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MONITORING PROGRESS REPORT

RACCOON ISLAND BREAKWATERS
TE-29

Fifth Priority List Demonstration Project
of the Coastal Wetlands Planning, Protection, and Restoration Act
(Public Law 101-646)

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PREFACE

This manuscript is the first of two reports that presents monitoring data collected under the auspices of the Louisiana Department of Natural Resources / Coastal Restoration Division (LDNR/CRD) during the first year following construction of the Raccoon Island Breakwaters Demonstration project (TE-29). Monitoring data are presented and discussed within the context of the specific project goals and objectives of the monitoring plan. Since this is the first report in the monitoring phase of the project, all data collected through 21 July 1998 are presented.

INTRODUCTION

The Isle Dernieres barrier island chain, located along the Louisiana coast, is experiencing some of the highest rates of erosion of any coastal region in the world (figure 1). Between 1887 and 1988 the average annual rate of land loss was 69.6 ac yr^{-1} (28.2 ha yr^{-1}), while the average rate of shoreline retreat was 36.4 ft yr^{-1} (11.1 m yr^{1}) (McBride et al. 1991). This condition has led to the rapid landward migration (barrier island rollover) and disintegration of the Isle Dernieres, as well as a decrease in the ability of the island chain to protect the adjacent mainland marshes and wetlands from the effects of storm surge, salt water intrusion, an increased tidal prism, and energetic storm waves (McBride and Byrnes 1997). The Isles Dernieres formed approximately 500 years ago as a result of the abandonment of the Caillou headland (part of the Lafourche delta complex) by the Mississippi River (Frazier 1967). The Isle Dernieres barrier island arc is segmented into four islands: East Island, Trinity Island, Whiskey Island, and Raccoon Island (figure 1). A voluminous literature on the modern evolution of these barrier islands has attributed high rates of land loss in the region to the synergistic effects of global sea-level rise, subsidence, tropical and extratropical storm activity, inadequate sediment supply, and significant anthropogenic disturbances (Boyd and Penland 1981; Dingler and Reiss 1990; List et al. 1997; McBride et al. 1989; Penland et al. 1988; Penland and Ramsey 1990; Roberts et al. 1987).

In the early 1990's, the state of Louisiana proposed the implementation of a near-term strategy for large-scale restoration of its barrier islands through mining of offshore sand deposits (Wetland Conservation and Restoration Task Force 1992; 1993; van Heerden and DeRouen 1997). Since then barrier island restoration projects have been completed on East, Trinity, and Whiskey Island, and plans are underway to restore East Timbalier Island in 1999. As part of a comprehensive barrier island restoration plan along the Isle Dernieres, the Raccoon Island Breakwaters Demonstration (TE-29) project was initiated to demonstrate the effectiveness of segmented breakwaters in mitigating shoreline erosion along the Louisiana barrier islands and to evaluate the potential role of breakwaters in future barrier island protection and restoration efforts. Segmented breakwaters are designed to reduce incident wave energy and create new diffraction and refraction patterns that cause a reduction in potential sediment transport and promote accretion or stability along the beach. Pope and Dean (1986) have identified four engineering design criteria that govern the performance of a segmented breakwater system which include: 1) breakwater length; 2) gap width; 3) distance from the breakwater to the shoreline; and 4) depth of water at the breakwater. Dally and Pope (1986) have indicated that permeability and crest height also play an important role in the performance of segmented breakwater systems. Figure 2 presents an equilibrium shoreline response to a single breakwater and a detached segmented breakwater system along an open sandy coast.

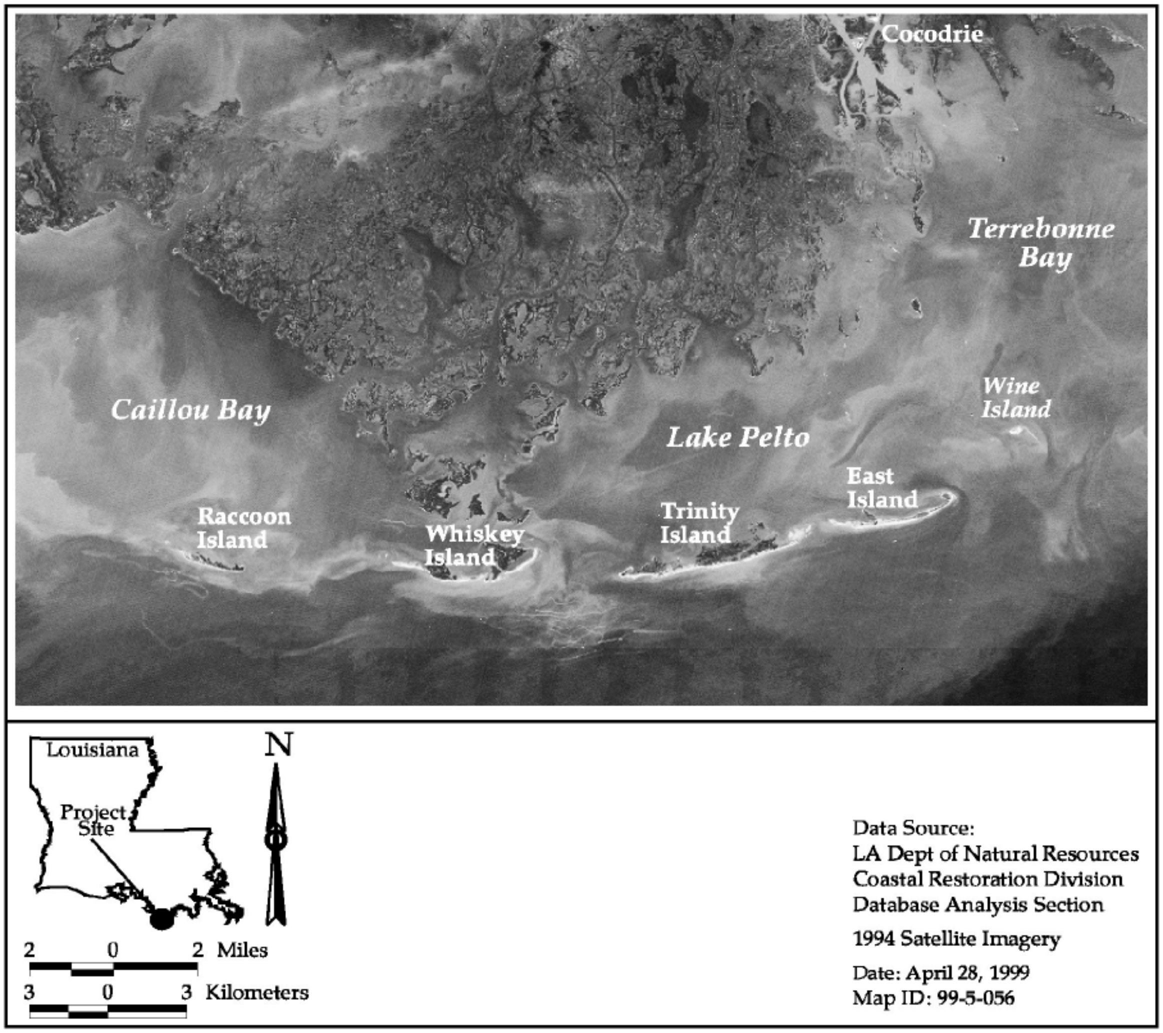

Figure 1. The Isles Dernieres barrier island chain, Terrebonne Parish, Louisiana.

In June and July of 1997 eight experimental segmented breakwaters were constructed approximately 300 ft (91 m) off the southeastern shore of Raccoon Island, Louisiana (29º 04' N, 90º 56' W) (figure 3). The dimensions of the individual breakwaters were as follows: 300 ft (91 m) structure length; 300 ft (91 m) gap width; 10 ft (3 m) crest height; 10 ft (3 m) crest width; and 3:1 side slopes (figure 4). The structures were constructed in water depths ranging from 2 to 6 ft (0.6 to 1.8 m). Construction was completed on 16 July 1997.

The primary objective of the project is to protect critical nesting habitat of the Brown Pelican (*Pelecanus occidentalis*) from an encroaching shoreline by reducing the rate of shoreline erosion along the eastern end of Raccoon Island. During the last century this reach of coast has experienced more than 32 ft yr^{-1} (9.8 m yr^{-1}) of erosion (McBride et al. 1992). As a result the interior marshes have been gradually decreasing in size. Approximately 23 ac (9.3 ha) of island marsh are expected to indirectly benefit from the detached breakwater system (USDA 1994). The specific project goals are as follows: 1) to reduce the rate of shoreline retreat and promote the deposition of sediment along the beach and upper shoreface by decreasing incident wave energy landward of the breakwaters; and 2) to maintain a buffer that can effectively protect the back-barrier marsh from direct wave attack from the Gulf of Mexico.

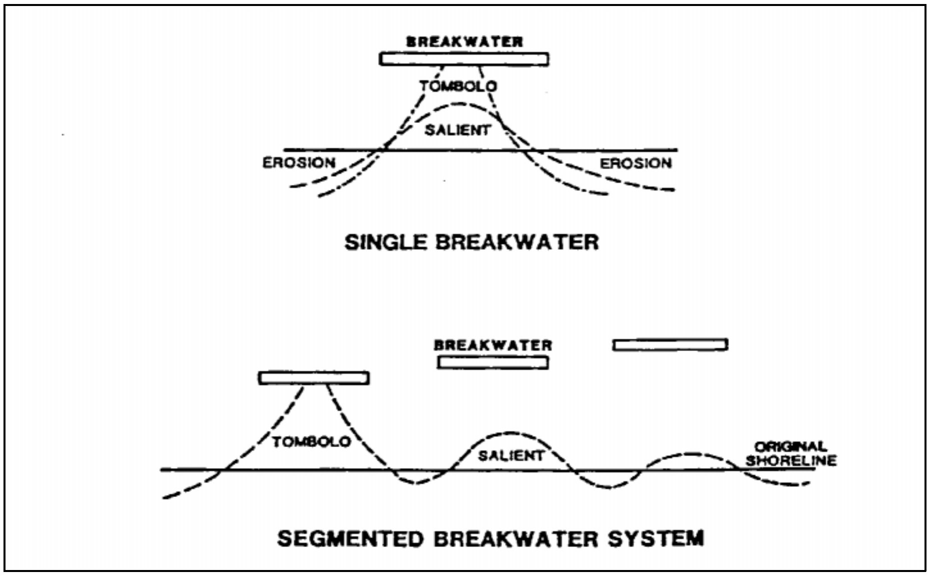

Figure 2. Equilibrium shoreline response to a single breakwater and a detached segmented breakwater system along an open sandy coast (from Dally and Pope 1986).

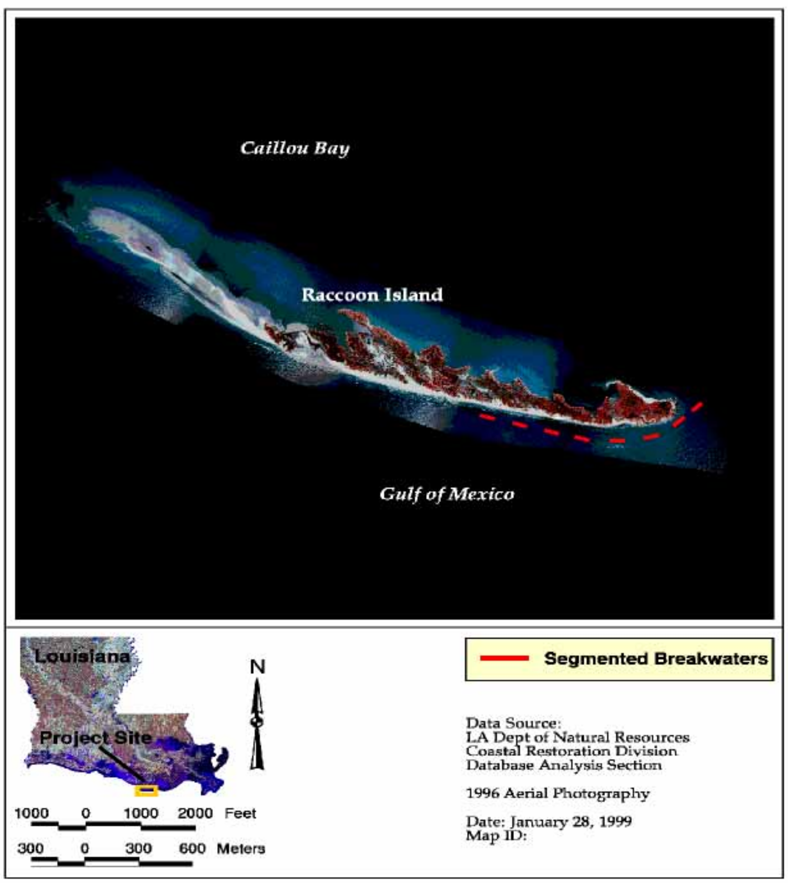

Figure 3. Location map of the Raccoon Island Breakwaters Demonstration (TE-29) project.

