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

Lake Borgne and MRGO Shoreline Protection
CWPPRA Priority Project List 12
State No. PO-32

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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 July 12, 2005.

Ecological Review
Lake Borgne and MRGO Shoreline Protection

In August 2000, the Louisiana Department of Natural Resources (LDNR) 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 Lake Borgne and Mississippi River Gulf Outlet (MRGO) Shoreline Protection (PO-32) project is located in St. Bernard Parish, Louisiana (Figure 1). The goal of this project is to preserve the existing marsh land bridge between Lake Borgne and the MRGO and thus prevent the coalescence of the two water bodies. The project consists of two reaches, the first of which is located on the southernmost bank of Lake Borgne between Doullut's Canal and Jahncke's Ditch. The 18,820 linear foot reach is comprised of 76 acres of marsh and 24 acres of open water. The second reach is located on the north bank of the MRGO channel extending eastward from Doullut's Canal to Lena Lagoon. This 14,360 linear foot reach is comprised of 173 acres of marsh and 192 acres of open water (United States Army Corps of Engineers 2004).

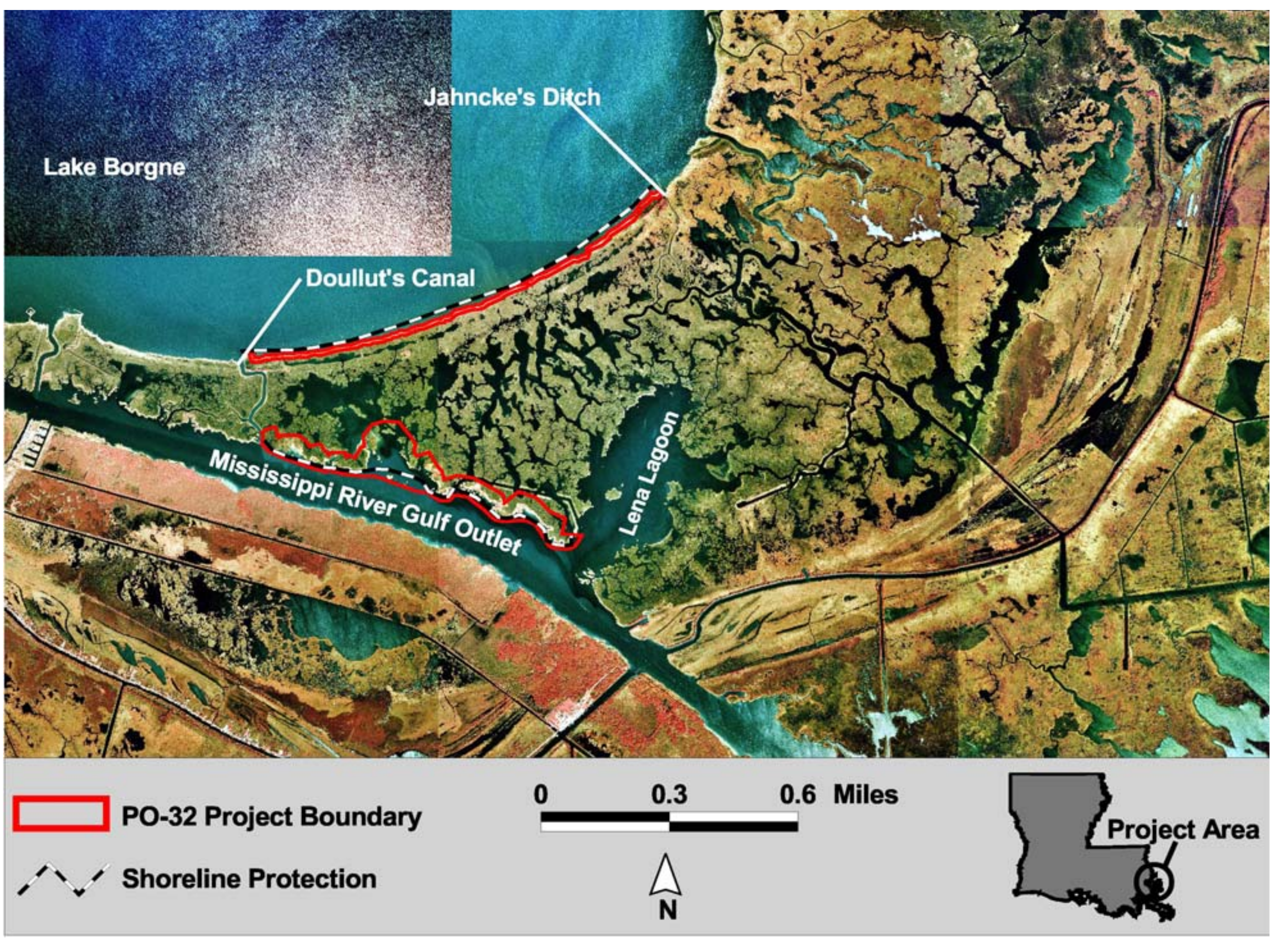

Figure 1. Lake Borgne and MRGO Shoreline Protection project boundaries and structure locations.

Prior to construction of the MRGO in the 1960s, the area was most likely an intermediate to brackish marsh. After construction of the MRGO, the 1978 habitat classification data indicated that the area had converted entirely to brackish marsh (USEPA 2000/2001). Construction of the MRGO drastically altered salinity regimes in project area marshes, gradually converting the area to its present saline marsh state and steadily decreasing total wetland acreage (USEPA 2000/2001). The area will remain saline marsh and continue to erode unless the navigational dimensions of the MRGO are altered. Some bottomland hardwood forest and scrub/shrub species exist in the area but the dominant vegetation is *Spartina alterniflora (*smooth cordgrass), with concentrations of *Schoenoplectus pungens* (threesquare), *Distichlis spicata* (seashore saltgrass), and *Spartina patens* (marshhay cordgrass) (USACE 2004).

