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

GIWW Bank Restoration of Critical Areas in Terrebonne
CWPPRA Priority Project List 10
State No. TE-43

September 9, 2004

Mark A. Stead
Restoration Technology Section
Coastal Restoration Division
Louisiana Department of Natural Resources

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 9, 2004.

Ecological Review
GIWW Bank Restoration of Critical Areas in Terrebonne

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 GIWW Bank Restoration of Critical Areas in Terrebonne (TE-43) project is located in Terrebonne Parish, Louisiana, ten miles east of the Lower Atchafalaya River and ten miles southwest of the city of Houma (Figure 1). The project boundary extends approximately 38,000 feet (Figure 2) along the southern shoreline of the GIWW (Gulf Intracoastal Waterway) and encompasses 1,603 acres of fresh emergent marsh, and 1,721 acres of open water.

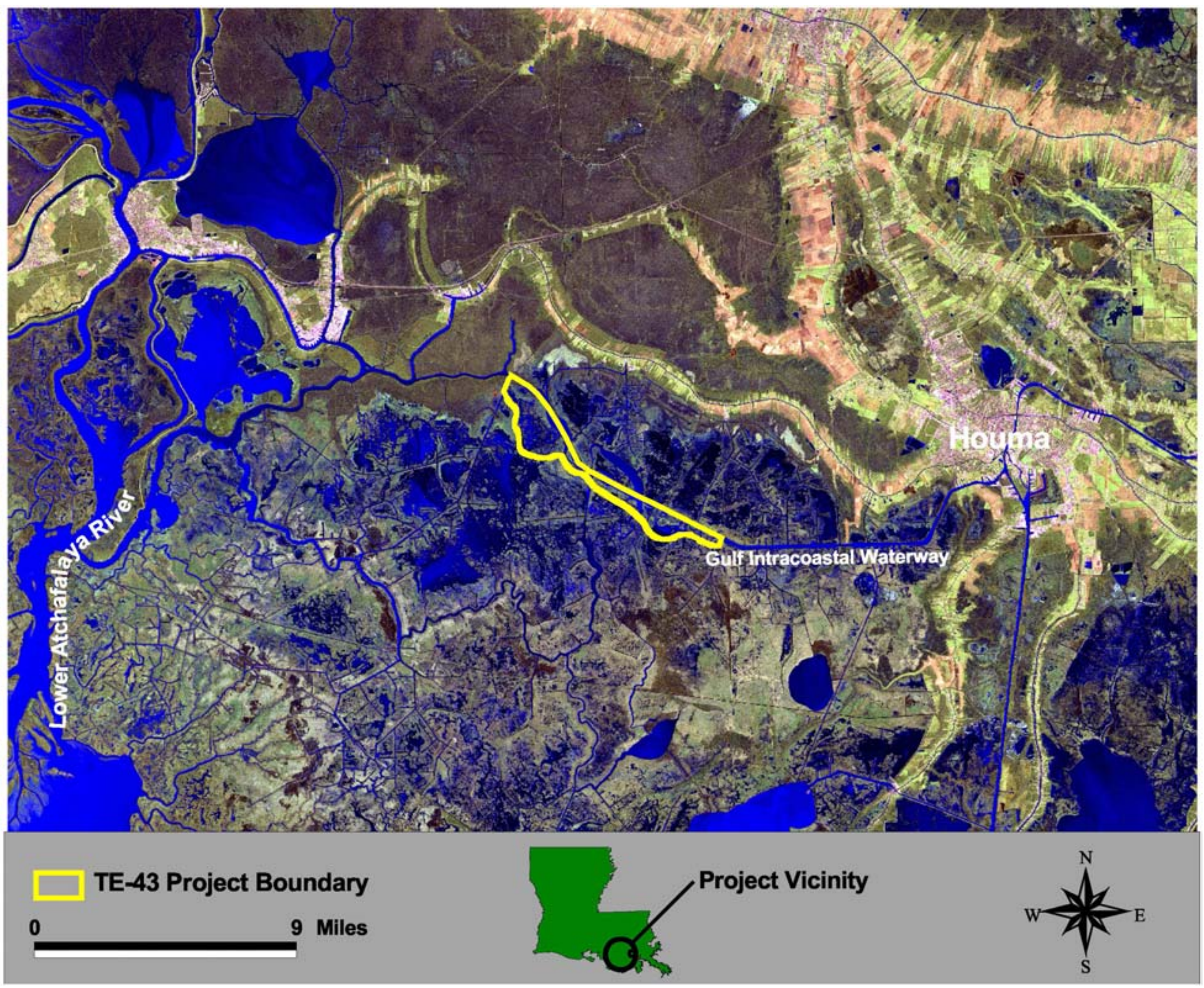


Figure 1. GIWW Bank Restoration of Critical Areas in Terrebonne (TE-43).

