Bayou De Cade

Ridge and Marsh Creation Project

TE-0138

Coastal Wetland Planning, Protection, and Restoration Act PPL 26

Final (95%) Design Report

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1.0 INTRODUCTION

1.1 Authority

The Coastal Wetlands Planning, Protection and Restoration Act (CWPPRA) is federal legislation enacted in 1990 to plan, design, and construct coastal wetlands restoration projects. The legislation (Public Law 101-646, Title III CWPPRA) was approved by the U.S. Congress and signed into law by former President George H. W. Bush.

The Bayou De Cade Ridge and Marsh Creation Project (herein referred to as TE-0138) was selected as part of the CWPPRA 26th Priority Project List and funded for Engineering and Design with the National Oceanic and Atmospheric Administration's National Marine Fisheries Services (NOAA/NMFS) serving as the lead federal sponsor and the Louisiana Coastal Protection and Restoration Authority serving as the local sponsor and is also performing the engineering and design.

1.2 2017 Coastal Master Plan

The 2017 Coastal Master Plan for Louisiana identifies projects designed to build and maintain land, reduce flood risk to citizens and communities, and provide habitats to support ecosystems. The master plan consists of eight different project types, including ridge restoration and marsh creation. Master Plan Project Number 03a.MC.101 includes the creation of 12,100 acres of marsh between Lake De Cade and Lake Mechant to restore wetland habitat and degraded marsh. TE-0138 is located within the footprint of this project and is considered to be consistent with the plan.

1.3 Project Setting

The TE-0138 project is located in the Lake Mechant Sub-basin of the Terrebonne deltaic complex in the south-central portion of the Mississippi River Delta Plain. The Lake Mechant basin is located in the over-lapping portions of the Teche and Lafourche delta complexes and was formed approximately 3,000 to 4,000 years before present. The project area experiences high rates of subsidence as the Holocene deltaic sediments continue to compact at various depths. Additionally, the project area is no longer adequately nourished by the sediment and water of the Mississippi River. Subsidence rates in the region are estimated to be between 6 and 20 mm. Since 1932, the Terrebonne Basin has lost approximately 20 percent of its wetlands. Current loss rates range from approximately 4,500 to 6,500 acres per year. This rate amounts to the loss of 90,000 to 130,000 acres over the next 20 years.

1.4 Project Goals

The primary goals of TE-0138 are to create 397 acres and nourish approximately 104 acres of intermediate marsh adjacent to Lake De Cade and restore 11,726 linear feet of ridge habitat along the northern bank of Bayou De Cade. Sediment for marsh creation will be hydraulically dredged from a borrow source located in Lake De Cade and sediment for ridge restoration will be mechanically dredged from Bayou De Cade.

1.5 Land Rights Assessment

The entire marsh creation fill area is located on property owned by Apache Louisiana Minerals, LLC (Figure 1). The borrow area, pipeline conveyance corridor and equipment access routes are located within State-owned water bottoms.

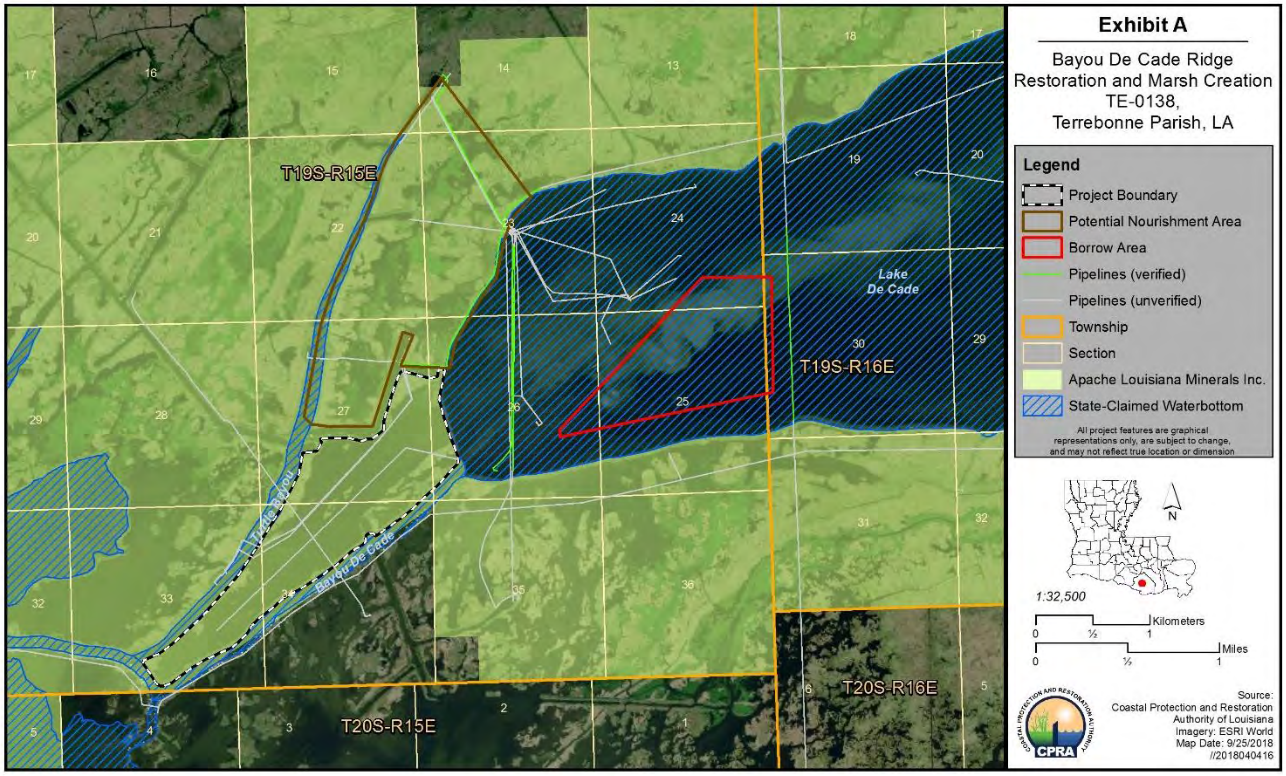

Figure 1: Land Ownership Map

2.0 CULTURAL RESOURCES

The NMFS submitted a letter to the State Historic Preservation Office (SHPO) on June 28, 2018 requesting a determination of effect for any Area of Potential Effects (APE) within the project area, proposed borrow area, and dredge access corridor. For consistency with the National Historic Preservation Act, the NMFS and CPRA reviewed historic records and archives of potential cultural resources in the project vicinity and did not anticipate construction activities disturbing any of the known sites. However, on August 17th NMFS received a letter from SHPO requesting a Phase I cultural resource survey for specific segments of the project area excluding the fill area and Lake De Cade rim. SHPO stated in the letter that the property had not been surveyed for historic properties and that the project area has potential to yield archaeological deposits. The Phase I cultural resource survey was conducted September 28th - October 4th 2018 by Earth Search, Inc. A summary of progress letter was sent out on October 9th stating that there was no evidence of cultural deposits or features in the project area. A draft report is expected at the end of October. SHPO and Earth Search, Inc. correspondence is included in Appendix A.

3.0 OYSTER LEASE ASSESSMENT

According to the CPRA Oyster Lease database, no active oyster leases are present in the proposed borrow area and the marsh fill areas.

4.0 HYDROLOGY

4.1 Tidal Datum Determination

The tidal datum is a standard elevation defined by a certain phase of the tide and is used to measure local water levels. The primary objective for computing the tidal datum is to establish the target construction fill elevation that maximizes the duration that the restored marsh will be at intertidal elevations throughout the 20-year project life. Establishment of the tidal datum for TE-0138 occurred in the early stages of preliminary engineering since it pertains to many aspects of the project design including surveys, geotechnical analysis, and constructability.

A tidal datum is referenced to a fixed point known as a benchmark and is typically expressed in terms of mean high water (MHW), mean low water (MLW), and mean tidal levels (MTL) over the observed period of time. MHW is the average of all the high water elevations observed over one tidal epoch. MLW is the average of all the low water elevations observed over one tidal epoch. MTL is the mean of the MHW and MLW for that time period. A normal tidal epoch lasts approximately 19 years; however, since this project is located near the Gulf of Mexico and has anomalous sea level changes, a water level data set covering 10 years was used.

The Coastwide Reference Monitoring System (CRMS) monitoring station CRMS0398was utilized to obtain water surface elevations for the 10-year analysis period. The monitoring station is located north of the project area on Turtle Bayou (29.389°N, 90.9168°W, Figure 2). Water surface elevations were collected on an hourly basis from August 21, 2007 through August 21, 2017. These water levels, as well as salinity and water temperature, are collected via an underwater sonde located in the open water area of Turtle Bayou. A detailed summary of the tidal datum calculations is shown in the Design Calculations Packet in Appendix B. The results of the tidal datum determination for the CRMS0398 Station are as follows:

- MHW = 0.76 ft, NAVD88 - Geoid 12A
- MLW = 0.37 ft, NAVD88 - Geoid 12A
- MTL = 0.57 ft, NAVD88 - Geoid 12A

4.2 Percent Inundation Determination

The vertical positioning of marsh platforms and the frequency with which the marsh floods strongly influence plant communities and marsh health. Historically, tidal range between mean high water (MHW) and mean low water (MLW) has been the accepted range for healthy marsh. This approach has worked well in tidal salt marshes where most of the water level variability is due to astronomical tides. Across Louisiana's coastal wetlands, however, non-tidal influences such as meteorological events, river discharge, and management regimes often have significantly more influence on water levels than astronomical tides. Therefore, we propose using percent inundation in combination with tidal range as a proxy for marsh health. Percent inundation refers to the percentage of the year a certain elevation of land would be flooded based on the water levels found in that region.

To determine percent inundation the CRMS0398 water level data was utilized. For example, the 10 percent inundation elevation was determined to be 1.119 ft., NAVD88 – Geoid12A. This elevation correlates to the 10% exceedance probability over a 1-year period. The results of the percent inundation determination for CRMS0398 during the 10-year data set are shown in Table 1.

Figure 2: CRMS0398 Station Location

Table 1: Percent Inundation Elevations (ft., NAVD88 – Geoid 12A)

Percent Inundation	TY0 Elevation	TY20 Elevation (Including SLR)
1%	1.649	2.129
10%	1.119	1.599
20%	0.939	1.419
30%	0.839	1.319
MHW	0.796	1.276
40%	0.739	1.219
50%	0.649	1.129
60%	0.549	1.029
65%	0.489	0.969
70%	0.429	0.909
MLW	0.414	0.894
80%	0.259	0.739
90%	0.039	0.519

The mean salinity at CRMS0398 is 1.58 part per thousand, which correlates to the project being classified as in intermediate marsh. Table 2 provides the optimal marsh inundation ranges within the Louisiana Coastal Zone for each marsh type. The Intermediate marshes, as found within the TE-0138 project area are most productive when flooded between 10% and 90% of the time. The project team utilized best professional judgment to identify target constructed marsh elevations that would maximize short-term and long-term marsh function while taking into account sea level rise (SLR). This determination is further discussed in Section 7.0.

Table 2: Optimal Marsh Inundation Ranges within the Louisiana Coastal Zone (CPRA Marsh Creation Guidelines, 2018)

Marsh Type	Optimal Inundation Range
Fresh	10% - 90%
Intermediate	10% - 90%
Brackish	10% - 65%
Saline	20% - 80%

4.3 Sea Level Rise

All projects within the CWPPRA program are built and evaluated based on a 20-year project life and are expected to continue to perform the objectives mentioned in Section 1 throughout the design life. Therefore, to properly design the project to meet the 20-year goal, certain natural processes are assessed.

One process is Sea Level Rise (SLR). SLR can be broken down into two components, Eustatic (or Global) Sea Level Rise and Subsidence; the latter of which will be described in Section 6.3. Sea Level Rise refers to a global change in water level. The value associated with Sea Level Rise is based on an average rate of increase of global water level.

