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

**Grand Lake Shoreline Protection**
CWPPRA Priority Project List 11
State No. ME-21

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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 September 14, 2004.

**Ecological Review**
**Grand Lake 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 environmental data 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 Grand Lake Shoreline Protection (ME-21) project is located in the Mermentau Basin in Cameron Parish, Louisiana. The project area encompasses the southern shore of Grand Lake from Superior Canal to the mouth of Catfish Lake and may include an optional structural increment that extends westward to Tebo Point (Figure 1). The total area of the Grand Lake Shoreline Protection project is approximately 1,162 acres and is primarily composed of fresh emergent marsh (445 acres) and open water (717 acres) habitats (USACE 2001). Approximately 37,800 feet of Grand Lake shoreline will be protected through the construction of a foreshore rock dike, with an option to protect 5,700 feet of shoreline around Tebo Point.

*Coast 2050* identified elevated water levels and wave energy generated by strong frontal winds as the major factors contributing to the rapid erosion of the southern shore of Grand Lake [Louisiana Coastal Wetlands Conservation and Restoration Task Force and the Wetlands Conservation and Restoration Authority (LCWCRTF&WCRA) 1999]. Erosion rates calculated by comparing aerial photographs from 1978-1979 to those taken in 1997-1998 revealed that 11 to 32 feet of shoreline was lost annually (USACE 2001). Construction of the foreshore rock dike will prevent the lake from breaching into adjacent open water areas (Lake Benoit and Long Lake) and will protect interior marsh, which without the structure, will be subjected to increased wave energy (LCWCRTF&WCRA 1999). The proposed strategy of protecting and stabilizing the southern shoreline of Grand Lake is supported by the *Coast 2050* Region 4 Ecosystem Strategies which promote the stability and protection of bay, lake, and gulf shorelines for the preservation of interior wetlands and the maintenance of favorable hydrologic conditions.

## II. Goal Statement

- Stop erosion along approximately 37,800 linear feet of the southern bank of Grand Lake and as a result save 445 acres of interior emergent marsh that is expected to be lost over the 20 year project life.
- Increase submerged aquatic vegetation (SAV) coverage to 80% in the open water areas from a baseline of 10% over the 20 year project life.
- Create 50 acres of emergent marsh between the Grand Lake shoreline and the foreshore rock dike over the 20 year project life.
- Stop erosion along the shoreline of Tebo Point and as a result save 28 acres of emergent marsh that is expected to be lost over the 20 year project (optional goal).

