relative effectiveness to the other alternatives.

- ***Aerial Photography:*** Controlled aerial photography will be collected along the western boundary of Rockefeller Wildlife Refuge from just east of Joseph's Harbor to the west. Aerial photography will provide a view of the effectiveness of the different alternatives and a comparison of the erosion rates of the Refuge beyond the control section. Although less accurate than surveys, the aerial photography will provide a larger scale evaluation for the test section. Aerial photography will be performed concurrent with topographic/hydrographic surveys (pre-construction, post-construction, and remaining quarterly intervals for one year) for a total of five sets of photographs. Aerial photography will be geo-referenced and provided in digital format. Ground targets having known geographic coordinates will be placed to improve accuracy of geo-referencing. Common shoreline features will be traced using CAD or GIS software and compared to supplement the survey data.

- ***Ground Photography:*** Ground-level photography will be collected during each survey. The photography will help document shoreline change, integrity of the breakwaters, wave attenuation, and other aspects of the project. At a minimum, photographs will be taken of the ends of each alternative, the adjacent shoreline, and the control site. Every attempt will be made to collect the photos from set locations. Ground-level photography will provide cost effective small-scale evaluations that may be missed in the surveys or aerial photos. Shifting armor stone, small-scale shoreline changes, and local slumps due to scour or soil failure are some of the examples of additional information that may be detected from ground-based photography.

- ***Wave Gauges:*** Five wave gauges will be installed to measure wave attenuation at the breakwater alternatives. One wave gauge will be installed offshore of the structures to collect the incident waves. A gauge will also be located leeward of each of the three breakwaters. A fifth gauge will be located in the control area on the same depth contour as the three in the lee of the structures to determine the non-affected incident wave. Proposed locations for the wave gauges are shown in Figure 8. Wave data should be collected for six months, preferably between September and March, although these months may be adjusted based on the construction timeline. During this period there are typically numerous frontal passages which are preceded by strong southeast winds that increase water level and wave height. The wave data, in addition to tide data, will be applied to evaluate design estimates of wave transmission at each breakwater. This information will be used to calibrate the predicting equations and optimizing the design for the full 9.2 mile project. In combination with the beach profile survey data, the wave data can be applied towards predictions of erosion thresholds for with- and without-project conditions.

- ***Tide Gauges:*** A tide gauge will be installed and operated concurrently with the offshore wave gauge to measure water surface elevations. The tide data will be correlated to data from other stations along the Louisiana coast (such as at Calcasieu Pass), for which long-term records exist, so that long-term water level trends at the Refuge can be better inferred. In addition, the tide data can be applied with the wave data for calibration of wave transmission equations and optimization of the full 9.2 mile project.

- ***Settlement Plates:*** Settlement plates will be installed to measure the magnitude and rate of settlement of each structure. Up to 16 settlement plates will be installed during construction and surveyed by the contractor. Settlement of the plates will be measured during each monitoring survey. Locations of the settlement plates are shown in Figure 8.

  The extremely soft soils offshore of the refuge will consolidate over time. Predictions will be made on the settlement rate for each alternative. The measured settlements will be used to refine the design template and determine if design modifications are necessary.

The monitoring plan will provide detailed design evaluations and relative performance of each of the alternatives. At a minimum, the following analyses will be conducted for the monitoring plan (Shiner Moseley and Associates, Inc. 2005):