To determine a most likely change in sea level over time at the project site, CPRA utilized its Planning Division to assist with calculating this value. The Planning Division attempted to bracket this rate by providing a lower and higher value to account for uncertainty. The calculated range for possible sea level rise by 2032 is 0.5 ft to 0.9 ft. Given the assumption of rising sea level, the marsh elevation required to attain a given percentage of annual inundation increases over the duration of the project life (Figure 3).

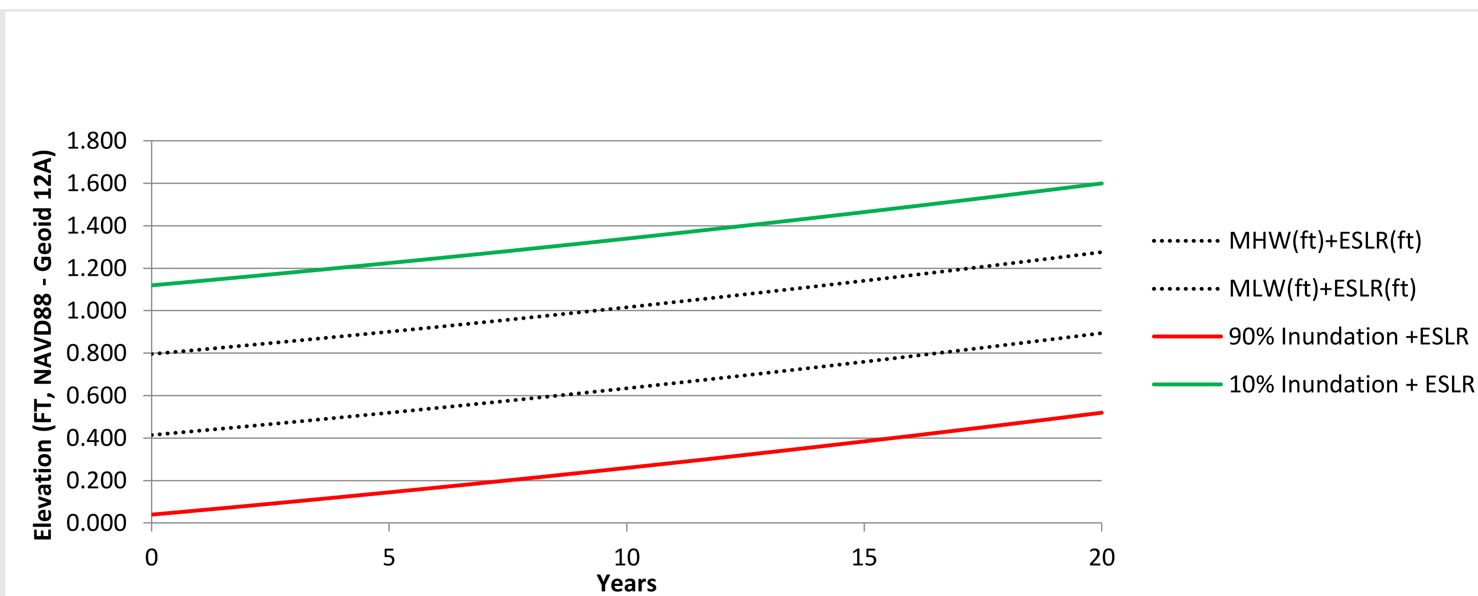

Figure 3: Water level elevations for 20-year project life in response to Eustatic Sea Level Rise (ESLR)

5.0 DATA COLLECTION

In order to properly design and construct the proposed marsh creation and ridge restoration project, an accurate and concise representation of the marsh landscape and the underlying soils is required. This was accomplished through the use of bathymetric, topographic, magnetometer, and subsurface geotechnical investigations.

5.1 Bathymetric, Topographic and Magnetometer Surveys

A detailed topographic and bathymetric survey of the project area was performed from October 2017 to February 2018 by Oceaneering International, Inc. The surveying team utilized two permanent secondary monuments, TE-34-SM-01 and TE-28-SM-A, to establish horizontal and vertical control during the survey. The positions of these monuments were verified by performing static observations on each monument. The horizontal positions are referenced to LA State Plane NAD83 and the vertical positions are referenced to NAVD88 – Geoid 12A. The revised monument data sheets are provided in Appendix C.

Topographic and bathymetric survey transects were surveyed with a 250-foot spacing within the marsh fill area and a 1,000 foot spacing within the borrow area (Figure 4). Additional centerline and transect surveys were collected along all spoil banks and the lake rim. Existing mudline elevations were collected at 25-foot intervals along each transect utilizing both bathymetric and topographic survey methods. Topographic surveys were performed on board an airboat, shallow draft flat bottom boat, and by foot. Bathymetric surveys were performed on board a 26-foot aluminum hull vessel with an Odom Echotrac 3200 digital fathometer. The data was uploaded in real time to the Hypack navigation software so that water depths would be recorded and merged with the Leica RTK positions.

In addition to the planned topographic and bathymetric survey lines, the survey team also performed an average marsh elevation survey. Oceaneering, Inc. was accompanied by Joshua Sylvest (CPRA, Thibodaux Regional Office) at the time of the survey. Mr. Sylvest used his expertise to direct the survey team to the target areas of healthy marsh. This survey consisted of 20 elevation shots located in 5 different areas near the project area. The average elevation at each location is summarized in Table 3.

Oceaneering, Inc. also performed a magnetometer survey of the marsh fill area and the borrow area to locate any pipelines or obstructions (Figure 5). A Geometrics 882 cesium magnetometer was utilized and correlated to a position with RTK GPS using the Hypack Navigation Software package. For each magnetic finding, a closed loop path was run with the magnetometer. The path completely enclosed the original finding location, while maintaining a distance of approximately 25 feet from that location.

Table 3: Average Marsh Elevation Summary

Survey Location	Average Elevation (NAVD88, Geoid - 12A)
M-1	0.88
M-2	0.77
M-3	0.71
M-4	0.60
M-5	0.80
Average	0.75