During the examination of the area for Coastal Wetlands Planning, Protection and Restoration Act (CWPPRA) 12th Priority Project List (PPL) consideration, shoreline erosion rates along the Lake Borgne reach were estimated to be 9 feet per year and 24 feet per year along the MRGO reach (USACE 2004). The major causes of shoreline erosion are wind-blown waves in Lake Borgne and vessel wakes along the MRGO. Interior marsh loss is very low according to the USACE 1988/90 land loss data, but the vegetation may be surviving at a sub-optimal elevation (USACE 2002). Further compromising marsh sustainability are the local rates of subsidence and eustatic sea level rise. Also known as relative sea level rise, it is estimated that these processes result in the loss of 1.5 feet of elevation per century or 3.6 inches of elevation over the 20-year project life (USACE 2004).

Coast 2050 has identified the maintenance of shoreline integrity of Lake Borgne, restoration and maintenance of the land bridge between MRGO and Lake Borgne with created marshes and shoreline protection, and restoration and stabilization of the entire north bank of the MRGO as Region 1 ecosystem strategies that will preserve marsh and maintain shoreline integrity (Louisiana Coastal Wetlands Conservation and Restoration Task Force and the Wetlands Conservation Restoration Authority 2001).

II. Goal Statement

Stop erosion along approximately 18,820 feet of Lake Borgne shoreline and along approximately 14,360 feet of the MRGO shoreline.

III. Strategy Statement

A continuous foreshore rock dike will be built along the shoreline of Lake Borgne and along the MRGO shoreline. A flotation channel will be dredged adjacent to the rock breakwater with the material placed beneficially between the shoreline and the foreshore structure for marsh establishment.

IV. Strategy-Goal Relationship

Shoreline protection and stabilization in the form of a foreshore rock dike should attenuate shoreline retreat by baffling high-energy wind-blown and boat-induced waves providing protection to existing marsh.

V. Project Feature Evaluation

Geotechnical Evaluation

A partial geotechnical investigation was conducted for both project reaches. A total of 13 borings (6 undisturbed and 7 general) were collected and analyzed to determine the area soil classifications. No sophisticated analysis of the borings was conducted. This analysis would have helped to determine the geophysical properties of area soils (e.g., compaction coefficients) and encouraged a more suitable design of the proposed project features. In general, soil types present in the project area include Fausse clay, Clovelly muck, and Lafitte muck. Lafitte muck occurs in the interior area and along much of the MRGO shoreline. Clovelly muck occurs in a broad band along the Lake Borgne shoreline and along some of the MRGO shoreline. Fausse clay occurs only in the eastern and western extremes of the Lake Borgne shoreline (USACE 2002). Soils with the characteristics of those in the area typically are easily compressible, generally low bearing, with relatively low shearing capacities which means they are incapable of supporting heavy loads such as those related to dike construction. Therefore, a geotextile fabric and light weight core aggregate are incorporated into the design to better distribute the weight exerted upon the area soils.

The Coastal Engineering Division (CED) of LDNR requested that the USACE submit a revised estimate for consolidation settlement and slope stability analyses which the USACE had based the designs of the Lake Borgne and MRGO Shoreline Protection (PO-32) project calculations on. This information was required to determine the estimated structure crest heights over the duration of the 20 year project life due to consolidation settlement. The reaches the USACE derived their extrapolations from were Miles 50-54 of existing shoreline protection along the MRGO channel, MRGO North Bank Dike (DACW29-94-B-0113). This project was built with a multiple lift construction in 1994 to an elevation of +3 feet NAVD-88 and raised to an elevation of +4 feet NAVD-88 in 1999 (the lift was called MRGO North Bank Dike, DACW29-99-B-0057). The 16,200-linear foot structure was placed 20 – 600 feet offshore along the -3 foot depth contour.

The lack of such geotechnical data is concerning because the elevated rate of structure settlement immediately after construction causes the structure to sink below water level prior to the scheduled construction lifts thus lowering its effectiveness. The in-situ organic soils located along the MRGO reach are generally weaker than the soils located along the Lake Borgne reach. In fact, it has been determined by the USACE that the soils in the MRGO reach are approximately 25% weaker than the soils in the Lake Borgne reach. These observations, along with monitoring results from the aforementioned project along the MRGO channel, were used to evaluate the historical settlement data from the MRGO and to extrapolate an estimated settlement for the Lake Borgne reach. Slope stability analyses using the sliding block procedure were determined for the two project reaches and resulted in acceptable safety factors. Having reviewed the revisions to the settlement and slope stability analyses submitted by the USACE, CED concurred with the revised submittals. Due to the consolidation of the underlying soils, the underlying soil layers will strengthen over time resulting in a more stable foundation.

Structure Designs

Both breakwaters will consist of a 3-foot layer of armor stone placed on top of a crushed stone core. The core will rest on a layer of foundation geotextile fabric with a separating geotextile fabric placed between the two different kinds of stone. The gradation of the armor stone will be of major importance especially on the MRGO side so as to avoid the problems encountered along

Freshwater Bayou Canal in the CWPPRA-funded Freshwater Bayou Wetland Restoration (ME-04) project. Both MRGO and Freshwater Bayou experience high intensity waves and boat wakes. The stone used to protect the shoreline, if not properly graded, may be shifted around by the force of the waves created by deep draft barges as was the case with the ME-04 project. Landward disposal of flotation channel dredged material will be beneficially placed to maximum height of +3.5 feet NAVD-88 and at least 10 feet away from the landward toe of the dike feature to promote conditions for marsh establishment (USACE 2004). A long-term schedule of the maintenance events has been laid out in the preliminary design report for each breakwater.