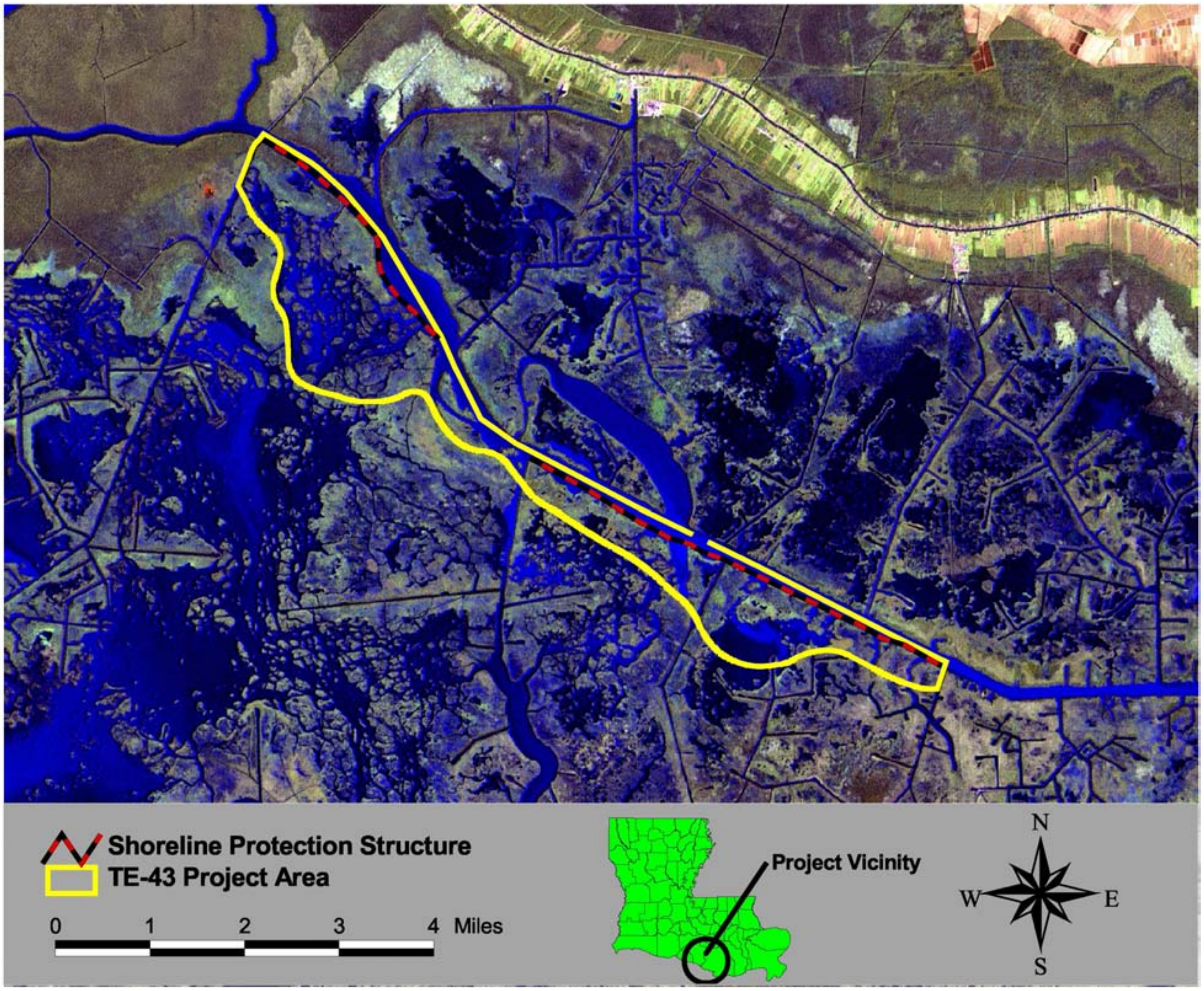


Figure 2. GIWW Bank Restoration of Critical Areas in Terrebonne (TE-43).

Coast 2050 identified construction of the GIWW and oil and gas access canals, altered hydrology, herbivory and subsidence as the major factors contributing to the rapid erosion of marsh in the vicinity of the project area (Louisiana Coastal Wetlands Conservation and Restoration Task Force and the Wetlands Conservation and Restoration Authority [LCWCRTF&WCRA] 1999). Within the project area, increased Atchafalaya River flow and boat traffic through the GIWW have resulted in breaches in the shoreline bank and subsequent scouring of the interior marsh. The GIWW Bank Restoration of Critical Areas in Terrebonne project intends to address these causes of landloss by stabilizing the southern bank of the GIWW.

One of the original goals in the TE-43 Wetland Value Assessment Project Information Sheet states that placement of a shoreline protection structure along the bank of the GIWW would create a conveyance channel to direct Atchafalaya River freshwater flow to specific locations of need (United States Department of Agriculture [USDA 2000]). Implementation of this strategy would expand the zone of beneficial influence of Atchafalaya River flow by distributing it downstream in eastern marsh areas where it is needed, while reducing the perceived high water levels in the specific project area (LCWCRTF & WCRA 1998). Reduced wetland losses would be expected in downstream marsh areas due to the increased flow of fresh water and nutrients (USDA 2000). These effects were not evaluated in the Ecological Review due to the difficulty in quantifying the effectiveness of this project in achieving such a broad objective.