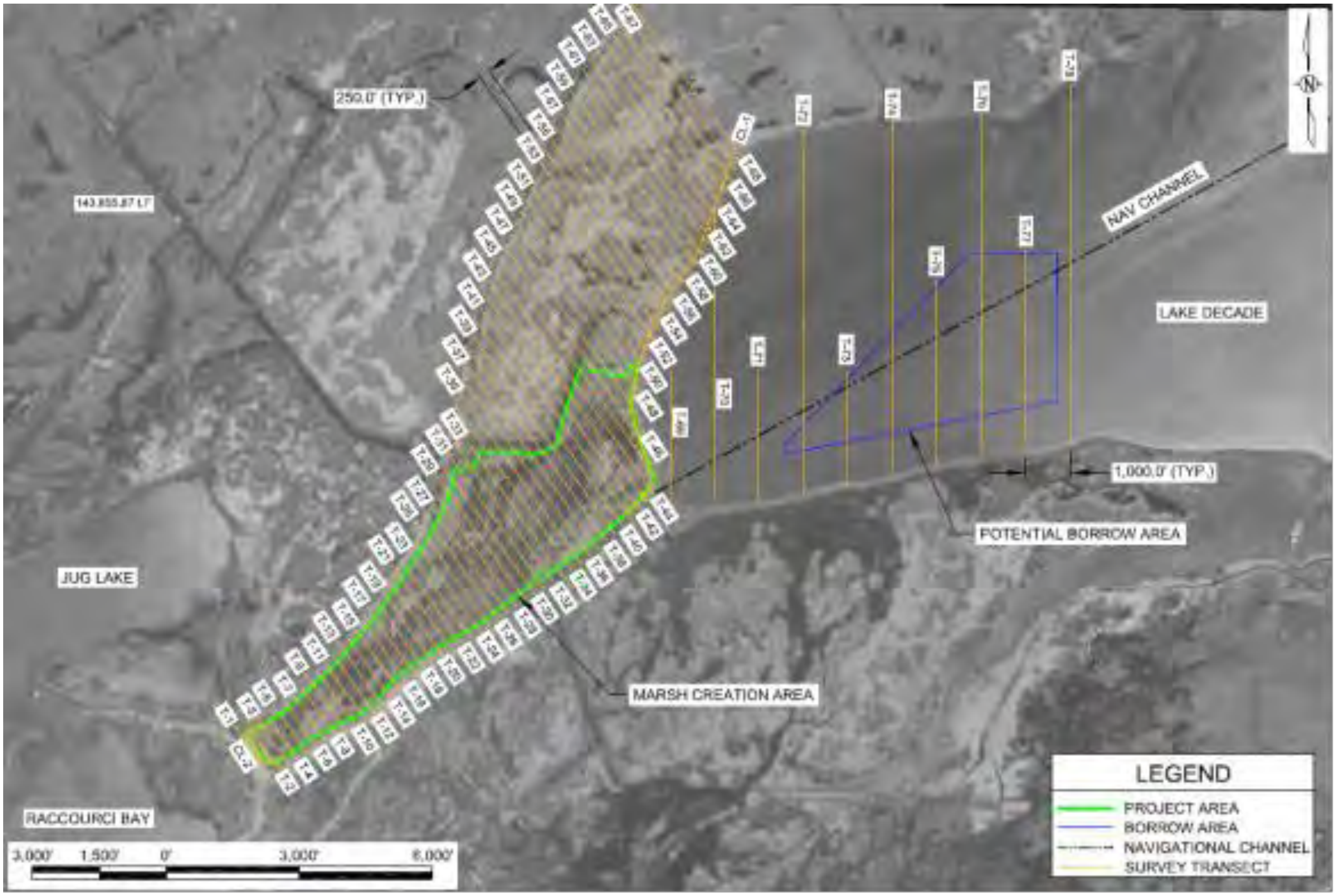

Figure 4: Bathymetric and Topographic Survey Layout

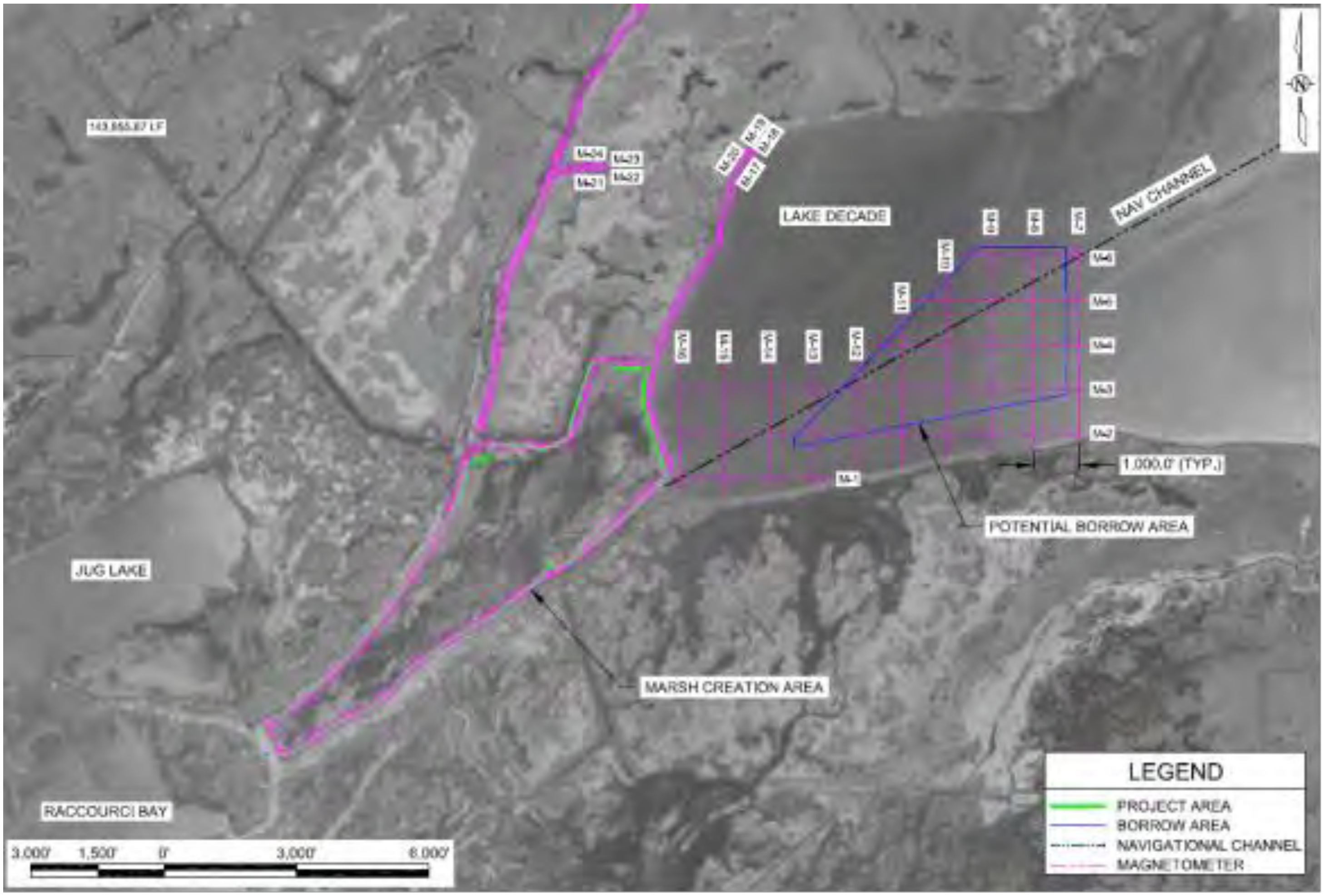

Figure 5: Magnetometer Survey Layout

The magnetometer survey recorded 397 unidentified magnetic anomalies within the survey area. Of these anomalies, 268 were adjacent to the marsh fill area and 105 of these anomalies were within or adjacent to the borrow area. All magnetic anomalies were further investigated and are shown in the survey report found in Appendix D. In the cases where magnetic anomalies were related to existing pipeline infrastructure, the existing lines were hand probed in order to determine the depth of cover along the line throughout the entire project area. Many of the magnetic anomalies were determined to be insignificant ferrous objects that are buried or submerged. There were no pipelines located within any of the proposed project features.

5.2 Geotechnical Field Investigation

In order to determine the suitability and physical characteristics of the soils in the TE-138 project area, a geotechnical subsurface investigation and geotechnical engineering analysis was conducted by Fugro USA Land, Inc. Fugro was tasked to collect soil borings, perform laboratory tests to determine soil characteristics, perform global slope stability analysis of the proposed earthen containment dikes and ridge, estimate the total settlement of the proposed earthen containment dikes, earthen ridge and marsh creation fill areas, and determine an adequate cut-to-fill ratio for the dredge operations.

Soil conditions were evaluated in the marsh creation fill areas and the marsh creation borrow area by advancing 15 soil borings to depths ranging from approximately 16 to 60 feet below the existing mudline. Additionally, 15 cone penetration test (CPT) soundings were advanced to an approximate depth ranging from 40 to 60 feet below mudline within the confines of the marsh creation area. The soil boring and CPT locations are shown in Figure 6. Additional field exploration information can be found in Appendix E: Geotechnical Reports.

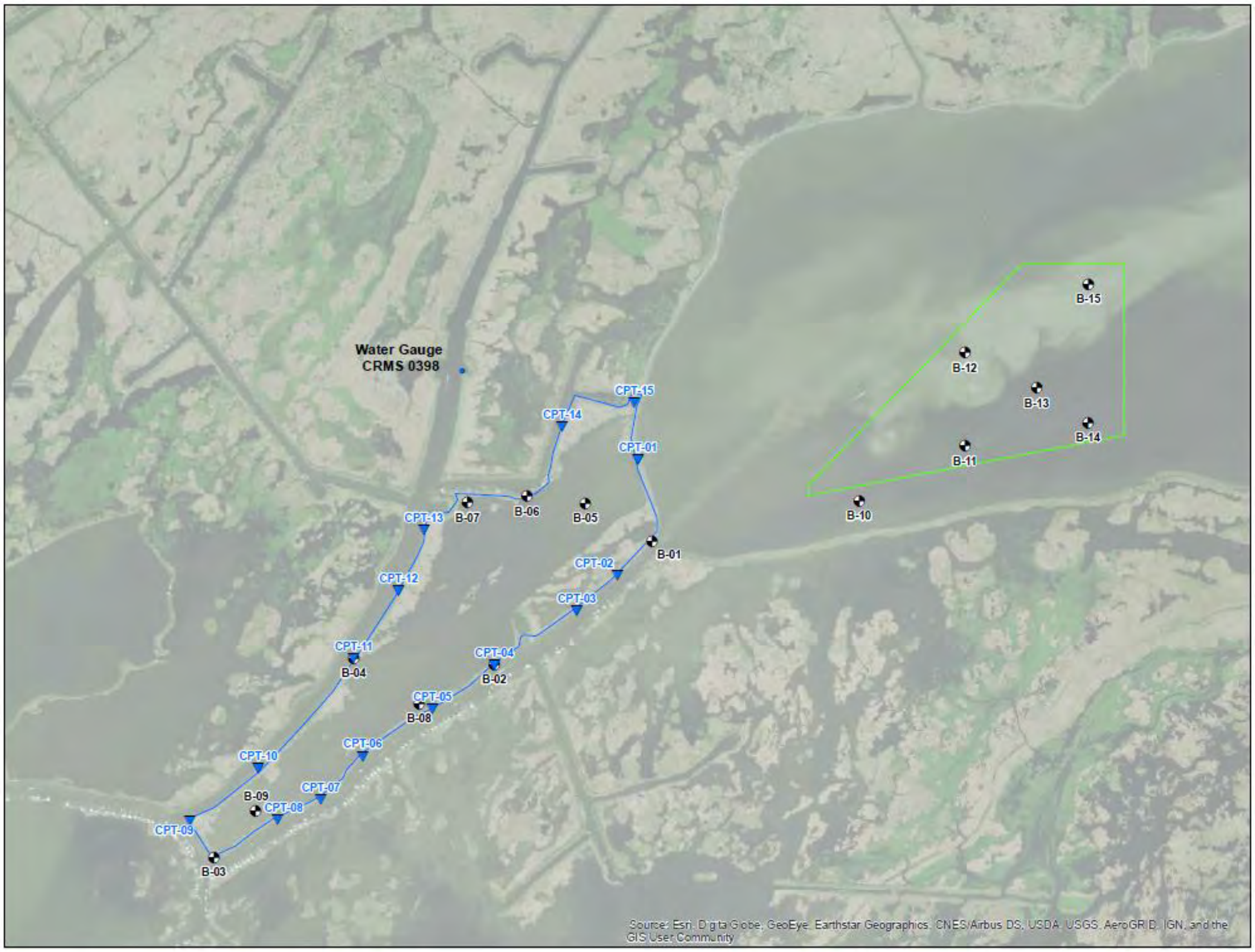

Figure 6: Geotechnical Investigation Site Plan

5.3 Geotechnical Laboratory Analysis

Fugro, Inc. developed a laboratory testing program for all geotechnical samples to establish adequate information on classification and soil strength to facilitate engineering and design. The laboratory testing included material classifications, shear strength testing, compressibility and corrosion characteristics, and settling column tests on borrow area samples. The geotechnical data collection and data analysis report can be found in Appendix E: Geotechnical Reports.

5.4 Subsurface Conditions

The data collected during the geotechnical field investigation was used to develop three subsurface profiles to generally show the distribution of subsurface conditions across the section lines (Figure 7).

Figure 7: Subsurface Soil Strength Profiles (A-A', B-B', C-C')

The earthen materials encountered during the geotechnical data collection mostly consist of soft clays with interbedded sand and silt layers. Subsurface profile B-B', located along the earthen ridge alignment indicates a more sandy zone located between elevations -5.0 and -13.0 ft. NAVD88 – Geoid12A. Subsurface profile A-A', located along the northern containment dike alignment indicates a more fat clay and lean clay distribution of material types.

5.5 Hazardous, Toxic, and Radioactive Waste

Gulf Engineers and Consultants performed a Phase I Environmental Site Assessment (ESA) in accordance with the scope and limitations of ASTM E 1527-13 Standard Practice for Environmental Site Assessments: Phase I Environmental Site Assessment Process. Based on the review of federal, state, and local environmental databases, historical research, interviews, and site investigations, the assessment revealed no recognized environmental condition (REC) on the property, and no further investigation of the property is recommend at this time. The final report is included as Appendix F.

5.6 Phase I Cultural Resources Survey

The phase I cultural resources survey consisted of the following data collection methods: All banklines along the Turtle Bayou and Bayou De Cade within the marsh creation cells were visually inspected for eroding cultural deposits. In addition, wherever topographic relief was sufficient, pedestrian survey consisting of shovel testing augmented by hand-auger testing was undertaken. Transect spacing and subsurface testing intervals were no greater than 30 m (98.4 ft.). Shovel tests measured approximately 30 cm x 30 cm (12 in x 12 in) and were excavated to sterile subsoil. Auger tests were excavated from the base of the shovel test to a depth not exceeding 2 m (6.6 ft.) below surface. Wherever possible, excavated soils were screened through ¼ in mesh. Very clayey soils were carefully “trowel-sorted” and examined for artifacts. All tests were backfilled upon completion. The cultural resources survey did not extend beyond the boundaries of the proposed marsh creation cells and was designed to meet the standards of the Department of Culture, Recreation and Tourism, Division of Archaeology, for Phase I Cultural Resources investigations and reports. A summary of the field investigation is included in Appendix A.

6.0 MARSH CREATION AND RIDGE RESTORATION DESIGN

6.1 Marsh Creation Area Description

The proposed marsh creation area is located along the northern bank of Bayou De Cade and adjacent to the western shoreline of Lake De Cade. The site consists of 387 acres of open water and 75 acres of broken marsh. Survey data indicates that approximately 74% of existing mudline elevations are between -1.0 and -3.0 ft. NAVD88, Geoid – 12A (Table 4).

Table 4: Existing Elevation Distribution within Fill Area

Elevation Range (NAVD88 - Geoid 12A)	Percent Occurrence
-4.0 to -3.0	0%
-3.0 to -2.0	38%
-2.0 to -1.0	36%
-1.0 to 0	15%
0.0 to +1.0	10%
+1.0 to +2.0	1%

The marsh creation area is impounded and it is nearly 100% contained by existing spoil banks along Bayou De Cade, Turtle Bayou, and unnamed oilfield access canals. The elevations of the spoil banks range from +0.5 feet to +7.5 feet NAVD88. The boundary of the marsh creation area along Lake De Cade is frequently repaired by Apache Corporation in order to prevent breaching of the lake rim.

A fixed crest weir is located on the northern boundary of the marsh creation area and has historically been used to control the water level within the impounded area. In recent years this weir has become damaged and is no longer inhibiting water flow as originally designed.

Several inhabited camps are located along the northern boundary of the marsh creation area. These camps and their associated infrastructure have been included in a "No Work Area" during construction activities.

The SONRIS database maintained by Louisiana Department of Natural Resources (DNR) indicates that up to three oil and gas pipelines were permitted within the marsh creation area; however, the magnetometer survey did not confirm the presence of these pipelines. In addition, the landowner (Apache Corporation) has confirmed that there are no pipelines within the marsh creation area.

6.2 Marsh Creation Area Layout

The features described in section 6.1 played an important role in the development of the marsh creation area footprint. The location and orientation of the marsh creation area could affect dredging logistics, dredging production rates, and construction duration. Additionally, the environmental impacts to existing coastal landscape should be minimized as much as practically possible.