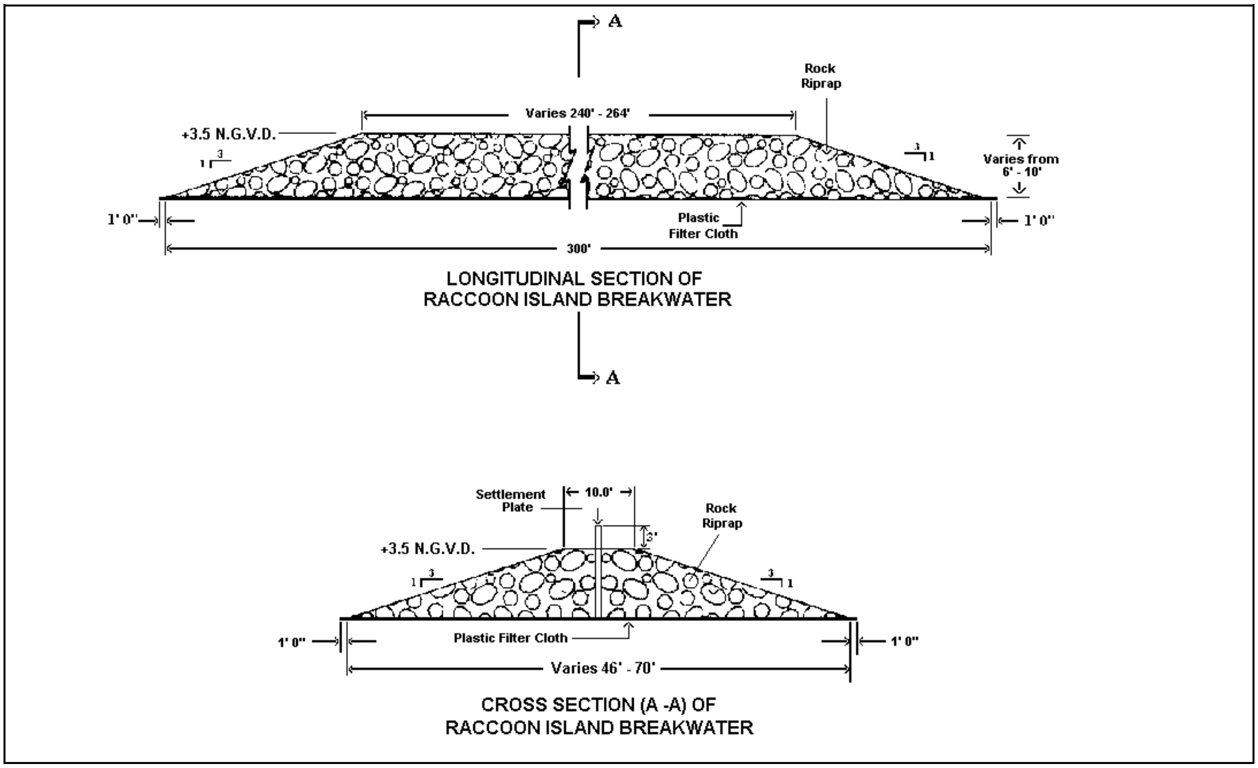

Figure 4. Longitudinal section and cross section of breakwater structure.

METHODS

This investigation examines topographic, bathymetric, and wave data collected during the first 15 months of monitoring to: 1) evaluate the influence of the breakwaters on incident wave conditions; 2) quantify shoreline changes along the project area within the context of historical changes; and 3) quantify volumetric changes landward of the breakwater system (the beach and upper shoreface) and elevation changes along the entire project area. These analyses will quantify the morphologic response that followed installation of the segmented breakwaters during the first 15 months of monitoring and provide a preliminary assessment of project performance.

Topographic/Bathymetric Surveys

In April 1997 Morris P. Hebert, Inc. (MPH) established seventeen transects (P4-P20) along the southeastern shore of Raccoon Island, in the vicinity of seven proposed breakwater locations (1-7), and conducted a pre-construction topographic and bathymetric survey (figure 5). Four transects were established west of breakwater 7 (P17-P20) and thirteen transects were established along azimuths that coincided with the center of the breakwaters and the gaps between breakwaters (P4-P16). In addition, several transects were established north of breakwater 1, in the vicinity of P1, P2, and P3. During construction in July 1997 an additional breakwater (0) was added to the project north of breakwater 1 in the vicinity of these transects. Topographic surveys were conducted with an electronic total station. Horizontal and vertical control were established using a static Global Positioning System (GPS) technique. The benchmark used in this survey was Dreux 2, which is a National Geodetic Survey benchmark (PID No. AU3293) that is also part of the Louisiana High Accuracy Reference Network (HARN). GPS receivers were positioned on Dreux 2 and on the Terrebonne Parish benchmark, located along the eastern end of Raccoon Island. Horizontal coordinate data were referenced to the Louisiana Coordinate System (South Zone), North American Datum (NAD) of 1983. Elevations were referenced to the North American Vertical Datum (NAVD) of 1988. Bathymetric surveys were accomplished using a Raytheon DE719C fathometer.

In April 1998 SJB Group re-occupied seventeen of the original transects (P4-P20) established by MPH in 1997 and established three additional transects (P1, P2, P3) in the vicinity of breakwater 0. Topographic and bathymetric surveys were accomplished using an electronic total station. Horizontal and vertical control were established using the same techniques described above for the 1997 pre-construction survey. During the survey inclement weather hampered field operations and data were not collected beyond wading depth along P17-P20 and beyond wading depth seaward of the breakwaters along P10-P16. Consequently, bathymetric data were unavailable for comparison with pre-construction data in the offshore areas along the western end of the project area.

Topographic data were also collected by a team of scientists from the Coastal Studies Institute at Louisiana State University (CSI/LSU). Beach surveys were conducted in the vicinity of breakwaters 4, 5, 6, and 7, located at the western end of the project area (figure 6). The results of these analyses are presented in three reports that were submitted to the LDNR/CRD during 1997 and 1998 (Stone et al. 1997; 1998a; 1998b). These data will be discussed briefly within the context of the contracted survey data to elucidate temporal changes in the morphologic evolution of the upper shoreface. In addition, local bathymetric information and historical sea-floor changes will be examined to characterize long-term changes along the inner shelf and lower shoreface of Raccoon Island. These

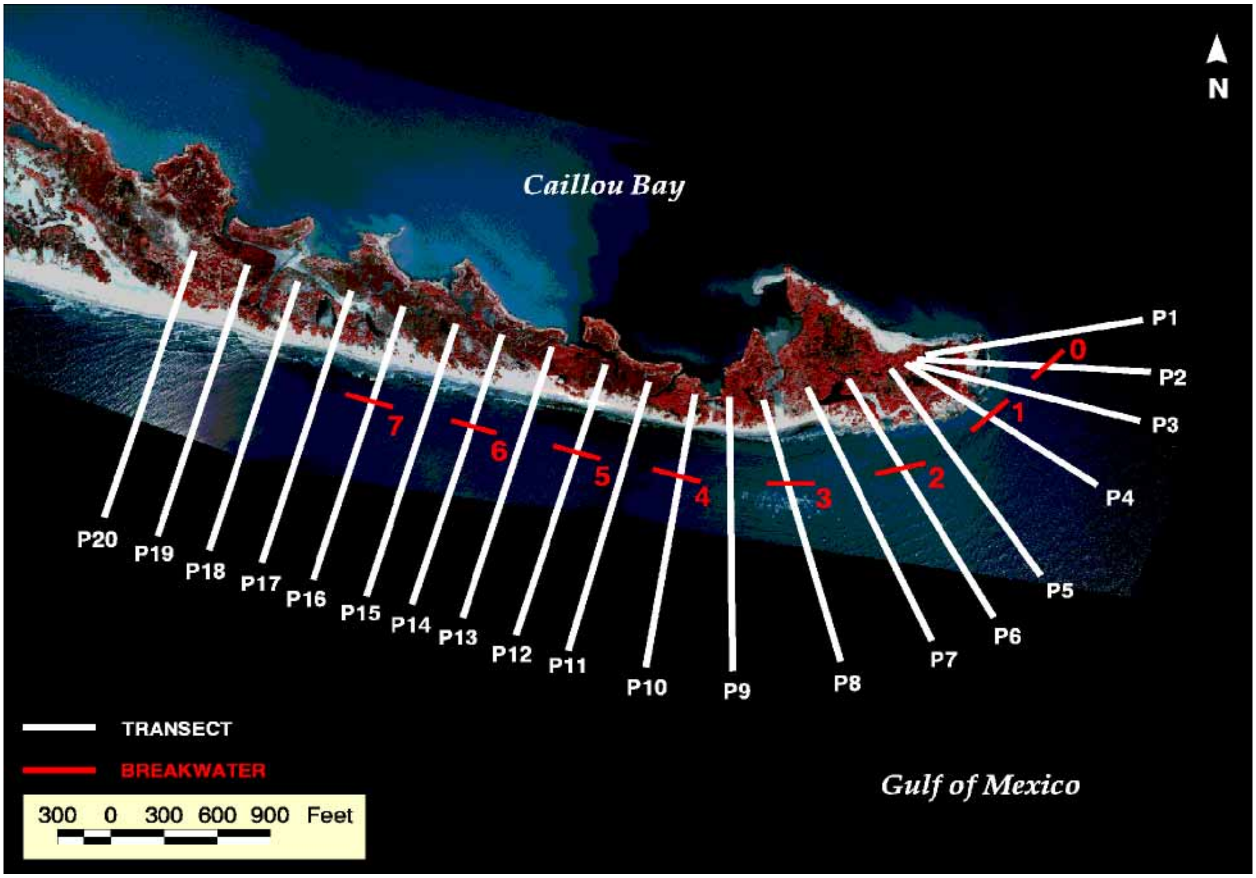

Figure 5. Location of survey transects and breakwaters along the eastern end of Raccoon Island.

data are relevant because patterns of sea-floor change are related to the rapid erosion and disintegration of the Louisiana barrier islands (List et al. 1997).

Wave Measurements

Wave measurements were conducted during October 1997, March 1998, and July 1998 by CSI/LSU personnel to quantify the influence of the segmented breakwaters on the incident wave field. During the field deployments instantaneous water level measurements were taken with four precise, Paroscientific digital quartz pressure transducers (figure 6) (Stone et al. 1997). Significant wave height, peak wave period, and wave-energy were determined from spectral analyses of the raw water-level data. For a more detailed description of the wave data analysis procedures, refer to Stone et al. (1997; 1998a; 1998b).