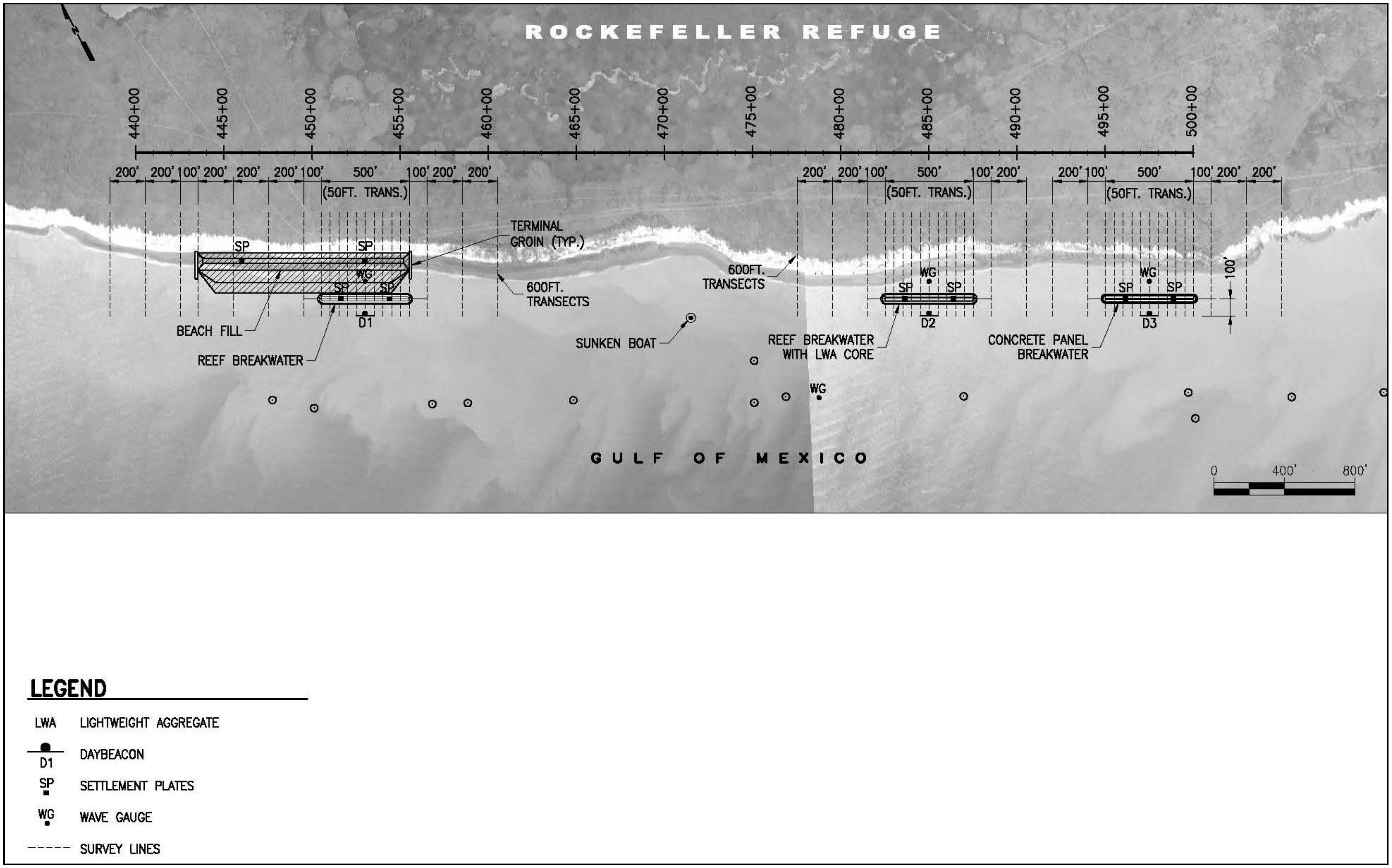

Figure 8. Layout for monitoring plan (Shiner Moseley and Associates, Inc. 2005).

- ***Comparative Survey Analyses:*** As-built construction surveys will be used as a comparison to post-construction surveys to determine shoreline changes, volume changes, and changes in the general cross section of the profile. This analysis will be the basis for assessing the relative effectiveness of each alternative constructed. The surveys will be directly compared to the control site to determine the effectiveness of each alternative in reducing or abating erosion or increasing accretion.

- ***Wave Transmission:*** Wave and tide data will be applied to refine the transmission estimates for the detached breakwaters under storm conditions. This refinement will be used to extrapolate transmission coefficients outside the collected data ranges and refine the potential erosion scenarios for Rockefeller Wildlife Refuge. The revised transmission coefficients will then be used to refine the alternative design; if necessary, recommendations will be made for potential modifications that would optimize the project.

- ***Settlement Analyses:*** Settlement of each plate will be measured and compared to the predicted settlement. Modifications to the prototype design templates will be accomplished based on the settlement plate data. Small changes in the settlement rate and/or soil bearing capacity will directly affect the construction template. This applies to all the alternatives tested.

- ***Shoreline Change Analyses:*** In addition to the shoreline change directly within the project and control areas, the aerial photos will be analyzed to evaluate shoreline change along adjacent areas of the Refuge for the entire year. In addition, the aerial photos collected in 2002 will be used to evaluate shoreline changes since that time. Representative erosion rates will be calculated and the relative effectiveness of the alternatives will be calculated and evaluated based on the long-term shoreline data.