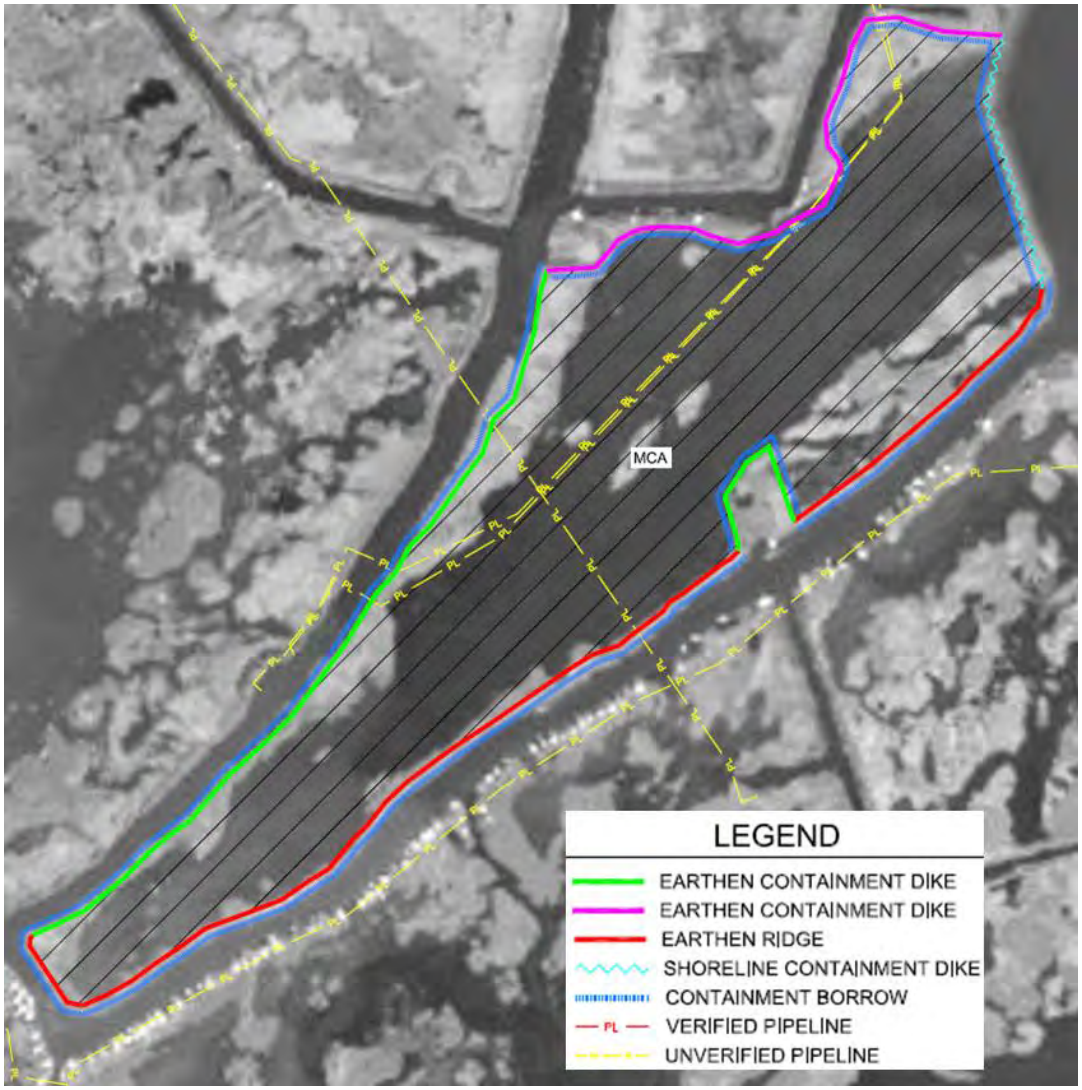

Figure 8: Marsh Creation Area Layout

The layout of the marsh creation area (Figure 8 and Table 5) minimizes the required fill volumes for containment dike and ridge restoration by utilizing the existing spoil banks along Bayou De Cade, Turtle Bayou, and the Lake De Cade shoreline. In addition, several reaches of the containment dike and the entire earthen ridge will be constructed by mechanically dredging earthen material from the exterior of the marsh creation fill area. This practice will eliminate the need to backfill these borrow areas with hydraulically dredged material.

The earthen ridge project feature is located along the northern bank of Bayou De Cade. Much of this alignment is located along the remnants of a shoreline berm, which minimizes the amount of mechanically dredged material required for construction. In addition, the primary borrow area for the ridge feature is located in Bayou De Cade rather than the interior of the marsh creation area. Bathymetric surveys and associated volume requirements indicate that a secondary borrow area is located on the interior of the marsh creation area will not be needed to supplement the exterior borrow area. However, the project team intends to permit an interior borrow area to complete the construction of the earthen ridge should project site conditions change between the time of the bathymetric survey and the completion of construction. The construction contractor will be required to exhaust all of the exterior borrow area prior to utilizing the secondary borrow area.

Two lengths of containment dike will borrow material from the interior of the marsh creation fill area: the northern reach in the vicinity of existing camps and the eastern reach along Lake De Cade. The northern reach borrow area is located on the interior in order to eliminate impacts to the camps. The eastern reach of earthen containment dike, also referred to as shoreline containment dike, is located along the western shoreline of Lake De Cade. In order to protect the dike from the high wave energy associated with the lake, the dike will be located on the interior of the existing earthen shoreline protection berm. An interior borrow area is needed along the lake rim in order to minimize the equipment reach requirements during construction. An exterior borrow area would require the construction contractor to borrow from the lake bottom, reach over the existing lake rim that is in place, and construct the earthen shoreline dike as shown in the construction plans. This would likely require the material to be handled multiple times, which would result in a cost increase.

Table 5: Summary of Project Features

Project Feature	Length (ft)	Footprint Area (Acres)
Marsh Creation Area	-	473
Earthen Containment Dike (Interior Borrow)	1,789	1
Earthen Containment Dike (Exterior Borrow)	13,410	10
Shoreline Containment Dike (Interior Borrow)	2,321	2
Earthen Ridge (Exterior Borrow)	11,131	21

The footprint acres for each project feature were calculated using AutoCad Civil3D following the design of all project features. The footprint acres of the earthen containment dike, shoreline containment dike, and earthen ridge represent the area where fill material will be placed on the existing mudline.

6.3 Marsh Creation Settlement Analysis

As part of the Geotechnical Engineering task performed by Fugro, Inc., a settlement analysis was performed to determine the optimal construction elevation of the marsh creation fill area. The final elevation of the created marsh (at Target Year 20) is governed by two forms of settlement: (1) the settlement of the underlying soils in the marsh creation areas caused by the loading exerted by the placement of the dredged fill material, and (2) the self-weight consolidation of the dredged material. These processes are illustrated in Figure 9 below.

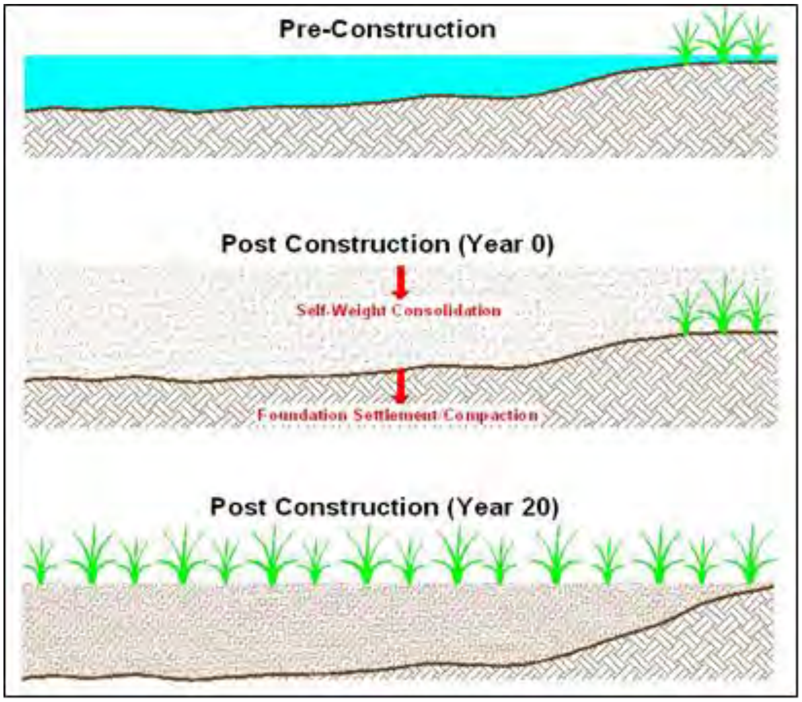

Figure 9: Marsh Creation Settlement Processes

Fugro, Inc. utilized the *PSDDF – Primary Consolidation, Secondary Compression and Dessication of Dredged Fill* computer software. This computer program utilizes the previously collected geotechnical data to produce the time-rate settlement of the dredge fill and the foundation soils.

The parameters required to evaluate the consolidation of the dredge fill material were developed based on the borings located within the marsh creation borrow area in Lake De Cade. The borings were combined into two composite samples to accurately reflect the composition of the dredged material once placed within the fill area. There was little variability identified between the two composite samples, therefore an average of the two composite samples was utilized. Consolidation information was used to develop void ratio versus log stress and permeability versus void ratio. These relationships provided the input parameters needed for the PSDDF software. An initial void ratio of 7.0 was assumed for the dredged fill material. This void ratio is based on information gathered from the column settling tests and from the Stark (2005) correlation with plasticity index.

For the foundation settlement analysis, Fugro, Inc. developed foundation soil compressibility parameters for seven soil layers to be included as input into PSDDF. These parameters represent a composite sample of parameters collected from the soil borings and CPTs and provide the basis of the foundation settlement calculations.

Settlement curves of differing initial construction marsh fill elevations and construction durations were analyzed over the 20-year design life. As discussed in Section 5.0, the goal of the project is to have the 20-year elevation fall within the intermediate marsh type inundation range, 10% to 90%. The intertidal range is included within the evaluation of the marsh fill elevation to provide additional insight into the performance of the newly created marsh at specific future project years.

All marsh creation construction scenarios were evaluated with the assumption that the pre-construction mudline elevation is -2.0 ft NAVD88, Geoid - 12A. This elevation was determined based on the existing elevation distribution shown in Table 4.

The project team evaluated settlement using three different construction fill scenarios with differing target elevations (Figure 10). The first scenario, “1 lift @ 5 Total Feet” produced an initial elevation of +3.0 ft. NAVD88, Geoid - 12A and a final elevation of 1.13 ft. NAVD88, Geoid – 12A. In this scenario, settlement was modeled with the entire volume of marsh creation material being placed within the fill area instantaneously, which fails to account for settlement of the fill material during the construction period. Based on experiences with past projects, the project team determined that this construction scenario did not accurately represent the actual marsh creation construction process.

Past marsh creation projects of similar features utilized hydraulic dredges that fill the marsh creation areas with a production rate of approximately 20,000 cubic yards per day. The volume required to fill the marsh creation area during the planning phase of the project was approximately 3,000,000 cubic yards, so the estimated hydraulic dredging duration is 150 days.

With this information, the next construction scenario, “9 Lifts @ 10 Total Feet”, consisted of raising the marsh creation elevation 2 ft in the first 15 days of dredging, followed by 1-foot increments every 15 days for a total of 150 days. This methodology allows the marsh creation settlement model to account for settlement of the marsh fill elevation during the duration of construction.

A third construction scenario, “9 Lifts @ 9 Total Feet”, consisted of raising the marsh creation elevation in 1-foot increments every 15 days for a total of 150 days. This third scenario was needed to provide a range of potential marsh fill elevations to be evaluated. Figure 10 presents the results of these settlement analyses as a time-rate settlement plot over the duration of the project life – Year 0 through Year 20. Year 0 is representative of the completion of dredging activities plus 30 additional days for the marsh creation fill area elevation to be accepted as complete.