The Lake Borgne structure is a 18,820-foot foreshore composite-core rock dike constructed along the southern shoreline of the lake rim from the east bank of Doullut's Canal to the west bank of Jahncke's Ditch. It will initially be constructed with a top elevation of +4 feet NAVD-88 (including 1 foot of freeboard to account for settlement) and along the -2.0 foot NAVD-88 contour with a 5-foot crown width and side slopes of 1 (V) on 2 (H). The 90th percentile historical sea level statistics for the area were added to average wave height and mean high water (MHW) elevation (+1.44 feet NAVD-88) to determine a design wave height that needed to be stopped to halt erosion. An additional construction lift will be required for the Lake Borgne dike due to increased settlement rates and poor soil conditions in the area. It is estimated that the dike will settle approximately 2 feet in 3 years after which a construction lift will be applied. This lift should sustain the dike's effectiveness for the bulk of the remaining project life (Figure 2). Details of the construction lift are shown in the plans and specifications.

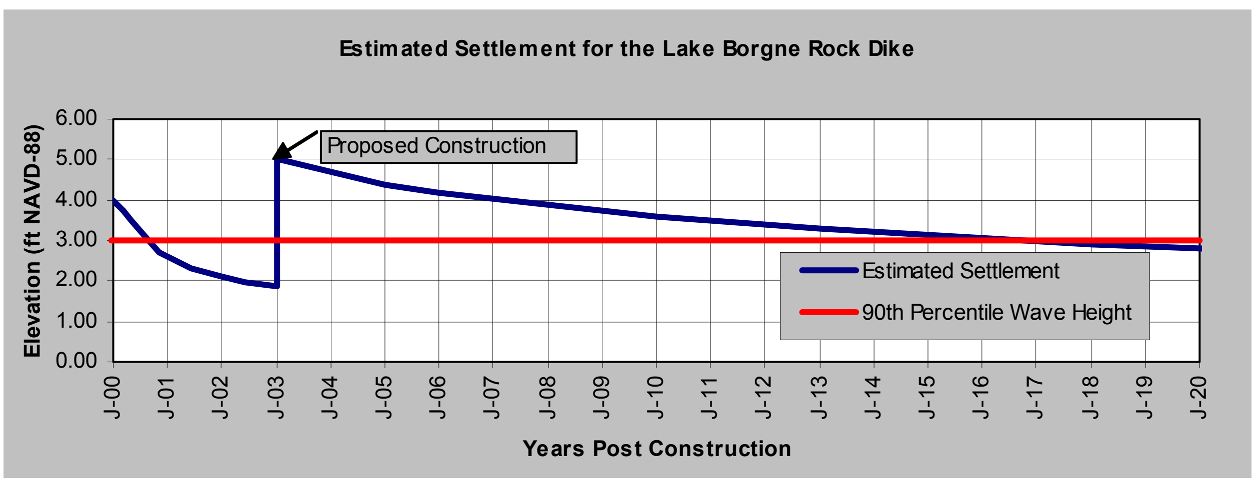

Figure 2. Estimated settlement of the foreshore rock dike on the Lake Borgne reach and the 90th percentile design wave height (USACE 2004).

The second structure is a 14,360-foot foreshore composite-core rock dike constructed along the north shore of the MRGO from the east bank of Doullut's Canal to the west bank of Lena Lagoon. It will initially be constructed with a top elevation of +4 feet NAVD-88 (3-foot minimum elevation to block 90th percentile waves with a 1 foot freeboard to account for settlement), with a 5-foot crown, and side slopes of 1 (V) on 1.25 (H) (Figure 3). Based upon subsurface soil conditions and previous construction experience in the project area, the USACE recommends that the rock breakwater along the MRGO be built in a series of three construction lifts. This multi-lift construction plan will allow soils in the project area to adjust to the weight of the breakwater materials over time and will result in better performance and lower long-term operation and maintenance costs for the project.

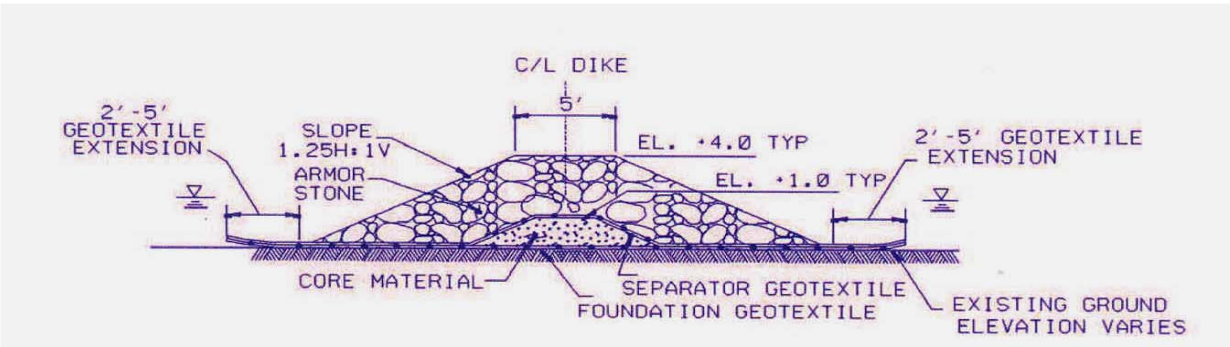

Figure 3. Typical dike section for first construction lift on MRGO (USACE 2004).

Typical breakwater dimensions for the second construction lift of the MRGO are a 5-foot wide crown set at elevation +5 feet NAVD-88, 1 (V) on 1.25 (H) side slopes front and rear (Figure 4). Typical dimensions for the third construction lift are a 5-foot wide crown set at elevation +5 feet NAVD-88, 1 (V) on 2 (H) side slopes front and rear (Figure 5) (USACE 2004). The engineer and design team anticipate that the third and final breakwater construction lift will provide a stable section for the 20-year design life (Figure 5).