Due to poor soil foundations in the project area, the initial engineering design called for the construction of a concrete sheetpile structure. However, following the initial 30% Design Review in May 2003, high construction costs associated with building the concrete sheetpile structure forced the project team to reconsider the viability of a foreshore rock dike. The dike, composed of either rock or rock and lightweight aggregate, would be constructed closer to the bank of the GIWW and was considered to be a more cost effective alternative to the sheetpile structure. Consequently, an additional 30% Design Review meeting was held in May 2004 to assess the probability of success and the cost and benefits of the revised engineering design.

II. Goal Statement

- Reduce erosion along 38,000 linear feet of the southern bank of the GIWW over the 20-year project life.
- Achieve a 40% increase in submerged aquatic vegetation (SAV) coverage in the open water portion of the project area, resulting in an additional 836 acres of SAV habitat by the end of the 20-year project life.
- Save approximately 366 acres of interior emergent marsh that is expected to be lost without the shoreline protection structure over the 20-year project life.

III. Strategy Statement

Construction of a hard shoreline stabilization structure will secure critical lengths of deteriorated channel bank.

IV. Strategy-Goal Relationship

The construction of a 41,000 foot shoreline protection structure will effectively stop erosion along a 38,000 foot section of the southern GIWW shoreline by dissipating wake energies. By stabilizing the southern GIWW shoreline, the interior marsh will be maintained at or near current levels. Sediment accretion and SAV colonization is expected to occur behind the shoreline protection structure due to the occasional overwash of waves and the reduction of turbidity in the interior open water areas.