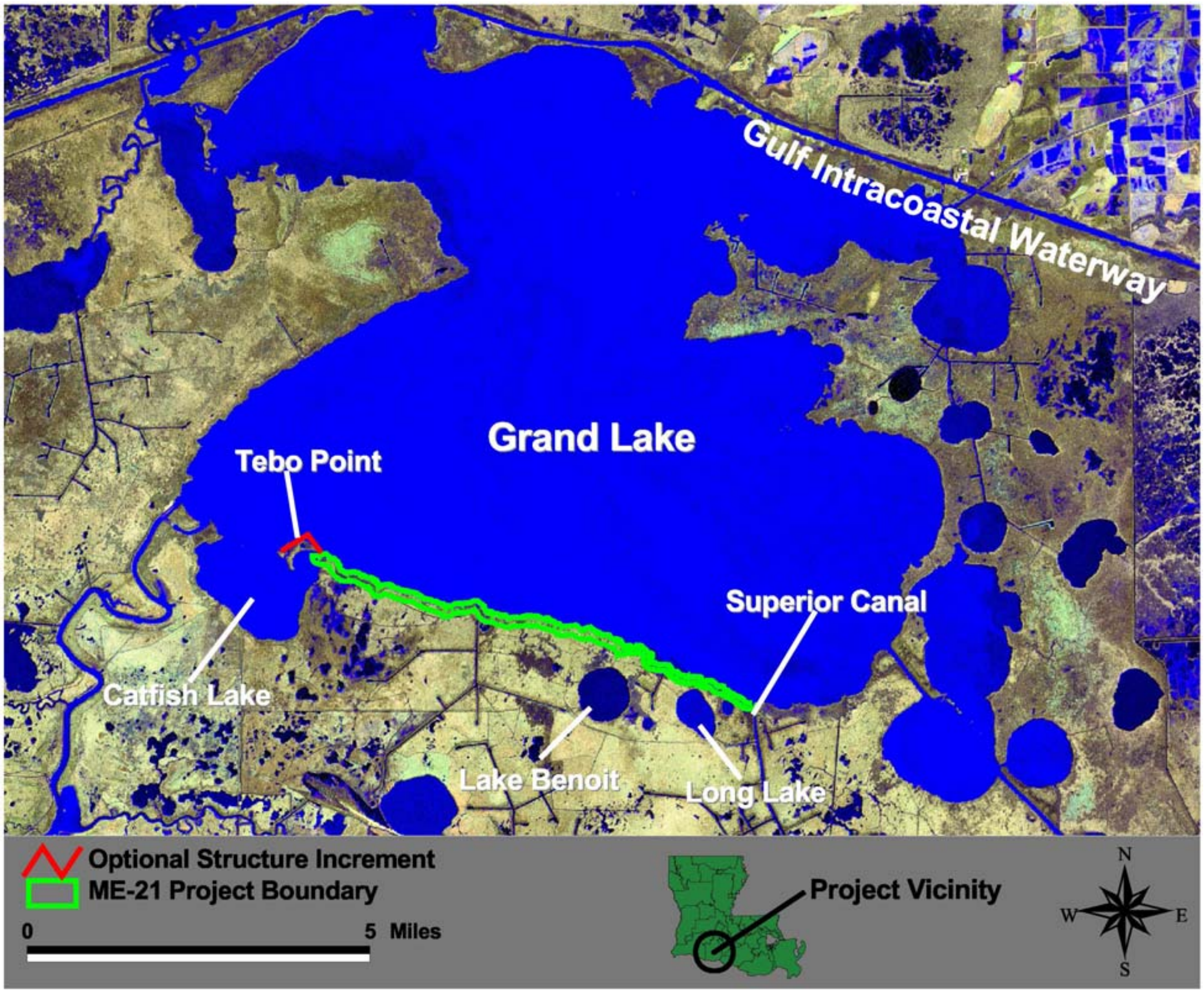


**Figure 1**. **Grand Lake Shoreline Protection project area.**

## III. Strategy Statement

The project goals will be achieved through the construction of an approximately 37,800 foot foreshore rock dike along the southern shore of Grand Lake from Superior Canal to the mouth of Catfish Lake with the option of including an additional 5,700 feet of structure around Tebo Point.

## IV. Strategy-Goal Relationship

The construction of a foreshore rock dike will stop erosion along the southern Grand Lake shoreline by dampening wind generated waves. The stabilization of the lake shoreline will in turn protect interior marsh from being exposed to wave energy. Marsh accretion is expected to occur behind the shoreline protection structure due to the occasional overwash of waves and subsequent deposition of sediment. Additional marsh creation benefits will be achieved through the strategic placement of dredged spoil from the digging of the flotation canals.

The construction of the foreshore rock dike is expected to increase the overall percentage of SAV coverage in the area behind the shoreline protection structure from 10% to 80%. SAV habitat creation is expected to occur due to the reduction of turbidity in the shallow open water areas and the resulting increase in overall light penetration.

## V. Project Feature Evaluation

A 37,800 foot foreshore rock dike will be constructed along the southern shore of Grand Lake 200 feet from the existing shoreline at the -1.0 NAVD-88 foot contour from Superior Canal to the mouth of Catfish Lake. In addition, an optional plan is in place to extend the structure an additional 5,700 feet westward around Tebo Point and continuing southwest to protect the entire island (Figure 1). The crest elevation of the rock dike structure will be built at an approximate height of +3.0 ± 0.25 feet NAVD-88 (Figure 2). Settlement is expected to occur during construction. To offset this initial loss, the contractor will add rock material to the structure as needed to achieve the desired design height before demobilization. The breakwater will have front and back side-slopes of 1(V) on 1.5(H) and a crest width of 4 feet. All stone sizing will conform to standard 24 inch rock gradation placed on 200 pound/inch$^2$ geotextile fabric. Fish dips measuring 50 feet wide and lined with a layer of rock will be constructed every 1,000 feet to allow organism egress and ingress.