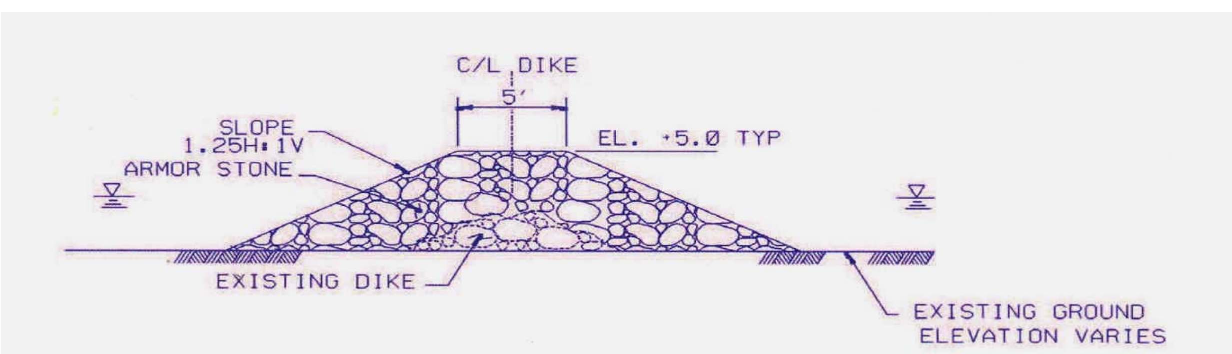

Figure 4. Typical dike section for second construction lift on MRGO (USACE 2004)

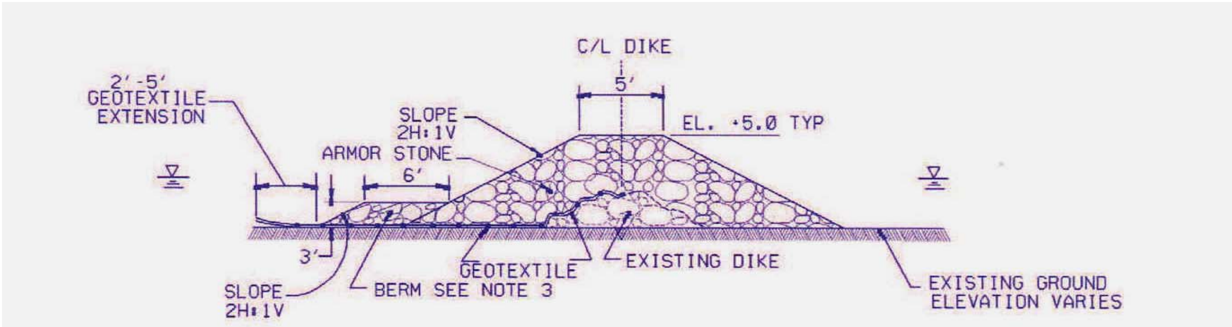

Figure 5. Typical dike section for third construction lift on MRGO (USACE 2004).

The initial lifts should lessen the need for maintenance, but maintenance lifts, when and if failure occurs, have been devised and incorporated into an operations and maintenance plan. Figure 6 below depicts a typical cross-sectional layout of the MRGO structure once completion of the 3rd construction lift has been applied to the previous two lifts.

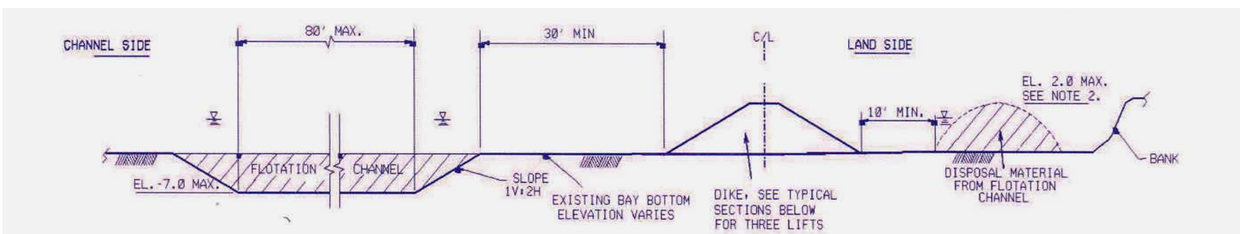

Figure 6. Typical dike layout with flotation and disposal for first, second, and third construction lifts on MRGO (USACE 2004).

It is estimated that the dike will settle approximately 2 feet in the first year with a cumulative settlement of 3 feet in the first two years (Figure 7). The third and final construction lift will include a channel side berm. This berm will be 3 feet high and 6 feet wide with a side slope of 1 (V) on 2 (H) overlain on geotextile material, and it will be used to reduce the amount of launching should the toe of the structure become compromised (USACE 2004). The MRGO structure will not attain its final height until the second and third construction lifts have been constructed and the dike settlement rates have reached equilibrium. Additional analyses were conducted to determine if the elevation of the lifts could be lowered and to determine if coordinating the timing of the Lake Borgne and MRGO 2nd construction lifts were feasible. It was determined that coordinating the lifts, such that they occur on both project reaches at the same time, did not result in any additional project benefits or cost savings. The elevation of the construction lifts would have been lowered to +4 feet NAVD-88 from +5 feet NAVD-88, but the results showed that lowering the elevation meant adding an additional operations and maintenance (O&M) lift later in the project life. The structure will need a maintenance lift after year thirteen to account for additional settlement that will occur beyond that point.