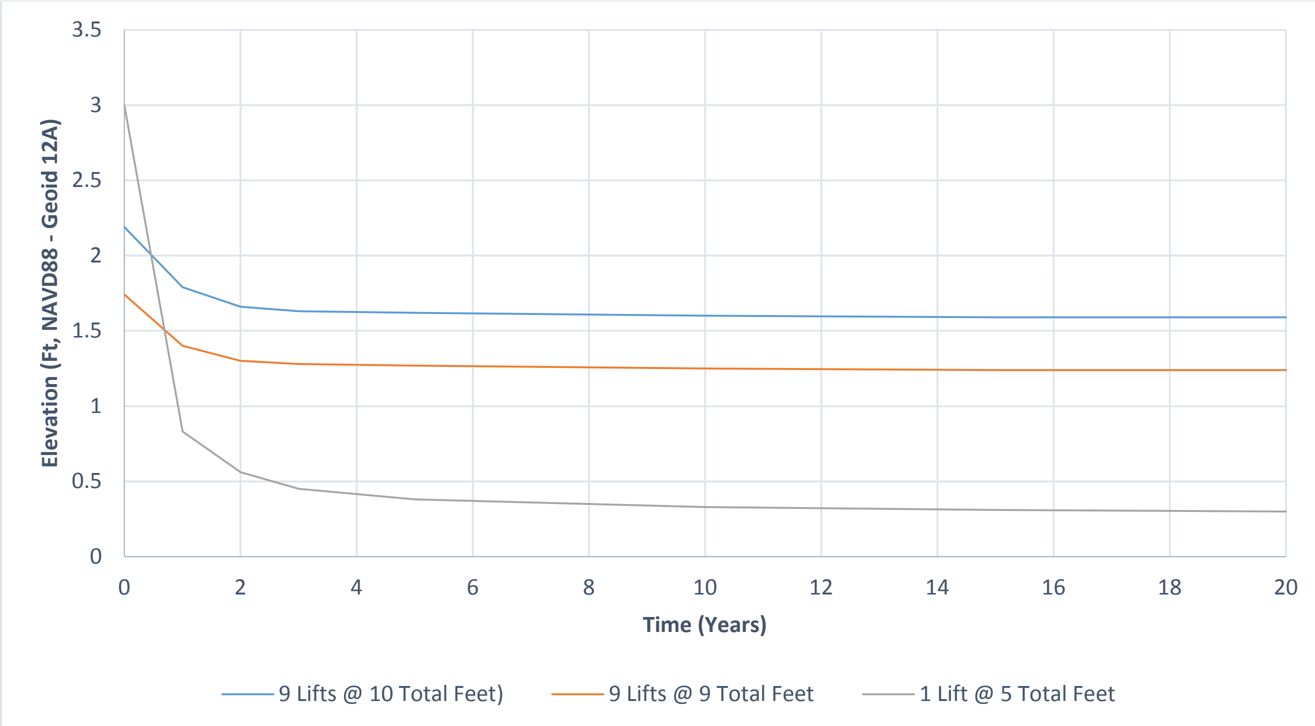

Figure 10: Time Rate Settlement of Marsh Fill (without subsidence)

6.4 Subsidence Rates

In addition to the settlement caused by marsh fill, the natural process of subsidence is considered when evaluating the final elevation of the marsh fill. Subsidence is defined as the rate of local vertical land movement. Causes of subsidence include natural processes such as tectonics (faulting), Holocene sediment compaction, and removal of subsurface fluids associated with the oil and gas industry.

The CPRA Planning Division has produced a range of subsidence values across coastal Louisiana for use in the design of restoration projects (Figure 11).

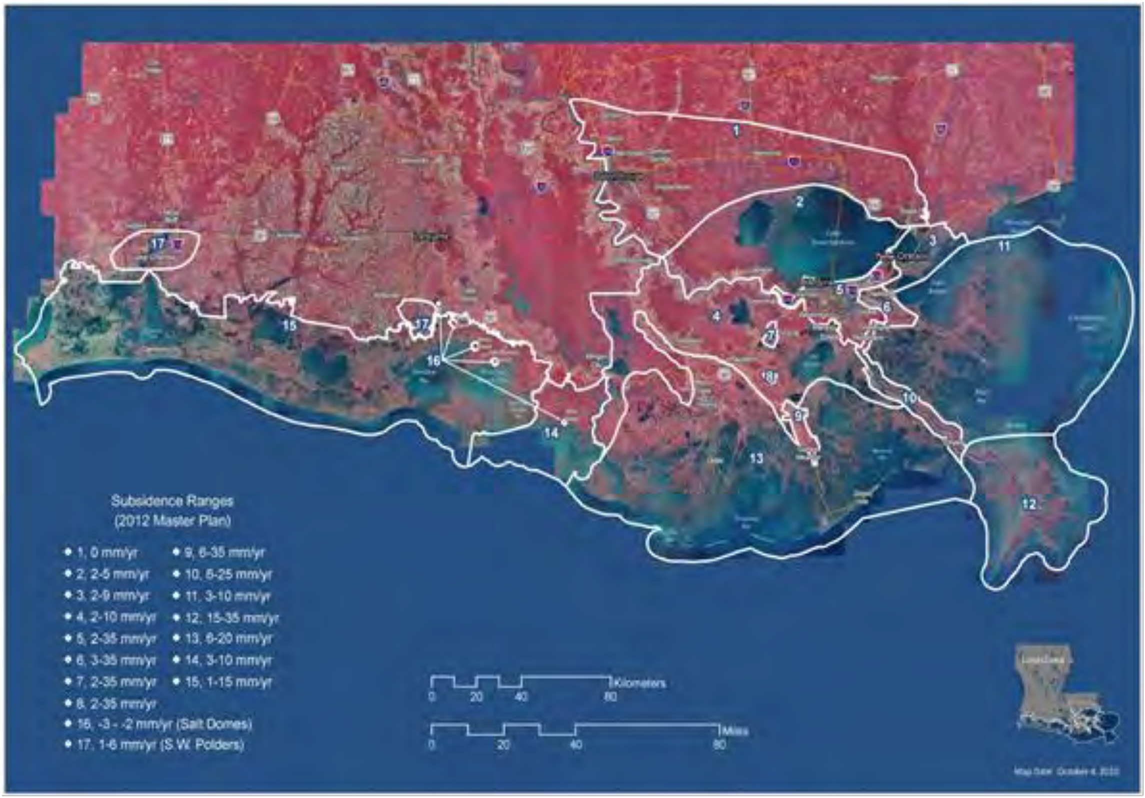

Figure 8: Coastal Louisiana Subsidence Rates (CPRA Planning Division)

The TE-0138 project falls within the area having a subsidence range of 6-20 mm/year. The project team has chosen to use 7 mm/year as the governing rate due to past experiences near the project area. This value equates to a total of 140 mm (5.5 inches) of total subsidence over the project life. This rate was used to further develop the marsh creation settlement curves to include the rate of subsidence (Figure 9).

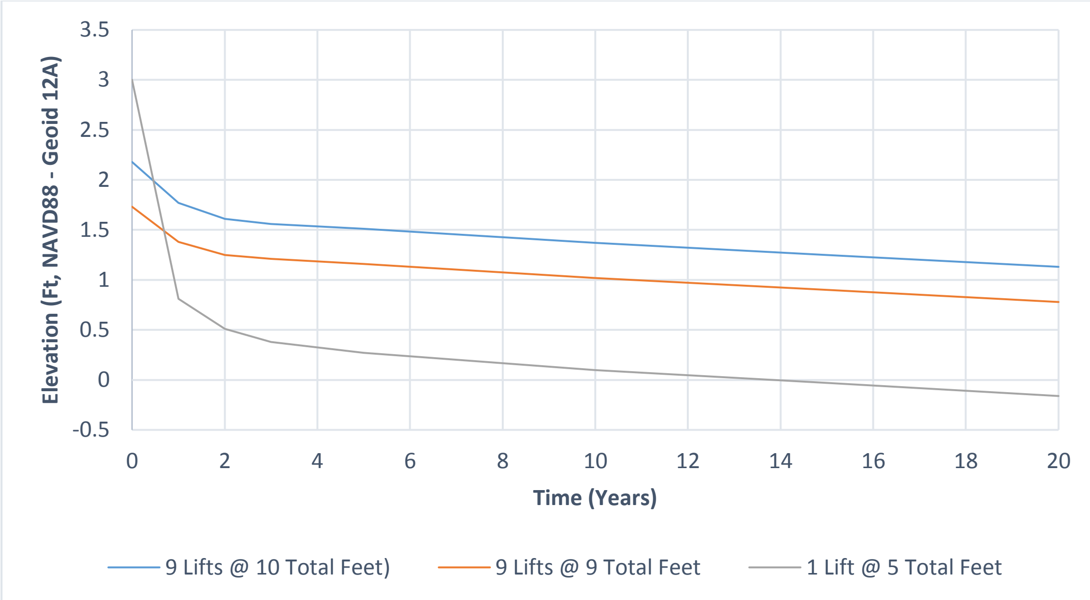

Figure 9: Time Rate Settlement of Marsh Fill (with Subsidence)

After including all forms of settlement (self-weight consolidation, foundation settlement, and subsidence), the settlement curves were compared to the surface water elevations discussed in Section 5.0 (Figure 10). After review of this data, the project team determined that a constructed marsh fill elevation of +1.75 ft. NAVD88 – Geoid12A would achieve the marsh elevation goals established in Section 5.0. This construction elevation would achieve a marsh elevation within the 10% inundation range by Year 4 and within the intertidal range by Year 10. The marsh would not be expected to settle below the intertidal range until Year 18 and would remain within the 90% inundation range for the life of the project.

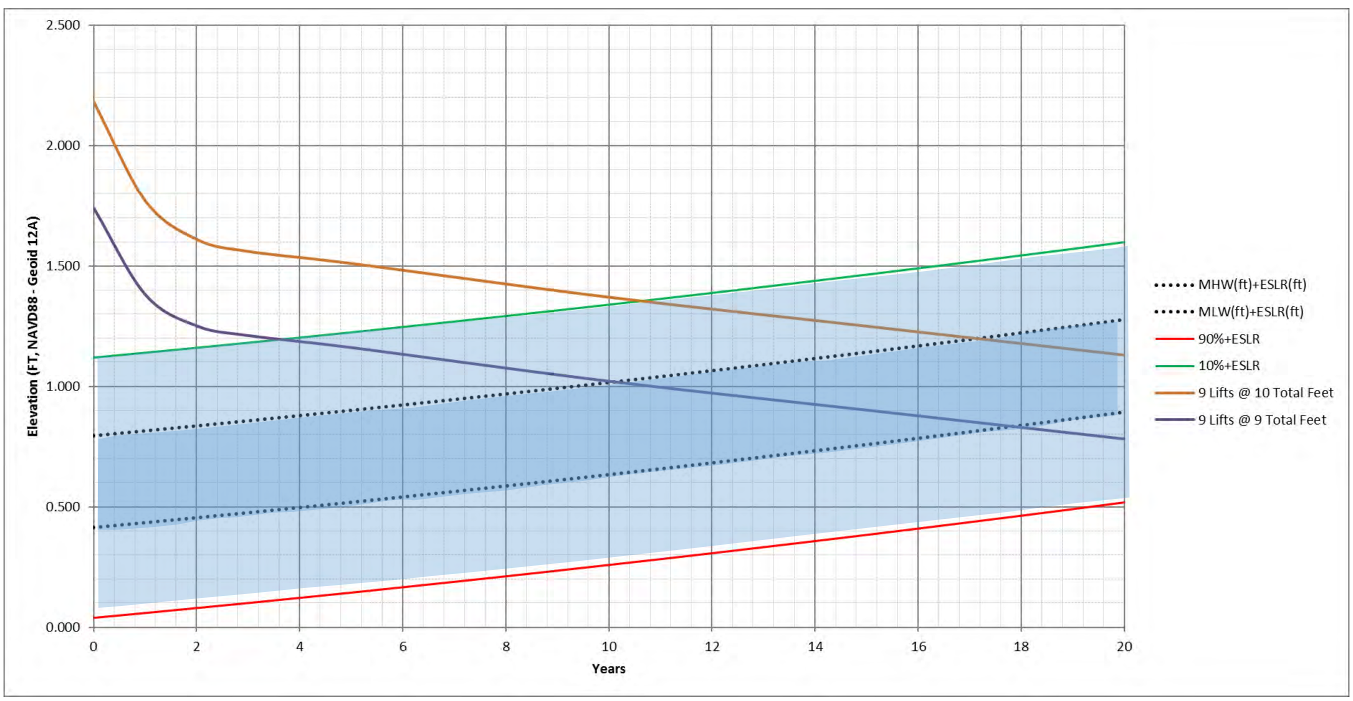

Figure 10:: Time Rate Settlement Compared with Tidal Datum

It is important to note that the Construction Marsh Fill Elevation (CMFE) is the elevation of the marsh fill slurry 30 days after the completion of dredging activities. The maximum elevation of marsh fill slurry during construction is anticipated to be +2.2 ft. NAVD88 – Geoid12A. The construction contractor will cease dredging operations to allow the marsh elevation to settle to the target elevation (1.75 NAVD88 – Geoid12A) by the time of construction completion at day 30. A construction tolerance of ±0.25 ft. will be allowed by the project inspector to account for uncertainties associated with achieving the target marsh elevation across the entire marsh fill area. A maximum marsh fill elevation of +2.5 ft. NAVD88-Geoid12A is being assumed for the marsh creation area