V. Project Feature Evaluation

The initial geotechnical report, which included analysis of 48 soil borings collected at the -1.5 to -4.0 foot contour, revealed a poor soil foundation at the project site (Burns Cooley Dennis, Inc. 2003). Upper soils were typically highly organic, classified as high plasticity clays with organic matter, organic clays or peats. The geotechnical report analyzed the applicability of using three different shoreline protection structures in the project area including a foreshore rock dike, rock dike with lightweight aggregate core, and a concrete sheetpile structure. A foreshore rock dike with lightweight aggregate core is constructed by laying down lightweight rock on top geotextile fabric which is then covered with rip rap material. Concrete sheetpile structures are normally constructed by fitting thin concrete sheets between concrete pilings. It was determined in February 2003 that a foreshore rock dike structure and a lightweight aggregate core dike structure built at the -1.5 to -4.0 foot contour to an elevation of +4.0 feet NAVD-88 using 1(V):2(H) side slopes would incur ultimate settlements ranging from 2.8 to 8.6 feet and 2.5 to 6.7 feet, respectively. Such structural settlement would require significant maintenance. As a result, the geotechnical report suggested a concrete sheetpile wall structure as an alternative to either of the foreshore dike structures.

Following the initial 30% Design Review meeting in May 2003, it was determined by state and federal project engineers that the concrete sheetpile wall was not a viable option, due to high projected cost. A third option, using a combination of a foreshore rock dike (Figure 3) and a rock dike with a lightweight aggregate core (Figure 4), was proposed as a cost effective alternative to the concrete sheetpile wall. The overall height of the rock dike structures will be reduced in the new design compared to the engineering plans analyzed in the original geotechnical report. It is expected that by reducing the elevation of the rock dike from +4.0 feet NAVD-88 to +3.5 feet NAVD-88, and by moving the structure closer to shore at the -0.5 to -2.5 foot contour, less rock will be necessary to achieve an adequate height. As a result, overall pressure on the soil foundation will be reduced. In addition to reducing the height of the structure, it will be necessary to build the rock dike in three separate construction phases. Phase I will consist of constructing the rock dike to an initial elevation of +1.5 feet NAVD-88. Construction of phase II will start four months after phase I and includes adding additional rock material to the existing structure until an elevation of +3.5 feet NAVD-88 is achieved. Significant settlement is expected after construction of phase II, therefore, construction of phase III will begin one year after phase I and will call for the addition of rock material to top off the existing structure to achieve a final elevation of +3.5 feet NAVD-88. With the three phase construction plan, the rock dike and rock dike with lightweight aggregate core are expected to ultimately settle an average of 1.9 feet (Burns Cooley Dennis, Inc. 2003).

The supplemental geotechnical report, which was conducted to evaluate the new rock and composite dike structure design, assumed that the soils at the -0.5 to -2.5 foot NAVD-88 contour would be similar to the soils collected for the initial geotechnical report. Therefore, no new soil borings were collected for the supplemental geotechnical report.

Due to high construction costs, the rock dike utilizing a lightweight aggregate core will be built only in areas where structure settlement is predicted to be particularly high. The rock dike with lightweight aggregate core will be used in soil foundations where the rip rap rock structure would need to be built at a slope greater then 1V:2.5H. In contrast to the rip rap rock dike, the lightweight aggregate core will be constructed entirely in one stage. The lightweight core material must be covered with rock in one step and as quickly as possible to avoid losses of the lightweight core due to wind and wave action.