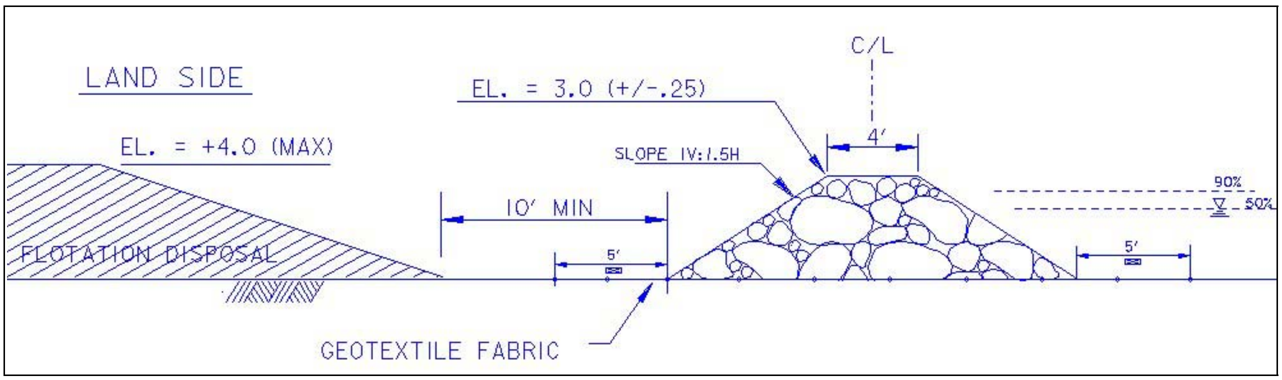


**Figure. 2: Typical dike section (USACE 2004).**

Originally the crest elevation of the shoreline protection structure for the Grand Lake project was designed at +3.5 feet NAVD-88 which was calculated by adding the following three factors: mean water elevation, 90% wind setup, and 90% wave height. However, protecting against 90% of the wave height was considered a conservative estimation of the conditions in the Grand Lake project area. Project engineers felt that designing the rock dike to protect against ½ of the 90% wave height would reduce the cost and overall pressure on the soil foundation while still providing adequate shoreline protection. As a result, the current structure elevation design of +3.0 feet NAVD-88 was determined through the addition of the Grand Lake mean water level (+1.45 feet), 90% wind setup (0.50 feet), and ½ of the 90% wave height (0.85 feet). This design technique results in 0.2 feet of the rock dike remaining sub-aerial during storm conditions.

The geotechnical analysis (USACE 2003) revealed a relatively poor soil foundation in the project area. The soils near the southern bank of Grand Lake consist of soft and organic clays with occasional lenses of soft clay, silt, silty sand and occasional wood. Pleistocene deposits reside nine feet underneath the upper swampy marsh deposits and consist of interbedded, highly oxidized, stiff clays. The geotechnical analysis indicated that the foundation clays are over consolidated and little consolidation settlement is expected to occur (USACE 2003). After construction, lateral spreading will cause settlement of approximately 1.76 feet with a second lift expected in three years to maintain a crest elevation of +3.25 NAVD-88. It is estimated that after the three year maintenance lift the structure will ultimately settle to a crest height of +2.56 feet NAVD-88 by year twenty. The initial placement elevation for a the Grand-White Lakes Landbridge Protection (ME-19) project, which is in the vicinity of the Grand Lake Shoreline Protection project, was built at an elevation of +2.5 NAVD-88.

According to the settlement consolidation curves, the structure elevation will fall below mean water level (+1.45 feet NAVD-88) two years post-construction, one full year before the scheduled maintenance lift planned for year three (Figure 3). It is conceivable that once submerged the foreshore rock dike will become somewhat less effective as a shoreline protection structure, and a possible threat to navigation. However, project team members determined that the benefits of the shoreline protection structure would not be significantly reduced in view of the fact that the structure would be submerged for a relatively short period of time. In addition, the dredged material placed on the landward side of the rock dike would offer further protection to the Grand Lake shoreline. To avoid possible threats to navigation, the structure will be adequately marked.