6.5 Earthen Containment Dike Design

Earthen containment dikes are required to contain the hydraulically placed fill material within the marsh creation area. As mentioned above, most of this project area is contained by surrounding spoil banks and natural earthen berms; however, in order to fully contain the placed slurry material, the elevation of these spoil banks will be increased to +4.0 feet NAVD88 – Geoid 12A. This elevation will provide nearly 1.5 feet of freeboard above the maximum anticipated marsh fill elevation of +2.5 feet NAVD88 – Geoid 12A, described above. This amount of freeboard will provide the dredge contractor the ability to pump above the +1.75 elevation in order to reach the CMFE after the required 30-day wait period. Figure 11 and Figure 12 summarize the typical cross section for the earthen containment dike.

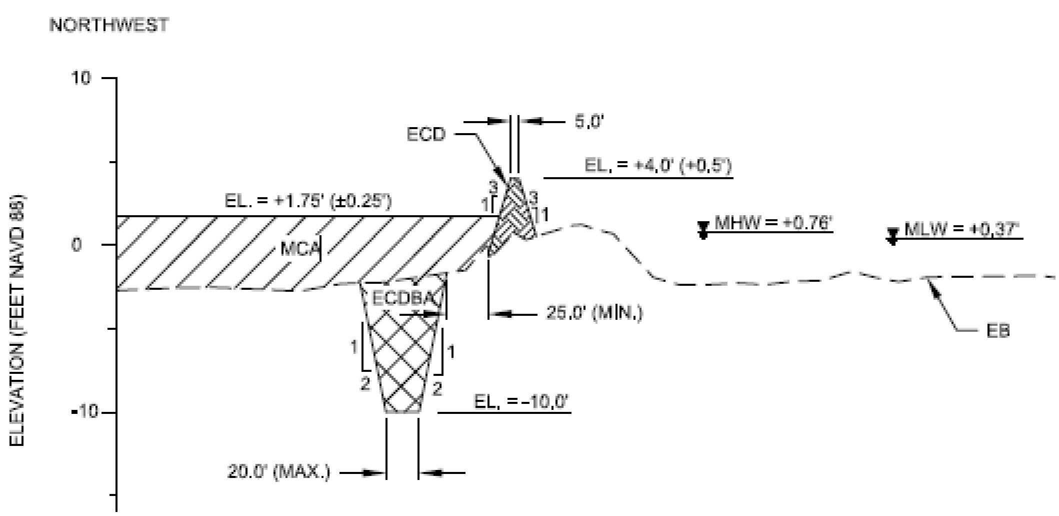

Figure 11: Earthen Containment Dike Typical Cross Section – Interior Borrow

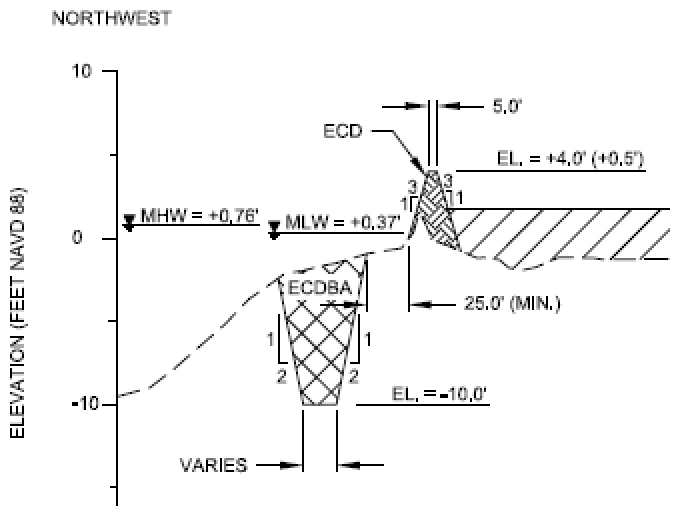

Figure 12: Earthen Containment Dike Typical Cross Section – Exterior Borrow

The earthen containment dike located along the Lake De Cade shoreline will be located on the protected side of an existing earthen berm, which is maintained by Apache Corporation, the landowner of the marsh creation area. Based on conversations with the landowner, there is no indication that the maintenance of this earthen berm will cease in the near term, and it is anticipated that this berm will provide the protection needed to the earthen containment dike during construction activities. However, in order to mitigate for the possibility that this earthen berm is no longer maintained at the time of construction, a shoreline containment dike design will be utilized. This dike will consist of a 10' crest width and 5H:1V side slopes (Figure 13) in order to endure additional erosion from the high wave energy environment associated with Lake De Cade. In addition to this larger dike, the required construction volume has been doubled so that the dike can be maintained, if needed, throughout construction.

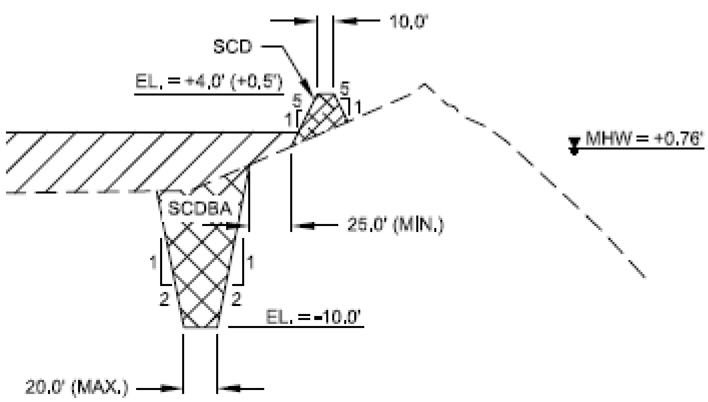

Figure 13: Shoreline Containment Dike Typical Cross Section

6.6 Ridge Restoration Design

The primary goal of ridge restoration is to provide a platform of dredged material to an elevation sufficient to support woody vegetation. This elevation was identified in the initial planning phase as +5.0 feet NAVD88 – Geoid 12A. The earthen ridge will have a +10 Ft. crest width and 7H:1V side slopes on both the interior and exterior of the ridge (Figure 14). As shown above in Section 5.0, the elevation is above the 1% inundation threshold and will allow for additional settlement for the duration of the project life. Similar to the earthen containment dike, the ridge restoration feature will consist of material that has been mechanically dredged from the Bayou De Cade, adjacent to the marsh fill area, and will be placed along the historical ridge along the northern shoreline of Bayou De Cade.

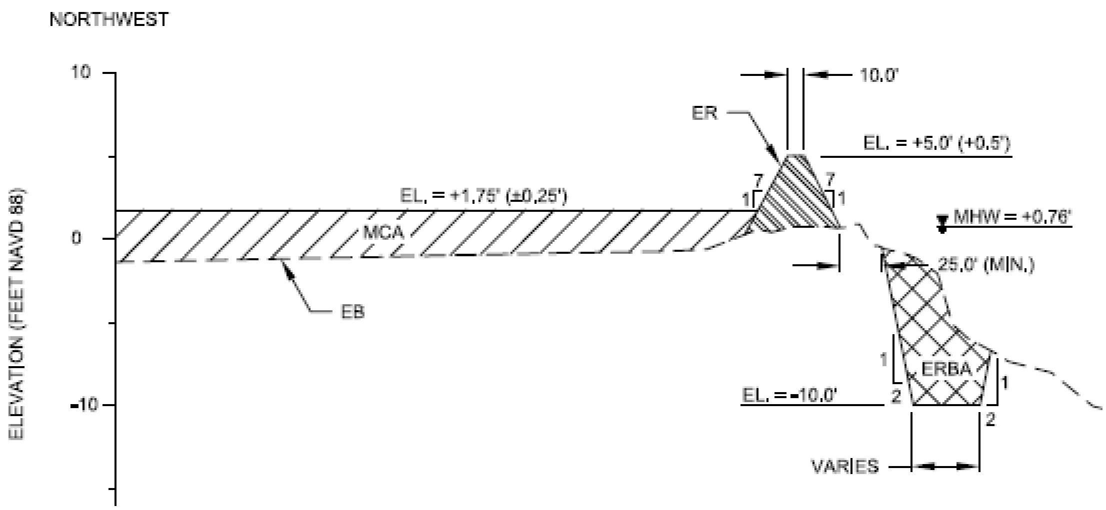

Figure 14: Ridge Restoration Typical Cross Section

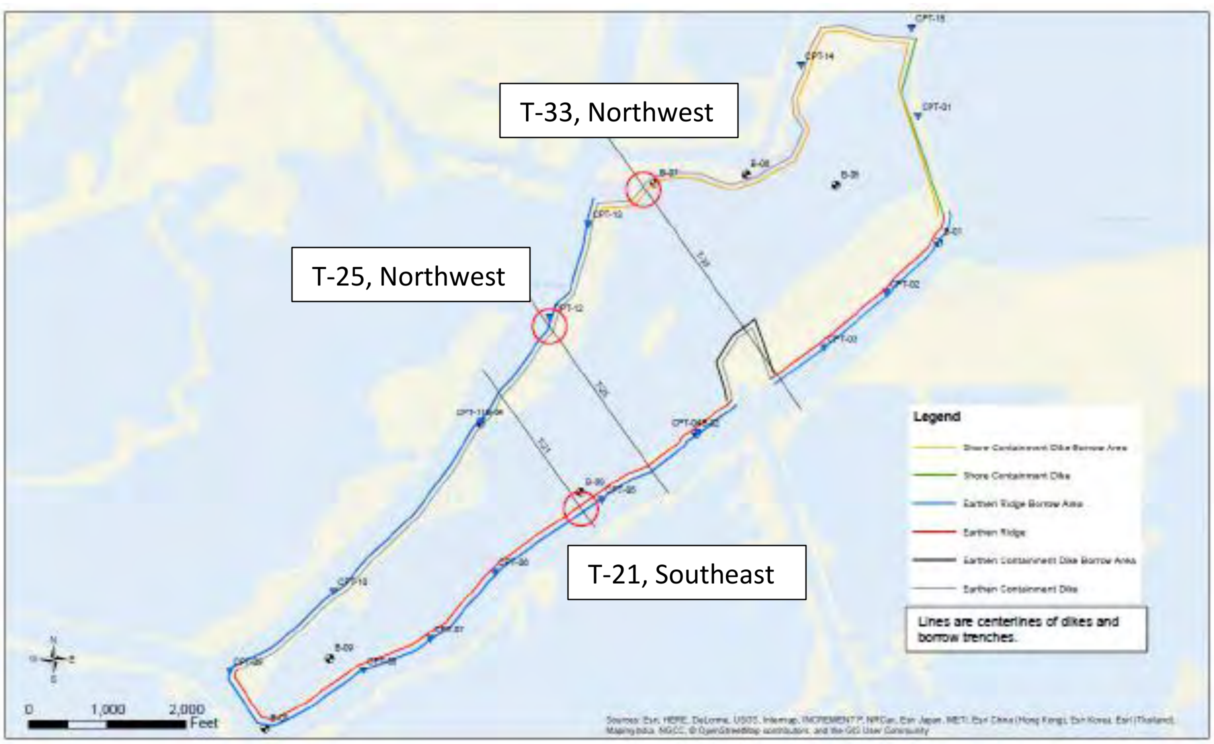

Figure 15: Location of Slope Stability Sections

Slope Stability Analysis – Earthen Containment Dike and Ridge

Slope stability evaluations for selected earthen dike, earthen ridge, and associated borrow areas were performed. Fugro, Inc. was provided with the design dimensions for all project features as well as the data collected as part of the topographic and bathymetric design survey. This information was used to develop "slope stability sections" (Figures 15 and 16). The locations are labeled as T-21, Southeast; T-25, Northwest; and T-33, Northwest. T-21, Southeast represents the governing cross section for Earthen Ridge with exterior borrow. The existing mudline elevation at this location is -2.0 Ft. NAVD88 – Geoid12A. T-22, Northwest represents the governing cross section for Earthen Containment Dike with exterior borrow. The existing mudline elevation at this location is -2.0 Ft. NAVD88 – Geoid12A. T-33, Northwest represents the governing cross section for Earthen Containment Dike with internal borrow. The existing mudline at this location is -1.0 Ft. NAVD88 – Geoid12A.