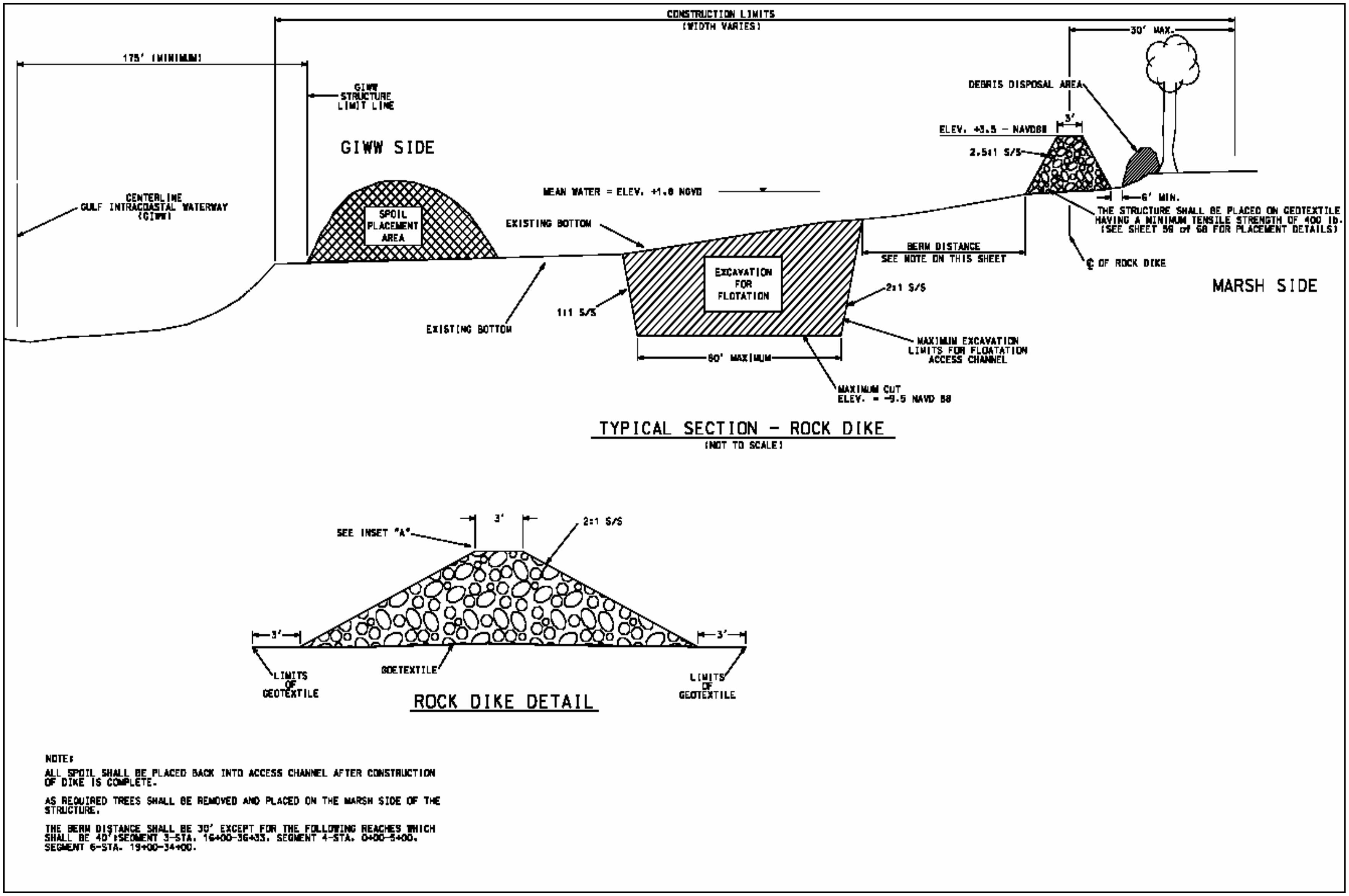
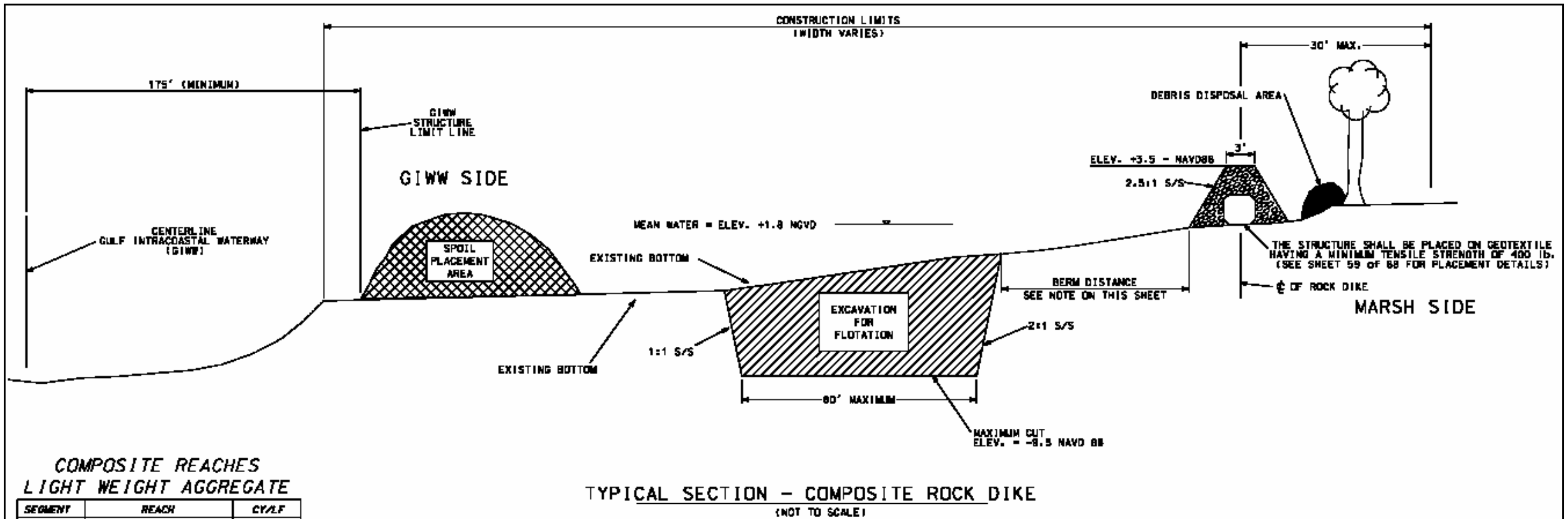
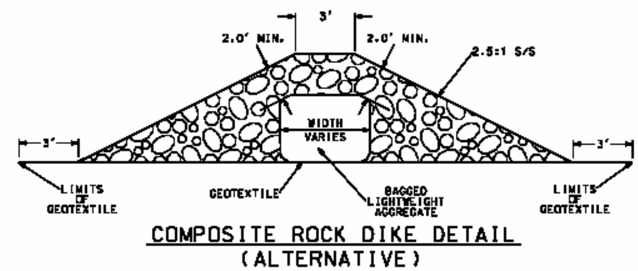