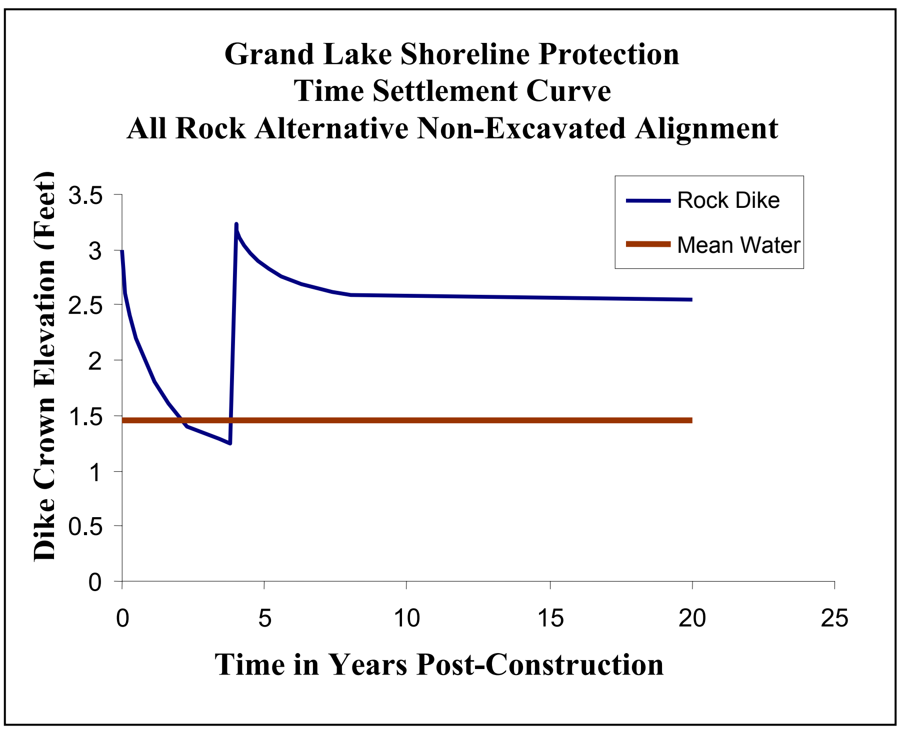


**Figure 3. Time settlement curve for proposed Grand Lake foreshore rock dike after construction.**

The need for a flotation canal to allow access for construction barges and equipment will produce a significant amount of dredged spoil. It is estimated that approximately 120 acres of fresh emergent marsh will be created through the beneficial use of the dredged material. Maximum allowable dredging depth of the flotation channel will be -5.0 feet NAVD-88. The spoil will be stacked at a target elevation of +3.0 feet NAVD-88 and at a maximum elevation of +4.0 feet NAVD-88. The material will be placed at a minimum of 10 feet landward from the toe of the foreshore rock dike and 50 feet seaward of the shoreline. It is expected that the dredged spoil, through the dewatering and consolidation process, will settle to a final elevation of +1.5 to +1.9 feet NAVD-88 at year twenty. This elevation is considered optimal for healthy unbroken marsh and is consistent with the surrounding marsh elevation in the Grand Lake project areas (USACE 2004).

A possible cultural resource site (Indian midden mound) exists near the western most edge of Tebo Point. At the 30% Design Review meeting for the Grand Lake Shoreline Protection project, it was believed that dredging a flotation canal near Tebo Point could destroy valuable cultural artifacts. However, a recent United States Army Corps of Engineers archeological survey of the area determined that the footprint of the midden mound at Tebo point was not as large as originally estimated. As a result, the dredging of the flotation canal for placement of the rock material around the shoreline of Tebo Point would not likely endanger any cultural resources. Construction of the rock dike at the shoreline of Tebo Point would likely preserve any cultural resources from erosional forces while providing protection to the western flank of the Grand Lake shoreline (Figure 1). The placement of the shoreline protection structure around Tebo Point is considered optional since the increment was not included in the original project plans or Wetland Value Assessment. The decision to exercise any part of the option will be made by the Contracting Officer of Record, during construction, provided the Coastal Wetlands Conservation and Restoration Task Force approves the project to the maximum length.

## VI. Assessment of Goal Attainability

Environmental data and scientific literature documenting the effects of the proposed project features in field application are evaluated below to assess whether or not, and to what degree the project features will achieve the desired ecological response.