Data Processing and Analyses

A Geographic Information System (GIS) database was developed to facilitate the data processing and analysis phase of this investigation. Substantial data processing was required to prepare survey coordinate data for beach profile analysis. Survey data were imported to ArcView® (a GIS) and reprojected to a Universal Transverse Mercator (UTM) coordinate system for surface interpolation. A triangulation-based (TIN) digital terrain model was then generated from each survey in order to produce two interpolated surfaces for comparison. A tool was customized in ArcView® to generate

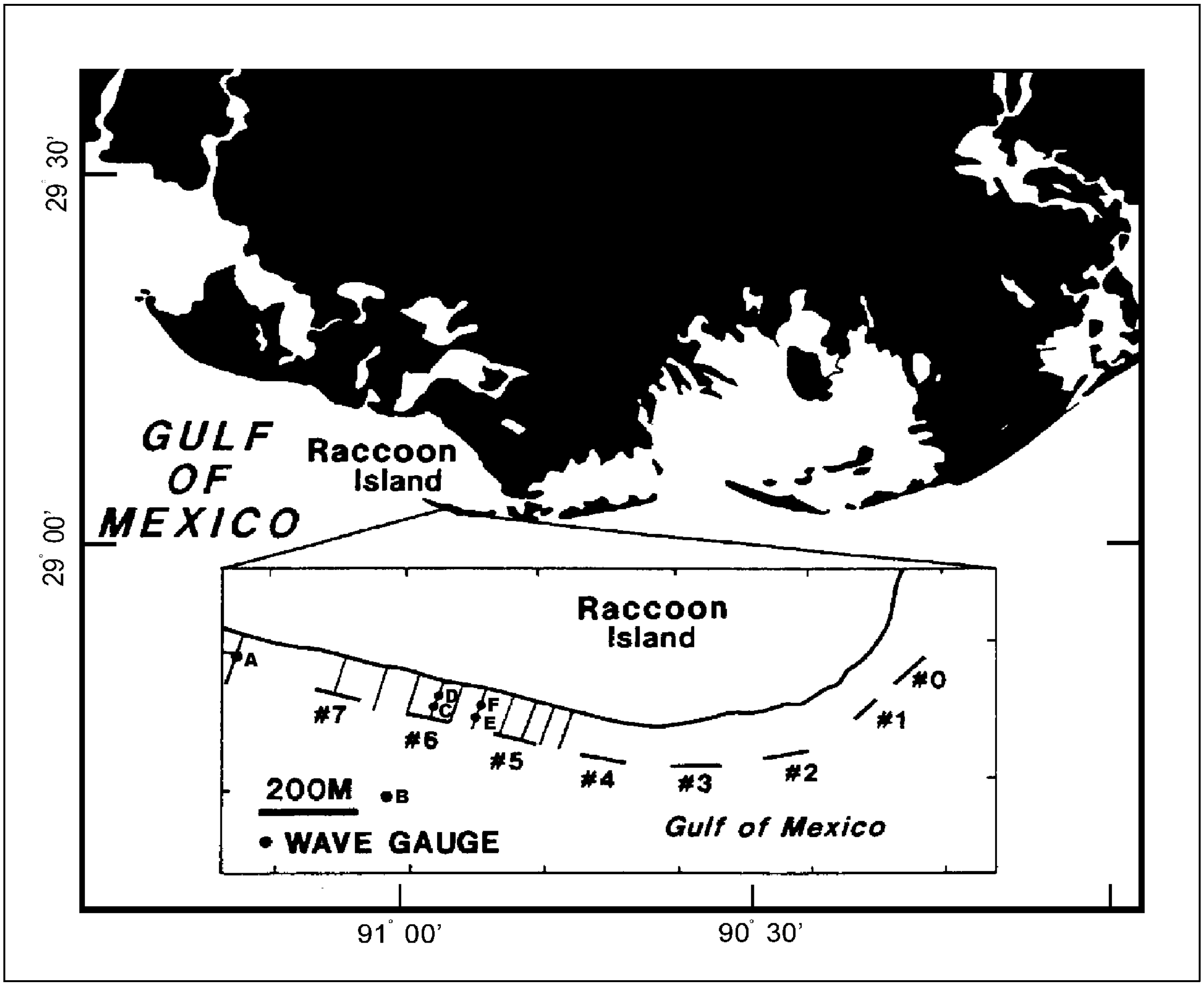

Figure 6. Project area, showing the location of the wave gauges deployed and transects established by LSU/CSI for the collection of topographic data and wave data (modified from Stone et al. 1997).

beach profiles from the surfaces based on specified inputs which included: (1) a transect start point, (2) a transect end point, and (3) a distance interval. Common start and end points had to be defined to compare beach profiles and calculate changes in beach volume and shoreline position. These points are listed in Appendix A and will be used as inputs for future survey analyses. Transect start points were selected landward of the foredune system and distance and elevation values were generated at 3.3 ft (1 m) intervals along the transect to the last point along the shorter of the two surveys.

Beach profile analyses, including comparisons of shoreline position and volume, were performed with the software Beach Morphology Analysis Package (BMAP Ver. 2). Shoreline position was defined as the location of the 2-foot (0.61 m) contour along the beach. Inspection of the beach profiles indicated that the 2-foot contour tended to coincide with a distinct break in slope along the upper beach. This position is an interpretation of the upper limit of wave activity at high tide; relative to geomorphology, this position generally is recognized as the berm crest or a scarp at the toe of the dune (see Byrnes and Hiland 1995). According to Stone et al. 1999, the NAVD88 0-foot contour is located approximately 1.64 ft (0.5 m) below Mean Sea Level (MSL), which puts the 2-foot contour at approximately 0.36 ft (0.11 m) above MSL. This location is close to Mean High Water (MHW), given that the mean diurnal tidal range is 1.18 ft (0.36 m) in the project area (National Ocean Service 1987). Shoreline change was calculated by subtracting the 1997 shoreline position (distance from the start point to the 2-foot contour along the beach) from the 1998 shoreline position. Breakwater compartment volumes were calculated by multiplying the cross-sectional area of individual beach profiles by the distance between the transects (300 ft). Surface elevation changes were computed using the Spatial Analyst extension of ArcView®. The output was calculated by subtracting the pre-construction 1997 interpolated surface from the post-construction 1998 interpolated surface.

RESULTS

Incident Wave Responses

Wave Period:
A comparison of peak wave periods at the wave gauge locations is presented in Figure 7A. The incident wave field varied considerably during each of the three instrumentation deployments. During the October 1997 deployment incident waves had a shore-parallel approach and the average peak wave period varied considerably from one site to the next. The average peak wave period measured directly landward of the breakwater (>5 s) was longer than at the other sites (<5 s). This reduction was the result of a low-pass-filter effect associated with rubble-mound breakwaters (SPM 1984). During the March 1998 deployment incident waves had a shore-oblique approach and the peak wave period was approximately 3 s at all sites. During the July 1998 deployment the area landward of the breakwaters was a closed water body and therefore wave measurements were not possible. The highest peak wave period (>6 s) was measured during this deployment at the offshore site, which would be expected during the summer months when swell waves (long period) are most common.

Wave Height:
The effect of the breakwaters on significant wave height is evident from the CSI/LSU data presented in Figure 7B. During the normally incident wave field (October 1997 deployment) wave heights landward of the breakwaters were reduced by 90% while a 0% reduction in wave height was measured in the gaps. During the March 1998 deployment there was a 70% reduction in wave height landward of the breakwaters and a 50% reduction in the gaps. Wave measurements were not taken landward of the breakwaters during the July 1998 deployment due to impounded sediment that had created a closed water body.

Wave Diffraction:
Wave diffraction in the lee of the breakwaters was most conspicuous during normally incident waves and significantly influenced the pattern of wave breaking at the shoreline. Landward of the center of the breakwaters diffracted waves converged in the vicinity of the shoreline resulting in a converging wave-breaking pattern, while waves diverged at the shoreline landward of the gap. This pattern of wave propagation landward of the breakwaters had a significant influence on sediment transport within the breakwater compartments and produced salients along the shoreline.

Morphologic Responses

Shoreline Changes:
Shoreline changes were calculated from beach profile data presented in Appendix B and Stone et al. (1997; 1998a; 1998b). Figure 8 presents shoreline change data during the first year of monitoring. The shoreline prograded in the lee of breakwaters along every transect except P2 and P6. This trend was more pronounced along transects to the west where the shoreline prograded more than 29 ft yr^{-1} (8.8 m yr^{-1}) in the lee of breakwaters 5 and 6, and more than 44 ft yr^{-1} (13 m yr^{-1}) in the lee of breakwater 4. Shoreline retreat occurred along all transects located in the gaps between breakwaters and averaged 22.4 ft yr^{-1} (6.8 m yr^{-1}). This pattern of shoreline progradation in the lee of breakwaters and shoreline retreat in the gaps was the result of salient development along the beach (figure 2). Figure 9 presents shoreline change data from Stone et al. (1998a). Between October 1997 and March

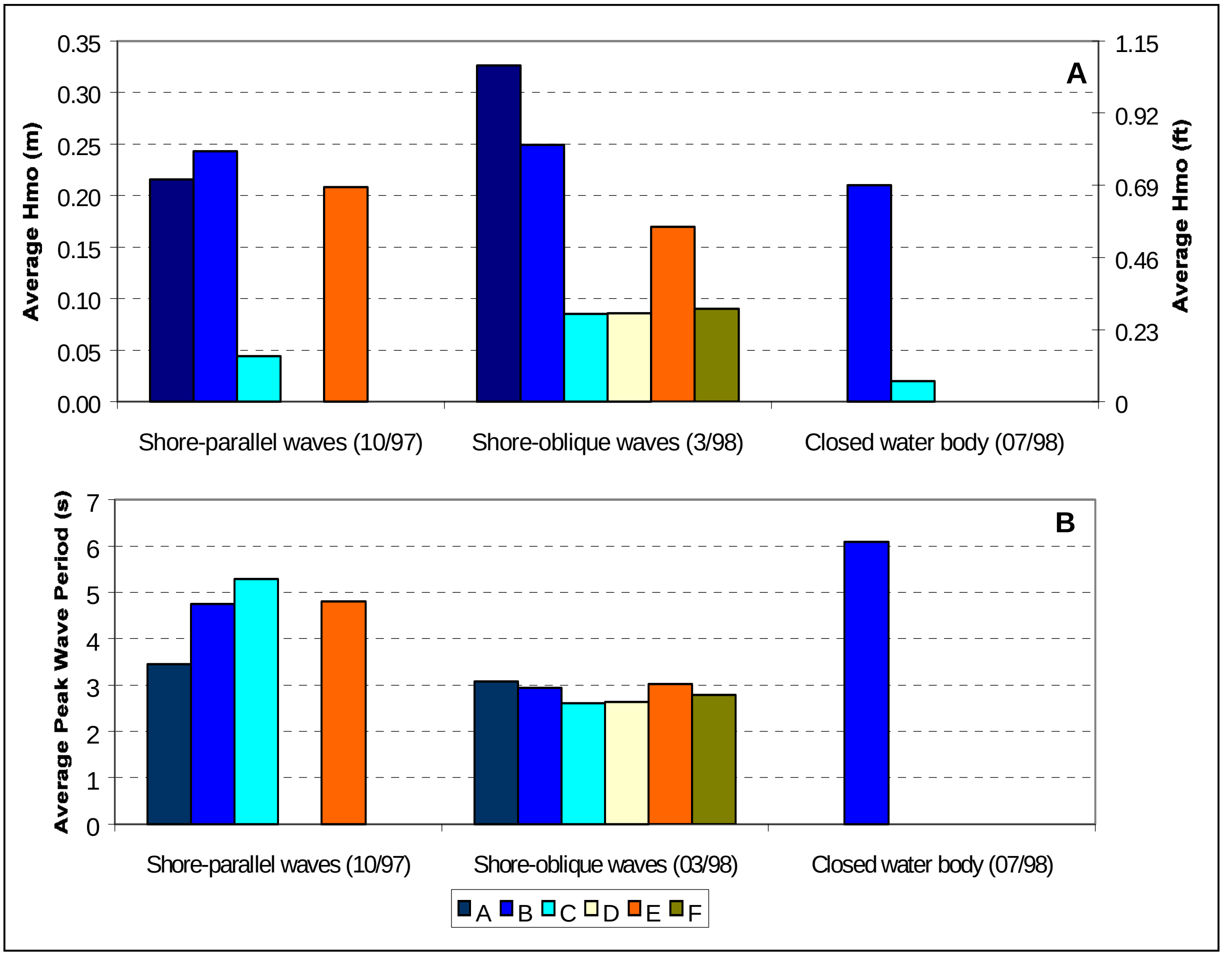

Figure 7. (A) Significant wave heights at the six locations where wave gauges were deployed during October 1997, March 1998, and July 1998 (from Stone et al. 1998b). (B) Peak wave periods at the six locations where wave gauges were deployed during October 1997, March 1998, and July 1998 (from Stone et al. 1998b). Note: letters in the legend correspond to wave gauge locations illustrated in figure 6.

1998 shoreline erosion averaged 7.9 ft yr^{-1} (2.4 m yr^{-1}) in the gaps and 3.1 ft yr^{-1} (0.9 m yr^{-1}) in the lee of the breakwaters. Since shoreline changes after 1 October 1998 were negative in the lee of breakwaters 4 through 7, all of the shoreline progradation in this area must have occurred before October 1998. Therefore, salient formation occurred rapidly along the western end of the breakwater system during the first three months following construction. It was during this initial phase of salient growth that the shoreline behind the breakwaters prograded and erosion rates in the gaps were highest. Sometime after 1 October 1997 (date of the CSI/LSU survey) the shoreline reached quasi-equilibrium landward of the breakwaters and the salients began to erode. The photograph in figure 10 shows a salient along the beach that developed only days after construction of a single breakwater.