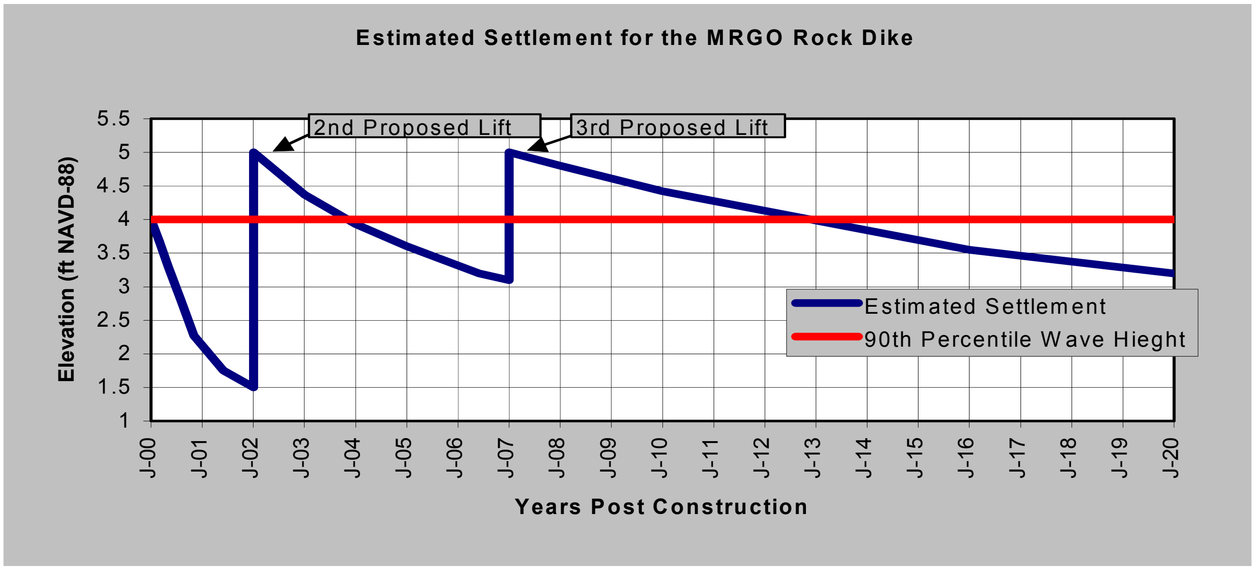

Figure 7. Estimated settlement on the MRGO reach vs. the 90th percentile design wave height (USACE 2004).

<u>Fish Dips</u>

A total of five fish dips will be incorporated into the design of the MRGO structure. However, no fish dips will be constructed on the Lake Borgne structure because no pathways for fish to access the marsh existed previously. Two of the fish dips will be constructed as per the design specifications while the other three will utilize existing linkages (openings) in the area already being used for access. The constructed fish dips will be built with bottom widths of 20 feet and at the -2 foot contour (USACE 2004). The five designed fish dips are less than what the National Marine Fisheries Service normally requires, but concessions have been made due to the minimal amount of fish traffic in the area. The proposed deposition of dredged material from the flotation channel will be controlled to avoid blocking the access gaps (USACE 2004).

<u>Marsh Creation</u>

Dredged material from the flotation channel (80-foot maximum bottom width) will be stacked to a maximum of +3.5 feet NAVD-88 and is expected to de-water down to an elevation similar to that of existing marsh conditions. Approximately 315,000 cubic yards of material will be available from the Lake Borgne flotation channel and 189,000 cubic yards from the MRGO channel which will initially create approximately 43 and 26 acres of marsh, respectively. The fill will be held 10 feet from the landward toe of the structure to minimize adverse impacts on the soils in close proximity of the foreshore structure (USACE 2004). Settlement analysis and calculations for the material have shown that the created marsh will be at or below 0.5 feet NAVD-88 by TY08 and settles below the existing healthy marsh elevation by TY04 (Figure 8).

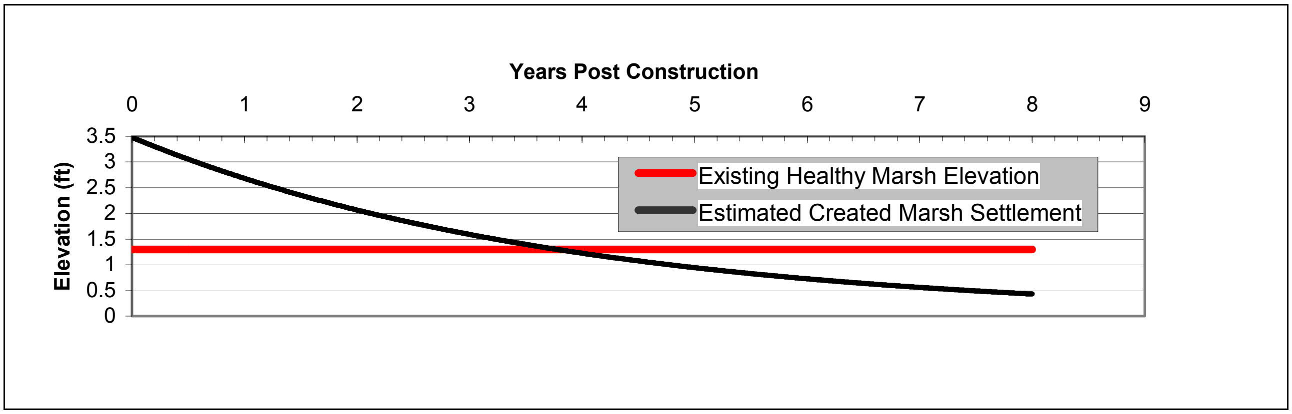

Figure 8. Estimated settlement of the created marsh behind the structures on Lake Borgne and the MRGO.

<u>Oyster Leases</u>

Lake Borgne contains a number of oyster leases that will need to be acquired as a result of dredging the floatation channel and constructing the shoreline protection feature. To minimize the impacts on the remaining oyster resource, turbidity screens will be installed in areas where dredging practices may take place. The oyster leases are close enough to the project area that secondary impacts from turbidity could be of issue. An oyster resource survey and subsequent appraisals have been conducted to determine the extent to which oyster leases will be impacted and to determine the fair market value of the portion to be acquired. In light of the recent Supreme Court decision, LDNR is currently reviewing its oyster lease acquisition program to determine what, if any, changes will be necessary. Once that is completed, LDNR will resume negotiations and acquisition.

VI. Assessment of Goal Attainability

Environmental data and scientific literature documenting the effects of the proposed project features in field application are included below to assess whether or not, and to what degree, the project features will cause the desired ecological response. Design parameters of previously constructed shoreline protection projects are summarized in Table 1 and discussed below.