<u>Armor Shoreline Protection</u>

A number of projects using traditional shoreline protection structures have been implemented in Louisiana coastal areas to protect lake, bay, and navigational channel shorelines (Table 1). Published results of projects funded under CWPPRA and through the State of Louisiana that have used rock shoreline protection structures constructed in environments similar to the Grand Lake Shoreline Protection project are discussed below.

- The Boston Canal/Vermilion Bay Bank Protection (TV-09) project was designed to abate wind-driven wave erosion along Vermilion Bay 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 1.4 to 4.5 feet of sediment was deposited behind the breakwater while the reference area continued to erode. The rock breakwater at the mouth of Boston Canal was successful in stabilizing the shoreline (Thibodeaux 1998).

- Lake Salvador Shoreline Protection Demonstration (BA-15) project evaluated a series of shoreline protection measures at Lake Salvador, 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. Shoreline surveys conducted behind the berm five months after construction indicated that the shoreline was still eroding. Subsequent surveys were not conducted due to poor weather conditions (LDNR 2000). The rock structure itself appears to be holding up well, showing little sign of deterioration and subsidence. The structure was designed to be constructed with a crest elevation of +4.0 feet NAVD-88. However, a 2002 survey of the rock dike determined that the average height of the structure was +2.51 feet NAVD-88. The average settlement of the structure, measured from 1998 to 2002, was approximately 0.29 feet. It was concluded that the rock dike was built to an inadequate crest elevation of +2.75 feet NAVD-88 (Darin Lee, LDNR, Personal Communications, July 19, 2002).

**Table 1. Design Parameters of Constructed Shoreline Protection Projects (Sorted by Construction Date).**

| Project Name | Project Number | Region | Construction Date | Depth Contour (NAVD-88) | Length of Structure (feet) | Height | Distance From Shoreline (feet) |
|---|---|---|---|---|---|---|---|
| Blind Lake | N/A* (State) | 4 | 1989 | N/A | 2,339 | 4.0 ft NAVD-88 | 70 |
| Cameron Prairie National Wildlife Refuge Shoreline Protection | ME-09 | 4 | 1994 | -1.0 ft | 13,200 | 3.7 ft NAVD-88 | 0-50 |
| The Freshwater Bayou Bank Protection | TV-11 (State) | 3 | 1994 | N/A | 25,800 | 4.0 ft NAVD-88 | N/A |
| Turtle Cove | PO-10 (State) | 1 | 1994 | N/A | 1,640 (rock gabion) | 3 ft (MWL) | 300 |
| Bayou Segnette | BA-16 (State) | 2 | 1994,1998 | N/A | 6,800 | 3.0-5.0 ft NAVD-88 | N/A |
| Boston Canal/Vermilion Bay Bank Protection | TV-09 | 3 | 1995 | N/A | 1,405 | 3.8 ft NGVD-29 | N/A |
| Clear Marias Bank Protection | CS-22 | 4 | 1997 | -1.2 ft | 35,000 | 3.0 ft NGVD-29 | 0-50 |
| Freshwater Bayou Wetlands Protection | ME-04 | 4 | 1998 | -1.0 ft | 28,000 | 4.0 ft NAVD-88 | 0-150 |
| Freshwater Bayou Bank Stabilization | ME-13 | 4 | 1998 | N/A | 23,193 | 3.7-4.0 ft NAVD-88 | N/A |
| Lake Salvador Shoreline Protection Demonstration | BA-15 Phase II | 2 | 1998 | -1.0 to 1.4 ft | 8,000 | Designed at 4.0 ft NAVD-88 built at 2.75 ft NAVD-88 | 100 |
| Perry Ridge Shore Protection | CS-24 | 4 | 1999 | N/A | 12,000 | 3.7 to 4.0 ft NAVD-88 | 60 |
| Jonathan Davis Wetland Protection | BA-20 | 2 | 2001 | N/A | 34,000 | 3.5 ft NAVD-88 | N/A |
| Bayou Chevee Shoreline Protection | PO-22 | 1 | 2001 | N/A | 5,690 | 3.5 ft NGVD-29 | 300 |

***N/A indicates that information was not available.**

- Intracoastal Waterway Bank Stabilization and Cutgrass Planting project at Blind Lake was a state only wetland restoration project constructed to prevent the Gulf Intracoastal Waterway (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. Data indicate that the project was successful in protecting the shoreline at Blind Lake and maintaining the hydrology of the Cameron-Creole watershed.