During the first year of monitoring the rate of shoreline retreat in the gaps was 10% lower than the long-term shoreline retreat rate. This finding indicates that the breakwaters were providing some protection to the beach as it responded to changes in the incident wave field induced by the segmented breakwaters. Shoreline retreat rates were highest east and west of the breakwater system.

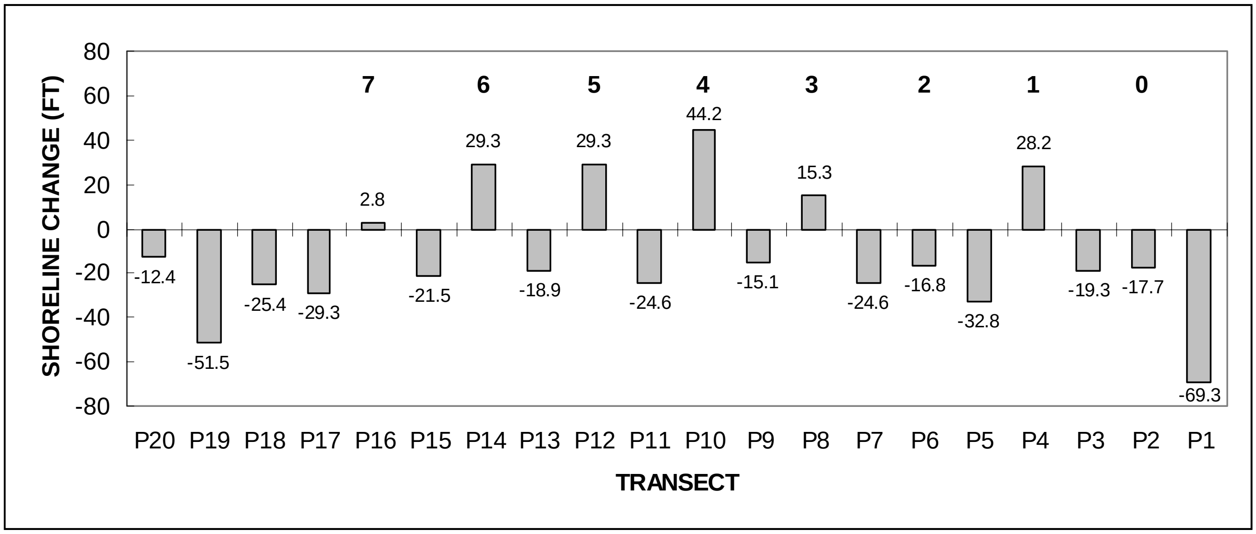

Figure 8. Shoreline changes along the project area from April 1997 to April 1998. The bold numbers above the bars indicate the location of the eight segmented breakwaters with respect to the individual transects.

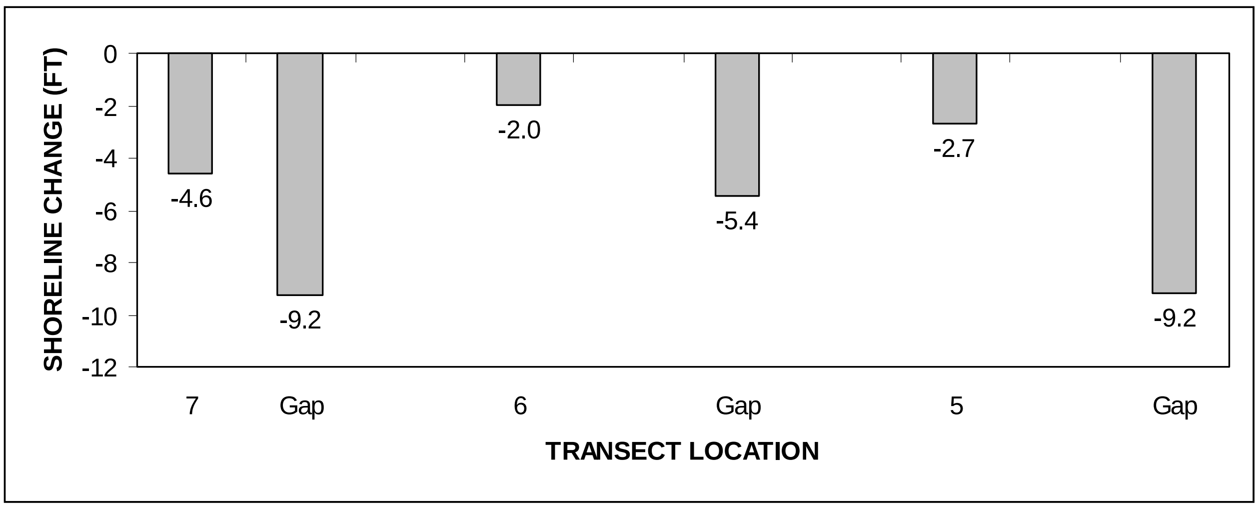

Figure 9. Shoreline changes along breakwaters 5, 6, and 7 from October 1997 through March 1998 (modified from Stone et al. 1998a).

Transects to the west of breakwater 7 (P17-P20) retreated at an average rate of 29.7 ft yr^{-1} (9.1 m yr^{-1}). This rate was 26% greater than the long-term average of 23.6 ft yr^{-1} (7.2 m yr^{-1}) but less than the short-term average of 58.1 ft yr^{-1} (17.7 m yr^{-1}) (McBride et al. 1991). Along the eastern end of the project area at P1 the shoreline experienced the highest rate of retreat, eroding more than 69 ft yr^{-1} (21 m yr^{-1}) during the first 12 months of monitoring.

Volume and Elevation Changes:

Volume changes between the dune and the breakwaters during the first year of monitoring are presented in figure 11. Increases in volume occurred along all transects except P17-P20, P5 and P2. The most substantial increases were measured along the western section of the segmented breakwater system. Along transects P10, P12, P14, and P16, sediment accumulated at a rate of more than 23.2 yds^3 ft^{-1} yr^{-1} (9.2 m^3 m^{-1} yr^{-1}). Along P1, sediment accumulated at a rate of 38.1 yds^3 ft^{-1} yr^{-1} (15.2

Figure 10. Rapid salient development in the lee of breakwater 7 during construction of the detached, segmented breakwater system at Raccoon Island, Louisiana.

m^3 ft^{-1} yr^{-1}) even though this transect experienced the greatest shoreline erosion rate. Volume changes were also positive along all transects located in the gaps, except P5, which decreased by 2.3 yds^3 ft^{-1} (0.9 m^3 m^{-1}). Transects west of breakwater 7 eroded at a rate of 6.4 yds^3 ft^{-1} yr^{-1} (2.5 m^3 ft^{-1} yr^{-1}). During the monitoring period more than 41,000 yds^3 (31,000 m^3) of sediment accumulated landward of the breakwaters, a rate of nearly 9.8 yds^3 ft^{-1} yr^{-1} (3.9 m^3 m^{-1} yr^{-1}). Figure 12 presents elevation changes that depict spatial patterns of erosion and deposition along the upper and lower shoreface. Accumulations of up to 2 ft (0.6 m) of sediment occurred in the immediate lee of all breakwaters and 2 to 4 ft of sediment accumulated in the lee of breakwaters 5, 6, and 7. Along the eastern end of the project area near breakwaters 0, 1, and 2, erosion seaward of the breakwaters and deposition landward of the breakwaters has steepened the shoreface.

The impoundment of sediment landward of the breakwaters during the first 15 months of monitoring produced changes in the nearshore morphology that significantly altered the functioning of the breakwaters (Stone et al. 1998b). By July 1998 the gaps between breakwaters 3 through 6 had filled in with sediment creating a closed shallow water body landward of the breakwaters (figure 13). The formation of a beach seaward of these breakwaters changed the primary location of wave breaking and prevented incident waves from impacting the breakwaters and island shoreline. The presence of small washover fans in the gaps between breakwaters (figure 13) suggests that aperiodic overtopping of the beach occurs when water levels are raised during storms; it is during these events that incident waves may also impact the island shoreline.

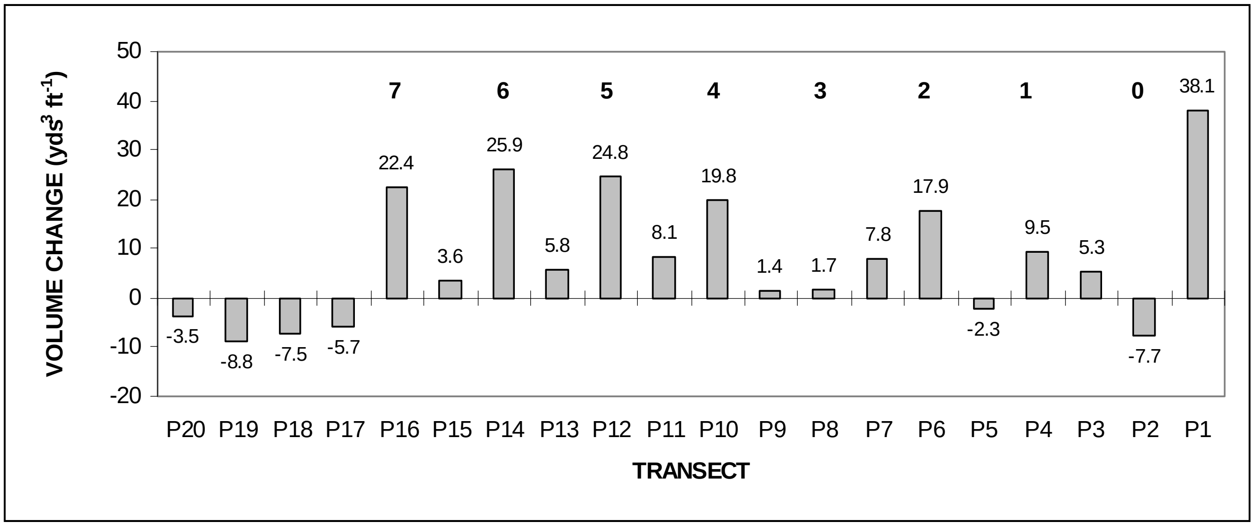

Figure 11. Volume change of individual transects along the project area during the first year of monitoring. The bold numbers above the bars indicate the location of the eight segmented breakwaters with respect to the individual transects.

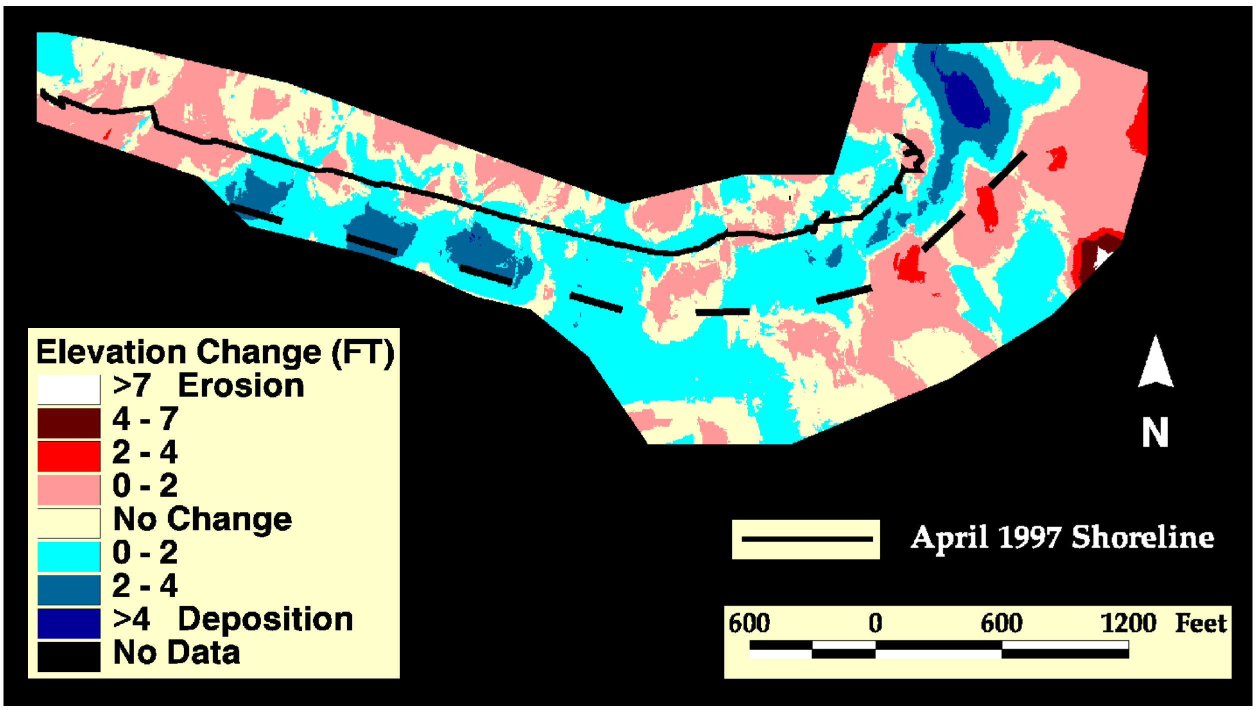

Figure 12. Elevation changes along the project area between April 1997 and April 1998.