Table 1. Design parameters of constructed shoreline protection projects (sorted by construction date).

Project Name	Project Number	Coast 2050 Region	Construction Date	Depth Contour (ft)	Structure Length (ft)	Structure Elevation (ft NAVD-88)	Distance from Shoreline (ft)	Preliminary Monitoring Results
Blind Lake (State)	N/A	4	1989		2,339	4.0	70	Positive
Cameron Prairie National Wildlife Refuge Shoreline Protection	ME-09	4	1994	-1.0	13,200	3.7	0-50	Positive
Freshwater Bayou Bank Protection (State)	TV-11	3	1994	N/A	25,800	4.0	N/A	
Bayou Segnette (State)	BA-16	2	1994, 1998	N/A	6,800	3.0-5.0	N/A	
Turtle Cove (State)	PO-10	1	1994		1,640[+]	3*	300	Positive
Boston Canal / Vermilion Bay Bank Protection	TV-09	3	1995	N/A	1,405	3.8**	N/A	Positive
Grand Isle Bay Side (State)	N/A	2	1995		4,500			
North Grand Isle Breakwaters (State)	N/A	2	1995					
LeBranche Shoreline (State)	PO-03b	1	1996					
Vermilion River Cutoff Bank Restoration	TV-03	3	1996		6,520			
Clear Marais Bank Protection	CS-22	4	1997	-1.2	35,000	3.0**	0-50	Positive
Freshwater Bayou Wetlands Protection	ME-04	4	1998	-1.0	28,000	4.0	0-150	Positive
Freshwater Bayou Bank Stabilization	ME-13	4	1998	N/A	23,193	3.7-4.0	N/A	Positive
Lake Salvador Shoreline Protection Demonstration	BA-15 Phase II	2	1998	-1.0-1.4	8,000	2.51	100	Positive
Quintana Canal (State)	TV-4355NP1	3	1998		3,650			
Perry Ridge Shore Protection	CS-24	4	1999	N/A	12,000	3.7-4.0	60	
Barataria Bay Waterway West Side Shoreline Protection	BA-23	2	2000		9,400	4.0		
Jonathan Davis Wetland Protection	BA-20	2	2001		34,000			
Bayou Chevee Shoreline Protection	PO-22	1	2001		8,875	3.5**	300	No results
Chenier Au Tigre Sediment Trapping Demonstration	TV-16	3	2001					
Barataria Bay Waterway East Side Shoreline Protection	BA-26	2	2001		17,600			
GIWW Perry Ridge West Bank Stabilization	CS-30	4	2001					

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Table 1. Design parameters of constructed shoreline protection projects ([sorted by construction date] continued)

Project Name	Project Number	Coast 2050 Region	Construction Date	Depth Contour (ft)	Structure Length (ft)	Structure Elevation (ft NAVD-88)	Distance from Shoreline (ft)	Preliminary Monitoring Results
Mandalay Bank Protection Demonstration	TE-41	3	2003	-1 to -3	1,494	1.5-3.0	10-200	
Grand-White Lake Land Bridge Protection	ME-19	4	2004	-1 to -2	12,000	2.5	50-200	No results
Barataria Basin Land Bridge Shoreline Protection, CU 3	BA-27c	2	2004	0	10,700	3.5	0-50	No results
CU 2				-2	6,329	3.5	50-600	No results
CU 1				-2.5	3,700	3.0	50-100	No results

Note: * denotes structure elevations at mean water lever
** denotes structure elevations in feet NGVD-29.
+ denotes that structure was rock-gabion instead of rip-rap

Shoreline Protection on Bays and Lakes

CWPPRA and State-authorized shoreline protection projects similar to the Lake Borgne and MRGO Shoreline Protection project have been implemented on other bay, lake, and cove shorelines as a means of protecting those banks from erosive elements.

- Bayou Chevee Shoreline Protection (PO-22) is located on the southern shoreline of Lake Pontchartrain just west of Chef Menteur Pass within the northern section of the Bayou Sauvage National Wildlife Refuge. The project is broken into two coves (northern and southern). Construction was completed in 2001 with the initial as-built survey completed in 2002. The total length of the project was 8,875 feet with both rock dikes constructed using 200-400 pound rock placed at an elevation of +3.5 feet NGVD-29 (LDNR 2003). The first post-construction survey work was slated to be completed in 2004. As-built shoreline position was documented in 2002 (Carter 2003). To date, only an as-built survey and pre-construction data collection have been completed so evaluation of project effectiveness at this time is impossible. After the 2004 shoreline position is documented, the rate of shoreline movement during the first 2 years post-construction will be calculated from the project and reference areas to determine the project's effectiveness at addressing shoreline erosion (Carter 2004).

- Barataria Basin Landbridge Shoreline Protection (BA-27), Phases 1, 2, 3, and 4 are located in Jefferson and Lafourche Parishes and encompass a variety of shoreline protection techniques along approximately 107,500 feet of shoreline. Geotechnical investigations have revealed poor soil conditions throughout the area prompting the testing of non- traditional protection techniques that included rock dikes consisting of either earthen cores, lightweight aggregate cores, or lightweight aggregate cores with a furrow (to reduce the load) beneath the rip rap structure, as well as, testing of concrete sheetpiles as an alternative to the rock dikes. In 2001, all of the test sections for Phase 1 of the project were completed. One year after all the test sections were constructed, surveys were conducted to determine the settlement rates and to estimate 10-year settlement. The concrete sheetpile wall sections showed very little movement vertically or horizontally but the rock and composite dike sections experienced significant amounts of settlement ranging from 2.7 -3.5 feet over the first year (USDA-NRCS 2002). In 2004, construction units 1 (test section of sheetpile, rock, and composite aggregate), 2 (rock), and 3 (rock) were all completed. A monitoring plan has been devised and once the 2006 surveys have been completed an analysis of effectiveness will be produced.