VI. Assessment of Goal Attainability

Shoreline protection methods employing rock breakwaters as the primary project feature have been a staple in Louisiana's coastal restoration efforts since the inception of the Coastal Wetlands Planning, Protection and Restoration Act (CWPPRA). Rock structures have been the method of choice due to attractive characteristics such as ease of construction, low cost, and durability. However, the weight of rock is often a concern as excessive settlement can occur at project sites that exhibit soft soils. Recently, projects have tested the effectiveness of other shoreline protection strategies besides the traditional rock design (*e.g.*, sheetpile, concrete panels, geotextile tubes, sunken barges, and breakwater with lightweight aggregate core).

<u>Findings from Previously Constructed Shoreline Protection Projects</u>

- The Lake Salvador Shore Protection Demonstration (BA-15) project tested the effectiveness of four types of segmented wave-dampening structures in highly organic, unconsolidated sediments with poor load-bearing capacities (Lee et al. 2000). The four treatments (gated apex structures, geotextile tubes, angled timber fences, and vinyl sheet pile bulkheads) were constructed parallel to the shoreline at a distance of 300 feet offshore. Although it was shown that some structures (geotubes and vinyl sheet pile bulkheads) reduced average wave heights when winds were perpendicular to the structures and the shoreline, evidence indicates that the four experimental treatments did not influence shoreline erosion rates.

This is most likely because the structures were placed too far offshore allowing waves to regenerate shoreward of the structures. Thus, the effectiveness of the shoreline protection features in reducing erosion was reduced.

Further problems with this project involved the experimental design. The treatments were not randomly placed along the shoreline, and their close proximity to one another resulted in noticeable treatment interactions. As a result, statistical testing of the data was not possible and definitive conclusions regarding the treatments' influence on shoreline erosion rates could not be drawn. Lee et al. (2000) made the following recommendations regarding future shoreline protection projects:

> *"First, further investigation of structure placement should be conducted to prevent regeneration of waves between the structures and the shoreline. Next, the effects of bottom scour and bathymetric effects should be identified to estimate benthic sediment movement and its effect on shoreline configuration. Finally, settlement plates need to be installed on all shoreline protection structures and monitored throughout the project life when placed in poor load-bearing environments like Lake Salvador."*

- The Holly Beach Breakwaters (CS-01b) state project was designed to reduce wave energy effects along 7.3 miles of coast between Holly Beach and Ocean View Beach in southwest Cameron Parish, Louisiana. The long-term (1883-1994) shoreline erosion rate in the project area was 4.3 feet per year (Underwood et al. 1999). A total of 85 segmented breakwaters were constructed in different phases parallel to shore from 1991-1994. The breakwaters averaged 150 feet in length with 300-foot gaps and were built in 4-6 feet of water approximately 250-600 feet from shore. The breakwaters were constructed with a crown width of 9 feet and 4 feet above mean sea level (MSL).

  The results from 1990 to 1995 indicated a net accretion of sediment; however, that occurred only in the easternmost breakwaters. The breakwaters have failed to reverse net erosion rates in the central and western portions of the project area. The initial sediment deposition was very rapid, regardless of breakwater distance from shore. After the initial deposition, a reduction in the sediment volume occurred, especially in the middle and western breakwaters. Proximity of the breakwater to the sediment source, which was presumed to be longshore dominated, from east to west, seemed to play an important role in the shoreline response (Underwood et al. 1999). The distance of the breakwater from shore did not seem to influence shoreline response in the initial construction phase; however, as breakwaters were constructed up-current, the breakwaters constructed 600 feet from shore lost the ability to trap sediment transported longshore (Underwood et al. 1999).

  The Holly Beach breakwaters have failed to reverse net erosion rates in the central and western portions of the project area, and as a result, the Holly Beach Sand Management (CS-31) project was implemented to restore the littoral drift system. This beach nourishment was accomplished through the placement of approximately 1.7 million cubic yards of dredged sediment on the beach. No monitoring results for this project are currently available.
- The Raccoon Island Breakwaters Demonstration (TE-29) project was constructed along the eastern gulf shoreline of Raccoon Island in June and July of 1997. The project was intended

to demonstrate the effectiveness of segmented breakwaters in mitigating shoreline erosion along one of Louisiana's barrier islands and to evaluate their potential role in future barrier island restoration projects. Eight experimental segmented breakwaters were constructed 300 feet off the southeastern shoreline of Raccoon Island in 2-6 feet of water. Each breakwater was 300 feet in length, with a 10-foot crown at a crest elevation of +4.5 feet NAVD-88, and 1(V):3(H) side slopes. The gap between each breakwater was 300 feet.