The slope stability analysis was performed utilizing the SLOPE/W (GEO-SLOPE, 2015) computer software. This software was used for limit equilibrium slope stability analyses in conjunction with the Morgenstern and Price method, entry and exit search modes, and optimized non-circular potential failure surfaces. Unit weight and shear profiles were developed from the subsurface profiles described in Section 5.4. Additionally, construction equipment loading was included for all applicable slope stability evaluations. For these project features, a Factor of Safety (Fs) greater than 1.2 is desired to prevent slope failures during the construction activities. Table 6 provides the critical factor of safety for the three slope stability sections. The results of all slope stability analyses can be found in Appendix G: Slope Stability Analyses.

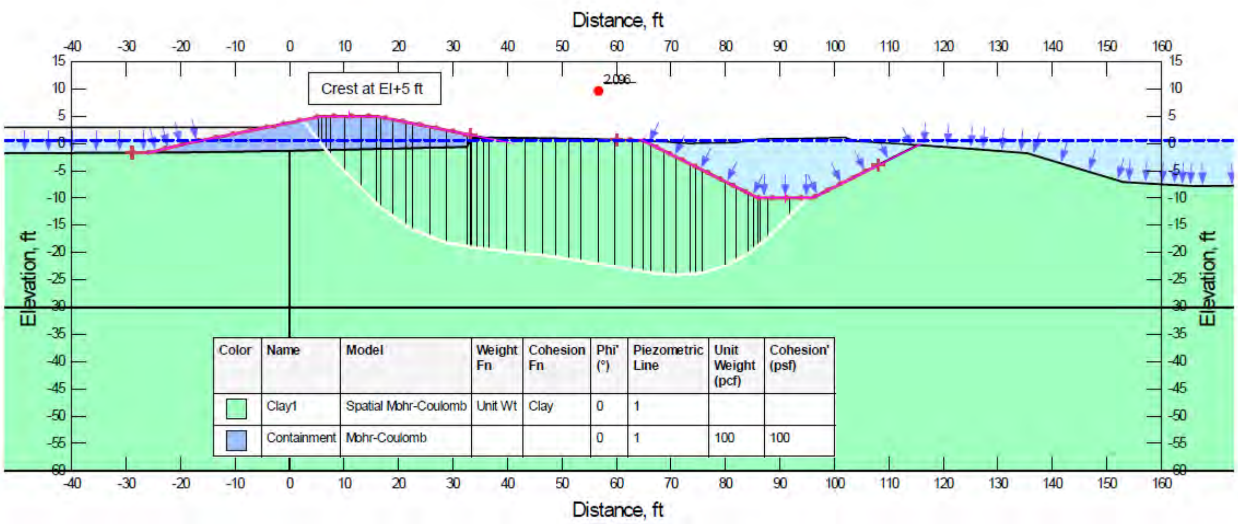

Figure 16: Slope/W Stability Analysis

Table 6: Minimum Factors of Safety

Slope Stability Section	Minimum Fs	Failure Location
T-21, Southeast	1.927	Interior slope of Earthen Ridge – prior to marsh placement

T-25, Northwest	2.197	Exterior Borrow Area Slope
T-33, Northwest	1.959	Interior slope of Earthen Dike – prior to marsh placement

<u>Settlement Analysis – Earthen Containment Dike and Earthen Ridge</u>
Settlement analysis of the earthen ridge was performed using the Settle3D (Rocscience, 2018) computer software. Section T-21 was use as the configuration to be modeled within the computer program. Underlying soil parameters were calculated using the all subsurface exploration data as described in Section 5.4. The existing mudline was set equal to 0.0 ft. NAVD88, Geoid 12A. The total settlement of the ridge crest is expected to be 0.6 Ft. over the life of the project. The ridge crest elevation at TY20 (2040) including subsidence is expected to be +3.7 Ft. NAVD88, Geoid 12A. The time rate settlement curve of the ridge elevation is shown below (Figure 17)

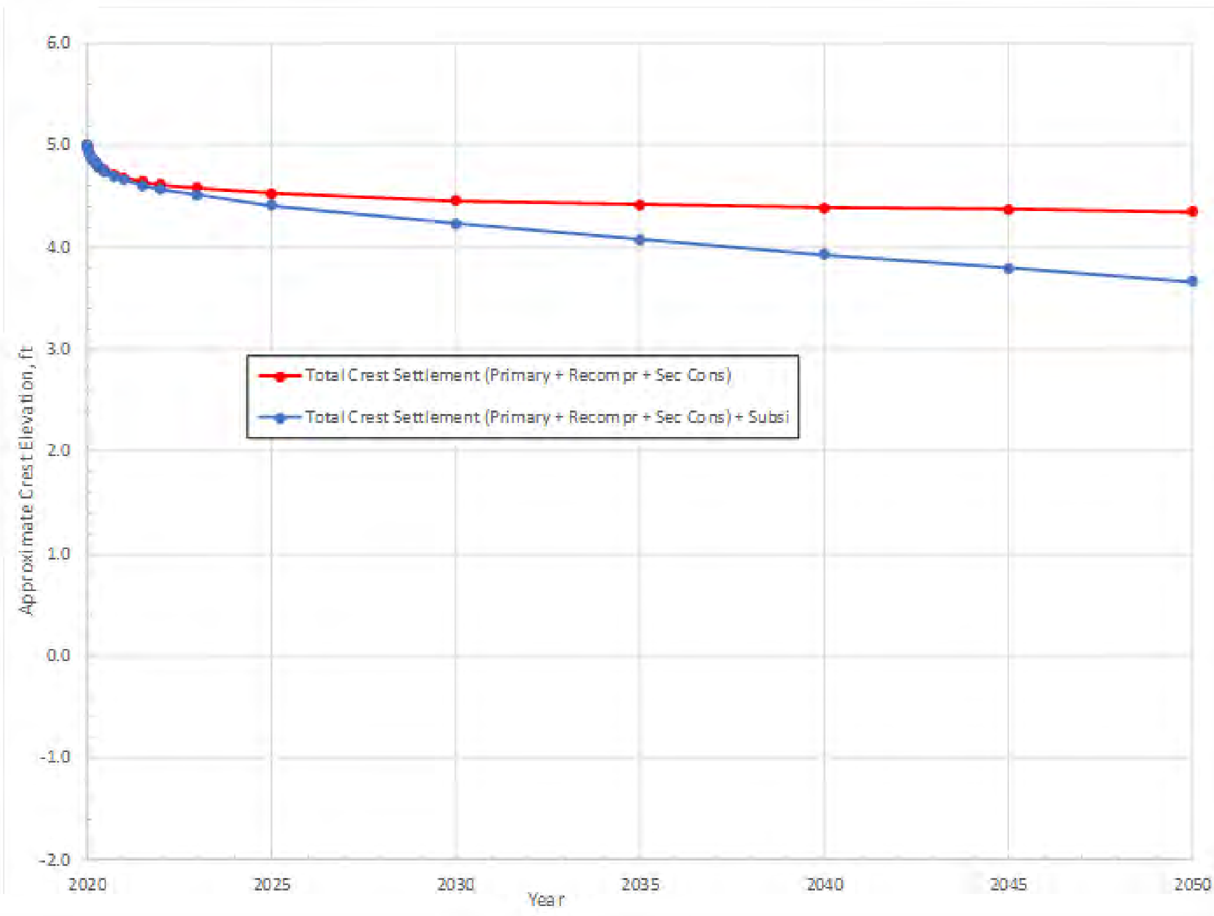

Figure 17: Time Rate Settlement Curve – Ridge Crest Elevation

6.7 Project Feature Volume Estimates

The volume of material needed to construct all project features, including the marsh creation area, earthen containment dikes, and earthen ridge, must be known in order to properly design the borrow area for each feature and to produce an accurate construction cost estimate.

Marsh Creation Volumes

The volume required to fill the marsh creation area is based on existing elevation within the marsh fill area, the construction marsh fill elevation, and the hydraulic dredge fill material properties. The existing elevations within the fill area were determined by the data collected with the design topographic and bathymetric surveys. The construction marsh fill elevation was determined in the above sections as being +1.75 ft. NAVD88 – Geoid12A. However, the elevation used to determine the required fill volume will be evaluated based on hydraulic dredge fill material properties and past project experiences. Analysis of the in-situ borrow area void ratios compared to the in-place void ration of the hydraulic dredge fill material indicate that a marsh fill elevation of +1.5 Ft NAVD88 – Geoid12A should be used to accurately determine the volume of material required to reach the target elevation of +1.75 ft. NAVD88 – Geoid12A. In addition, a cut to fill ratio of 1.2 was applied to the quantities to be dredged for all hydraulic dredging. This value is used to account for losses that occur during the dredging processes and is based on discussions with the geotechnical engineer and past project experiences. This required fill volume was calculated through the use of AutoCad Civil3D and then verified using the average end area method within a Microsoft Excel Spreadsheet. These two calculated quantities had a 3% error between the two.

Earthen Containment Dike and Ridge Volumes

The volume of material required to construct the earthen containment dikes and earthen ridge is also based on the elevation along the alignment of the project features, the construction elevation, and the mechanical dredge fill material properties. These fill volumes were calculated through the use of AutoCad Civil3D. A cut to fill ratio of 1.5 was applied to the quantities to be dredged for all mechanical dredging. This value is used to account for losses that occur during the dredging process and is based on discussions with the geotechnical engineer and past project experiences.

Table 7: Summary of Required Fill and Available Borrow Volumes

Feature	Required Fill Volume (Cu. Yds.)	Required Cut Volume - Interior (Cu. Yds.)	Required Cut Volume – Exterior (Cu. Yds.)	Available Borrow Volume - Interior (Cu. Yds.)	Available Borrow Volume – Exterior (Cu. Yds.)
Earthen Containment Dike	69,110	49,913	53,753	105,949	65,266
Shoreline Containment Dike	8,768	26,304	-	31,763	-
Earthen Ridge Restoration	74,567	-	111,851	-	166,899
Marsh Creation Fill Area	2,473,335	2,968,001		4,871,719	-

6.8 Marsh Creation Borrow Area Design

The marsh creation borrow area is approximately 348 acres in size and is located in the southwestern portion of Lake De Cade (Figure 18). This borrow area was carefully chosen to avoid the oil and gas infrastructure located in this area. In order to minimize water quality impacts, the cut depth of the borrow area will be limited to 10 feet below the existing mudline (Figure 19).