- The Lake Salvador Shoreline Protection Demonstration (BA-15) project evaluated a series of shoreline protection measures in Lake Salvador in St. Charles Parish, Louisiana. Phase two of this project was conducted in 1998 and evaluated the effectiveness of a rock berm to protect the lake shoreline from higher energy wave erosion. The rock structure itself appears to be holding up well, showing little sign of deterioration and subsidence. Recent surveys of the area revealed that the rock dike was successful in stabilizing the shoreline and some accretion is occurring behind the structure (Curole et al. 2001). However, the effectiveness of the structure over the long term may be in question since it was not built according to design specifications. The rock dike was designed to be constructed with a crest elevation of

+4.0 feet NAVD-88. A 2002 survey of the rock dike determined that the average height of the structure was +2.49 feet NAVD-88. The average settlement of the structure, measured from 1998 to 2002, was approximately 0.26 feet. It was concluded that the rock dike was built to an inadequate crest elevation of +2.75 feet NAVD-88 (Darin Lee, Personal Communication 2002).

- The Turtle Cove Shoreline Protection (PO-10) was initiated in 1993 to protect a narrow strip of land in the Manchac Wildlife Management Area which separates Lake Pontchartrain from an area known as "The Prairie" (O'Neil and Snedden 1999). Wind-induced waves contributed to a shoreline erosion rate of 12.5 feet per year. A 1,642-foot rock-filled gabion was constructed 300 feet from shore at an elevation of 3 feet above mean water level with the goal of reducing erosion and increasing sediment accretion behind the structure. Post construction surveys conducted during the period of October 1994 to December 1997 revealed that the shoreline had prograded at a rate of 3.47 feet per year in the project area (O'Neil and Snedden 1999). The rate of sediment accretion, as determined from elevation surveys conducted in January 1996 and January 1997, was 0.26 feet per year (O'Neil and Snedden 1999). The soils in "The Prairie" and Turtle Cove area consist of Allemands-Carlin peat which is described as highly erodible organic peat and muck soils (USDA 1972). Due to the weak and compressible nature of the subsurface soils, the gabions settled 0.59 feet in just over two years (October 1994 to January 1997) (O'Neil and Snedden 1999). Also, five years after construction, the rock-filled gabion structure exhibited numerous breaches and required extensive maintenance in August 2000 (John Hodnett, LDNR, Personal Communication August 2004).

- The Boston Canal/Vermilion Bay Bank Protection (TV-09) project was designed to abate wind-driven wave erosion along Vermilion Bay (estimated at 7 feet per year) and at the mouth of Boston Canal (Thibodeaux 1998). To accomplish that goal, a 1,405-foot foreshore rock dike was constructed in 1995 at an elevation of +3.8 feet NGVD-29 along the bank of Boston Canal extending into Vermilion Bay. In 1997, two years after construction, the project was estimated to have protected 57.4 acres of marsh and to have deposited 1.4 to 4.5 feet of sediment behind the breakwater while the reference area continued to erode. The rock breakwater at the mouth of Boston Canal has been successful in stabilizing the shoreline (Thibodeaux 1998) with an overall shoreline gain for the area from 1998-2001 of 15.04 acres. The project also appears to be maintaining the integrity of approximately 466 acres of wetlands and stabilizing 14.3 miles of the Vermilion Bay shoreline (Thibodeaux and Guidry 2004).

<u>Shoreline Protection on Navigation Channels</u>

There are also several examples of projects involving the use of shoreline protection to stop erosion along navigation canal banks.

- The Cameron Prairie National Wildlife Refuge Shoreline Protection (ME-09) project, constructed in 1994, is located in north-central Cameron Parish and includes 350 acres of freshwater wetlands (Barrilleaux and Clark 2002). A 13,200-foot rock breakwater was constructed at an elevation of +3.7 feet NAVD-88, 50 feet from (and parallel to) the northern shore of the GIWW to prevent wave action from eroding the bank and breaching into the interior marsh. Aerial photography and survey points were used to monitor any changes in land-to-water ratio and shoreline position. Three years after construction, results indicate that the project area shoreline advanced 9.8 ± 7.1 feet per year while the reference area retreated 4.1 ± 3.1 feet per year (Barrilleaux and Clark 2002). A two-sample t-test reveled a significant difference was detected between the shoreline change rate and the project reference areas ($P < 0.001$) (Barrilleaux and Clark 2002). Shoreline change data were collected in 1995, 1997, 2000 and 2003. Between the 2000 and 2003 surveys mean shoreline change rates were calculated to be +13 ± 15.4 feet per year and -2.1 ± 2.1 feet per year for the project and reference areas, respectively (Mouledous and Guidry 2004). The data indicate that the project has continued to be effective in preventing erosion at all project area stations.

- The Clear Marais Bank Protection (CS-22) project was constructed in 1997 to prevent breaches in the GIWW shoreline and subsequent erosion of the interior marsh while preventing saltwater intrusion (Miller 2001). Approximately 35,000 linear feet of rip-rap was placed 50 feet from the northern shoreline of the GIWW at an elevation of +3.0 feet NGVD-29. Results indicate that the foreshore rock dike has been effective in preventing erosion of the GIWW shoreline. Data collected in May 1997 (as-built), May 2000, and May 2003 have been analyzed to indicate whether the project has been effective in preventing erosion within the severe, moderate, and mild erosion area classifications six years post construction (Miller and Guidry 2004). Areas experiencing severe erosion prior to construction gained 1.89 feet per year, areas experiencing moderate erosion gained 3.02 feet per year, and areas experiencing mild erosion gained 17.00 feet per year (Miller and Guidry 2004). Overall the project area gained an average of 7.66 feet per year as compared to the reference area which is losing 9.10 feet per year (Miller and Guidry 2004).