The results of monitoring conducted in October 1997 indicated that the breakwaters reduced incident wave height by 90% behind the structures and 0% in the gaps. Results from March 1998 indicated that the breakwaters reduced obliquely incident waves by 70% behind the structures and 50% in the gaps (Armbruster 1999). During the first twelve months of monitoring, the rate of shoreline retreat in the gaps between breakwaters 4 through 7 averaged 22.4 feet per year, and in the lee of the breakwaters, the shoreline experienced an average net progradation of 29.8 feet. Vertical accretion of sediment of 4 feet was measured in the lee of the breakwaters. By July 1998 sediment accretion behind breakwaters 3-7 led to the formation of a continuous emergent sand body (*i.e.*, tombolo), while the eastern shoreline behind breakwaters 0-2 continued to erode. The erosion behind breakwaters 0-2 was probably associated with the shorelines exposure to easterly and northeasterly directed waves that accompany winter cold front passages, a steeper shoreface which reduces wave attenuation in the surf zone, a decrease in sediment transported to the area from the west, and the extremely high velocity tidal currents between the shoreline and the breakwaters (Armbruster 1999, Stone et al. 2003).

Monitoring data indicates that a complex shoal, the erosional remnant of historical Raccoon Island, likely played a role in wave attenuation and was the likely source of the sediment that accreted behind the breakwaters (Armbruster 1999, Stone et al. 2003). The deposition of sediment in the lee of the breakwater, and the creation of reverse salients, were unanticipated and further study of the effects of the breakwaters was undertaken (Stone et al. 2003). The study by Stone et al. (2003) concluded that the breakwaters modified wave conditions, thereby facilitating the capture of sediment moving onshore from the shoal. Preferential deposition of sediment occurred behind breakwaters number 3-7 because of their position relative to tidal channels and tidal bays (Stone et al. 2003).

Summary/Conclusions

Soils found along the Louisiana coast are typically extremely soft, organic, silt-clays which are subject to high rates of erosion. These soils possess very poor load-bearing capacities and consequently are poor substrates for construction of rock dikes typically used in shoreline protection efforts (Howard et al. 1984). Therefore, it is important to test the effectiveness of alternative hard-structure techniques in protecting vulnerable shorelines.

It should be noted that both the CS-01b and TE-29 projects were successful in part due to the availability of a source of sediment. However, conditions are different for this project; there is a lack of availability of sediment supply at the Rockefeller Wildlife Refuge site. Therefore, in this sediment-lean environment, any potential for longshore transport of sediment is not feasible. Consequently, there is no projection that any accretion of sediment will occur behind the various test shoreline protection structures.

The design and layout of the test sections appear to be acceptable. In the Lake Salvador Shore Protection Demonstration project, the treatments were not randomly placed along the shoreline, and their close proximity to one another resulted in noticeable treatment interactions. As a result, statistical testing of the data was not possible and definitive conclusions regarding the treatments' influence on shoreline erosion rates could not be drawn. For the Rockefeller Refuge Gulf Shoreline Stabilization project test sections reviewed in this document, Shiner Moseley and Associates, Inc. (2005) considered wave diffraction for spacing of the breakwater alternatives, and estimated that a breakwater spacing that exceeds five times the wavelength will allow the breakwaters to function independently of each other. In addition, the excessive distance from the shoreline that led to the reduced effectiveness on past projects has been addressed in this project. Consideration was given to knowledge that to prevent any potential wave regeneration between the breakwater and the shoreline, a fetch of 200 feet or less would effectively limit the erosive waves that could harm an un-vegetated shoreline (Shiner Moseley and Associates, Inc. 2005).

Random variability in local geological conditions may affect the test results more than would any differences among the competing designs. Without replication (building more than one of each design) the relative effectiveness of the designs is essentially unknowable. Monitoring a control area, although worthwhile, does not improve this data gap. Recent aerial surveys show that shoreline erosion rates vary by more than fifteen feet per year over short distances in the vicinity of the test area (Shiner Moseley and Associates, Inc. 2005). The geotechnical survey reports spatial variability in the mechanical properties of the soils that may affect subsidence more than would the differences in breakwater construction (Shiner Moseley and Associates, Inc. 2005). Therefore, limitations exist in interpreting the results of data obtained from monitoring the test sections of this endeavor.

VII. Recommendations

Based on the evaluation of the conceptual design and confidence in goal attainability for Rockefeller Refuge Gulf Shoreline Stabilization, the Louisiana Department of Natural Resources, Coastal Restoration Division recommends that the Rockefeller Refuge Gulf Shoreline Stabilization project be considered for CWPPRA Phase 2 authorization.

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