- 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. The rate of sediment accretion, as determined from elevation surveys conducted in January 1996 and January 1997, was 0.26 feet per year.

  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 (LDNR 1999).

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

- The Freshwater Bayou Wetlands Protection (ME-04) project is positioned on the western bank of Freshwater Bayou Canal across from the proposed 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. Penland et al. (1990) estimated relatively low rates of subsidence and sea level rise, at 0.13 inches per year. 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 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. A two-sample t-test reveled a significant difference was detected between the shoreline change rate and the project reference areas ($P < 0.001$).

- The Clear Marais Bank Protection (CS-22) project was constructed in 1997 at an elevation of +3.0 feet NGVD-29 to prevent breaches in the GIWW shoreline and subsequent erosion of the interior marsh while preventing saltwater intrusion (Miller Draft Report 2001). Approximately 35,000 linear feet of rip-rap was placed 50 feet from the northern shoreline of the GIWW. Results indicate that the foreshore rock dike has been effective in preventing erosion of the GIWW shoreline. A net gain of 13 feet per year occurred behind the rock structure while the reference area continued to erode (Raynie and Visser 2002).

<u>Submerged Aquatic Vegetation</u>

Submerged Aquatic Vegetation plays a crucial role in the littoral zone of aquatic ecosystems (Wetzel 1983). Submerged Aquatic Vegetation dissipates the energy of wind and wave action, reduces the amount of bottom sediment resuspension, serves as effective traps for inorganic and organic particulates, and provides suitable forage for ducks, invertebrates and larval fish (Spence 1982, Foote and Kadlec 1988, Lodge 1991). It is widely understood that the limiting factor controlling the recovery of SAV in lakes is light attenuation (Sager et al. 1998). Submerged aquatic vegetation habitat creation is expected to occur behind the shoreline protection structure in White Lake due to the reduction of turbidity in the shallow open water areas and the resulting increase in overall light penetration.

<u>Summary/Conclusions</u>

Projects such as TV-09, BA-15, CS-22 and ME-09, that were designed to an adequate elevation and located in areas with relatively good soil foundations, where successful in reducing erosion and promoting accretion due to occasional overwash of waves and subsequent deposition of sediment. However, ME-04 and PO-10 were not as successful over the long term due to poor soil foundations, improper design, the use of substandard materials, and/or inadequate maintenance funds.

According to the geotechnical report (USACE 2004) the soil foundation in the Grand Lake Shoreline Protection project area is considered poor. In an effort to reduce the overall pressure on the soil foundation, the structure will initially be built at an elevation of +3.0 feet NAVD-88. A maintenance lift, which will raise the structure elevation to an approximate height of +3.25 feet NAVD-88, is expected three years post-construction. There is some concern that two years after initial construction the structure will sink below mean water level (+1.45 ft

NAVD-88), one year prior to the scheduled maintenance lift (year three). However, the structure will be submerged for a relatively short period of time before the scheduled lift at year three is implemented and it was determined by the project team that the benefits of the project would not be significantly reduced. In addition, the dredged spoil placed landward of the structure during construction will offer additional protection to the Grand Lake shoreline.

## VII. 95% Design Review Recommendations

Based on information gathered from similar restoration projects, engineering designs and related literature, the proposed strategies in the Grand Lake Shore Protection project will likely achieve the desired goals. At this time, the Louisiana Department of Natural Resources, Coastal Restoration Division recommends that the Grand Lake Shoreline Protection project be considered for CWPPRA Phase 2 authorization.

**References**


Barrilleaux, T.C. and N. Clark. 2002. Cameron Prairie Refuge Protection (ME-09) Comprehensive Report NO. 2. Louisiana Department of Natural Resources. Baton Rouge, Louisiana. 20 pp.

Belhadjali, K. and K. Balkum. 2003. Grand-White Lake Land Bridge Protection (ME-19) Ecological Review. Louisiana Department of Natural Resources. Baton Rouge, Louisiana. 9 pp.