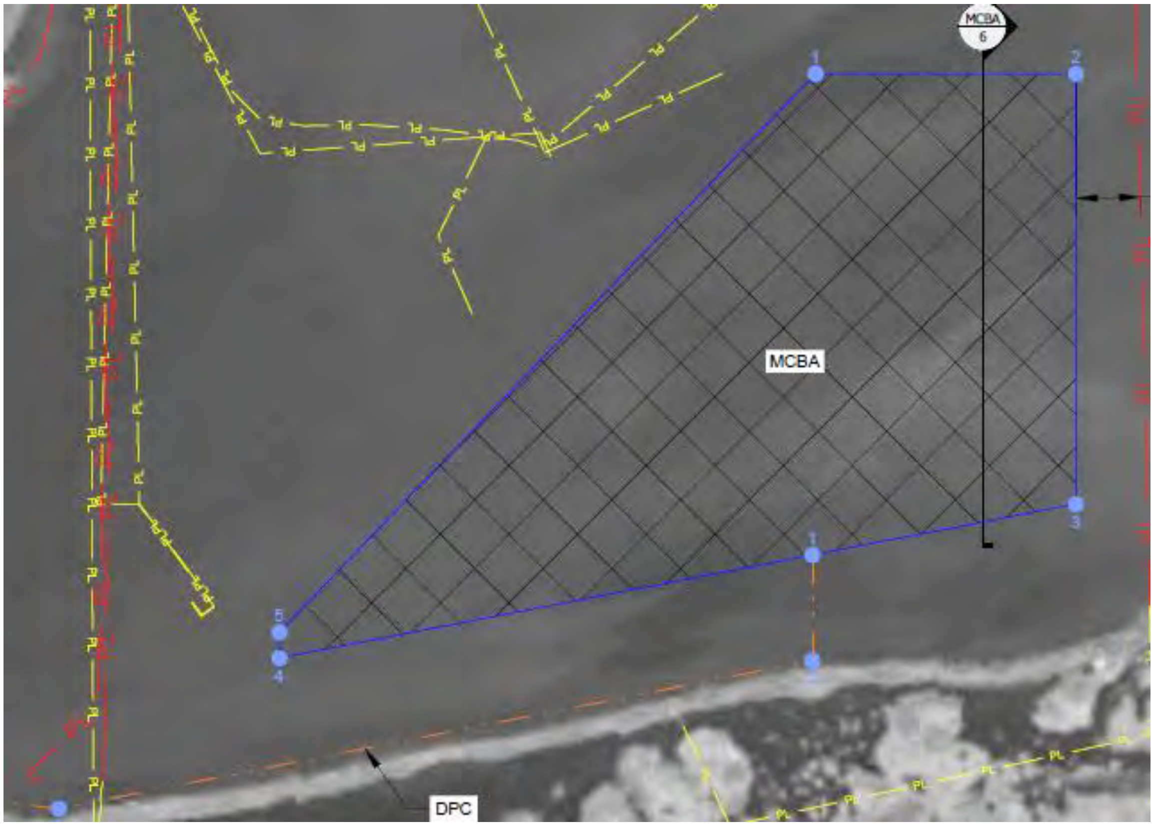

Figure 18: Marsh Creation Borrow Area Layout

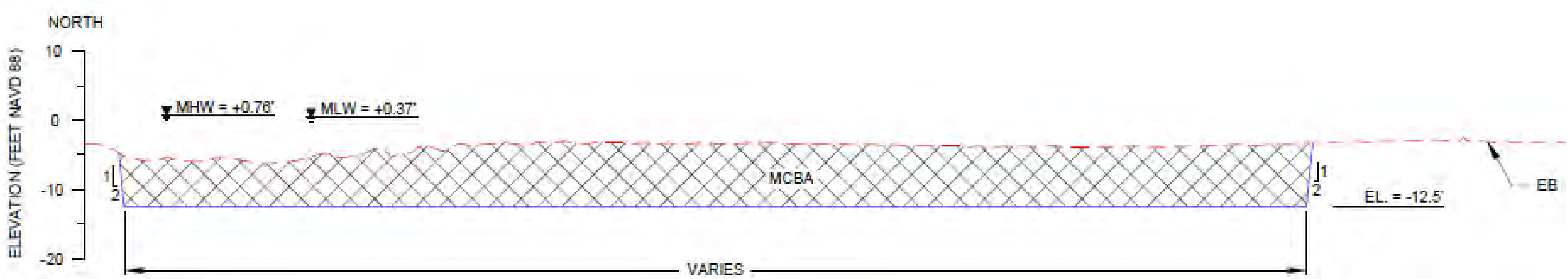

Figure 19: Marsh Creation Borrow Area Typical Cross Section

Mott MacDonald was tasked by the project team to analyze the wave environment along the shoreline of Lake De Cade. The goal of this analysis was to evaluate the potential changes to wave climate on Lake De Cade shoreline associated with the marsh creation borrow area. This analysis included a review of water surface elevation, wind statistics, and numerical modeling of wind-generated waves at the project site.

The wave modeling was conducted utilizing the SWAN model and the existing and proposed bathymetry data sets to analyze the changes in wave height on Lake De Cade with an emphasis on its shoreline under several environmental conditions. Analysis of the wave modeling results produced the following conclusions:

1) The largest changes in wave height within the dredge pit are observed under the longest fetch scenario. These changes are in the order of 0.4 ft. Under this condition, the wave heights along the lake shoreline increase 0.1 ft. This increase in wave height is considered negligible based on the wave's impact on the shoreline.
2) The largest change in wave height observed near the Lake De Cade shoreline occurred under the northwesterly wind condition. This scenario increased wave heights along the southern shoreline of Lake De Cade between 0.1 and 0.2 ft. This increase in wave height is also considered negligible based on the wave's impact on the shoreline, particularly in the area of the rock revetment.

Additional information regarding the wave modeling task can be found in Appendix H: Borrow Area Wave Modeling.

7.0 DREDGE PIPELINE CORRIDOR

A dredge pipeline corridor is needed to provide a route for the construction contractor to lay hydraulic dredge pipe from the marsh creation borrow area to the marsh creation fill area. This pipeline corridor should be established with careful consideration for existing bathymetry, oil and gas pipeline infrastructure, marine traffic, and impacts to environmentally sensitive areas. Additionally, the length of the dredge pipeline corridor should be minimized to limit the required pumping distance between the borrow area and the fill area. The layout of the dredge pipeline corridor is shown below in Figure 20.

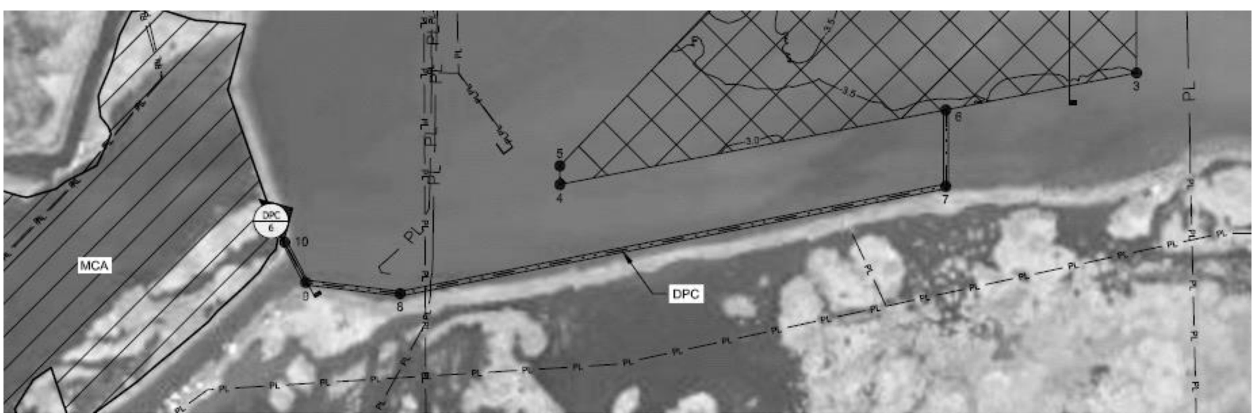

Figure 20: Dredge Pipeline Corridor

8.0 CONSTRUCTION COST ESTIMATE

An Engineer's Estimate of Probable Construction Cost was prepared for this project using the CWPPRA PPL 28 spreadsheet, CPRA Bid Tabulations of past projects, the CDS Dredge Unit Rate Cost Estimation spreadsheet, and additional CPRA developed cost estimation spreadsheets. A construction cost contingency of 20% is being applied to the Estimate of Probably Construction Cost. The intent of the cost contingency is to account for uncertainty associated with the design of the project. At this time, the project team is still quite uncertain about the maintenance of the land owner maintained earthen berm on the Lake De Cade shoreline. Future damage to this berm could cause significant impacts to the construction costs. The inclusion of this cost contingency will help to mitigate for the potential impacts. The estimated construction cost has been provided to the CWPPRA Engineering Workgroup in the current PPL 28 format. All assumptions and cost justifications can be found in Appendix I: Basis of Construction Cost Estimate.

9.0 MODIFICATIONS TO THE PHASE 0 PROJECT

The project features remain largely unchanged from the originally proposed Phase 0 project features. A few minor revisions were made in order to adapt the project features to the ever changing topography within the project area. The containment dike and ridge alignments were shifted slightly in order make use of the existing landforms to limit the quantity of material required to construct the project features. Additionally, the northern reach of the earthen containment dike was shifted southward to avoid negative impacts to the camps and associated infrastructure along Turtle Bayou. A summary of these changes are shown below (Table 8).

Table 8: Summary of Changes From Phase 0 Project

Project Feature	Phase 0	Preliminary (30%) Design	Percent Change
Marsh Creation Area	501 Acres	473 Acres	-5.5%
Earthen Ridge	11,726 LF	11,133 LF	-5.0%

10.0 RESPONSE TO PRELIMINARY (30%) DESIGN REVIEW COMMENTS

Following the completion of the Preliminary (30%) Design Review meeting, the TE-0138 project team received two comments from the CWPPRA Agencies. These comments and associated responses are shown below in Table 9.

Table 9: Comments and Response from 30% Design Review

Comment From	Comment	Person Responding	Response
Ronald Paille, USFWS	My only concern is that maybe the containment dike along Lake De Cade is not wide enough to withstand the lakeshore erosion and protect the created marsh.	**Travis Byland, CPRA**	The shoreline containment dike consists of a 10 ft. crest width and 5:1 side slopes rather than the 5 foot crest width and 3:1 side slopes found on the earthen containment dikes. In addition, the volume required to construct the shoreline containment dike has been doubled – thus allowing the entire dike length to be constructed a second time during construction. The O&M Plan accounts for an additional maintenance event of the shoreline containment dike during Years 1-3. The maintenance event will ensure the stability of the dike during the consolidation of the marsh platform.
John Petitbon, USACE	Only comment I have at this time would be concerning the shoreline containment dike along Lake De Cade. From the piece of the typical section provided, it appears the containment dike is inside of and	**Travis Byland, CPRA**	The shoreline containment dike consists of a 10 ft. crest width and 5:1 side slopes rather than the 5 foot crest width and 3:1 side slopes found on the earthen containment dikes. In addition, the volume required to

	protected by the existing lake rim. IF the complete alignment along the lake is not protected, you might want to consider increased dike size or some type of erosion protection along the lake.		construct the shoreline containment dike has been doubled – thus allowing the entire dike length to be constructed a second time during construction. The O&M Plan accounts for an additional maintenance event of the shoreline containment dike during Years 1-3. The maintenance event will ensure the stability of the dike during the consolidation of the marsh platform.

11.0 MODIFICATIONS TO THE PRELIMINARY (30%) DESIGN

The project features remain largely unchanged from the Preliminary (30%) Design. A "No Work Area" was added in the vicinity of the camps located along Turtle Bayou and Bayou De Cade. A summary of the changes is shown below in Table 10.

Table 10: Summary of Changes from Preliminary (30%) Design

Project Feature	Preliminary (30%) Design	Final (95%) Design	Percent Change
Marsh Creation Area	473 Acres	473 Acres	0%
Earthen Ridge	11,133 LF	11,131 LF	0%