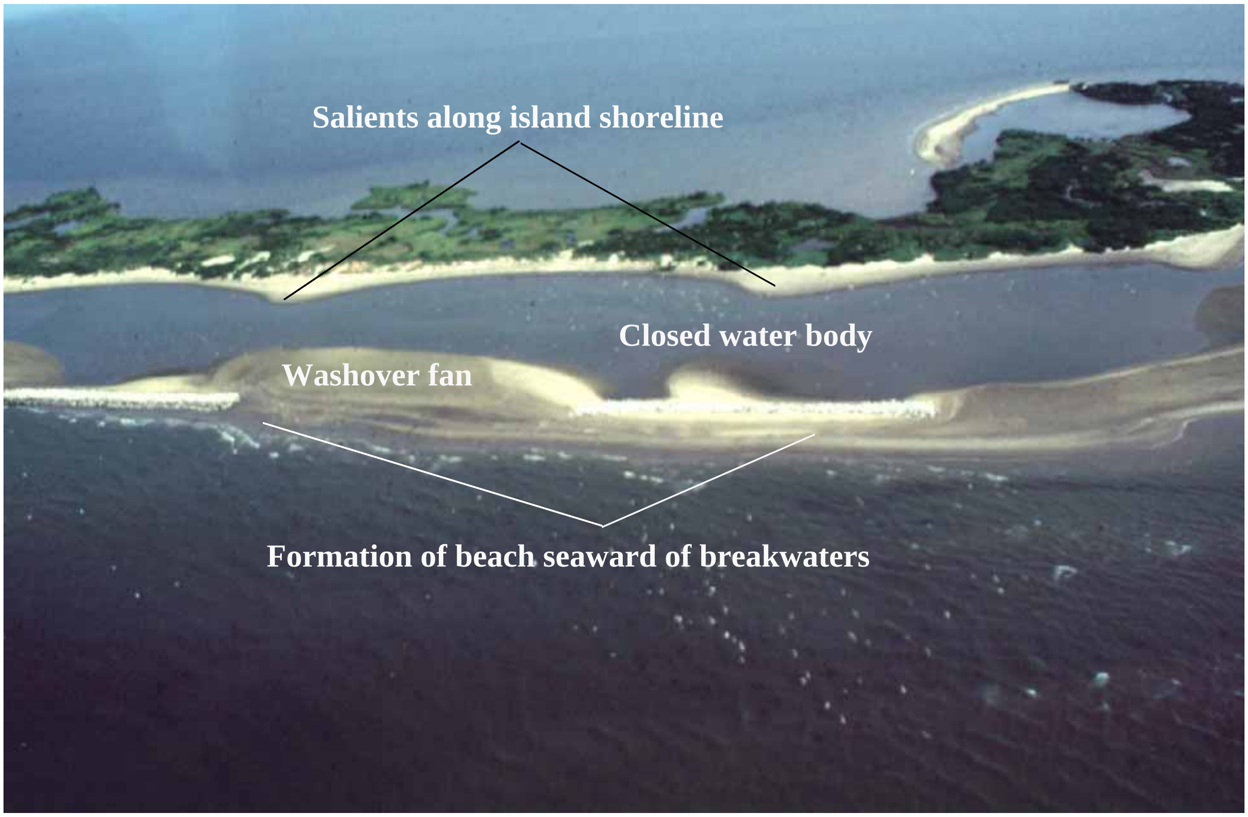

Figure 13. An emerged sand body along breakwaters 4 and 5 resulting from the persistent impoundment of sediments during the first 15 months after construction (photograph taken 27 August 1998).

DISCUSSION

Lower-Shoreface Morphology

Figure 14 presents local bathymetry from the 1980's (upper diagram) and a digital terrain model generated from the pre-construction survey data (lower diagram). The upper diagram identifies the location of a shoal complex along the eastern end of the project area and a protuberance in the 1 m (3.3 ft) isobath. The lower diagram illustrates a broad shallow platform (<5 ft NAVD 88), extending several hundred meters offshore, upon which all breakwaters, except 0, were constructed. The shallow platform probably constitutes the erosional remnants of historical Raccoon Island. A steepening of the shoreface west of the project area is evident and suggests that incident wave energy may be significantly lower along parts of the project area than along areas to the west. Sea-floor change data indicate that the platform has been undergoing substantial change during the last century (figure 15). Therefore, in addition to influencing incident wave conditions, the shallow platform probably plays a significant role in the cyclic and seasonal exchanges of sediment that occur between the beach and lower shoreface. From a management perspective, this is significant because the morphologic development of the beach and upper shoreface is related to the evolution of the lower shoreface and its influence on the local sediment budget.

Upper-Shoreface and Beach Responses

During the initial 15-month monitoring period substantial morphologic changes were measured along the beach and upper shoreface in the vicinity of the breakwaters. These changes varied considerably along the project site and were related to the influence of the segmented breakwaters on incident waves (salient development) and the influence of the shoal complex on local sediment supply and wave attenuation. Nearshore wave measurements indicate that the segmented breakwaters reduced incident wave energy and provided limited protection to the shoreline, which eroded at a lower rate than the areas east (P1) and west (P17-P20) of the structures (figure 8). During the first three months following construction of the breakwaters (July-September 1997) the formation and development of salients occurred rapidly along the shoreline in the lee of the breakwaters. This response was characterized by progradation of the shoreline in the lee of breakwaters and erosion in the gaps. After an initial phase of rapid shoreline adjustment, the salients began to erode.

Throughout the monitoring period, shoreline erosion was most pronounced along the eastern section of the breakwater system. This area faces the southeast, which is the direction of prevailing winds during the summer months, and the northeast, which is the direction of prevailing winds during winter cold front passages (Chaney 1999). Consequently, beaches probably experience higher wave-energy conditions on average than beaches along the western section, which are not impacted by waves produced during cold-front generated northerly winds. Another condition that may be exacerbating shoreline erosion along the eastern end is a steeper shoreface - water depth is greater landward and seaward of the structures than along the western section. A steeper shoreface decreases attenuation of waves as they propagate through the surf zone toward the beach. This higher average wave-energy condition may increase the potential for sediment transport along the beach thereby increasing shoreline erosion.

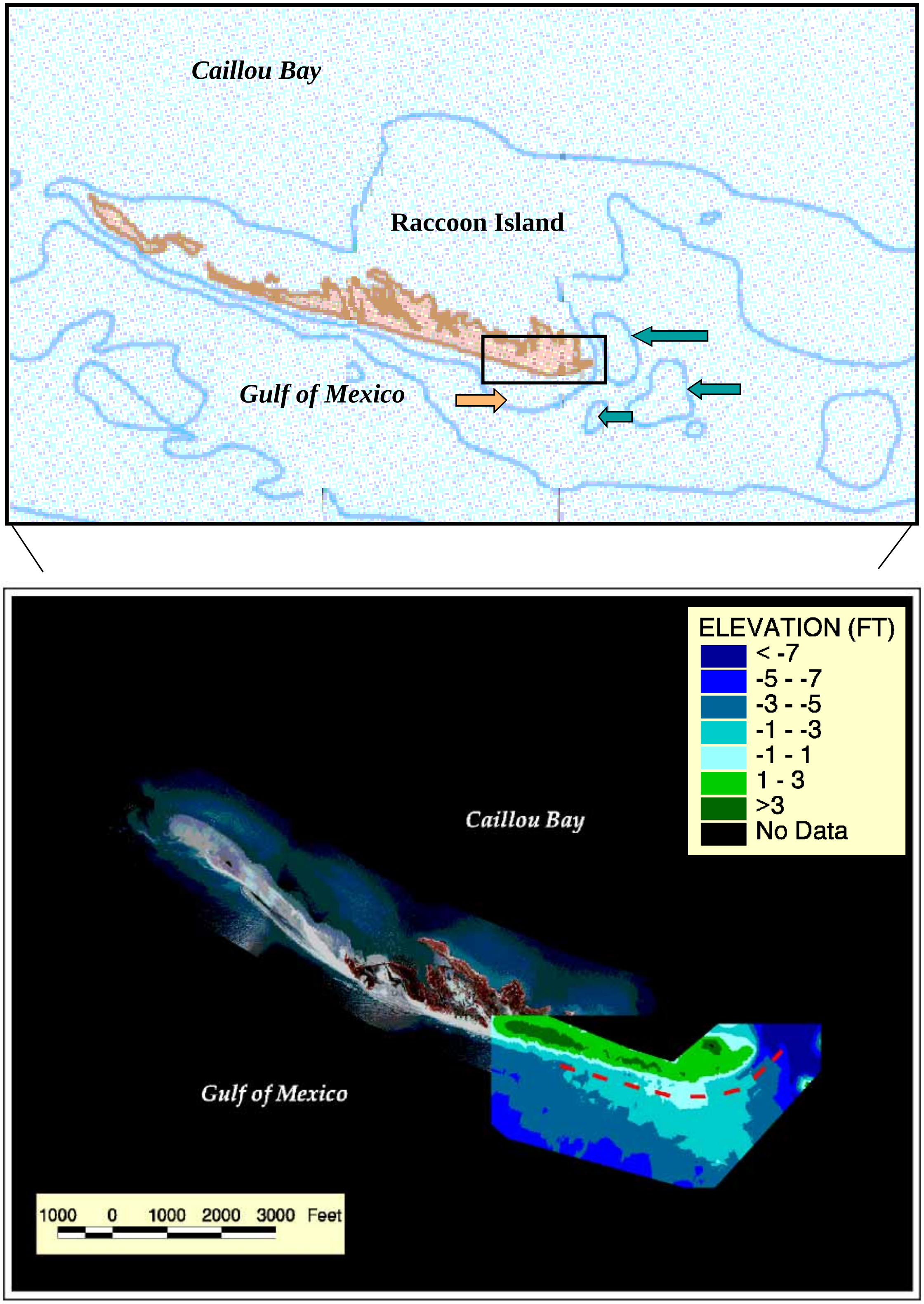

Figure 14. Regional bathymetry along Raccoon Island showing several shoals (blue arrows) and a distinct protuberance (gold arrow) in the 1 meter isobath near the eastern end of the island (upper diagram) (modified from List et al. 1994). A digital terrain model generated from the 1997 pre-construction survey data (lower diagram).