- The Intracoastal Waterway Bank Stabilization and Cutgrass Planting project at Blind Lake was a state wetland restoration project constructed to prevent the GIWW and Sweet Lake from coalescing with Blind Lake (LDNR 1992). A limestone foreshore rock dike built at an elevation of +4.0 feet NGVD-29 was placed 70 feet from the edge of the main channel along 2,339 feet of bank on a six inch layer of shell and filter cloth. Large stones were used to prevent movement of rocks and to allow sediments and organisms passage. In 1991, two years after project completion, an average increase in elevation of 0.32 feet in the area behind the dike was observed along transects from the deposition of suspended sediments (LDNR 1992). Data indicate that the project was successful in protecting the shoreline at Blind Lake and maintaining the hydrology of the Cameron-Creole Watershed (LDNR 1992).

- The Freshwater Bayou Wetlands Protection (ME-04) project is positioned on the western bank of Freshwater Bayou Canal across from the proposed Freshwater Bayou Bank Stabilization, Belle Isle to Lock (TV-11b) project (Vincent et al. 1999). Construction of this project was initiated in January 1995 and includes construction of water control structures and a 28,000-linear foot foreshore rock dike designed with a crown elevation of +4.0 feet NAVD-88. Analysis of initial monitoring data suggests that the rock dike reduced wave-induced shoreline erosion after construction. The average rate of shore progradation between

June 1995 and July 1996 was measured at 2.2 feet per year while the reference area continued to erode at an average rate of 6.7 feet per year (Raynie and Visser 2002). In contrast, between March 1998 and May 2001, the protected shoreline eroded an average of 2.6 feet per year while the reference area eroded at an average of 10.0 feet per year (Raynie and Visser 2002). Substandard recycled construction material and inadequate funds for maintenance of the structure, which were not disbursed in a timely manner, are believed to be the reason for the increase in erosion rates in the project area (Raynie and Visser 2002).

- The Freshwater Bayou Bank Stabilization (ME-13) project is located in Vermilion Parish on the west bank of Freshwater Bayou Canal. The main cause of wetland loss in the ME-13 project area is boat wake-induced shoreline erosion of the canal spoil banks and organic soils of the interior marsh (USACE and LDNR 1994). A 23,193 linear foot continuous rock dike, built to an elevation of +3.7 to +4.0 feet NAVD-88, was installed parallel to the western shoreline in 1998 to address this loss. Pre-construction data from the ME-13 reference areas on the east bank of Freshwater Bayou Canal indicated that the canal eroded at an average rate of 6.54 feet per year between April 1995 and July 1996 (Vincent and Sun 1997). Post-construction data collected from July 1998 through July 2003 revealed that the shoreline behind the constructed rock dike prograded on average 0.84 feet per year (Vincent 2003). During the same period, the unprotected reference areas eroded on average 11.94 feet per year (Vincent 2003).

Summary and Conclusions

The geotechnical investigation of the Lake Borgne and MRGO Shoreline Protection (PO-32) project area concluded that soils within the project area are highly compressible/compactable and erosive. Soils of this nature tend to have lower bearing capacities and cannot support the weight of heavy rock structures. The soils in the project area have historically failed to support rock structures as has been observed during field visits to a previous rock dike construction attempt (MRGO North Bank Dike DACW29-94-B-0113 and lift DACW29-99-B-0057) by the USACE along the MRGO channel that has sank nearly below water. Thus, designs of structures for use in the area must address the settlement issue by incorporating measures to lessen the load of proposed structures.

Engineering designs on this project have indicated that poor soil conditions can be offset by constructing dikes in multiple lifts which allow the structures to compress the soils and settle to a temporary state of equilibrium prior to adding more weight. Geotextile fabric, lightweight aggregate, and berms (used as counterbalances for slope stability) are other methods that have been incorporated into rock dike designs to minimize loading capacities and combat the poor soil conditions. Proper rock sizing in this type of environment is another key component to the success of rock structures placed on shipping canals due to the larger boat wakes. All of these strategies will be employed on this project to increase the potential for structure effectiveness.

In addition to the design specifications utilized on this project to increase the likelihood of success, the majority of the literature supports the usage of rock structures for protecting lake and channel shorelines. A review of both published and unpublished literature of previously constructed restoration projects similar in nature and design to the proposed project were used to confirm the efficiency of rock dikes as shoreline protection features. Monitoring results for the Lake Salvador

Shore Protection (BA-15), Boston Canal/Vermilion Bay Bank Protection (TV-09), Cameron Prairie National Wildlife Refuge Shoreline Protection (ME-09), Intracoastal Waterway Bank Stabilization and Cutgrass Planting at Blind Lake, and the Freshwater Bayou Bank Stabilization (ME-13) have shown that these projects have successfully reduced shoreline erosion in areas of poor soil conditions and some have even accreted land behind the structures. On the other hand, monitoring results for the Turtle Cove Shoreline Protection (PO-10) and the Freshwater Bayou Wetlands Protection (ME-04) have shown a lack of success with respect to structure integrity in areas with poor soil conditions potentially due to use of substandard materials and inadequate maintenance. These findings provided insight as to how effective the constructed projects were at achieving their specified goals and assisted team scientists and engineers in predicting how well similar designs may perform.

Breakwaters have stopped shoreline retreat and facilitated vegetation establishment in many areas of coastal Louisiana and could very well protect this particular stretch of land. The two structures proposed for this particular project should aide in protecting the marsh strip that separates the MRGO and Lake Borgne from erosion caused by intense wave action if the two structures' designs perform as presumed. We do, however, recommend intense monitoring and maintenance to account for and to repair any damage that may cause reduced benefits.

VII. 95% Design Review Recommendations

Based on the investigation of similar restoration projects and a review of engineering principles, the proposed strategies of the Lake Borgne and MRGO Shoreline Protection project should achieve the goal of stopping shoreline erosion. It is recommended that this project progress towards construction authorization pending a favorable 95% Design Review.

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