Figure 3. Typical Foreshore Rock Dike Section (USDA 2004).



COMPOSITE REACHES
LIGHT WEIGHT AGGREGATE

SEGMENT	REACH	CY/LF
2	0+00 to 11+00	0.64
2	11+00 to 21+00	0.51
2	21+00 to 30+50	0.56
2	30+50 to 41+00	0.50
2	64+00 to 76+00	0.91
3	0+00 to 13+00	0.58
4	7+00 to 18+00	1.16
4	27+00 to 39+50	1.02
4	39+60 to 60+00	1.99
4	50+00 to 59+00	1.50
5	16+00 to 24+03	1.62
6	0+00 to 4+50	0.81
6	4+50 to 16+00	1.65
6	40+00 to 45+00	1.66
6	45+00 to 58+00	1.52
6	58+00 to 68+00	1.53
6	86+00 to 99+90	1.50
7	0+00 to 7+00	1.47



NOTE:

WIDTH AND HEIGHT OF BAGGED LIGHTWEIGHT AGGREGATE IS VARIABLE. A MINIMUM OF 2' OF ROCK COVERAGE SHALL BE PLACED ON SIDES AND TOP OF BAGGED AGGREGATE.

ALL SPOIL SHALL BE PLACED BACK INTO ACCESS CHANNEL AFTER CONSTRUCTION OF DIKE IS COMPLETE.

AS REQUIRED TREES SHALL BE REMOVED AND PLACED ON THE MARSH SIDE OF THE STRUCTURE.

THE BERM DISTANCE SHALL BE 30' EXCEPT FOR THE FOLLOWING REACHES WHICH SHALL BE 40' (SEGMENT 3-STA. 16+00-36+33, SEGMENT 4-STA. 0+00-5+00, SEGMENT 6-STA. 19+00-34+00.

Figure 4. Typical Lightweight Aggregate Core Foreshore Rock Dike Section (USDA 2004).

The foreshore rock and lightweight aggregate core structures will be built using USACE-specified 1,000 pound rock which will be placed on class 1 geotextile fabric with a tensile strength of 400 pounds. Flotation canal access excavation will be an optional bid item dependent upon the contractor's discretion**.** In the event a flotation canal is dredged, the spoil will be used to backfill the canal once construction is completed. Traditionally, a 10 foot space is required between the toe of the rock dike and the area where the dredged spoil is placed to reduce pressure on the soil foundation. For the TE-43 project the rock dike will be placed against the bank of the GIWW in some areas. The close proximity of the rock dike to the shore will prohibit the contractor from placing the spoil from the flotation canal behind the structure for additional marsh creation benefits.

Despite the use of lighter structures at a lower crest elevation of +3.5 NAVD-88, some sections of the rock dike may ultimately settle to elevations that render it ineffective as a wave break. Water level data collected by the United States Geological Survey in the GIWW at Houma and in the GIWW at Bay Wallace (Station Numbers 07381331 and 073816505) indicate that the mean water level was 1.35 feet NAVD-88 (October 1999 to January 2004) and 1.73 feet NAVD-88, respectively (March 1998 to April 2004). Waves generated by boat traffic in the GIWW are estimated at 3.0 feet (USDA 2004). In response to the harsh environmental conditions in the GIWW, a detailed operations and maintenance plan has been prepared to ensure the structure remains at an effective design elevation of +3.5 NAVD-88 once construction is completed.

The geotechnical investigation prepared by Burns, Cooley, Dennis Inc. (2003) indicated that the structure will ultimately settle an average of 1.9 feet following construction completion. This analysis did not account for local rates of subsidence. Land within the *Coast 2050* Penchant Mapping Unit is subsiding at an estimated rate of 0.13-0.43 inches per year or 0.22-0.72 feet over the 20-year project life (Penland et al. 1989 and LCWCRTF&WCRA 1999). However, USDA and LDNR project engineers are confident that the high rates of subsidence within the project area will not reduce the effectiveness of the structure as a wave break. Additionally, during construction it is typical for the contractor to "overbuild" rock dike structures by as much as six inches to ensure adequate dike elevation. The anticipated "overbuilding" will help to negate the effect of the subsidence over the 20-year project life.

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. Published results of projects funded under the Coastal Wetlands Planning, Protection and Restoration Act and through the State of Louisiana that have used rock shoreline protection structures constructed in environments similar to the GIWW Bank Restoration of Critical Areas in Terrebonne 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. 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 structure 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 +2.51 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).

- 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 in August 2000 (John Hodnet, LDNR, Personal Communication August 2004).

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. 2003). 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 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).

Submerged Aquatic Vegetation

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 the GIWW due to the reduction of turbidity in the shallow open water areas and the resulting increase in overall light penetration.