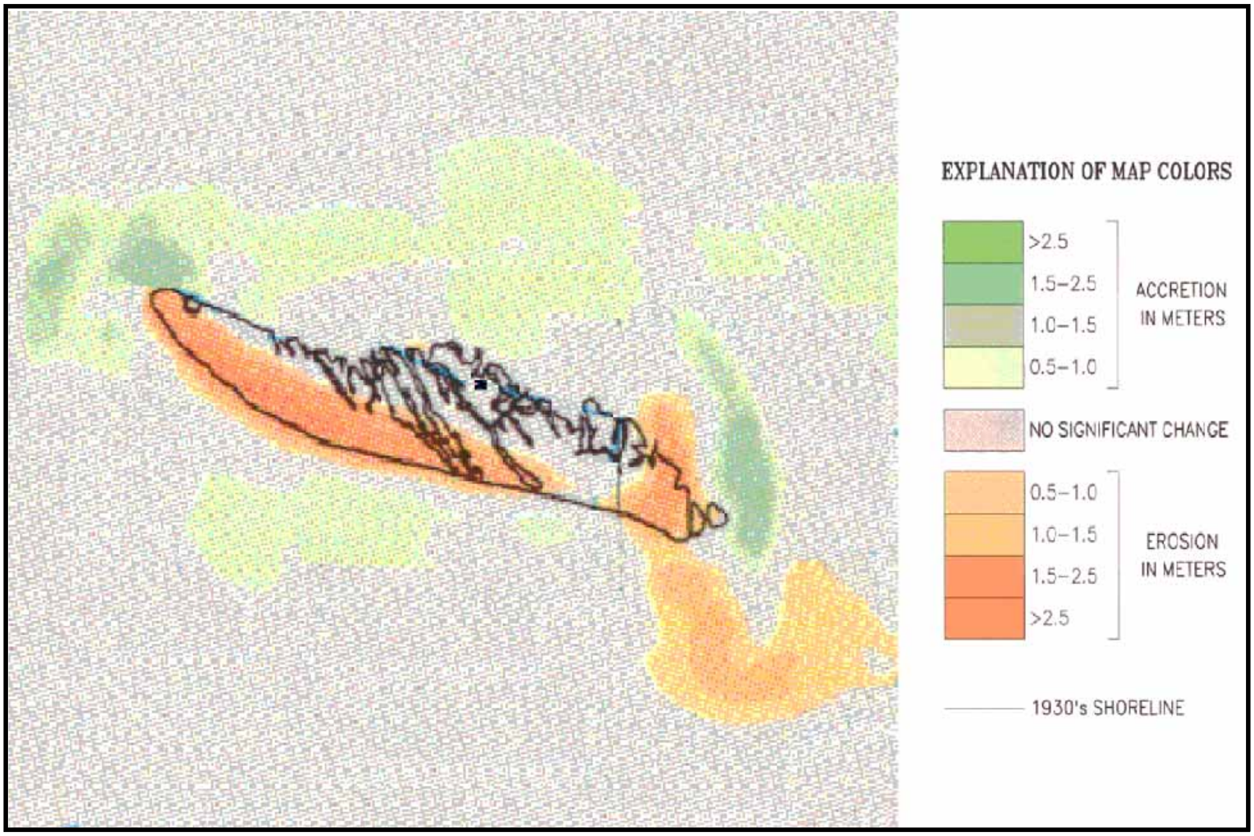

Figure 15. Sea-floor changes from 1930-1980 (modified from List et al. 1994).

In spite of continued shoreline erosion during the first year of monitoring, by April 1998 more than 9.8 yds^3 ft^{-1} yr^{-1} (3.9 m^3 ft^{-1} yr^{-1}) of sediment had accumulated between the dune and the breakwaters (beach and upper shoreface). This accumulation was most pronounced in the immediate lee of the structures, especially along the western section where more than 2 ft (0.6 m) of vertical accretion was measured, as well as in the gaps between breakwaters. Data from Stone et al. (1999) indicate that between October 1997 and March 1998 the maximum accumulation of sediment occurred in the immediate lee of the structures and decreased toward the gaps. By July 1998, however, the zone of maximum accumulation had shifted to the gaps between the breakwaters and to the seaward flank of the structures, which led to the formation of a continuous emerged sand body that extended from breakwater 3 to breakwater 7. This emerged sand body has displaced the zone of wave breaking seaward and sheltered the island from incident waves during conditions when water levels are not elevated sufficiently to overtop the berm. In addition, the newly formed beach has prevented incident waves from propagating through the gaps between breakwaters and depositing sediment in the lee of the structures. The emergence of washover fans in the gaps between several breakwaters (figure 13) indicates that sediments began to be transported to the areas landward of the breakwaters by overwash processes when the beach was overtopped during elevated water levels (storms). It is hypothesized that sediments will continue to be supplied to the project area until the source is exhausted. Along the easternmost breakwaters (0, 1, and 2) the shoreface appears to have steepened as sediment has accumulated landward of the structures and eroded along the seaward flank.

Figure 16. Sediment accumulation in the lee of breakwaters 3 and 4 less than two weeks after construction was completed (photograph taken 31 July 1998).

Sediments that accumulated along the project area during the first 15-months of monitoring were most likely not supplied from dredging operations conducted at East, Trinity, and Whiskey Island for the following reasons: 1) sediments began accumulating in the lee of the breakwaters only days after breakwater construction was completed in July 1997 (figure 16), yet dredging operations did not commence at East, Trinity, and Whiskey Island until early 1998; 2) sediments were mined from the bay and pumped into containment dikes constructed along the north side of the islands, which would have prevented large quantities of material from entering the gulfside surf and being reworked to the west; and 3) the dredged sediments were finer than the sediments that accumulated along the project area.

Implications for Coastal Management

Interpretation of wave and beach profile data has revealed a unique morphological response of the beach and upper shoreface to a series of eight detached segmented breakwaters. The rapid emergence of sand bodies in the immediate lee of the structures was unanticipated when considering our present understanding of detached segmented breakwaters. To our knowledge, no segmented breakwater system has caused this type of morphologic response. A net increase in volume between the dune and the breakwaters indicates that sediments were delivered to the project site from a source other than the beach and dune. The sediments comprising the upper shoreface deposits appear to have been supplied from an offshore source through cross-shore transport processes, as opposed to the capture of sediments transported from an alongshore source (Stone et al. 1999). The emergence of sand bodies in the immediate lee of the structures (termed “reverse salients” in Stone et al. 1999) suggests that sediments were transported through the gaps between the breakwaters during periods of onshore sediment transport. The formation of a beach along the seaward flank of several breakwaters provides additional evidence that sediments were supplied from a cross-shore source. These findings are significant with respect to the assessment of the potential use of segmented breakwaters along Louisiana's barrier islands because they indicate that present engineering criteria used to design segmented breakwaters (distance from shore to structure, depth of water at structure, structure length, and gap length) may need to be supplemented with additional criteria that account for the dimensions of the lower shoreface and the proximity of the structures to an offshore sediment source. Therefore, in order to predict the future performance of the Raccoon Island breakwaters project, a more comprehensive understanding of the following should be established: 1) the conditions that caused the preferential deposition of sediment along the western section of breakwaters; 2) the primary source of the sediment impounded in the immediate lee of the breakwaters and along their seaward flank; 3) the present volume of the source and its projected longevity; 4) the nearshore sediment transport dynamics; and 5) the precise roles of longshore and cross-shore transport at the project site (Stone et al. 1998c).

CONCLUSIONS

The morphologic development of the beach and upper shoreface in the vicinity of eight detached segmented breakwaters on Raccoon Island, Louisiana was quantified through the analysis of wave data and topographic and bathymetric surveys. Wave information collected by CSI/LSU personnel quantified the influence of the breakwaters on incident wave height and period. Data obtained from elevation surveys, conducted prior to construction of the breakwaters and during a 12-month period following construction, provided a detailed representation of the morphologic evolution of the beach and upper shoreface. Data collected through July 1998 indicate that the segmented breakwaters on Raccoon Island have decreased incident wave energy landward of the structures, significantly reduced the rate of shoreline retreat in the vicinity of breakwaters 3 through 7, and caused the impoundment of more than 41,000 ft^3 (>31,000 m^3) of sediment.

Data derived from wave gauge deployments in October 1997, March 1998, and July 1998 indicate that the breakwaters reduced incident wave heights by 90% landward of the breakwaters and by 0% in the gaps. During an obliquely incident (shore-oblique) wave regime breakwaters reduced wave heights by 70% landward of the breakwaters and 50% in the gaps. Landward of the center of the breakwaters, diffracted waves converged near the shoreline resulting in a converging wave-breaking pattern; waves diverged near the shoreline landward of the breakwater gaps. Wave diffraction in the lee of the breakwaters influenced the pattern of wave breaking at the shoreline, which played a significant role in the initial formation of salients along the shoreline and reverse salients in the immediate lee of several breakwaters.

Topographic and bathymetric data indicate that during the first three months following breakwater construction, salient development was rapid along the shoreline and sediment began to accumulate in the immediate lee of the breakwaters. By November 1997, the shoreline along the western section of breakwaters (4 through 7) reached a state of quasi-equilibrium and began to erode; sand bodies had also begun to emerge in the lee of several breakwaters. During the first twelve months of monitoring, the rate of shoreline retreat in the gaps between breakwaters 4 through 7 was reduced to 10% below the long-term average. In the lee of these breakwaters, the shoreline experienced an average net progradation of 29.8 ft (9.1 m) (salient growth). Vertical accretion of more than 4 ft (1.2 m) was measured in the immediate lee of breakwaters (reverse salient growth) while vertical accretion of 2 to 4 ft (0.6 to 1.2 m) was measured in the gaps. The persistent accumulation of sediment in the gaps and landward of the breakwaters resulted in the impoundment of more than 9.8 $yds^3\ ft^{-1}\ yr^{-1}$ (3.9 $m^3\ m^{-1}\ yr^{-1}$) of sediment during the first year of monitoring. By July 1998, a sand body had emerged in the gaps between breakwaters 3 through 6 and a beach had formed along their seaward flank. This beach appears to be protecting the island shoreline from direct wave attack and has significantly modified the wave climate behind the structures. Aperiodic overwashing of the beach during storms has produced small washover fans in the gaps, which appear to be in an embryonic stage of development. This new morphologic condition has inhibited the continued growth of the reverse salients in the immediate lee of the breakwaters, by preventing waves from propagating through the gaps, and displaced the zone of wave breaking seaward.

Along the eastern end of the project area, shoreline erosion rates exceeded the long-term average of 23.6 ft yr^{-1} (7.2 m yr^{-1}) during the first year of monitoring and the shoreface steepened as the zone seaward of the breakwaters eroded and the zone landward of the breakwaters accumulated sediment. Shoreline erosion along this section of the project area was probably exacerbated by the following three factors: 1) the shoreline's exposure to easterly and northeasterly directed waves that accompany winter cold front passages; 2) a steeper shoreface, which reduces wave attenuation in the surf zone; and 3) a decrease in sediments transported to the area from the west (along the gulfside shoreline from updrift beaches) during reversals in longshore drift.

Preliminary data suggest that a dynamic shoal complex, upon which the breakwaters were constructed, may have influenced local wave propagation and attenuation in the vicinity of the breakwaters and played a critical role in supplying sediment to the project area. The emergence of sand bodies directly landward and seaward of the breakwaters was unanticipated when considering our present understanding of detached segmented breakwaters and suggests that cross-shore sediment trapping may be occurring in the vicinity of the breakwaters. The present findings are significant when evaluating the effectiveness of segmented breakwaters in mitigating shoreline erosion along Louisiana's barrier islands because they indicate that additional criteria are needed to improve functional breakwater design. Future project performance will be influenced by the evolution of the remnant platform and its influence on the local sediment budget and tropical and extra-tropical storm activity. Although the data presented in this report are promising with respect to their implications regarding the role of segmented breakwaters in shoreline protection along the Louisiana coast, they are derived from 15 months of monitoring and should be viewed as preliminary.