Foote, A.L. and J. A. Kadlec. 1988. Effects of wave energy on plant establishment in shallow lacustrine wetlands. Journal of Freshwater Ecology 4:523-532.

Lee, D.M., G.P. Curole, D.L. Smith, N. Clark and H. Gaudet. 2000. Lake Salvador Shoreline Protection Demonstration (BA-15). Louisiana Department of Natural Resources. Baton Rouge, Louisiana. 47 pp.

Lodge, D.M. 1991. Herbivory on freshwater macrophtyes. Aquatic Botany 41: 195-224.

Louisiana Coastal Wetlands Conservation and Restoration Task Force and the Wetlands Conservation and Restoration Authority. 1999. Coast 2050: Toward a sustainable coastal Louisiana, the appendices. Appendix E—Region 3 supplemental information. Louisiana Department of Natural Resources. Baton Rouge, Louisiana. 173 pp.

Louisiana Department of Natural Resources. 1992. Intracoastal Waterway Bank Stabilization and cutgrass planting project at Blind Lake, Louisiana Department of Natural Resources. Baton Rouge, Louisiana. 3 pp. plus appendices.

Louisiana Department of Natural Resources, Coastal Restoration Division. 2000. Three-Year Comprehensive Monitoring Report: Lake Salvador Shoreline Protection Demonstration (BA-15). Louisiana Department of Natural Resources. Baton Rouge, Louisiana . 45 pp.

Miller, C. M. 2001 Clear Marais Shoreline Protection (CS-22) three-year comprehensive monitoring report. Louisiana Department of Natural Resources. Baton Rouge, Louisiana. 15 pp. plus appendices.

O'Neil, T. and G.A. Snedden. (1999). Turtle Cove Shoreline Protection (P0-10) Comprehensive Report. Louisiana Department of Natural Resources. Baton Rouge, Louisiana. 25 pp.

Penland, S. K., E. Ramsey, R. A. McBride, T. F. Moslow, and K. A. Westphal. 1989. Relative Sea Level Rise and Subsidence in Louisiana and the Gulf of Mexico. Coastal Geology Technical Report No. 3. Louisiana Geological Society. Baton Rouge, Louisiana. 108 pp.

Raynie, R.C. and J.M. Visser. 2002. CWPPRA Adaptive Management Review Final Report. Prepared for the CWPPRA Planning and Evaluation Subcommittee, Technical Committee, and Task Force. Baton Rouge, Louisiana. 47 pp.

Sager, E.P., T.H. Whillans and M.G. Fox, 1998. Factors influencing the recovery of submersed macrophytes in four coastal marshes of Lake Ontario. Wetlands. Vol 18. 2: 256-265.

Spence, D.H.N. 1982. The Zonation of Plants in Freshwater Lakes. p. 37-125. In A. MacFayden and E.D. Fords (eds.) Advances in Ecological Research. Vol. 12 Academic Press. New York, NY, USA.

Thibodeaux, C. 1998. Boston Canal/ Vermilion Bay Shoreline Protection (TV-09) three-year comprehensive monitoring report. Louisiana Department of Natural Resources. Baton Rouge, Louisiana. 21 pp.

United States Army Corps of Engineers. 2001. Candidate Project Information Sheet for Wetland Value Assessment: Grand Lake Shoreline Protection /Marsh Creation, Superior Canal to Tebo Point. (Unpublished) 7 pp.

United States Army Corps of Engineers. 2004. 95% P&S Design Review Package, South Grand Lake Shoreline Protection Project (ME-21). (Unpublished), 10 pp.

Vincent, K.A., Lt. Aucoin and N.S. Clark. 1999. Freshwater Bayou Wetlands (ME-04). Progress Report NO. 5. Louisiana Department of Natural Resources. Baton Rouge Louisiana. 37 pp.

Visser, J.M., C.E. Sasser, R.A. Chabreck, and R.G. Linscombe. 1999. Long-term Vegetation Change in Louisiana Tidal Marshes, 1968-1992. Wetlands 19: 168-175.

Wetzel, R.G. 1983. Limnology; Second Edition. Prentice-Hall, Englewood Cliffs, NJ, USA. Limnological Analyses. W.B. Saunders Co., Philadelphia, Pennsylvania, USA.