Summary/Conclusions

Projects including TV-09, BA-15, CS-22, PO-10, and ME-09 which were designed to an adequate elevation and located in areas with relatively good soil foundations were successful in reducing erosion and promoting accretion. Projects such as ME-04 and PO-10 were successful in reducing shoreline erosion but experienced some structural failures due to poor soil foundations, the use of recycled materials, and/or inadequate maintenance funds.

The soils in the GIWW Bank Restoration of Critical Areas in Terrebonne project area are extremely poor. As a result, the initial engineering design called for the construction of a concrete sheetpile structure, but high construction costs and design issues forced the project team to consider using a foreshore rock dike with and without a core of lightweight aggregate. The use of a lightweight aggregate core in the poorest soil reaches and construction of the rock dike in three phases may help maintain the elevation of the structure at or near +3.5 feet NAVD-88 in the short term. However, significant maintenance over the 20-year project life will be needed to avoid rendering the rock dike ineffective as a wave break.

VII. 95% Design Review Recommendations

Based on information gathered from similar restoration projects, engineering designs, and related literature, the proposed strategies in the GIWW Bank Restoration of Critical Areas in Terrebonne project will likely achieve the desired goals provided Operation and Maintenance funds are available for structure rehabilitation. It is recommended that this project progress towards construction authorization pending a favorable 95% Design Review.

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.

Burns Cooley Dennis, Inc. 2003. GIWW Bank Restoration of Critical Areas in Terrebonne Summary Geotechnical Analysis. 21 pp. + appendices.

Curole, G. P., D. M. Lee and N. S. Clark. 2001. Lake Salvador Shoreline Protection Demonstration (BA-15) Comprehensive Report NO.1. Louisiana Department of Natural Resources. Baton Rouge, Louisiana. 38 pp. Unpublished.

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.

Kelley, S. 1996. Bayou Segnette Wetlands (BA-16) Progress Report. Louisiana Department of Natural Resources. Baton Rouge, Louisiana. 4 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. 1998. Coast 2050: Toward a sustainable coastal Louisiana. Louisiana Department of Natural Resources. Baton Rouge, Louisiana. 161 pp.

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. 213 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. 1999. Three-Year Comprehensive Monitoring Report: Turtle Cove Shoreline Protection (PO-10). Louisiana Department of Natural Resources. Baton Rouge, Louisiana. 25 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.

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, New York, 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 Department of Agriculture. 1972. Soil Survey of St. James and St. John the Baptist Parishes, Louisiana. U.S. Department of Agriculture, Soil Conservation Service, La. 75 pp.

United States Department of Agriculture. 2000. GIWW Bank Restoration of Critical Areas in Terrebonne Parish. Wetland Value Assessment Report. U.S. Department of Agriculture, Natural Resources Conservation Service. Alexandria, Louisiana. 5 pp. plus appendices.

United States Department of Agriculture. 2002. Barataria Basin Landbridge Shoreline Protection Project (BA-27). Relative cost and Short Term Stability Evaluation Report. U.S. Department of Agriculture, Natural Resources Conservation Service. Alexandria, Louisiana. 7 pp. plus diagrams.

United States Department of Agriculture. 2004. 95% Design Review Final Design Report. TE-43 GIWW Critical Areas of Terrebonne (TE-43). U.S. Department of Agriculture, Natural Resources Conservation Service. Alexandria, Louisiana. 3472 pp.

Vincent, K. A. 2003. ME-13 Freshwater Bayou Bank Stabilization Summary Data and Graphics. Louisiana Department of Natural Resources, Coastal Restoration Division. Baton Rouge, Louisiana. 38 pp.

Vincent, K. A. and B. Sun. 1997. Freshwater Bayou Wetlands (ME-04): Phase 1, Progress Report No. 3. Louisiana Department of Natural Resources, Coastal Restoration Division. Baton Rouge, Louisiana. 6 pp.

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