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APPENDIX A

Start and end points of individual transects

Transect	Northing	Easting	Latdd	Longdd
P1	200151.560	3414158.078	29.04945442	-90.91600881
P1	200510.333	3415117.675	29.05043132	-90.91300176
P2	200103.174	3414113.998	29.04932180	-90.91614731
P2	200004.521	3415406.897	29.04903743	-90.91210249
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P3	199793.444	3414985.567	29.04846126	-90.91342340
P4	199988.904	3414060.093	29.04900811	-90.91631730
P4	199347.104	3414891.664	29.04723480	-90.91372238
P5	199939.799	3413890.251	29.04887478	-90.91684935
P5	198952.921	3414504.837	29.04615474	-90.91493738
P6	199840.468	3413667.234	29.04860386	-90.91754838
P6	198816.301	3414197.537	29.04578214	-90.91590057
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P10	199861.506	3412724.309	29.04867114	-90.92049888
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P16	199003.631	3410500.917	29.04633400	-90.92746617
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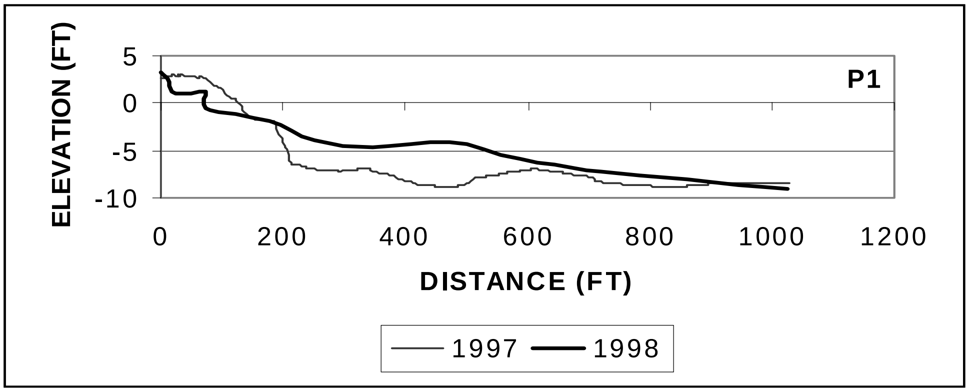
APPENDIX B

Beach Profiles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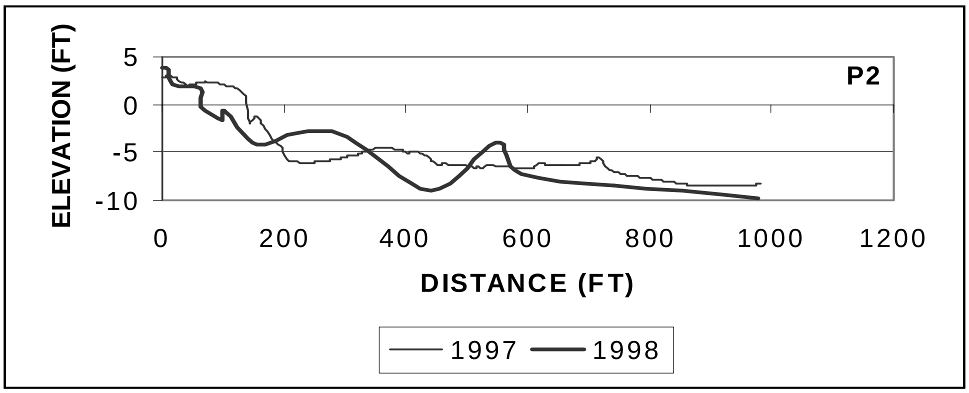
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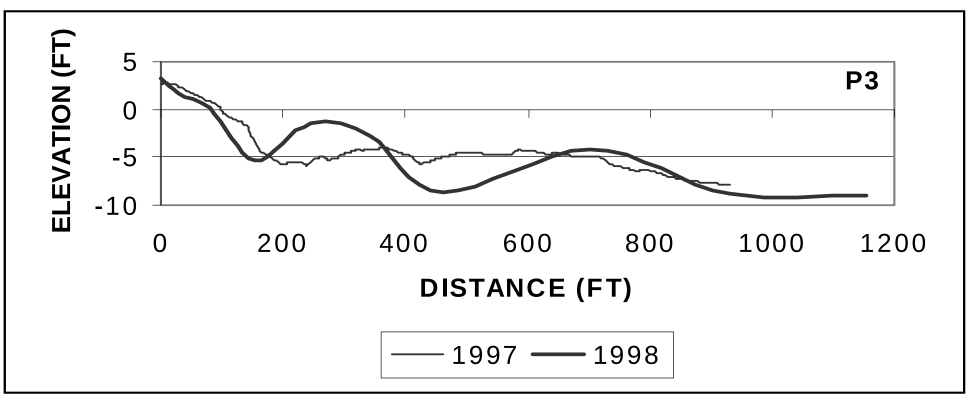
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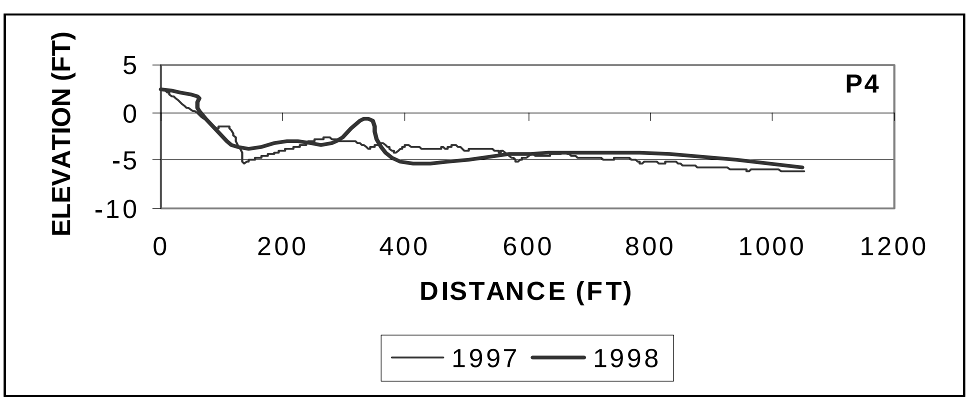
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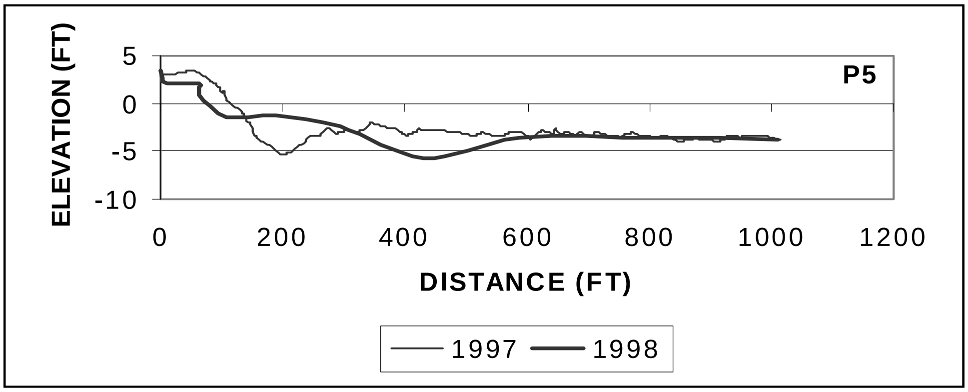
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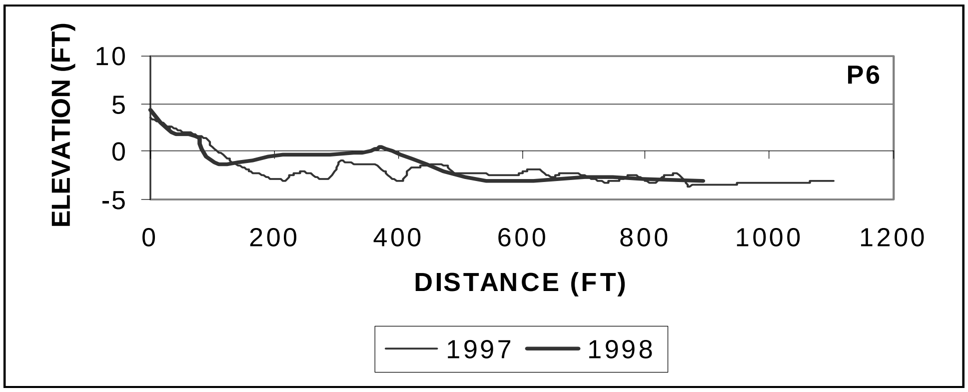
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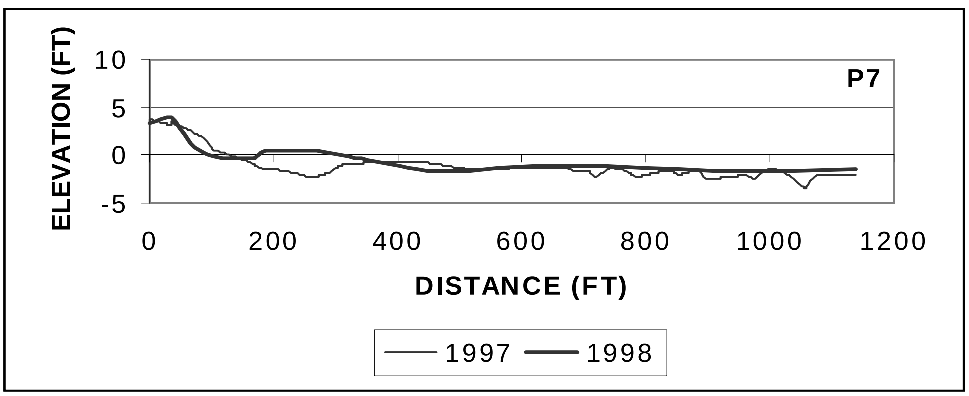
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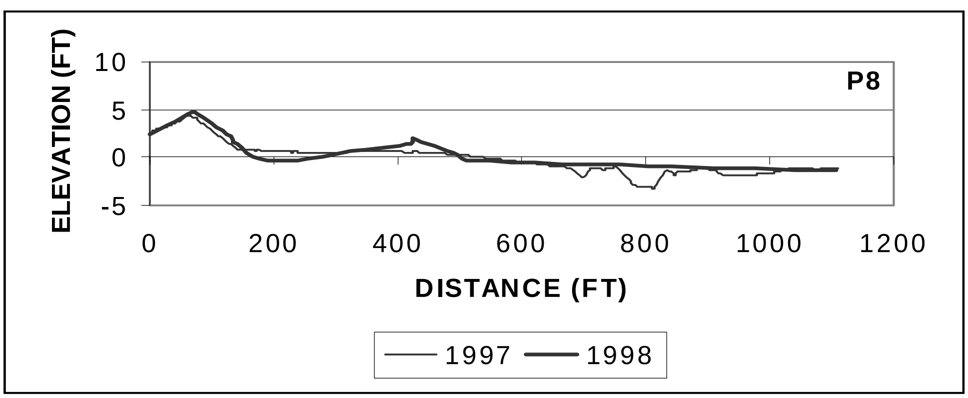
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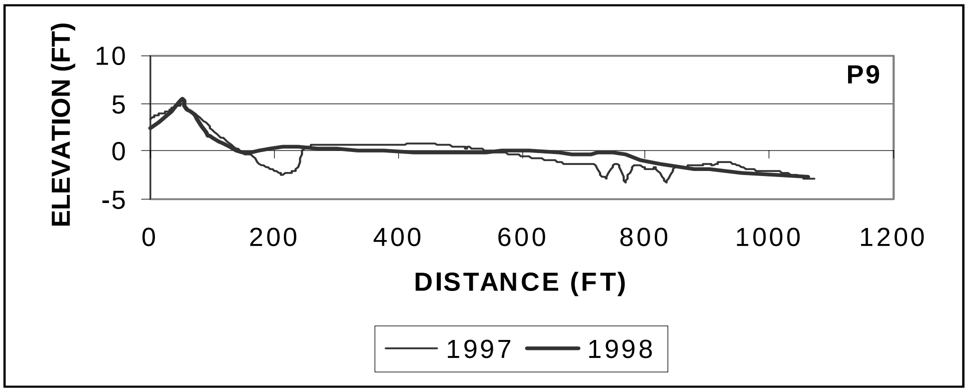
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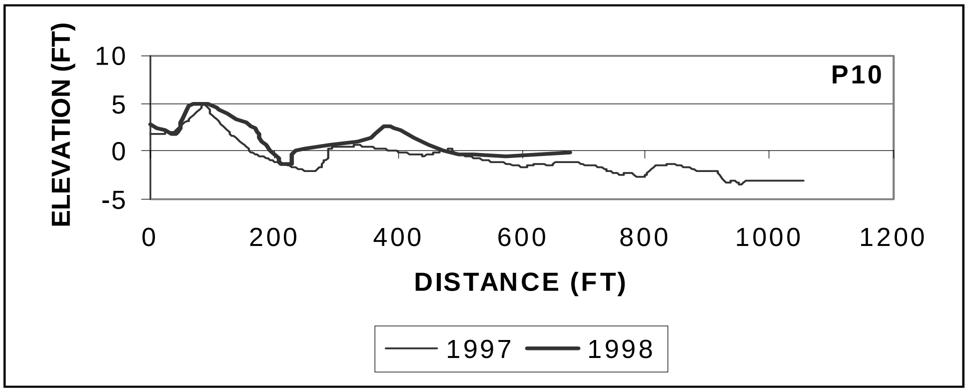
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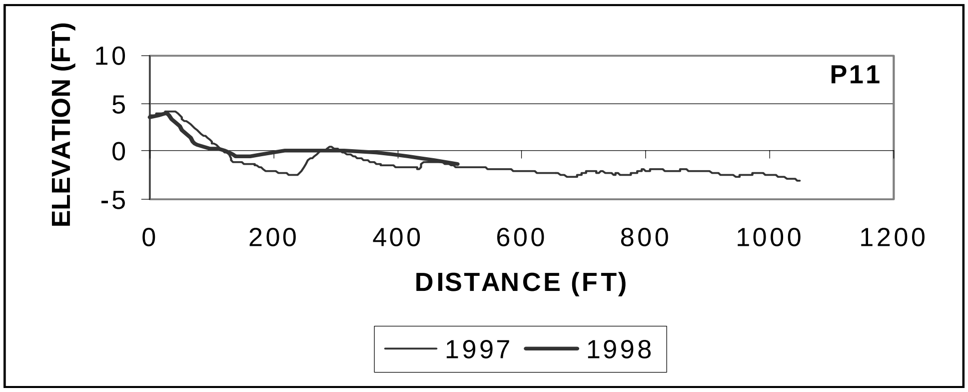
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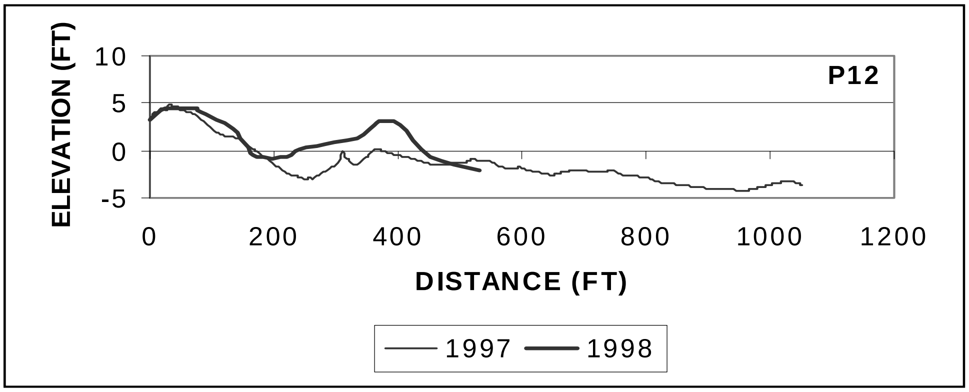
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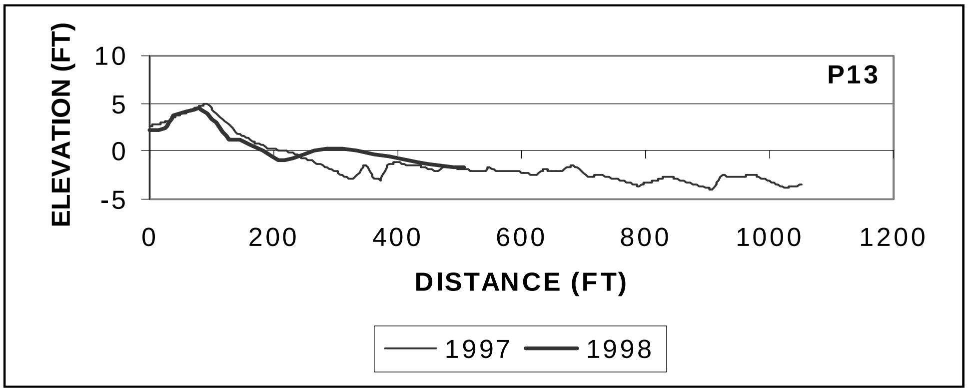
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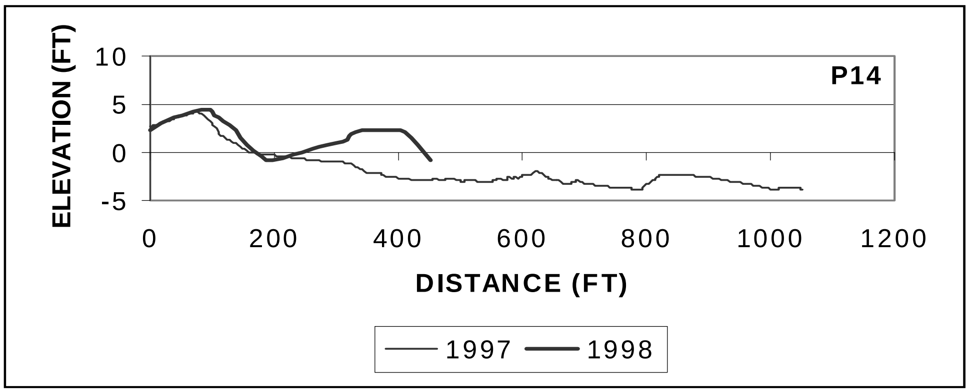
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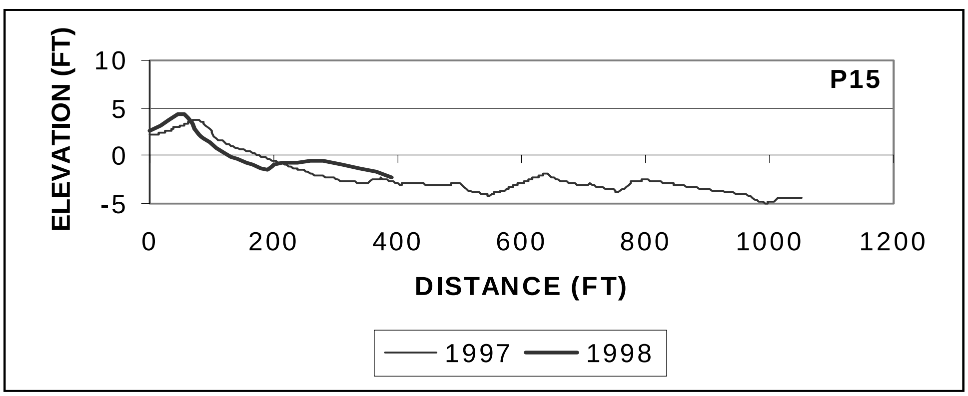
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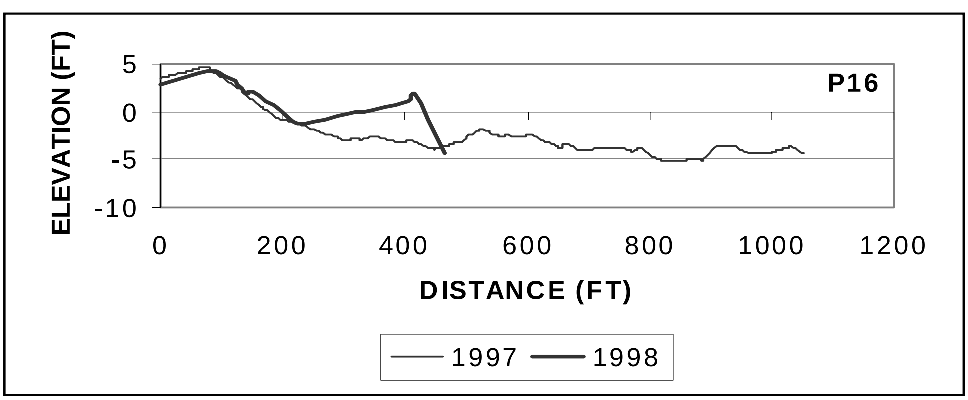
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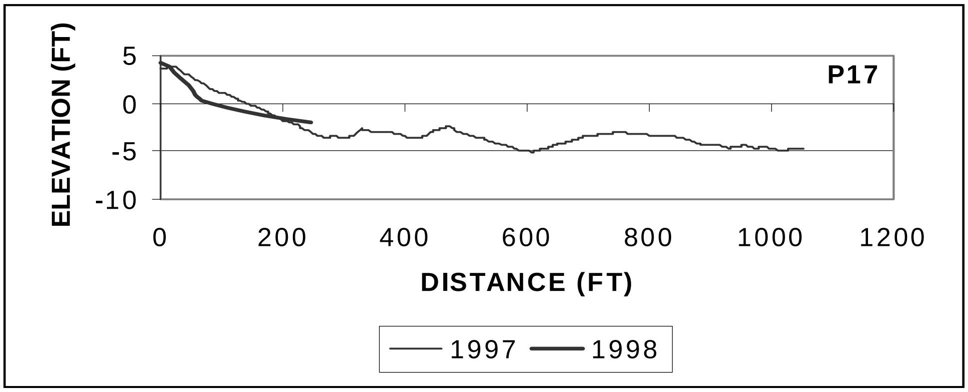
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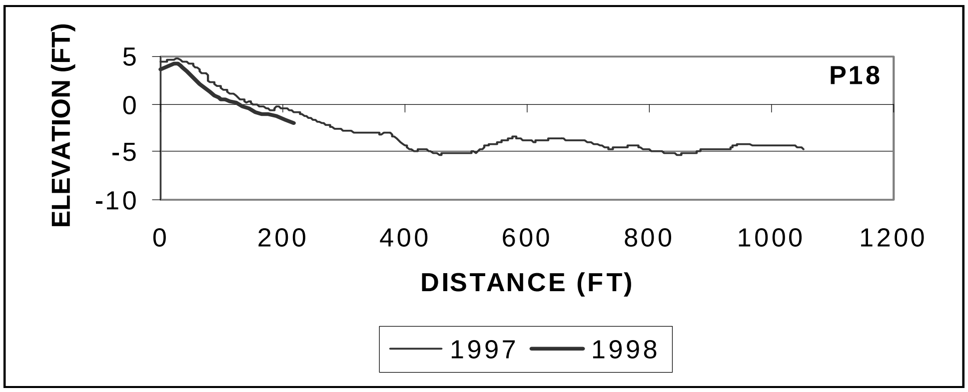
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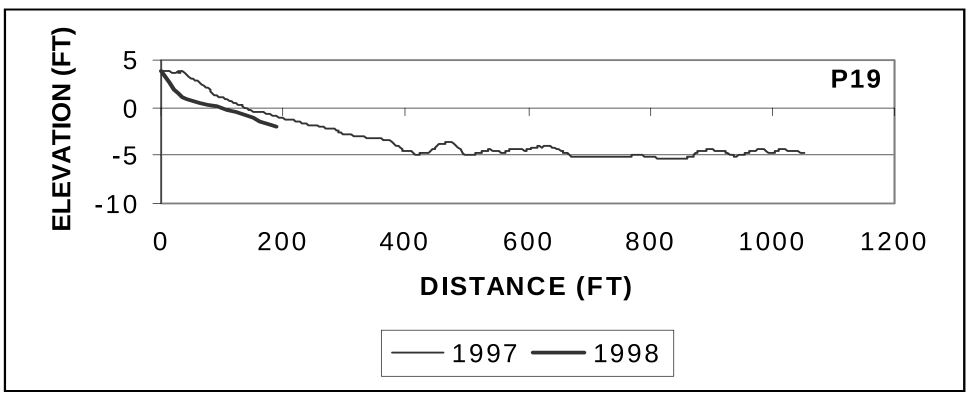
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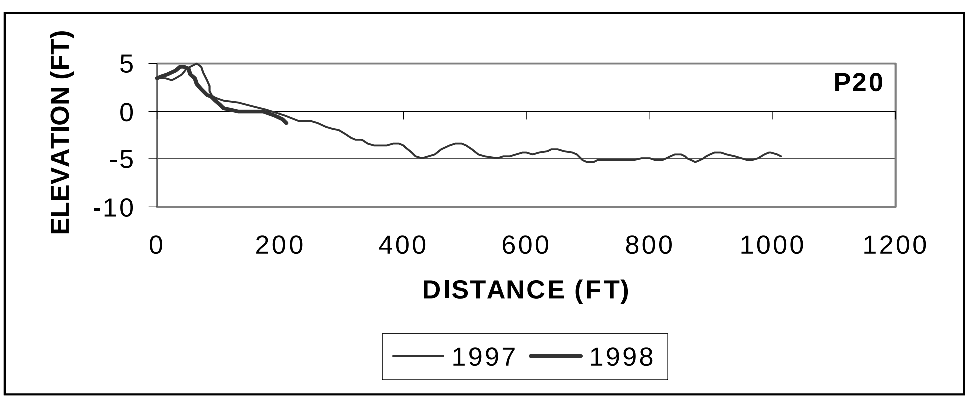
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